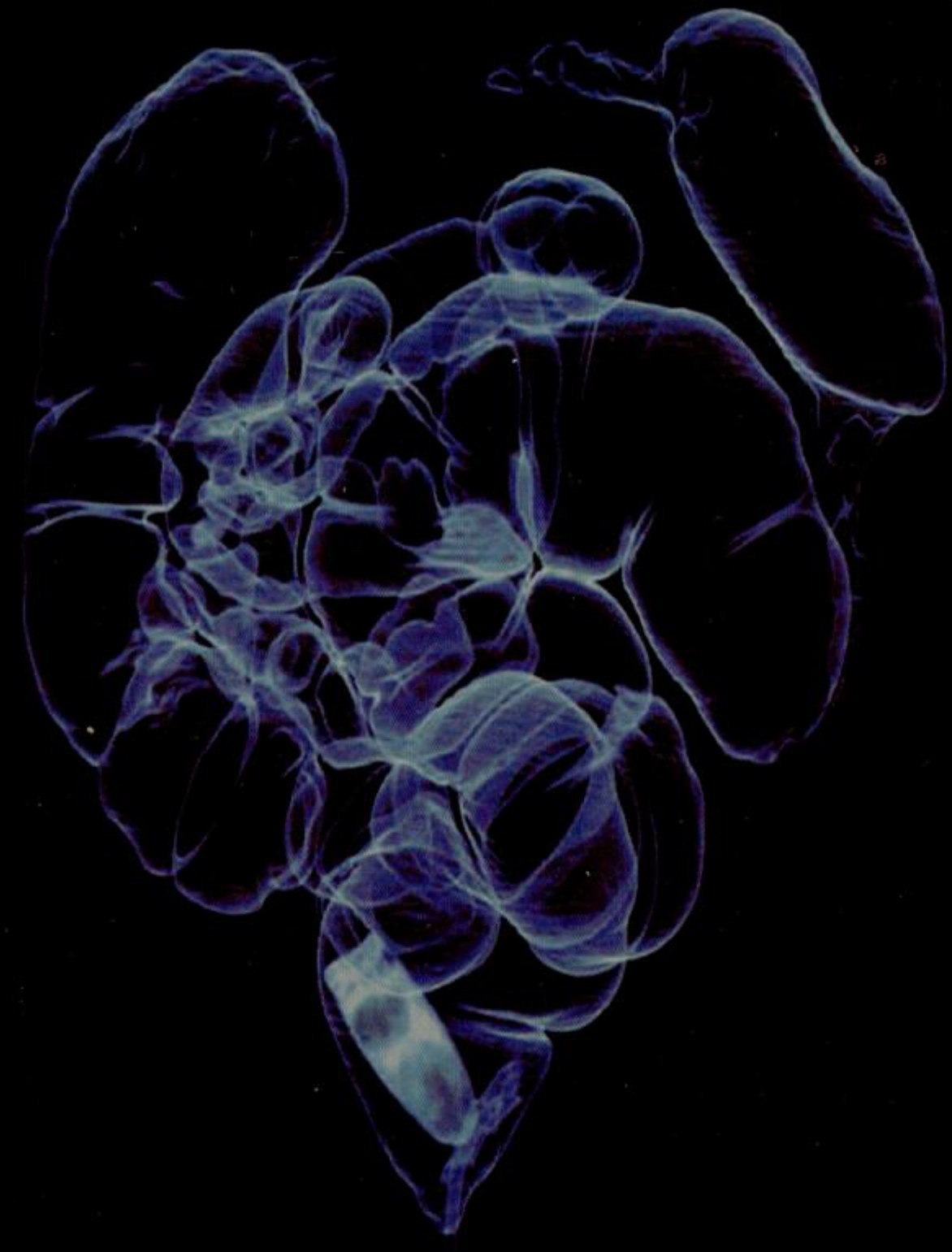
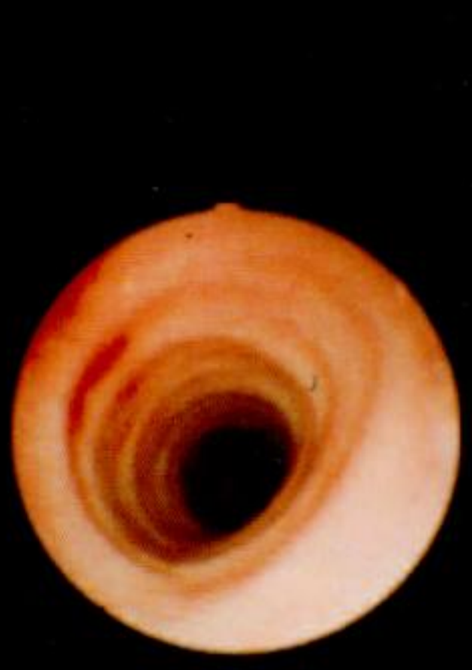
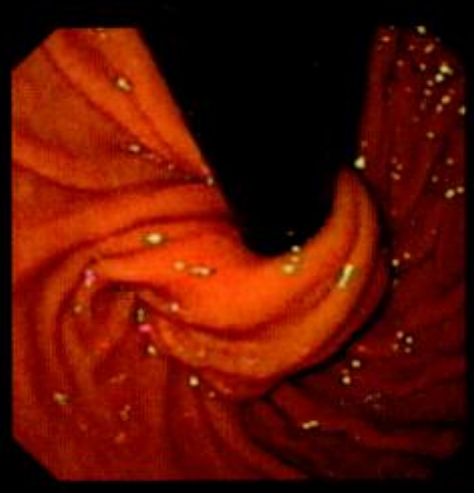
PEDIATRIC GASTROINTESTINAL ENDOSCOPY

Textbook and Atlas







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1 History Of Gastrointestinal Endoscopy And Pediatric Endoscopy

Samy Cadranel and Jean-François Mougenot

In the preface of his comprehensive and impressive book, *One Hundred Years of Digestive Endoscopy* published in Spanish in 2003, Francisco Villardell stated that during the last half century two achievements must be considered to be major advances in the field of gastroenterology: the adaptation of fiberoptics to gastrointestinal endoscopy, and, as a consequence, the discovery of *Helicobacter pylori*.[1,2] The role of *H. pylori* would not have been suspected without the pathologic and microbiologic study of biopsy material obtained with the endoscope. Attempts to inspect in vivo the internal cavities of the human body are probably as ancient as medicine itself. A challenge was to find a safe source of light that would not generate heat that could damage tissues. The development of fiberoptics led to the birth of modern gastrointestinal endoscopy.

The Precursors

The ancestor of the modern proctoscope, the Lichtleiter, was designed by Philip Bozzini (1773–1809) in Vienna in 1796 with a system of lenses illuminated by candlelight.[3] Subsequent instruments were designed based on the same principle: a light source external to the body created a light beam that was directed by lenses and mirrors towards the cavity. The term endoscope was first used in 1853 by Antonin Jean Desormeaux (1844–1894), a French surgeon working in Hôpital Necker in Paris.[4] The instrument was used mainly in urology, but also served as a rigid esophagoscope. The well-known instrument makers, Charriere, built the endoscope, and their name is still used to express the caliber of probes (French units). The Irish urologist Francis Richard Cruise (1834–1921) improved the illumination system and was able, in 1865, to examine not only the urinary tract, but also the rectum. At the end of the nineteenth century, the Erlangen school of digestive endoscopy was a center for innovation in gastroenterology. The first gastroscope was developed in Erlangen by Adolf Kussmaul (1822–1902), the inventor of the gastric aspiration pump.[5] However, all these early instruments were of limited use because they could not direct enough light to the site. They remained unsatisfactory until Thomas Edison invented the electric bulb in the United States. Gustave Trouvé (1838–1902), a French engineer, was the first to use internal illumination in 1873 to see the human body cavities with his polyscope, commercialized under the name Eureka (in French j'ai trouvé means "I found").[6] This instrument could not be used for prolonged periods of time because of the heat generated by the light bulb.

In 1881 Mikulicz performed the first gastroscopy in a human being using a rigid instrument that was 65 cm long and 14 mm in diameter.[7] This instrument, which was angulated to compensate for the anatomical angulations of the human esophagus, was equipped with a water circulation system to cool the light bulb and had channels for the light source and to introduce air.

Technical development of the endoscope evolved in three differing directions:

1. Closed tubes with optical systems were used mainly by German- or French-speaking clinicians such as Rosenheim, Elsner, Schindler, Sternberg, Korbsch, and Bensaude.[8–13]
2. Open tubes were developed by Chevalier-Jackson in Pittsburgh who claimed prophetically "that the vision was so clear that endoscopic investigation of the gastric cavity would become a routine procedure."[14]
3. Semiflexible endoscopes, such as the Schindler-Wolf gastroscope, were designed through collaboration between Rudolf Schindler from Münich and the instrument-maker Georg Wolf from Erlangen.[15] The rigid proximal part was followed by a flexible distal part composed of 6 units of 6 lenses, each with a total optical system containing 51 optical elements. Despite the increased flexibility of the Schindler gastroscope compared to the rigid instruments, some areas of the stomach could not be seen. Several attempts were made by H. Taylor in the UK and D. Chamberlin in the US to improve the mobility of the semiflexible endoscope.[16,17] The final model in 1955 was the popular Gastroflex, developed by the Frenchman Charles Debray.[18] The flexibility was greatly improved over earlier instruments, the diameter was reduced to 10 mm, and the light was sufficient to take good photographs.

The Fiberscope

In the hybrid semiflexible gastroscope built by the German instrument-maker Storz in 1966, lenses were used for visualization but the electric light bulb is replaced by optical fibers made of either glass or plastic. Plastic fibers were more flexible and durable than glass; however, glass optical fibers could be manufactured with diameters smaller than their plastic counterparts, and the quality of light transmission was superior in glass optical fibers. The difficulty of the procedure impressed Heinrich Lamm, a young medical student in Münich who attended Schindler's endoscopies. He was the first to imagine the application of fiberoptics to medicine, but was unable to continue his research when he immigrated to the United States fleeing Nazi persecution in the early 1930s.[19] The next improvements in fiberoptic technology were due to optical engineers such as Holger Moll-Hansen of Denmark and the American Brian O'Brien who considered the possibility of fiberoptics transmitting not only light, but also images. In 1953, in the confidential Dutch review "De Ingenieur," Abraham van Heel from Delft reported his experience of image transmission using fiber optics. The following year, two articles were published in the same issue of *Nature*—a brief note by van Heel on the "transport of images" and an extensive article on a flexible fiberscope by Harold Hopkins of London and his coworker Narinder Singh Kapany.[20,21] Hopkins and Kapany used a large number of very fine fibers while van Heel used a smaller number of larger fibers covered in a protective coat. Hopkins (well known for his invention of the zoom lense in 1949) was also recognized for his contribution to the development of "cold light."

The clinical application of fiberoptics to gastrointestinal (GI) endoscopy began as a result of a collaboration between Basil Hirschowitz and the physicist Larry Curtiss. They succeeded, with the aid of Corning Glass, in producing high quality fiberoptics resulting in the first clinical publication on gastroscopy in *Gastroenterology* in 1958.[22]

Prototype fiberscopes were made by American Cystoscope Makers (ACMI) in 1960 and a commercial model was produced in 1961 with the first color images published in the *Lancet*.[23] Because of the high prevalence of gastric cancer in Japan, the Machida Company developed fiberendoscopy and soon the technicians at Olympus, led by the engineer Kawahara, produced many fine models of high optical quality with side and front viewing.[24]

Max Epstein and coworkers at Northwestern University studied many technical aspects of fiberoptic endoscopy. They learned that a bundle of optical fibers could be drawn in a furnace in a manner that preserved their alignment. The resulting imaging structure is rigid because the individual fibers are fused together. The resolution of an aligned fiberoptic imaging structure is determined by the fiber diameter and is usually less than $\frac{1}{2}d$ where d is the fiber diameter. The fused multifiber is coated with an ultraviolet-cured polymer, which makes the structure quite flexible. This technique is similar to the one employed in the manufacture of optical fibers used in communication technology. The diameter of the individual fibers is on the order of 10 μm. They are soaked in binding epoxy during the winding process. The diameter of the imaging multifiber varies between 1 to 2 mm for miniature endoscopes such as angioscopes or pediatric bronchoscopes and 6 mm for large colonoscopes with lengths exceeding 2 m. Large multifibers may contain as many as 200,000 to 300,000 individual fibers, each providing one point of resolution or pixel.[25,26]

The gastroenterologist practicing 30 years ago had access to a therapeutic and diagnostic fiberendoscopic instrument. In the interim, endoscopy has benefited from computer technology, and today most endoscopy units are equipped with video-endoscopic equipment (see Chapter 2 "Endoscopic Equipment"). However, panendoscopy and enteroscopy (see Chapter 8 "Enteroscopy") do not readily permit examination of the more distal small intestine. Recently, development of the video-capsule (see Chapter 11 "Wireless Capsule Endoscopy") has facilitated visualization of the entire GI tract.

Fiberendoscopy In Pediatrics

Following the adaptation of fiberoptics for medical instruments during the late 1960s, endoscopy of the GI tract became a routine diagnostic and therapeutic tool in gastroenterology units throughout the world. Occasionally children were investigated in such units, but diagnosis of digestive diseases in children was mainly based on contrast radiology.[27,28] with technical improvements, especially reduction in instrument diameter, examination of the GI tract in children became feasible in the 1970s.[29,30] A few pediatricians began employing this new investigative technology in children.[31–38] In the beginning, collaboration with adult-trained endoscopists was necessary, but within a few years a few pediatric gastroenterologists had

become skilled endoscopists. Publications demonstrated the importance of pediatric endoscopy and its diagnostic and therapeutic value in contributing to our knowledge of many GI diseases in infants and children.[39–43] During the years 1978/1979, several papers confirmed the diagnostic benefit of endoscopy and biopsy compared with contrast radiology.[44–50] Although the literature was not readily accessible, similar skills were developing in Eastern Europe and Russia.[51–54] Less than 10 years after its introduction in pediatric gastroenterology, endoscopy was the subject of several books in Spanish, German, and English.[55–58] Today, training in gastroenterology is not complete without acquiring competence in diagnostic endoscopy.

The Instruments

The first pediatric fiberscope was the lateral viewing Olympus PGF-S which had no biopsy channel. In 1972, after a meeting of the European Society for Paediatric Gastroenterology in Hamburg, Olympus engineers adapted a slim industrial fiberscope for medical use. With this prototype instrument, safe endoscopy was performed in infants and children in Europe as well as in the United States.[29,30] Subsequently, the Olympus GIF-P (GI fiberscope), adapted from the slimmest EF-PA (esophagoscope) became commercially available and, despite its limited two-directional movement, was very useful in infants because of its small outer diameter (7.2 mm). The Olympus GIF-P2 followed and permitted movement in four directions. Similar instruments such as the ACMI TX7 and equivalent models by Machida, Fuji, Pentax, and Wolf became available. None of these instruments, however, was specifically designed for pediatric endoscopy, and their worldwide appeal was due mainly to their size and ease of use in adults.[59] For the newborn and small infants, some investigators used 5.3 mm bronchofiberscopes, although these instruments were not designed for the examination of the alimentary canal and were poorly suited for pediatric GI endoscopy.

In 1981, the first European workshop on pediatric GI endoscopy was held in Bern. Developmental priorities were discussed among "expert" European pediatric gastroenterologists and Olympus engineers. The Endoscopy division of Olympus Japan, directed by Kawahara, agreed to develop four new instruments for pediatrics: a slim general purpose 7.8 mm upper fiberscope, the GIF-XP; a slim 9.4 mm PCF colonoscope with variable flexibility; a very slim neonatoscope, such as the Olympus 5.3 mm N30 and an equivalent model by Pentax; and a lateral viewing duodenoscope.

In 2005, instruments exist that permit the safe examination of children of all ages. Many of these smaller instruments are part of the standard equipment found in an adult endoscopy unit. Whereas 15 years ago, the limiting factors were the quality of the instruments,[60] today there are instruments that can be used in children for most diagnostic and therapeutic problems. The improvements that have occurred in equipment and in sedation and anesthesia[61,62] in the past 30 years have transformed pediatric endoscopy and gastroenterology.

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Endoscopic Equipment

2

Jean-François Mougenot, Patrick Bontems, and Samy Cadranel

The use of flexible, fiberoptic endoscopy for the diagnosis of gastrointestinal (GI) disorders in children began in 1971.[1-4] Today, because of technical advances, fiberoptic endoscopes are being replaced by electronic video endoscopes, which use a different method of image transmission.[3-4] Both systems require a fiberoptic light guide and a complex objective lens at the distal end to focus the image. Their mechanical characteristics are similar. Endoscopes are waterproof, resistant to gastric acid and corrosive disinfectants and can be completely immersed for cleaning, decontamination, and disinfection.[5] They house an instrument channel to aspirate fluid and to introduce instruments, and two accessory channels to insufflate air and inject water.

Mechanical Design of Flexible Endoscopes

Distal Tip and Control Section

A typical fiberscope is shown in Figure 2-1 with nomenclature describing its various components. The control section is detailed in Figure 2-2. An end view of the distal tip of forward-viewing optic endoscope is illustrated in Figure 2-3. The instrument tip (Figure 2-4) is controlled by pull wires that are attached at the tip just beneath its outer protective shaft and extend along the length of the instrument shaft to the control section. The two angling controls for up/down and right/left movements have a friction braking system in order to temporarily fix the tip in any desired position.

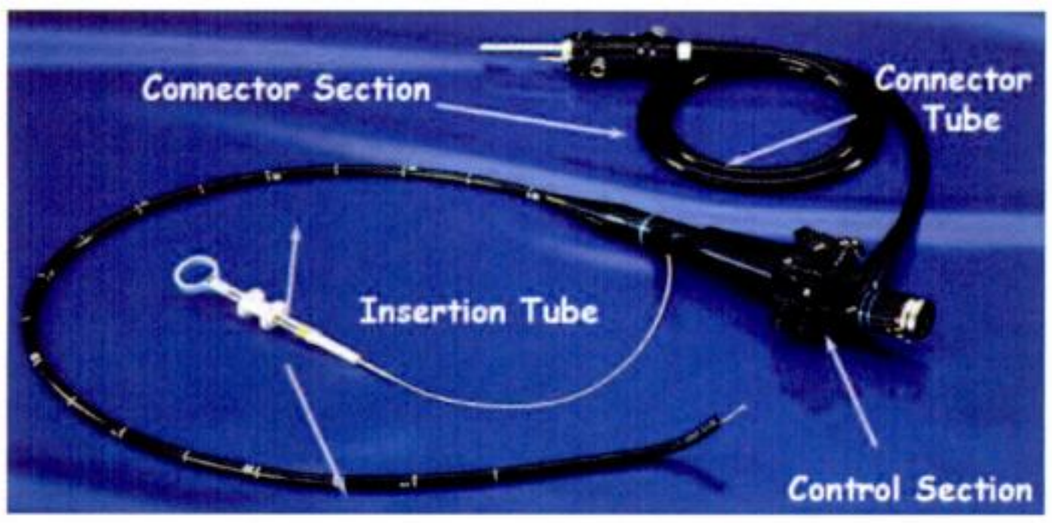


Figure 2-1. Various components of a fiberscope.

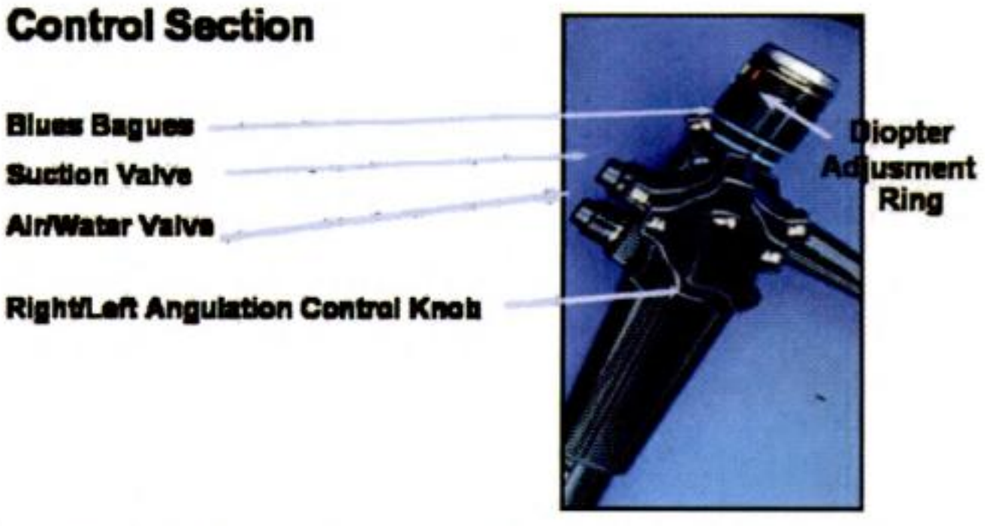


Figure 2-2. Control section of an Olympus fiberscope.

Insertion Tube

The construction of the insertion tube is shown in Figure 2-5. The various sheets of the tube are responsible for the mechanical properties of the endoscope. The instrument shaft is torque stable so that when the shaft is relatively straight, rotary or corkscrewing movements applied to the head are transmitted to the tip.

Air, Water, and Suction System

A cross-section (Figure 2-6) of the entire instrument illustrates the various internal channels for air, water, and suction. The functions of these channels are described in Figures 2-6 to 2-9. In the colonoscope, there is a separate proximal opening for the water channel that allows high-pressure flushing with a syringe. An operating channel (usually 2–3.8 mm in diameter) allows the passage of fine flexible accessories from a port on the endoscope control head through the shaft and into the field of view (see Figure 2-1). In some endoscopes, such as duodenoscopes with lateral-viewing optics, the distal tip incorporates a small

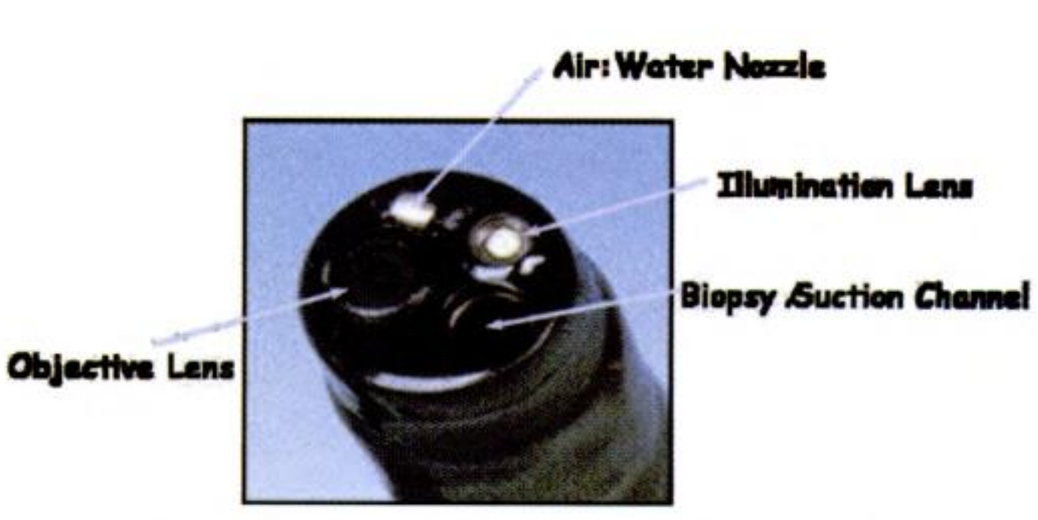


Figure 2-3. End view of the distal tip of a forward Olympus fiberscope.

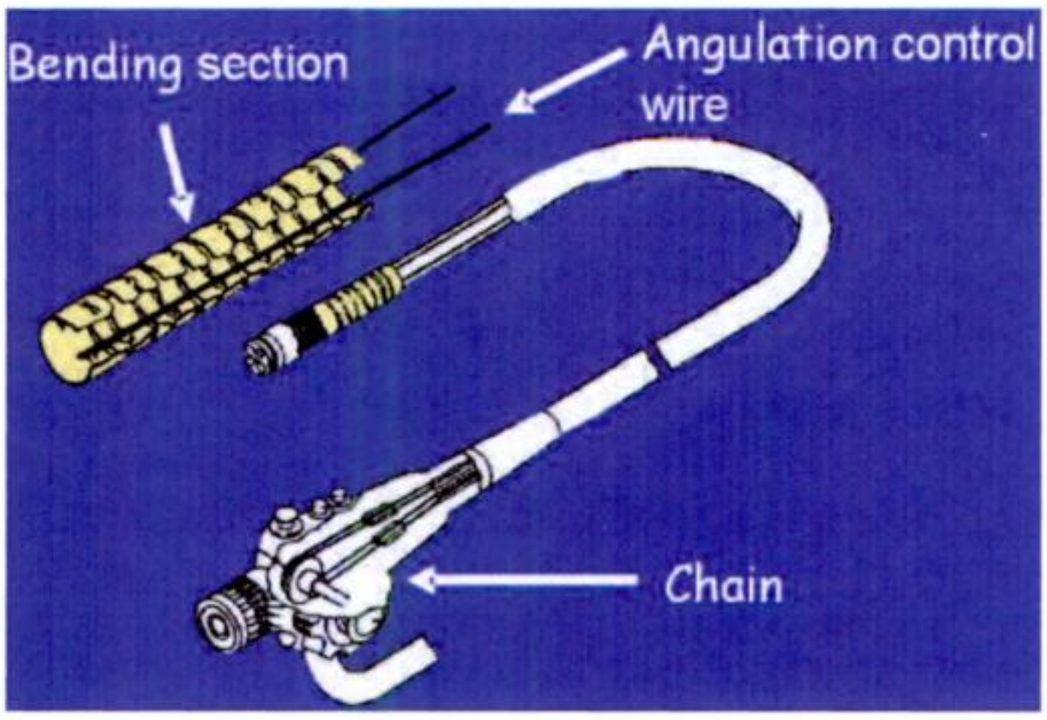


Figure 2-4. Bending section and angulation's system of a Fujinon endoscope.

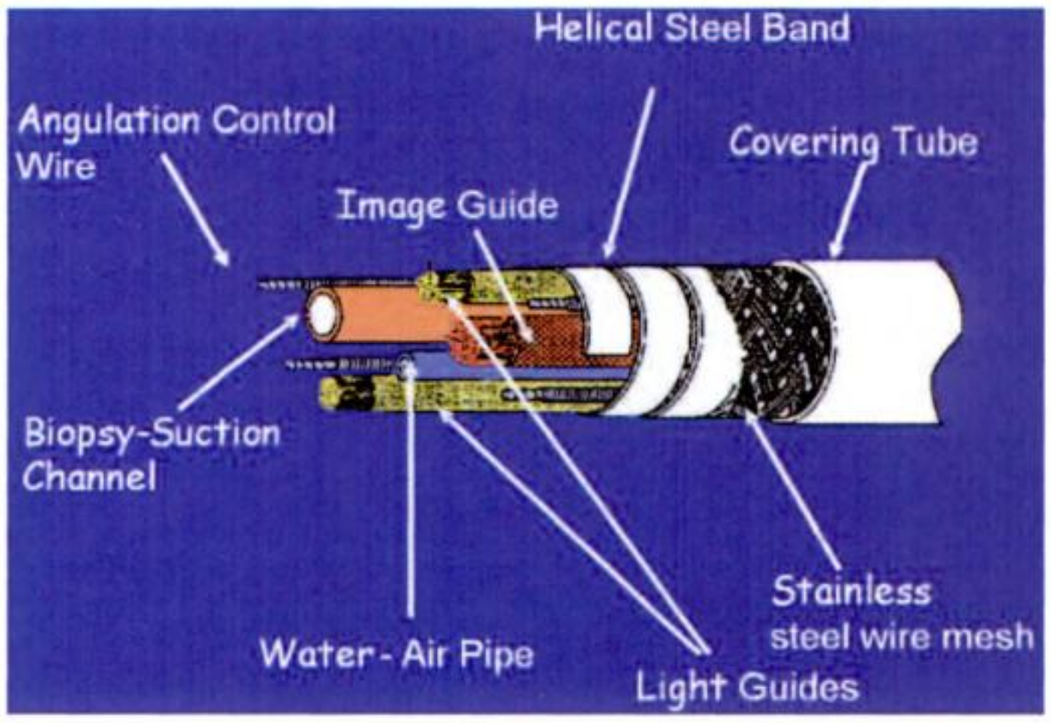


Figure 2-5. Internal components and construction of the insertion tube of a Fujinon flexible fiberscope.

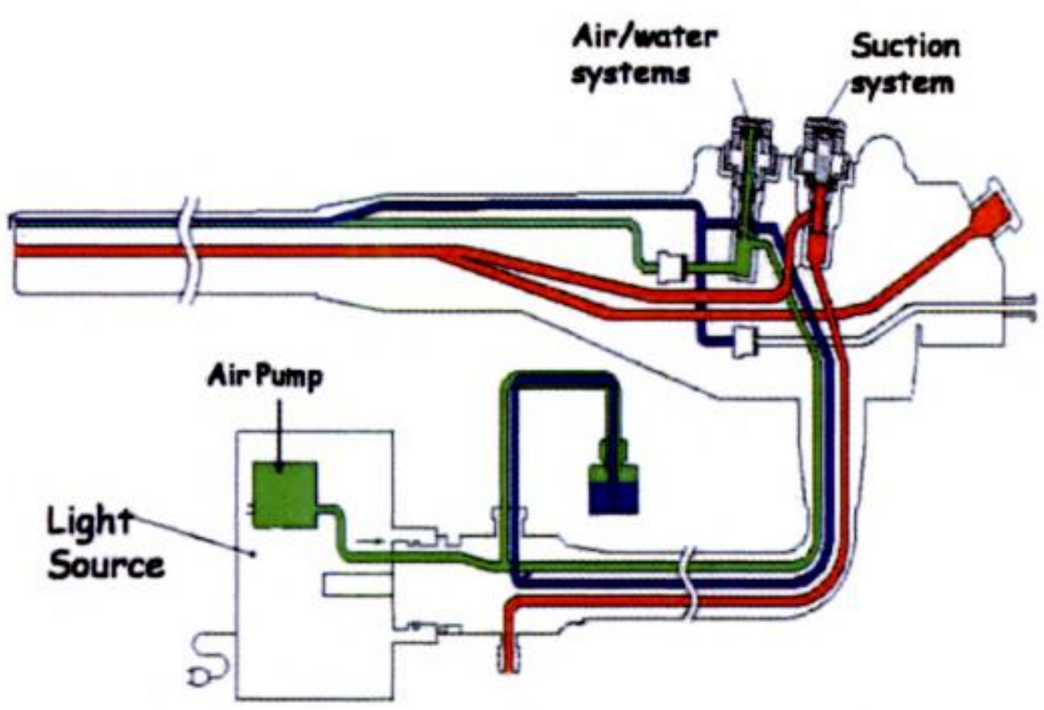


Figure 2-6. Air, water, and suction systems of a Fujinon endoscope.

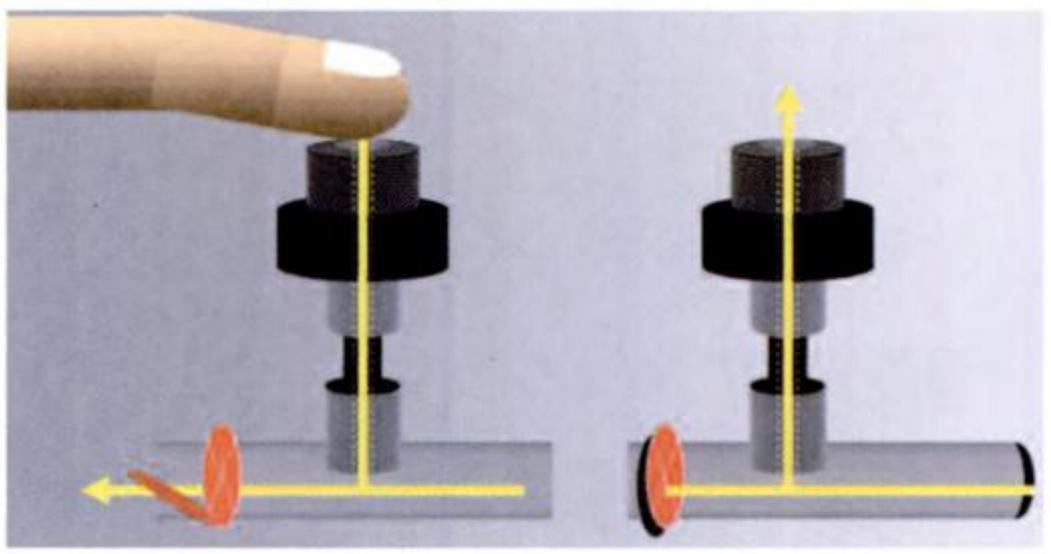


Figure 2-7. Air system. Air supplied by a pump within the light source unit is emitted from the nozzle on the distal tip when the opening in the air/water valve is covered.

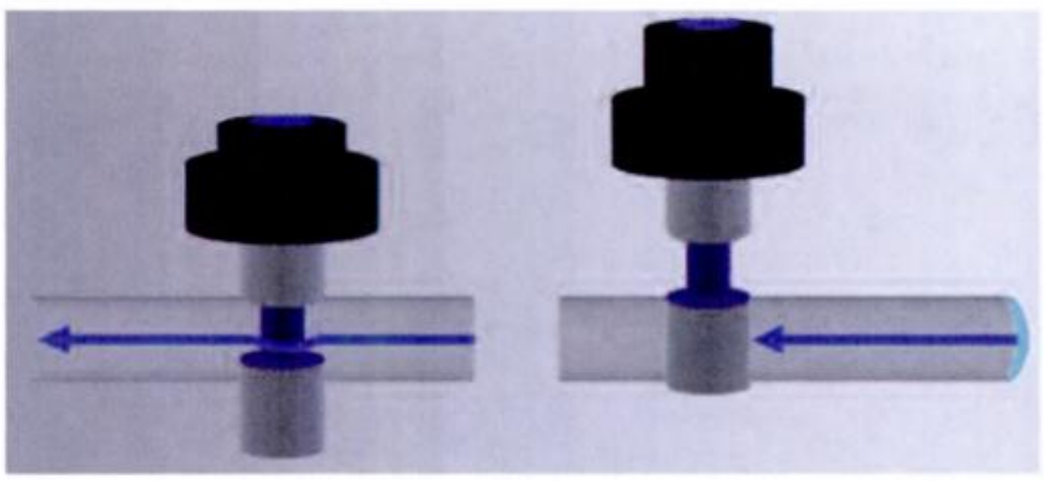


Figure 2-8. Water system. When the air/water valve is depressed, water is forced from the pressurized water container through the endoscope and out through a nozzle on the distal tip.

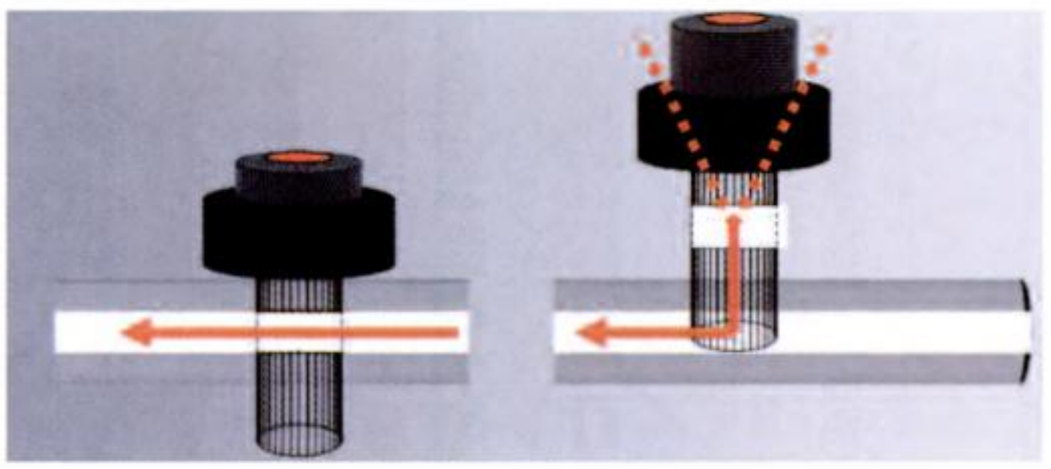


Figure 2-9. Suction system. Aspiration of either air or fluid through the endoscope is achieved by depressing the suction valve. The necessary negative pressure is provided by an external suction pump and collection bottle through a connector tube.

deflectable elevator, which permits some additional directional control of the accessories. This elevator is controlled by a special thumb lever.

FIBEROPTIC ENDOSCOPES

Optical Fibers and Total Internal Reflection

In the fiberoptic endoscope image, light transmission from the objective lens to the eyepiece is via bundles of long glass fibers (Figure 2-10) contained in cylinders of a material of lower refractory index. Each fiber is clad with a very thin layer of glass—the cladding glass having a lower index than the core glass. The coating acts as a mirror that reflects all light rays traveling along the core to the eyepiece (Figure 2-11).

Fiberoptic Bundles

Thousands of fibers aligned together make image transmission possible. For an image to be transmitted from one end of a fiber bundle to the other, the individual fibers must occupy exactly the same position at the two ends (Figure 2-12). This is called a "coherent bundle." The length and number of fibers within a fiberscope depend on the type and size of endoscope. The diameter of an optic fiber varies between 8 to 15 μm.

Optical System

The objective lens at the tip of the fiberscope forms an image of the object in view on the distal face of the image guide (Figure 2-13). This miniature image is limited by the size of the fiber bundle. The light representing this image is transmitted through the image guide and a duplicate image is formed on the proximal face of the bundle near the eyepiece. The bundle must be turned through 180 degrees to produce an upright image proximally because the objective lens produces an inverted image on the distal face of the bundle. The eyepiece or ocular lens functions as a magnifying glass and enlarges the tiny image at the tip of the bundle (see Figure 2-13).

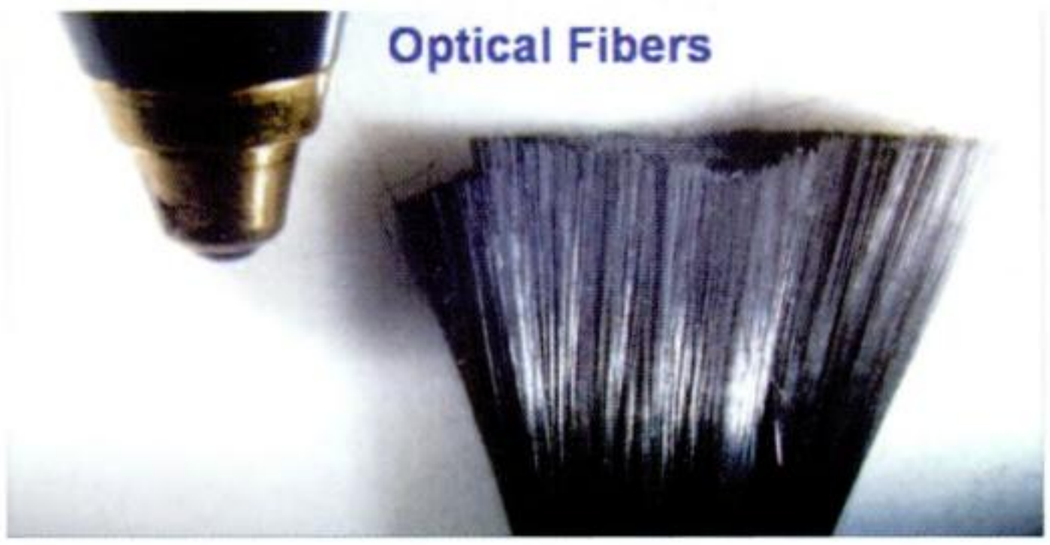


Figure 2-10. Optical fibers (Olympus).

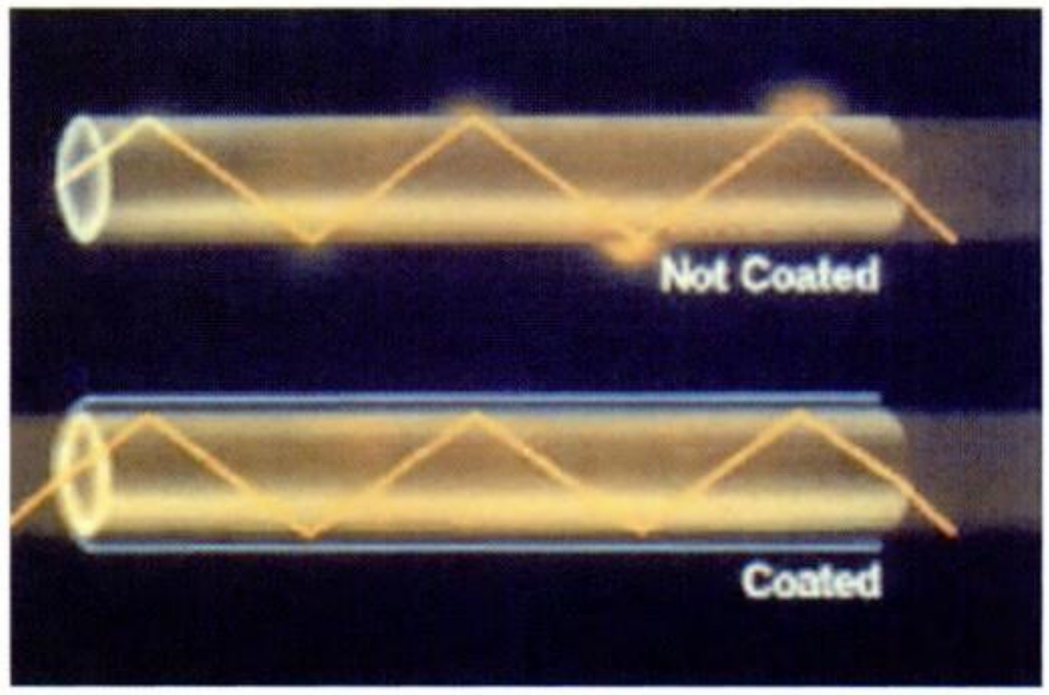


Figure 2-11. Path of light ray through an unclad and a clad glass fiber (Olympus).

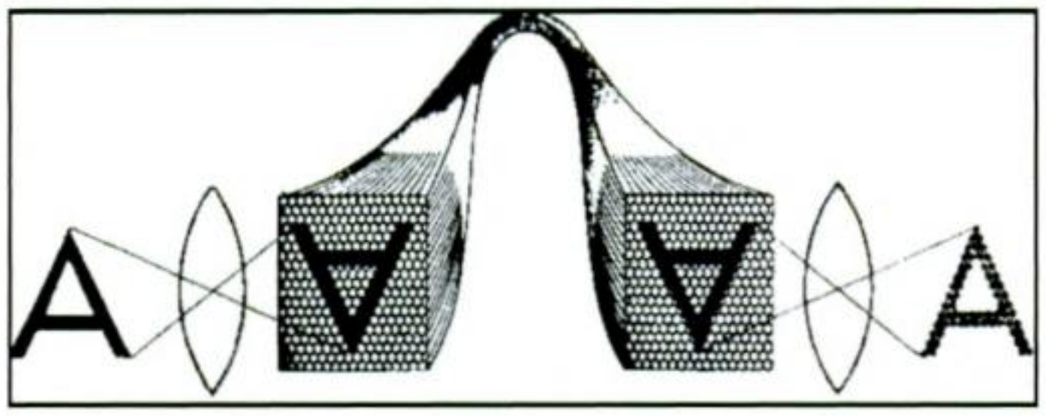


Figure 2-12. Alignment of fibers on the face of coherent fiber bundles (Olympus).

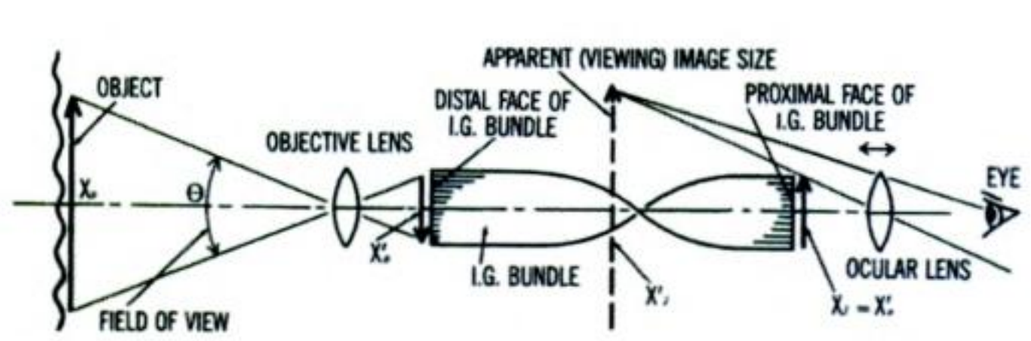


Figure 2-13. A basic fiberscope optical system. IG = image guide.

Video Endoscopes

In a video endoscope, the image is captured by a charge-coupled device (CCD) (Figures 2-14 and 2-15), transmitted electronically, and displayed on a video monitor. Viewing a monitor is more comfortable for the endoscopist, who does not need to look down through the eyepiece and who can view the image simultaneously with trainees and endoscopy assistants. However, there is substantial cost for video endoscopes and accessories.

CCD

CCDs are solid-state image sensors made of silicon semiconductor material. When a photon strikes the photosensitive surface of the CCD, it displaces an electron from a silicon atom. This produces a free negative charge and a positively charged hole is created by the absence of the electron in the regular crystalline structure of the silicon. To produce an image, the photosensitive surface is divided into a matrix of small, independent photosets, individually referred to as picture elements or pixels. An endoscope CCD may contain up to several hundred thousands pixels (Figure 2-16). A CCD is a black and white captor because the charge of the pixels depends simply on the intensity of the light. Two methods have been developed for color detection. The first uses a single-plate simultaneous color CCD chip technique in which color CCD pixels are arranged in a series of color filter stripes (Figures 2-17 and 2-18). The second uses a black and white or a sequential system CCD, which employs a rotating color filter wheel to illuminate all of the pixels with primary color strobe-effect lighting (Figure 2-19). When an image is focused on the surface of such sensors, the brightness of each discrete point in the image can be measured.

In a video endoscope, the CCD is located at the distal tip directly behind the objective lens (Figure 2-20). The components in the video endoscope tip include a fiberoptic light guide bundle to illuminate the GI mucosa, and an objective lens to focus the image on the CCD image sensor, and the sensor to capture the image. The CCD converts the light into an electronic signal that is sent to the processing unit where it is converted for output as a video signal in either RGB (red, green, blue) mode or Y-C (luminance-chrominance) for the monitor or other peripherals (printer, magnetoscope, computer).

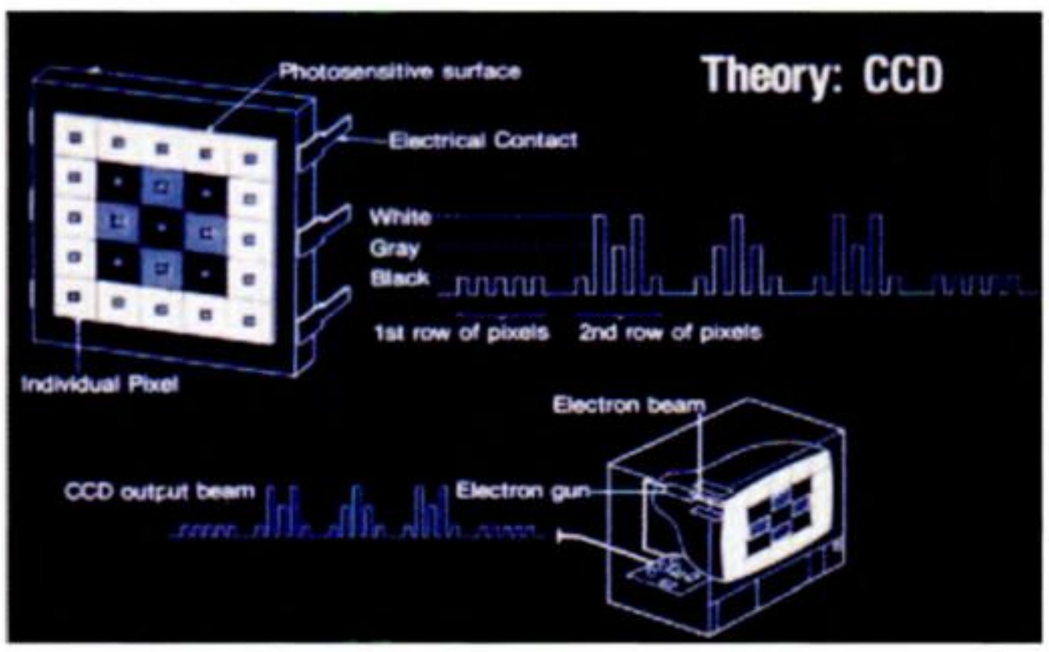


Figure 2-14. The photosensitive surface of a charge-coupled device image sensor is divided into a matrix of individual photosites called pixels (Olympus).

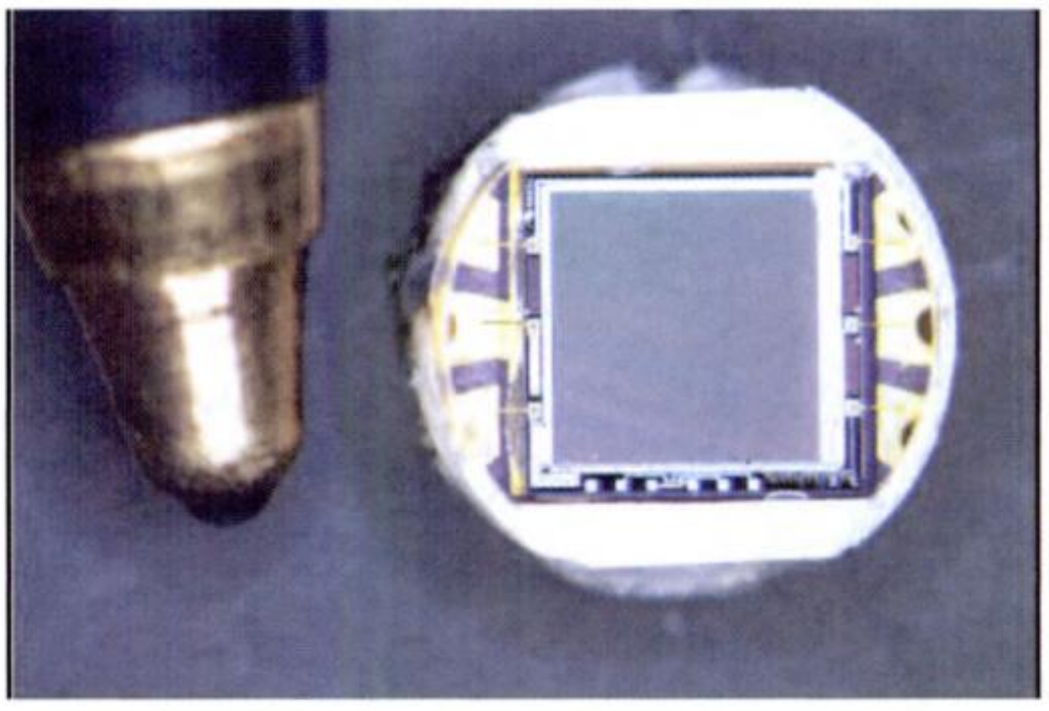


Figure 2-15. Olympus charge-coupled device chip.

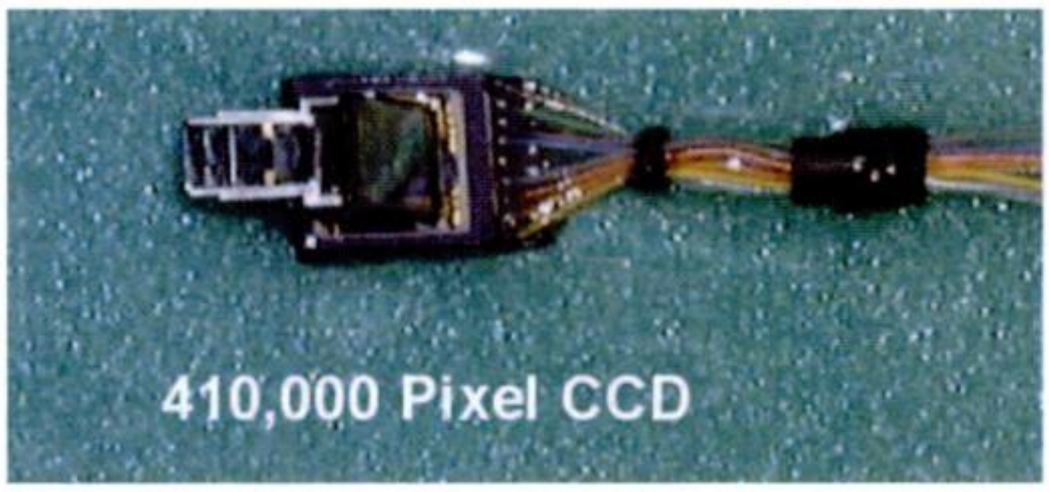


Figure 2-16. 410.000 pixels Fujinon charge-couple device (CCD) color chip.

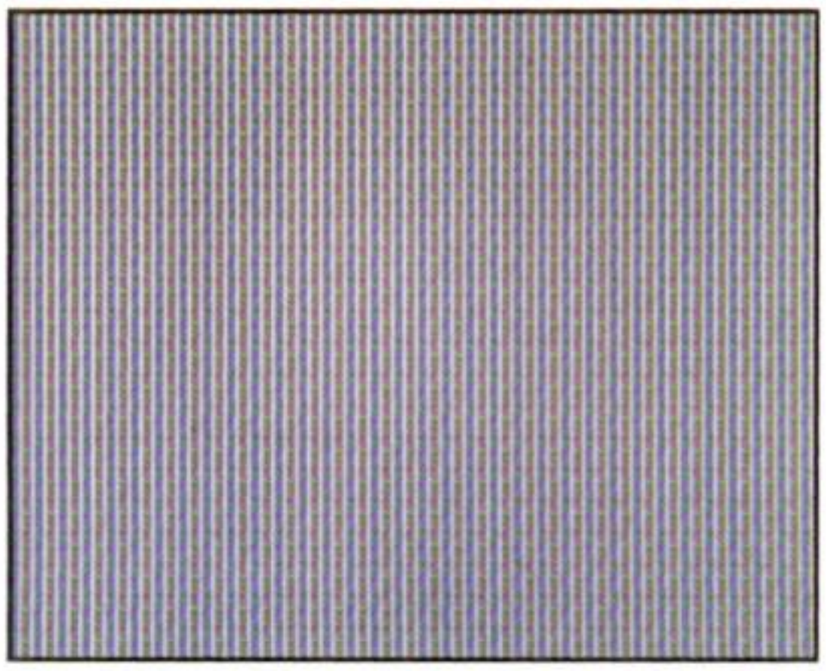


Figure 2-17. Static red, green, and blue filters in an Olympus charge-coupled device color chip.

ILLUMINATION

With fiberoptic endoscopes, illumination is provided from an external high-intensity light source delivered through one or two fiber bundles. But, since these light bundles do not transmit a spatial image, their fibers can be randomly arranged. To prevent reduction of light intensity, light bundles run without interruption from the tip of the instrument through its connector tube directly to the light source. The light source consists of a generator of cold light such as a xenon arc (300 W) or halogen-filled tungsten filament lamp (150 W), and a light transmission system with automatic light adjustment to ensure optimum brightness. A high-speed rotating filter (20 to 30 revolutions/second) is needed for the sequential RGB video endoscope. A parabolic mirror focuses the light onto the face of the bundle. Filters or a mechanical diaphragm control the transmitted light intensity. Usually the light sources made by different companies cannot be interchanged. Small light sources for fiberscopes are mobile and relatively cheap, and provide sufficient illumination for simple observation and standard photography. Large light sources are necessary for high quality photography and video recording with fiberscopes and for video endoscopes (Figures 2-21 to 2-23).

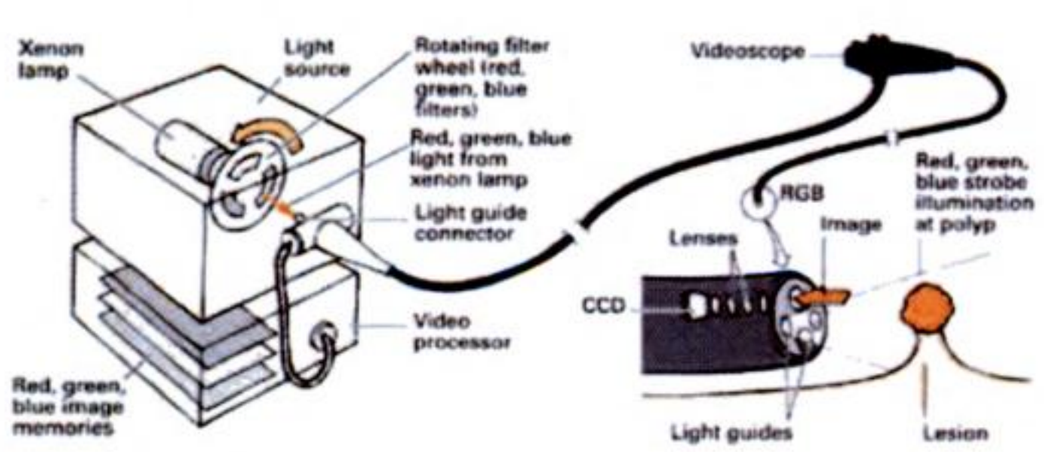


Figure 2-19. Sequential charge-coupled device (CCD) system.

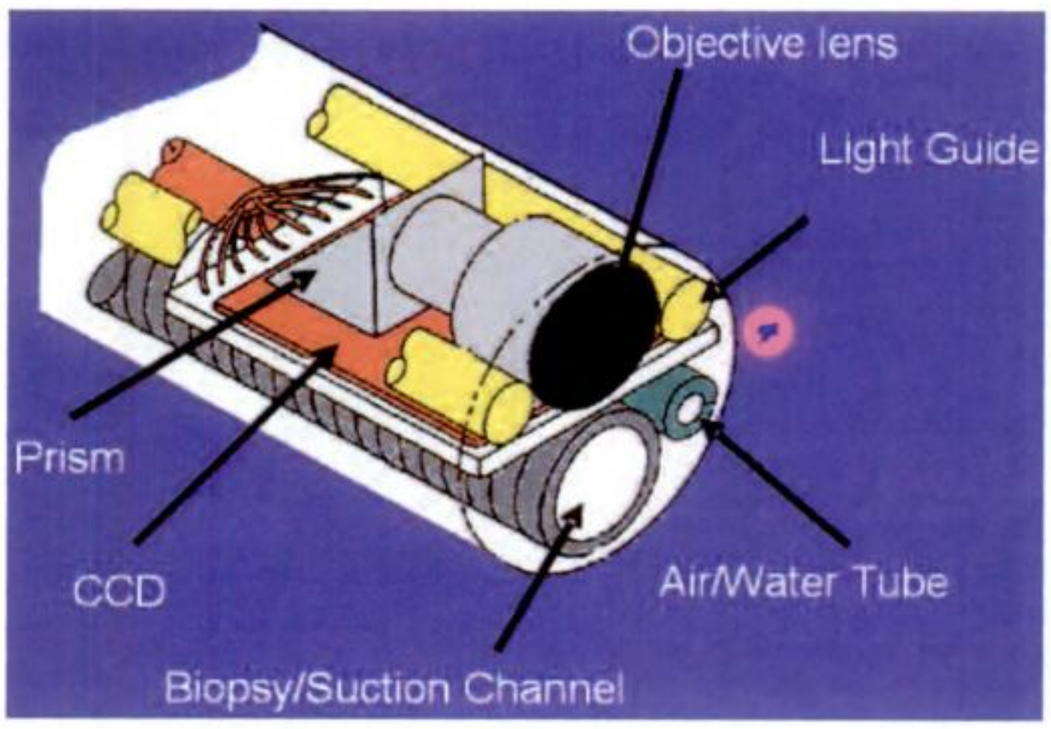


Figure 2-20. Components within a Fujinon video endoscope distal tip. CCD = charge-coupled device.

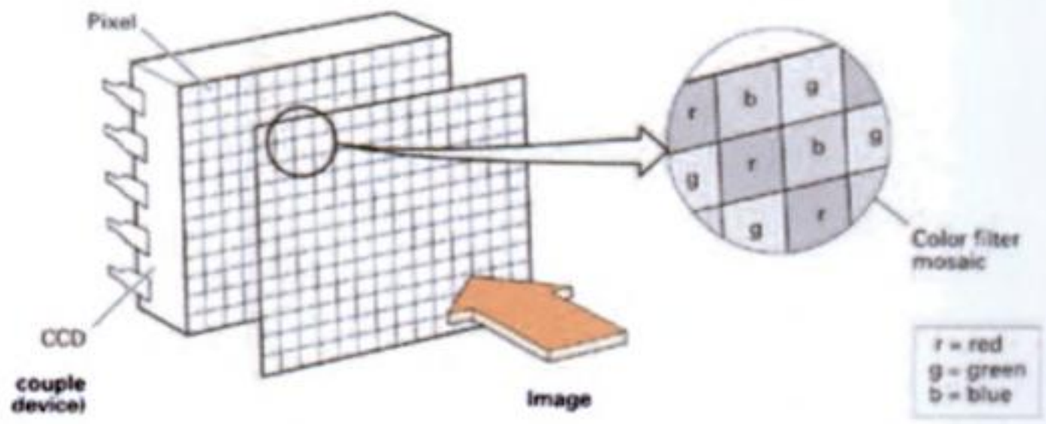


Figure 2-18. The charge-coupled device (CCD) color chip.

DIGITAL VERSUS ANALOG SIGNAL

The use of digital technology is increasingly displacing the analog format in the field of endoscopy. Digital formats are already the preferred technology in radiology, nuclear medicine, and cardiology. Analog signals are made up of continuously varying waveforms. Digital

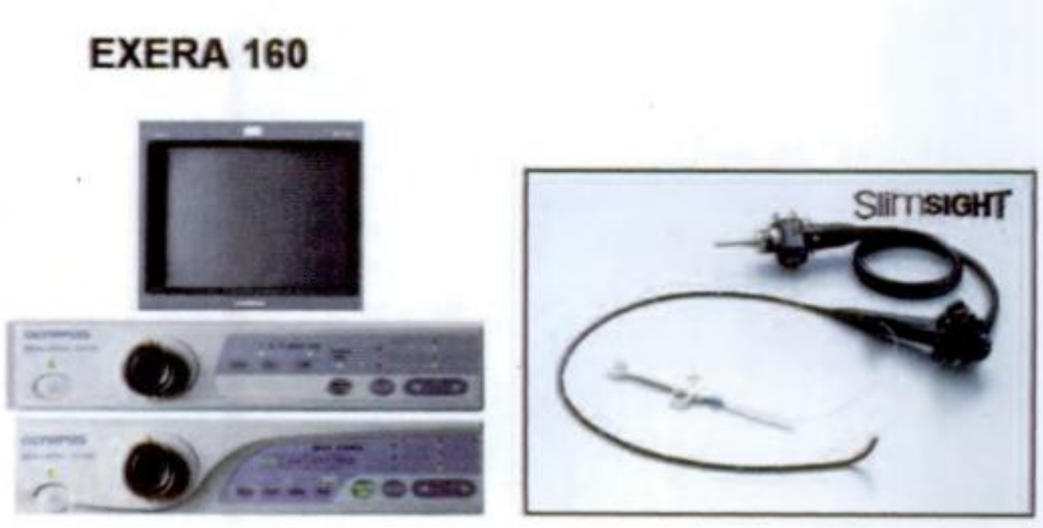


Figure 2-21. Olympus Exera 160 processor and light source.

Figure 2-22. Fujinon processor and light source EVE Σ 400.

Figure 2-23. Pentax processor and light source EPK-1000.

signals are based on a binary system. Digital technology offers several advantages in terms of high fidelity of transmission, unlimited duplication without loss of quality, and superior resolution. It facilitates quantitative analysis, and easy transfer of data to a personal computer. Digital video (DV) can be edited much more easily than material stored on an analog tape. It can be stored in structured archives, placed in electronic medical records, or imported into Internet Web pages that are accessible to multiple users. Images can be incorporated into "slide presentations." Finally, still images can be extracted for printed endoscopy reports.

Video Color Systems

Standard endoscopy monitors and computer monitors display RGB color. Each pixel is the product of the light coming from closely packed red, green, and blue phosphors. Because these phosphors are so close together, the eye blends the primary colors so that they are perceived as a single colored dot. In analog formats, typically, 8 bits of information are transmitted for each of the red, green, and blue components. With these 24 bits of information, over a million different variations of color are possible for each pixel.

Analog Video Signal

Various formats are available for analog video, including VHS (the lowest quality), s-VHS, Hi-8 and betaSP (the highest quality). They are composed of a luminance signal (transmitted in black and white) and color signals. For analog signals the type of connection between devices is extremely important to minimize noise. There are three basic types of connection. The simplest is the "composite connection." This uses a single coaxial cable to transmit the video signal. The luminance and color signal are combined and transmitted simultaneously. This is the lowest quality connection. A higher quality connection exists known as "S-Video." This separates the luminance signal onto one coaxial cable and the combined color signals onto another. The highest quality of connection is the "component video system," where the luminance signal and the red, green, and blue signals are each given their own coaxial cable. This is to be preferred for endoscopic usage.

DV Signal

If the video source is not digital, video capture devices are used to convert from analog to digital format. These usually consist of a video capture card in a computer, but a digital camcorder or a miniature stand-alone converter can also be used. A wide variety of analog video capture cards exist. Products differ in the type of video signal that they can digitize and in the quality of the digitized video produced. In most cases, when the video is digitized it is also compressed. Compression is necessary because of the huge volume of data being handled. A single frame of uncompressed video requires about one megabyte (MB) of storage space. This can be calculated by multiplying the horizontal resolution (720 pixels) by the vertical resolution (486 pixels), and multiplying this threefold to allow for the RGB color information. At the standard video rate of 30 frames per second, this would amount to about 30 MB per

second. In order to work with uncompressed video, one would need an extremely expensive disk array, capable of delivering this huge volume of data rapidly to the computer processor. The goal of compression is to reduce the data volume without affecting image quality. The amount of compression used depends on how the video is to be used. The widely used DV format (and variants such as DVCAM) compresses to a 5:1 ratio. Video accessed on the Web might be compressed to 50:1 or more.

For digital transmission, the most common form of connection is known as IEEE 1394, a standard for high-speed serial connections approved by the Institute of Electrical and Electronics Engineers. This standard is known by the trade names FireWire (Apple Computer) and i.LINK (Sony Corporation). The six wire IEEE 1394 cable transmits all information including video, audio, time code, and device control, thereby allowing control of the video source or camcorder from the computer. The ANSI/SMPTE 259M-1997 standard regulates the serial transfer of DV signals over a single video coaxial cable such as that previously used to transport analog signals in the composite video format. This standard, known as SDI (serial digital interface), allows high quality transmission of video, audio, and time code at less expense than the IEEE 1394 cable.

Advantages of the Digital Format in Endoscopy

The replacement of fiberoptic technology with video endoscopy has been a great advance. It has facilitated the use of video recordings and images, thus supporting the efficient storage and exchange of medical information. Increasingly, these are used in the assessment of trainees' procedural skills. Commercially available software allows the integration of pictures into endoscopy reports. The quality of video sequences obtained with digital technology is significantly better. Current technology permits direct saving of video images in digital format and is a valuable advance. Such equipment is currently sold by Sony. The DAVE (Digital Audio Video Endoscopy) website at Massachusetts General Hospital can be viewed at <www.thedaveproject.org> and is a collection of digital endoscopic video clips that can be accessed free of charge and downloaded to a personal computer. The DICOM (Digital Imaging and Communications in Medicine) standard <http://medical.nema.org/> consists of a series of documents that defines a method of communication for digital medical imaging devices. This standard is now in use by most medical imaging hardware manufacturers, except in endoscopy. The DICOM standard was created in order to facilitate the distribution and viewing of medical images. A single DICOM file contains a header, which stores information about the patient's name, the type of scan, image dimensions, etc, and the image data. As such, a structured archive of video sequences and images is held as single files on a server. Inexpensive DICOM server and viewing applications are readily found and can be shared by various departments such as radiology, nuclear medicine, and cardiology within a hospital. This can facilitate the correlation of data across disciplines.

Gastrointestinal Endoscopes

Most endoscopes share the same basic design principles, but they differ in their technical characteristics, especially length, diameter, stiffness, and distal lens orientation. In children, GI endoscopy is nearly always performed with instruments providing direct forward vision, via a 90° to 140° wide-angle lens.[6] But, for some purposes, such as endoscopic retrograde cholangiopancreatography (Figures 2-24 and 2-25), lateral-viewing instruments may be required.

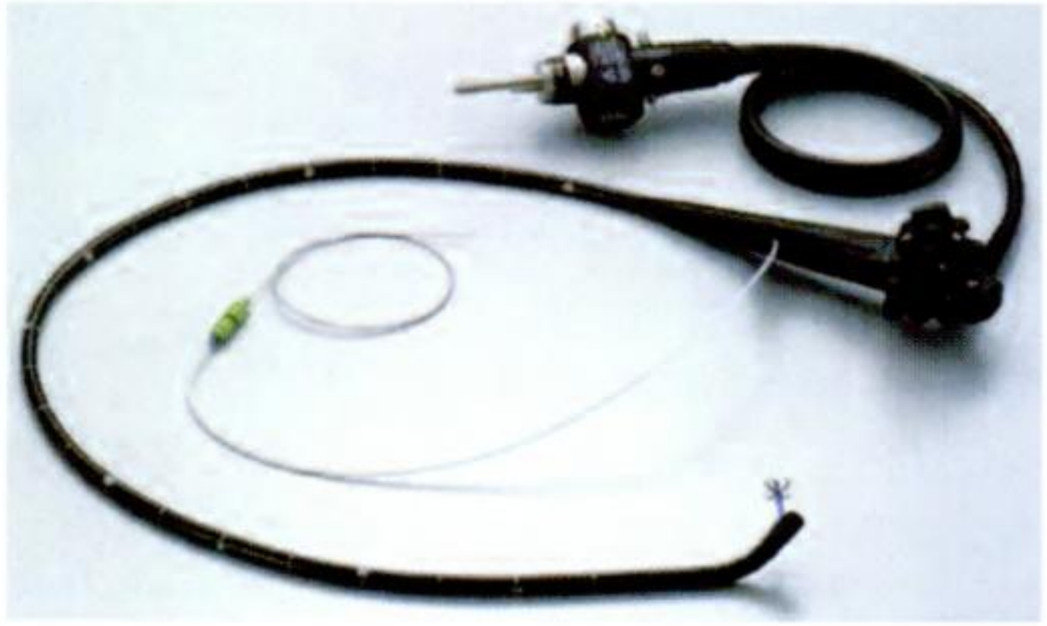


Figure 2-24. Videoduodenoscope Olympus.

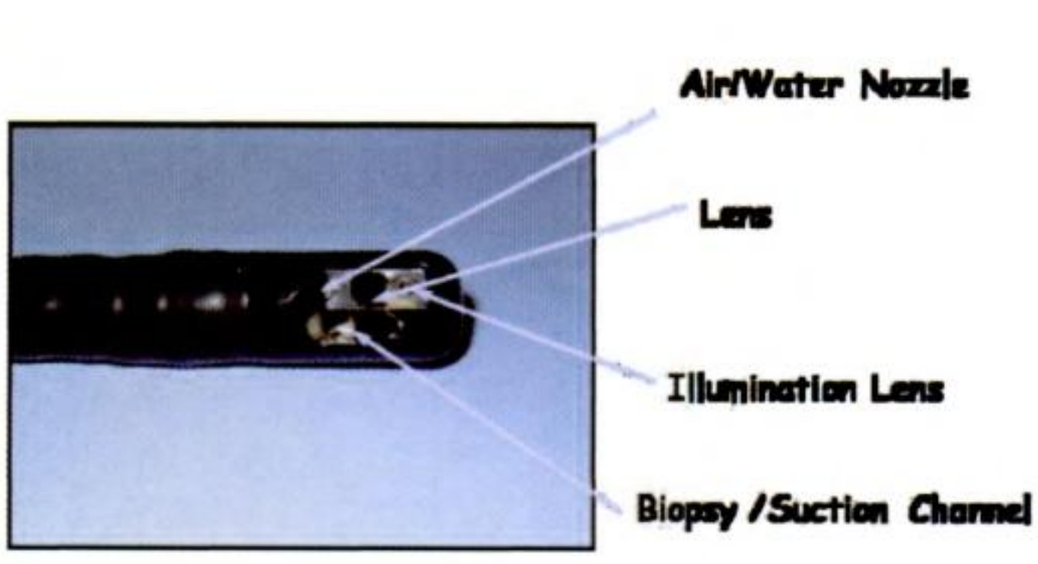


Figure 2-25. End view of distal tip section of Olympus duodenoscope.

In pediatric practice, an important consideration is the choice of an appropriate scope depending on the age and size of the patient. Several companies, such as Fujinon, Olympus, and Pentax, now produce a full range of endoscopes. It should be remembered that light sources, processors, video endoscopes, and some accessories are not interchangeable. Smaller endoscopes (5.7 to 6 mm) are preferred for neonates and infants. These smaller instruments have disadvantages in relation to image resolution, biopsy size, and durability. Moreover, only larger instruments with sufficiently large operating channels are suited for therapeutic endoscopy.

Gastroduodenoscopes

Gastroduodenoscopes are highly flexible instruments, have a quadridirectional bending capacity, and allow a complete inspection of the upper intestinal tract from the esophagus to the second or third portion of the duodenum. The gastric cardia can be inspected by retroflexion.

The following guidelines can help in the choice of an appropriate instrument: up to 15 kg, a 9 mm diameter; from 5 to 15 kg, 8 mm; in newborns (2.5 to 4 kg), 5 to 7 mm; less than 2.5 kg, 5 to 6 mm. In other words, only the ultra thin endoscopes such as GIF-XP160 (Olympus), GIF-N230 (Olympus), EG-470N5 (Fujinon), FG-15-W (Pentax), EG-1580 (Pentax) and EG-1870K (Pentax) are suitable for use in newborns. The GIF-XP20 (Olympus), GIF-XP160 (Olympus), GIF-XP-240 (Olympus), FG-24W (Pentax), and FG-1ZP (Fujinon) can be used in infants up to 2 years of age. Above that age it is better to use the GIF-P160 (Olympus). The EG-450PE5 (Fujinon) can be used in children 2 to 7 years old. In patients older than 7 years, the GIF-XQ40 (Olympus), GIF-160 (Olympus), EG-450WR5 (Fujinon), or EG-2470K (Pentax) are preferred. The scopes incorporating a 2.8 mm instrument channel are best for therapeutic procedures. General anesthesia with tracheal intubation permits the use of these instruments in patients as young as 3 months. Tables 2-1A and 1B summarize the technical characteristics of many gastroduodenoscopes suitable for pediatric practice.

Colonoscopes

Pediatric Colonoscopes

Pediatric single-channel colonoscopes have been developed with the following characteristics: length: 133 to 150 cm; diameter: 11.1 to 11.7 mm; accessory channel: 3.2 mm (Table 2-2). They have a narrow tip deflection radius and short bending section, adapted for pediatric use. At this time there is no colonoscope specifically designed for young infants. Despite their asymmetrical distal bending and excessive stiffness, tiny gastroduodenoscopes must therefore be used for colonic examination in infants less than one year of age.

Variable Stiffness Instrument

A variable-stiffness pediatric colonoscope has recently been produced by Olympus (Figures 2-26 to 2-29).[7] Rotating a knob on the control section modifies the flexibility of the shaft from highly flexible to twice the stiffness of a conventional instrument. It can be used in the floppy mode to pass through tight bends and then can be stiffened to prevent looping.

Magnetic Endoscope Imaging

Magnetic endoscope imaging (MEI) technology has made it possible to demonstrate loops and to locate the instrument tip during colonoscopic intubation.[8] Tiny wire coils are positioned at intervals along the colonoscope shaft (Figure 2-30). Each coil sequentially generates a low-strength magnetic field, which induces a current in larger receiver coils contained within a box alongside the patient. By calculating the strength of the current in each sensor coil, the exact distance from sensor coils to generator coils can be determined. The system generates a moving three-dimensional image on a computer monitor (Figures 2-31 and 2-32). This system, commercialized by Olympus as Scop Guide (Figure 2-33), is completely safe, except for patients with cardiac pacemakers, and can be a valuable help for beginners.

Carbon Dioxide

Nowadays few colonoscopists use CO_2 insufflation because colonoscopic bowel preparation regimens do not lead to production of gas in the colon. This eliminates the risk of gas explosion during electrocautery. Nevertheless, CO_2 insufflation may be of potential benefit for the patient's comfort because CO_2 is cleared much faster than air.[9] Colonoscopy with CO_2 insufflation can reduce painful abdominal distension. It requires low-pressure, metered-flow CO_2 delivery systems and a special CO_2 insufflation button.

Enteroscopes

Available enteroscopes are detailed in Tables 2-3 and 2-4, and in Figures 2-34 and 2-35.

Table 2-1A. Technical Characteristics of Gastroduodenoscopes

Endoscopes FUJINON	FV°	Depth View mm	WL mm	IT mm	Bending° Up/Down Right/Left	Ch ID mm
Fiberscopes						
FG-1ZP	105°	3–100	1030	7.8	210–90 100–100	2.2
FG-1Z	105°	3–100	1030	9.8	210–90 100–100	
Video-Endoscopes : 200 system						
EG-270N	120°	3–100	1100	5.9	210–90 100–100	2.0
EG-250PE 410K CCD	120°	5-100	1100	8.2	210–90 100–100	2.2
EG-250WR5 410K CCD	140°	5-100	1100	9.4	210–90 100–100	2.8
Video-Endoscopes : 400 system						
EG-470N5	120°	2–100	1100	5.9	210–90 100–100	2
EG-450PE5 410K CCD	120°	4–100	1100	8.2	210–90 100–100	2.2
EG-450 WR5 410K CCD	140°	4–100	1100	9.4	210–90 100–100	2.8
EG-450 ZW5 410K CCD Optical magnification ×100	140° Tele: 65°	6–100 Tele: 1.5–3	1100	9.8	210–90 100–100	2.8
Video-Endoscopes series 490 with Super CCD 1,200000 Pixels						
EG-490WR5	140°	6–100	1100	9.8	210–90 100–100	2.8
EG-490ZW5 Optical magnification ×100	140° Tele: 55°	6–100 Tele: 2–3	1100	10.8	210–90 100–100	2.8
Duodenoscope						
ED-450XL8 XL8: **detachable D8cap**	100° retro 15°	4–60	1250	12.5	130–90 90–110	3.2

Ch ID = channel inner diameter; FV = field of view; IT = insertion tube; WL = working length.

Table 2-1A Continued. Technical Characteristics of Gastroduodenoscopes

Endoscopes OLYMPUS	FV°	Depth View mm	WL mm	IT mm	Bending° Up/Down Right/Left	Ch ID mm
EOS						
GIF-XP20	100°	3–100	1030	7.9	210–90 100–100	2.0
GIF-P30	120°	3–100	1030	9.0	210–90 100–100	2.2
GIF-XQ40	120°	3–100	1030	9.8	210–90 100–100	2.8
EVIS (video) EXERA Gastroscopes						
GIF-XP-160 SlimSIGHT	120°	3–100	1030	5.9	180–90 100–100	2.0
GIF-160	140°	3–100	1030	8.6	210–90 100–100	2.8
GIF-Q160	140°	3–100	1030	9.5	210–90 100–100	2.8
GIF-Q160Z Zoom	140°/ 75° (tele)	8–100/ 1.5–3 (tele)	1030	10.9	210–90 100–100	2.8
Duodenoscopes						
PJF-160 special order	100°/ 5° retro	2–60	1235	7.5	120–90 90–90	2.0
TJF-160VR	100°/ 5° retro	5–60	1240	11.3	120–90 110–90	4.2
EVIS (video) 230, 240 and 260						
GIF-N-230	120°	3–50	960	6	H/B 180–180 D/G 160–160	2
GIF-XP-240	120°	3–100	1030	7.7	H/B 210–90 D/G 100-100	2.2
GIF-XQ-260	140°	3–100	1030	9.0	Idem	2.8
JF-240	100°	3–60	1240	12.6	H/B 120–90 D/G 110–90	3.2

Ch ID = channel inner diameter; FV = field of view; IT = insertion tube; WL = working length.

Table 2-1A Continued. Technical Characteristics of Gastroduodenoscopes

Endoscopes PENTAX	FV°	Depth View mm	WL mm	IT mm	Bending° Up/Down Right/Left	Ch ID mm
Series W						
FG-15W	95°	3–50	0925	5.3	180–180 160–160	2
FG-24W	105°	3–100	1050	7.8	210–120 120–120	2.4
FG-29W	120°	3–100	1050	9.8	210–120 120–120	2.8
Video Series 70K Gastroscopes						
EG-1580	140°	5-100	1050	5.6	210-120	2.0
EG-1870K	140°	5–100	1050	6.0	210–120 120–120	2.0
EG-2470K	140°	5–100	1050	8	210–120 120–120	2.4
Duodenoscopes						
ED-2370K	140°	5-100	1250	7,8	120/90 110/90	2.8
ED-3270K	140°	5–100	1250	13	120–90 110–90	3.2

Ch ID = channel inner diameter; FV = field of view; IT = insertion tube; WL = working length.

Table 2-1B. Main Characteristics of Specially Designed Forward-Viewing Gastroscopes

Type	Field of View	Outer Diameter mm	Biopsy Channel mm	Working Length mm
Large Channel	100–120°	11.2–13.2	3.7–6	1050–1160
Double Channel	100–120°	12.6–12.9	2.8 and 3.7/3.8	1010–1090

Table 2-2. Technical Characteristics of Colonoscopes Used in Pediatrics

Endoscopes	FV°	Depth View mm	WL mm	IT mm	Bending° Up/Down Right/Left	Ch ID mm
FUJINON						
G5						
EC-450	140°	3–100	1330	11.1	180–180	3.2
MP/LP5			1690		160–160	
410K CCD						
EC-450-WI5	140°	3–100	1520	12.8	180–180	3.8
410K CCD					160–160	
490 Series with Super CCD						
1,200000 Pixels						
EC-490ZWR	140°	6–100	1330	12.8	180–180	3.8
M/L	Tele: 55°	Tele:	1690		160–160	
Optical magnification ×100		2–3				
14" Monitor						
OLYMPUS						
EVIS						
160 EXERA						
PCF-160-AI/L	140°	3–100	1330	11.5	180–180	3.2
Innoflex			1680		160–160	
CF-Q160-AI/L	140°	3–100	1330	12.8	180–180	3.7
Innoflex			1680		160–160	
CF-Q160ZI/L	140°	7–100	1330	12.8	180–180	3.7
Zoom	50° Tele	2–3 Tele	1680		160–160	
CF-Q160DI/L	140°	3–100	1330	13.2	180–180	3.7
ScopeGuide			1680		160–160	
EVIS						
200-240						
PCF-240I	140°	4–100	1330	11.3	Idem	3.2
CF-Q260A1	140°	3–100	1330	12.2	Idem	3.2
PENTAX						
EC-3485 FK	140°	5–100	1500	11.7	180–180	3.5
					160–160	

Ch ID = channel inner diameter; FV = field of view; IT = insertion tube; WL = working length.

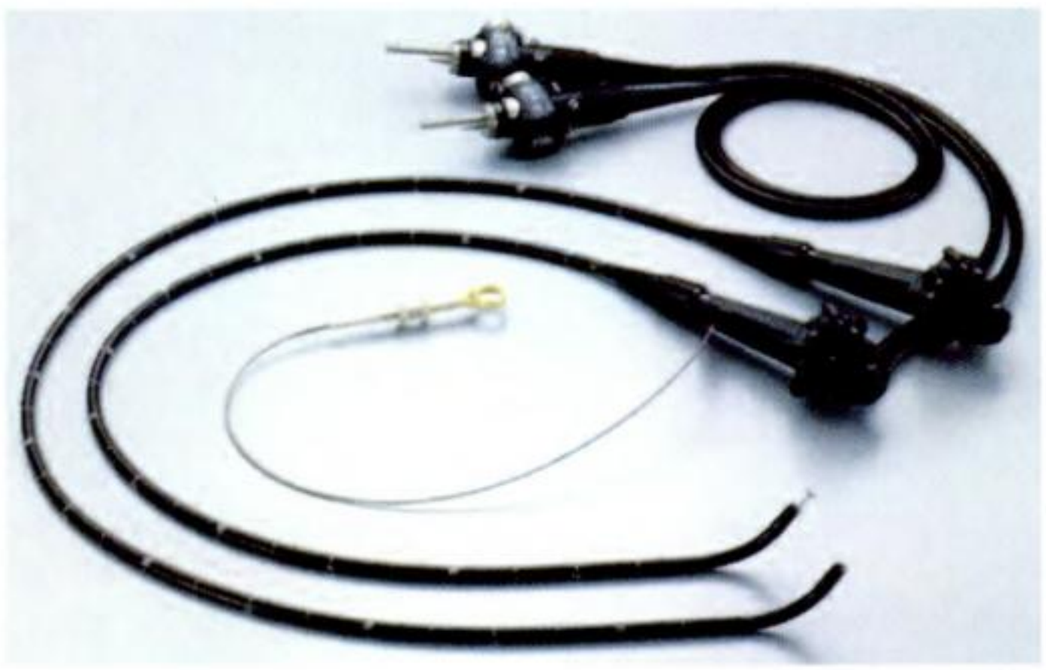


Figure 2-26. Variable stiffness Olympus colonoscopes.

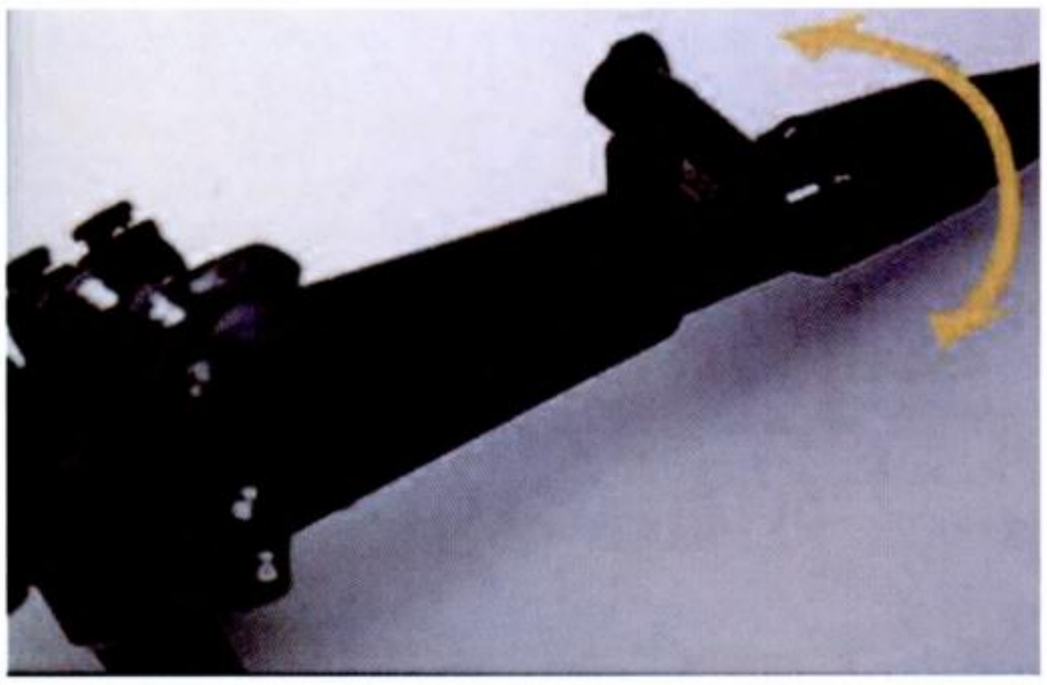


Figure 2-27. Variable-stiffness Olympus colonoscope: the dial below the head is twisted to increase or decrease shaft stiffness.

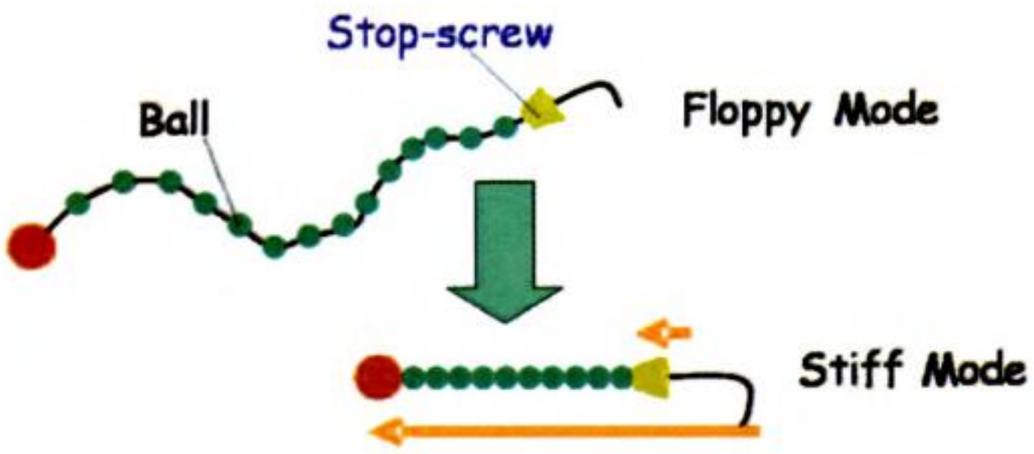


Figure 2-28. Principle of variable-stiffness Olympus colonoscope.

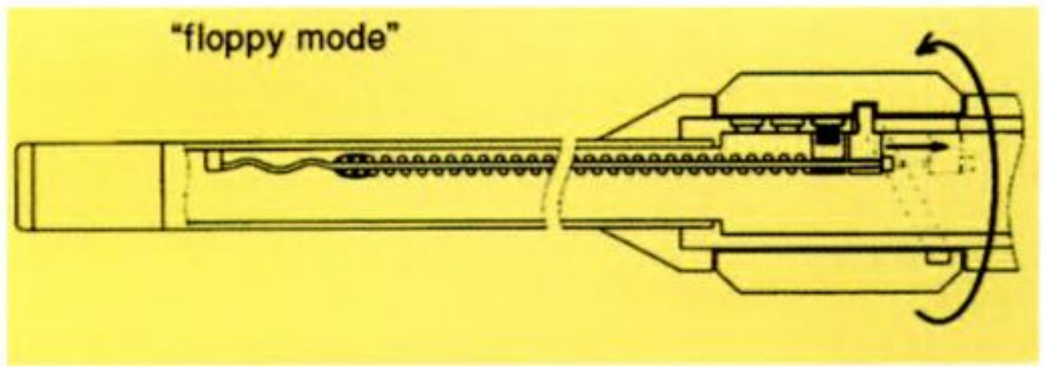


Figure 2-29. Design of variable-stiffness Olympus colonoscope.

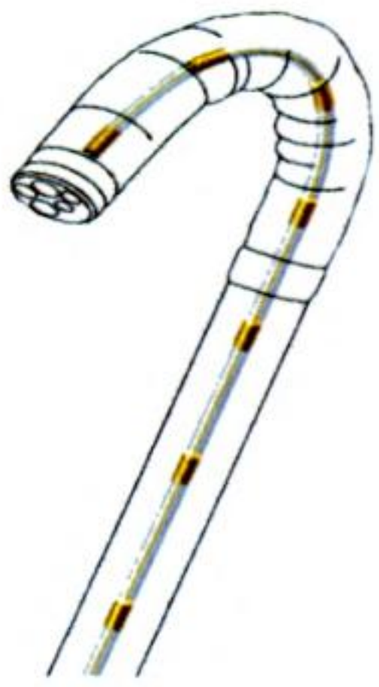


Figure 2-30. Magnetic endoscope imaging: small coils within the shaft of an Olympus colonoscope.

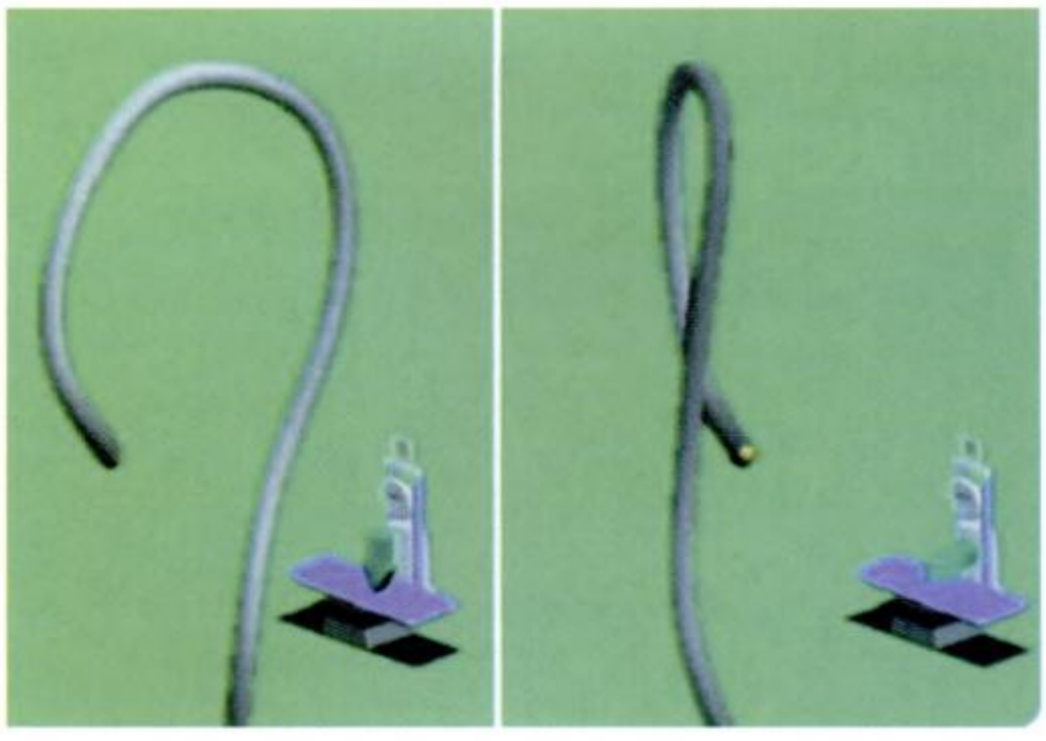


Figure 2-31. Magnetic endoscope imaging: the imaging display showing anterior-posterior and lateral view of a sigmoid loop.

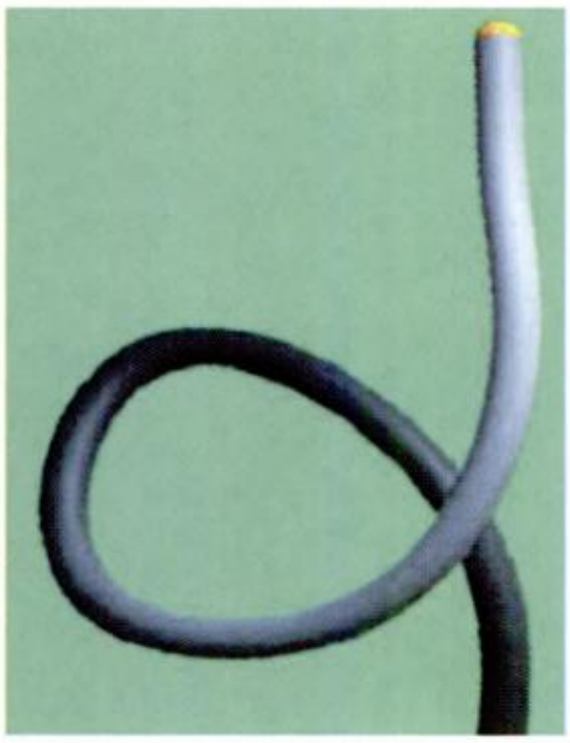


Figure 2-32. Magnetic endoscope imaging: an alpha loop.

Figure 2-33. Scope Guide, Olympus.

There are no enteroscopes and overtubes specifically designed for pediatric use because indications for this technique in children are rare. Overtubes, which stiffen the enteroscope within the stomach and upper duodenum, reducing looping and allowing advancement along the small bowel, are difficult to use in children and pose a risk of trauma to the pharynx and upper esophagus.[10]

Table 2-3.Characteristics of Commercially Available Enteroscopes Olympus

Olympus	SIF-10	SIF-Q140	SIF-Q240
Outer Diameter mm			
Distal end	11.2	10.4	10.2
Insertion Tube	11.3	10.5	9.8
Inner Diameter Channel Instrument mm	2.8	2.8	2.8
Total Length mm	1675	2500	2000
Bending			
Up/Down	180°/180°	180°/180°	180°/180°
Right/Left	160°/160°	160°/160°	160°/160°
Field of View	100°	140°	140°
Depth of View mm	5–100	4–100	4–100
Type of CCD	—	Color chip	Black & white chip

CCD = charge-coupled device.

Table 2-4.Characteristics of Commercially Available Enteroscopes Fujinon and Pentax

	Pentax VSB-3440	Fujinon EN-450P5/20 double balloon	Fujinon EN-410 WM23
Outer Diameter mm			
Distal end	11.5	8.5	10.5
Insertion Tube	11.7	8.5	10.7
Inner Diameter Channel Instrument mm	3.8	2.2	2.8
Total Length mm	2200	2000	2300
Bending			
Up/Down	180°/180°	180°/180°	180°/180°
Right/Left	160°/160°	160°/160°	160°/160°
Field of View	140°	120°	140°
Depth of View mm	5–100	5–100	4–100
Type of CCD	Color chip	Color chip	Color chip

CCD = charge-coupled device.

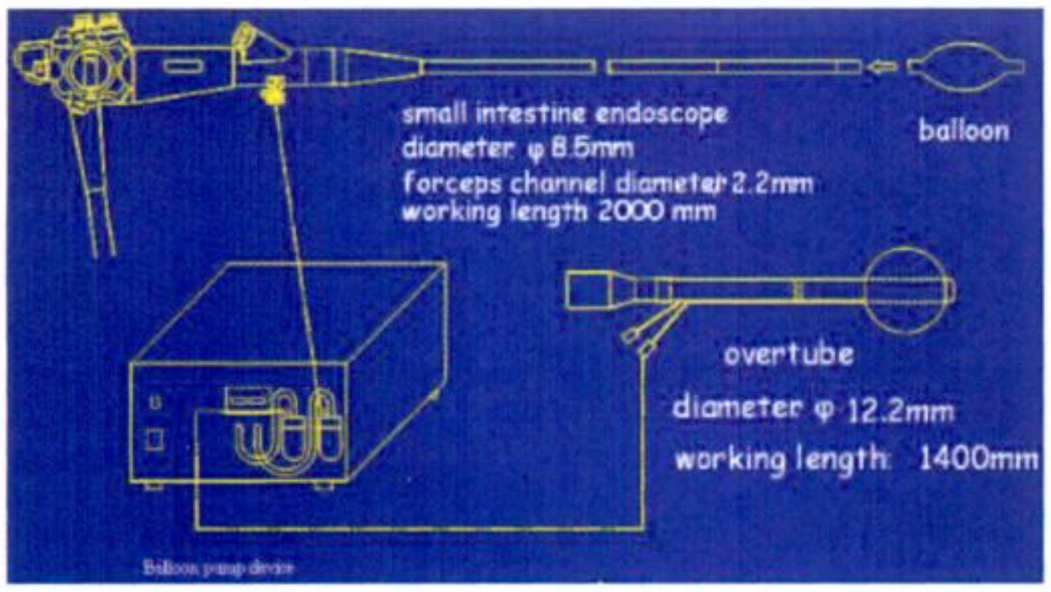


Figure 2-34. System of a Fujinon double-balloon enteroscope.

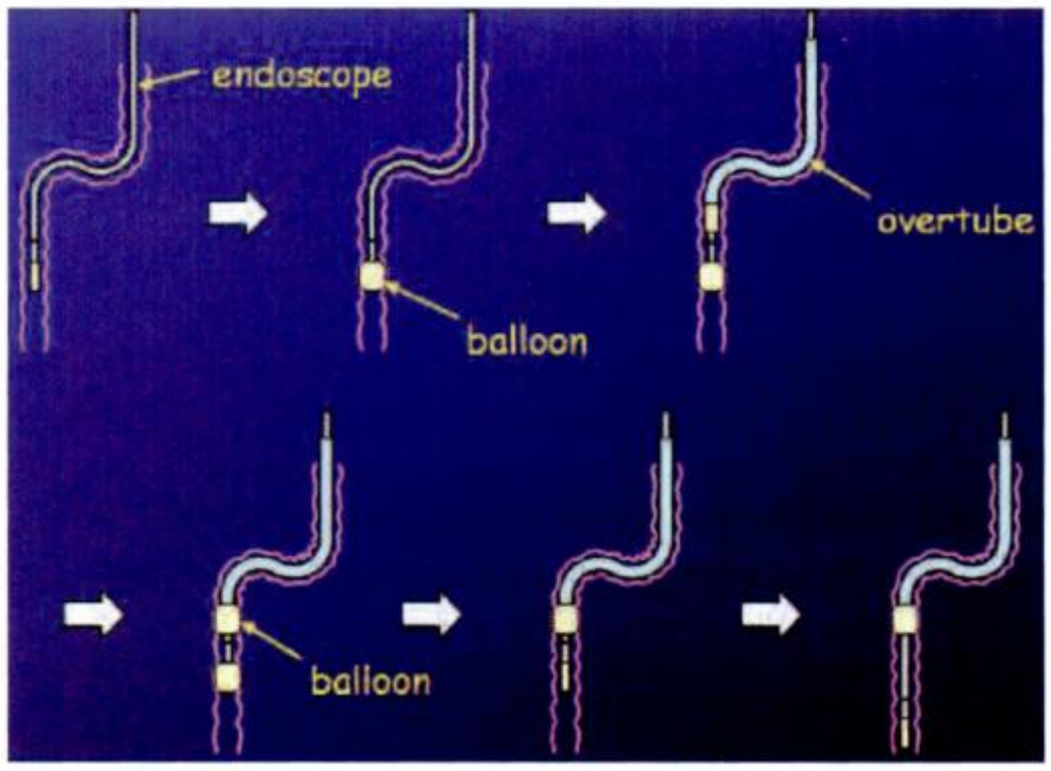


Figure 2-35. Insertion of a Fujinon enteroscope using the double-balloon method.

Advanced Technologies

High Resolution Endoscopes and Magnifying Endoscopes

In a video endoscope, the image resolution correlates directly with the pixel density of the CCD chip. The second generation Fujinon and Pentax video endoscopes are equipped with color CCD chips of 410K pixel density (Figures 2-36 and 2-37). Recently Fujinon have introduced instruments with 850K and 1200K pixel density. Such high resolution endoscopes offer superior ability to discriminate fine details in the non-magnified image.[11]

Some endoscopes, including the high resolution instruments, are equipped with an optical zoom facility using

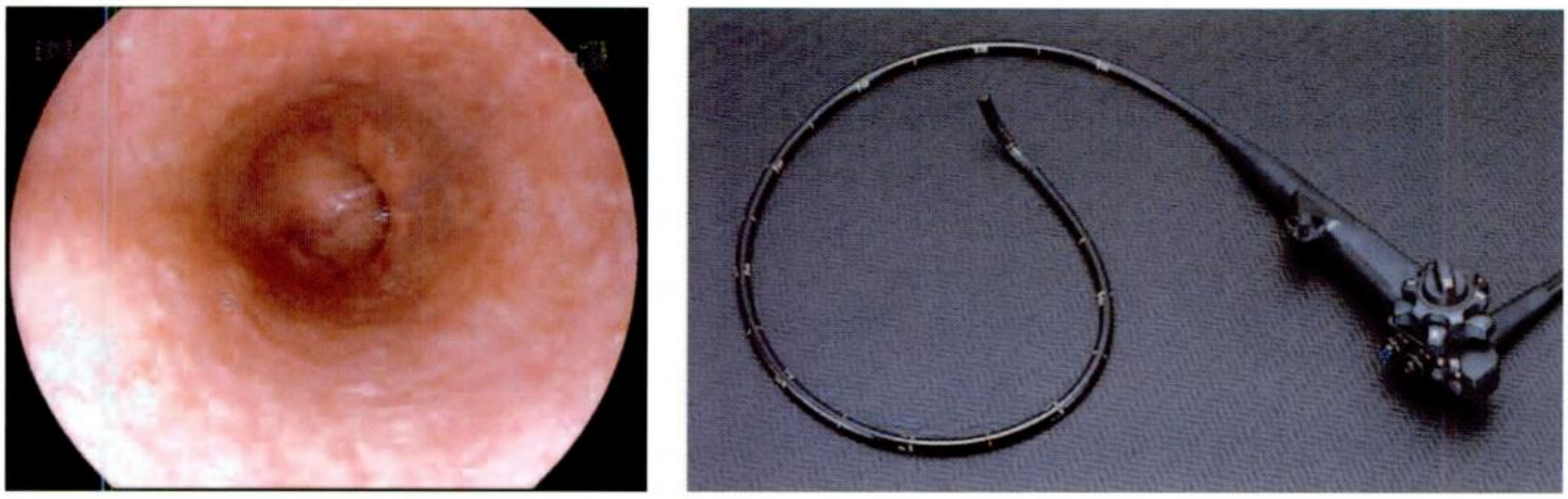


Figure 2-36. Picture acquired with Fujinon EG-490W5, a high-resolution endoscope.

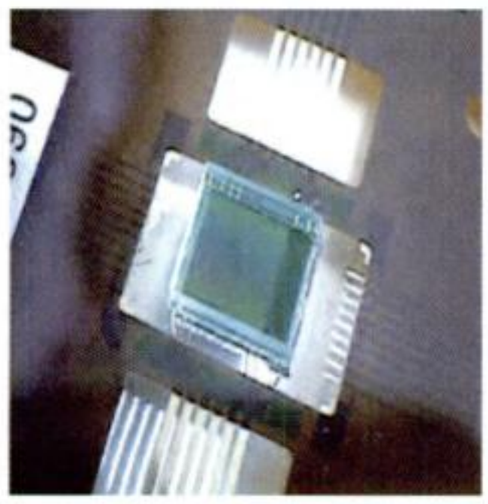


Figure 2-37. Pentax high resolution charge-coupled device (CCD).

a movable motor-driven lens in the tip of the scope (Figure 2-38). These scopes are referred to as magnifying endoscopes.[11] Once detected, a suspicious lesion can be examined closely using this type of instrument. By controlling the focal length, the scope can move very close to the mucosal surface. Increased optical magnification is obtained at the expense of reducing the visualized area. Electronic magnification also can provide a more detailed image, but only to a certain level. Image quality is lost because with each step up of electronic magnification the image contains fewer pixels compared with optical magnification.

Features of video endoscopes incorporating a high resolution CCD are shown in Tables 2-1 and 2-2 and Figures 2-39 to 2-44.

Echoendoscopes

Echoendoscopes that incorporate ultrasound probes allow detailed examination of the GI wall and its immediate surroundings (Figures 2-45 to 2-48).[12,13] Experience with pediatric endoscopic ultrasonography (EUS) is limited because GI tumors (the primary indication) are rare in children. The ultrasonic transducer at the endoscope tip is either a linear–array (electronically controlled convex-array) system (eg,

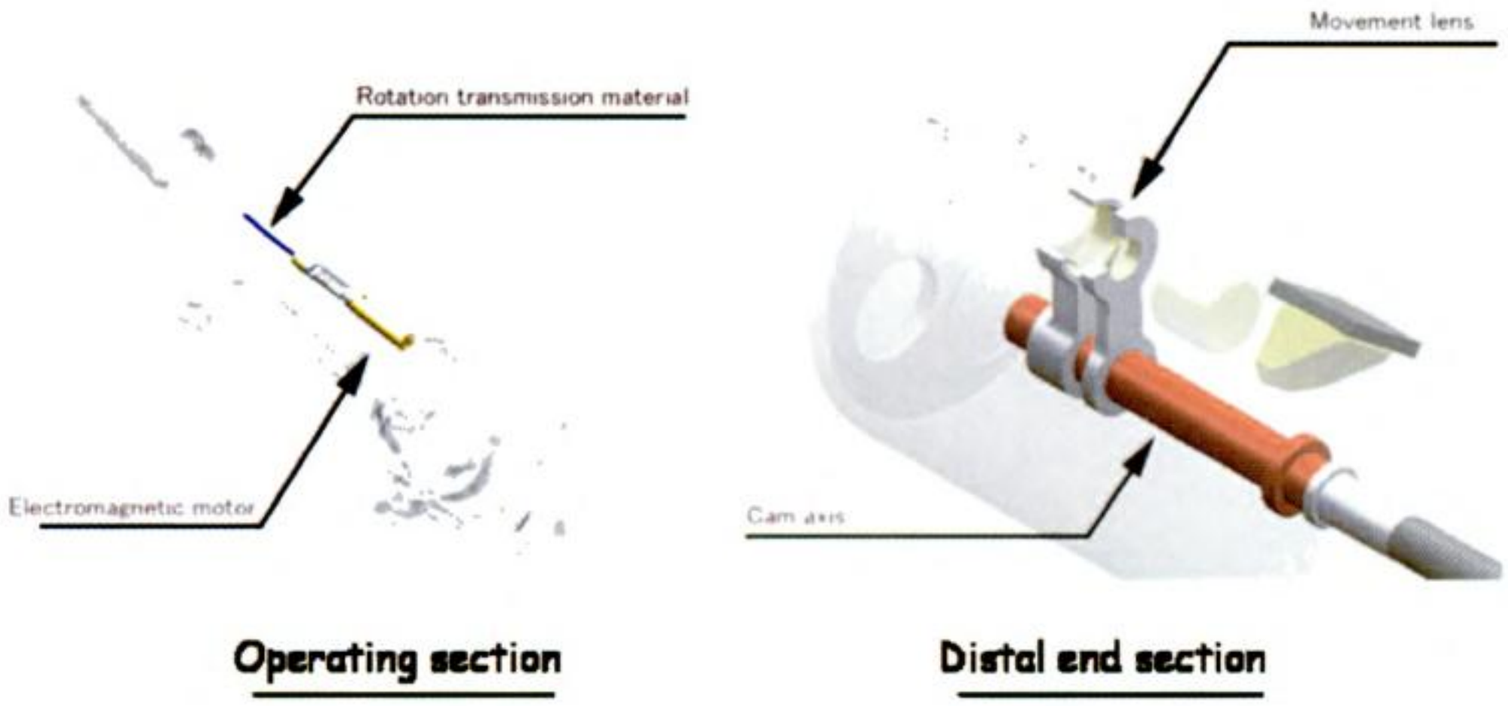


Figure 2-38. Mechanism of optical magnified Fujinon endoscope.

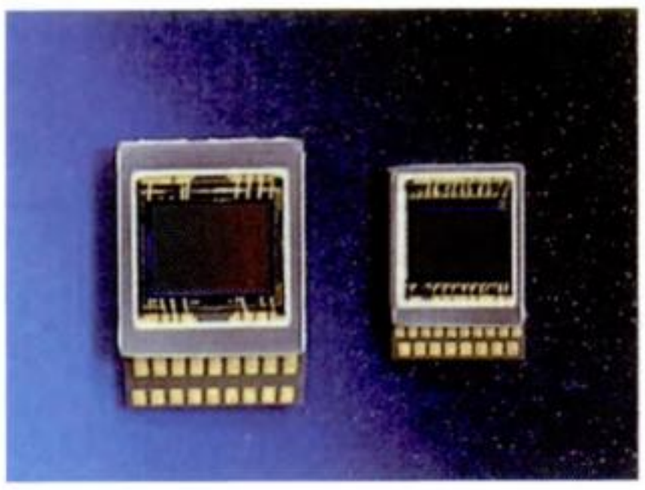


Figure 2-39. High resolution charge-coupled device (CCD) (Fujinon CCD right; conventional CCD left) 45% smaller in terms of area, permitting slimmer outer diameter of distal bending section.

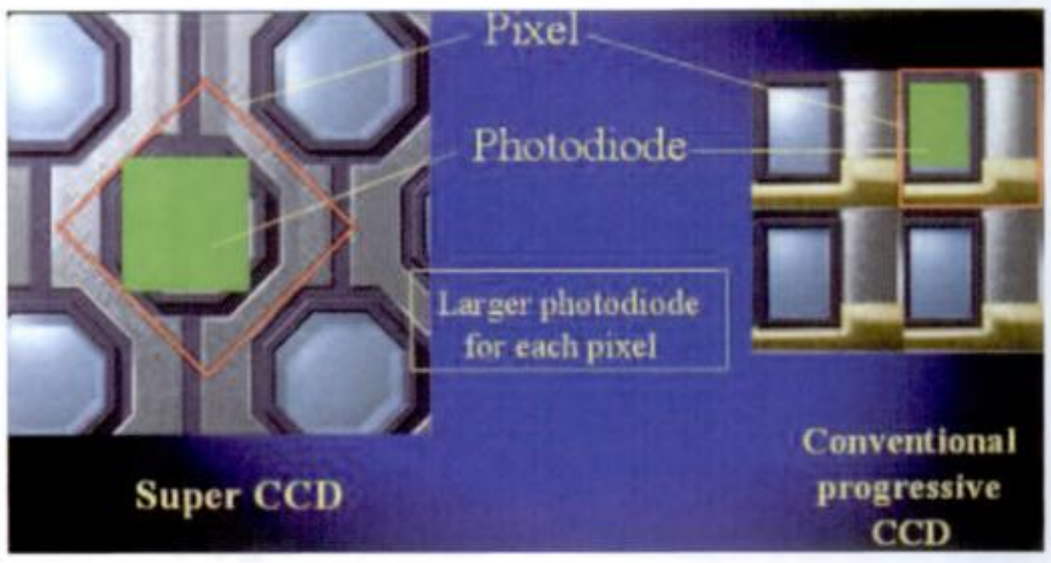


Figure 2-40. High resolution charge-coupled device (CCD) (left) with unique pixel layout makes light-receiving area per one pixel larger and achieves higher sensitivity than conventional CCD (right).

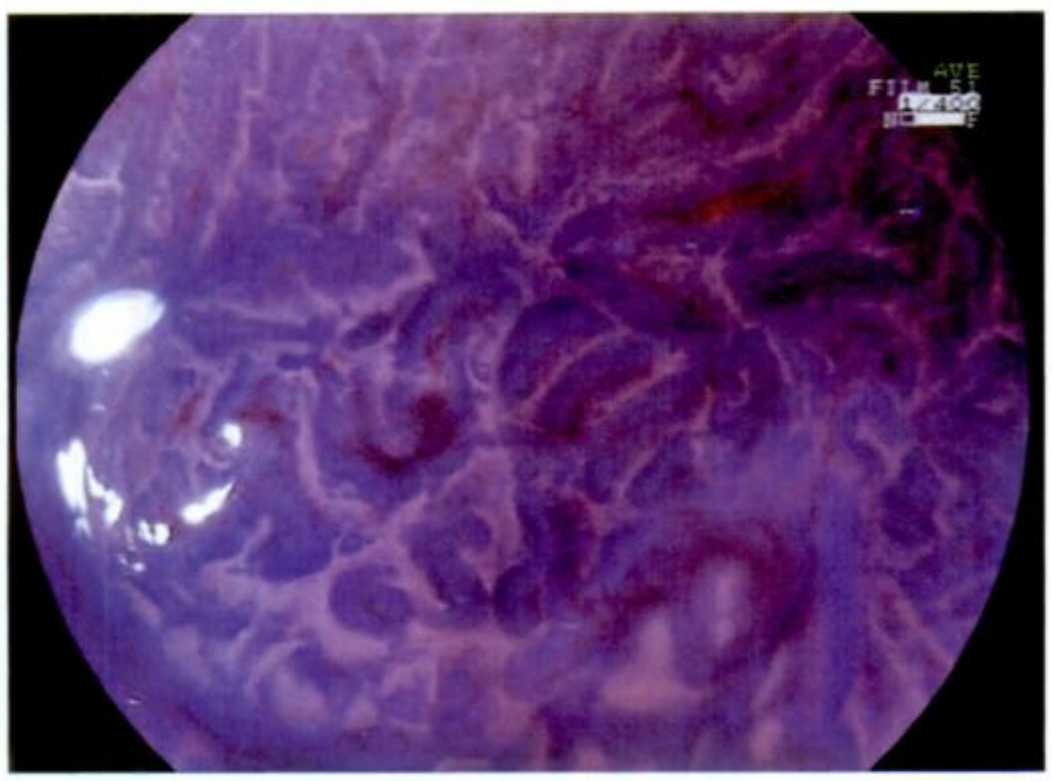


Figure 2-41. High resolution charge-coupled device (CCD) shows its power, especially in observing minute structure such as pit patterns in diagnosis of colonic polyps.

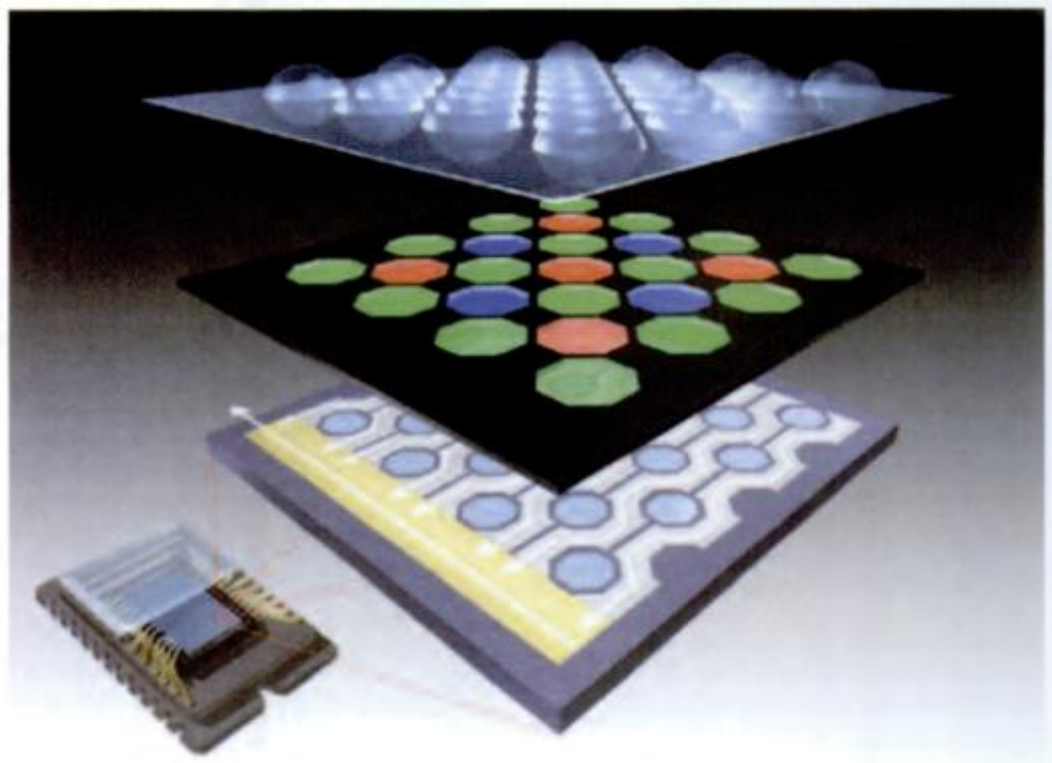


Figure 2-42. New generation of a Fujinon RGB filter ensuring best color reproducibility.

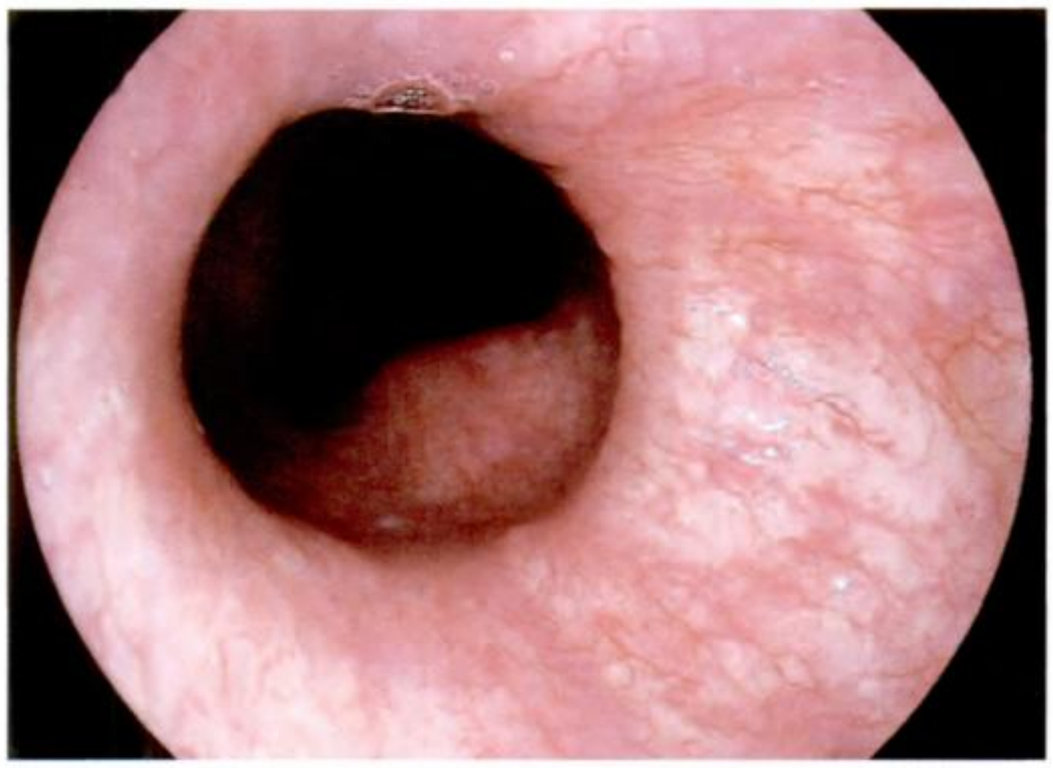


Figure 2-43. Visualization of tiny vessels of distal esophagus with high resolution charge-coupled device (CCD).

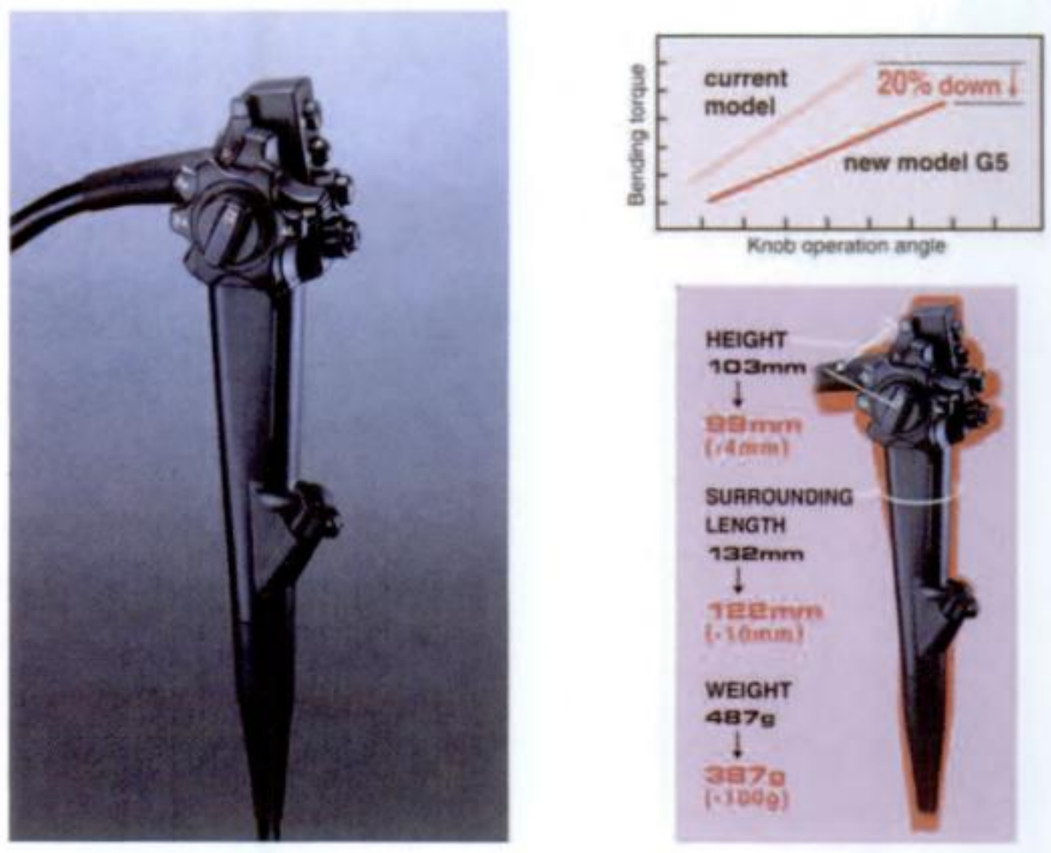


Figure 2-44. Features of newly developed G5 type Fujinon high resolution video endoscope.

Pentax EG-3830-UT) generating two-dimensional images longitudinal to the axis of the endoscope (see Figures 2-45 and 2-46) or a rotating radial (sector) scanning system (eg, Olympus GF-UM160) generating circular images (360°) at a right angle to the axis of the endoscope (see Figures 2-45 and 2-47). Both systems have a balloon surrounding the transducer. This is filled with water and provides a contact between the probe and the wall of the GI tract. EUS-guided fine-needle aspiration-biopsy can be performed with linear-type systems. Miniature through-the-scope systems are also available. Some have balloon sheaths to improve acoustic contact.

Depending on the type of high-frequency transducer, various instruments are available (Tables 2-5A to D). Some have an outer diameter as large as 10.5 to 12.8 mm, and intubation is difficult because they have a rigid section at the distal end of the shaft. Ultrasonic miniature probes can be passed through the channel of most endoscopes and can be used even in young children, but these high-frequency probes (20 MHz) offer a limited scanning area and depth of tissue penetration.

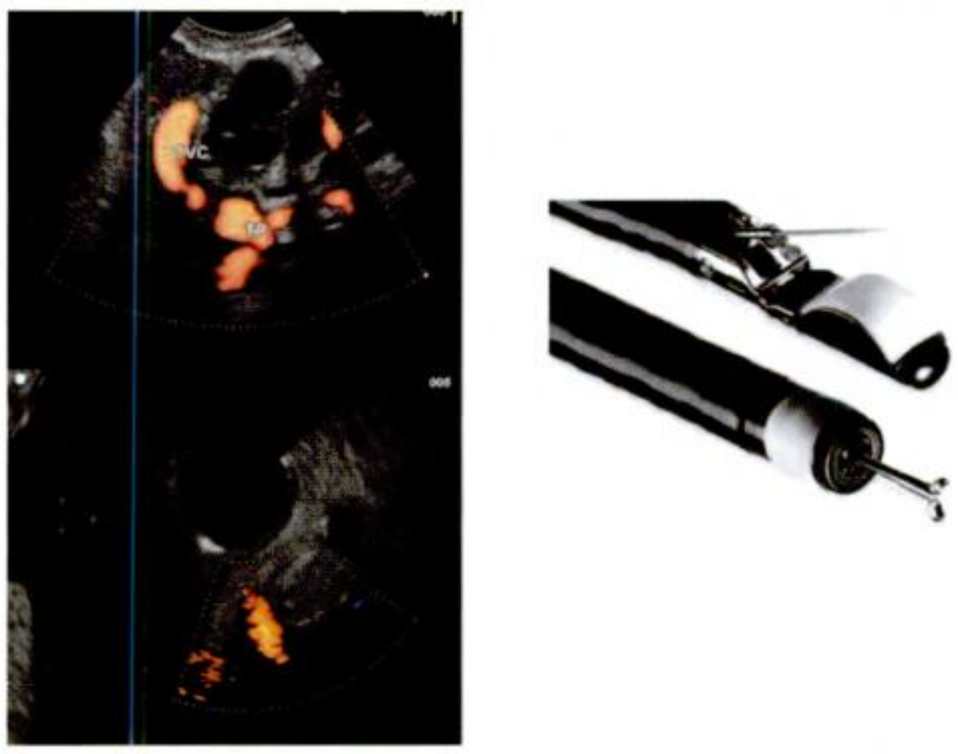


Figure 2-45. Ultrasound endoscopy linear array and radial scanning Pentax systems.

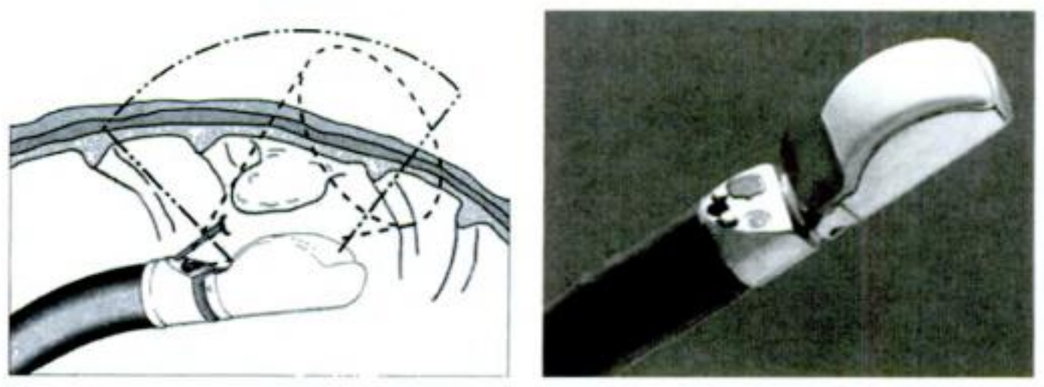


Figure 2-46. Ultrasound endoscopy linear array Pentax system.

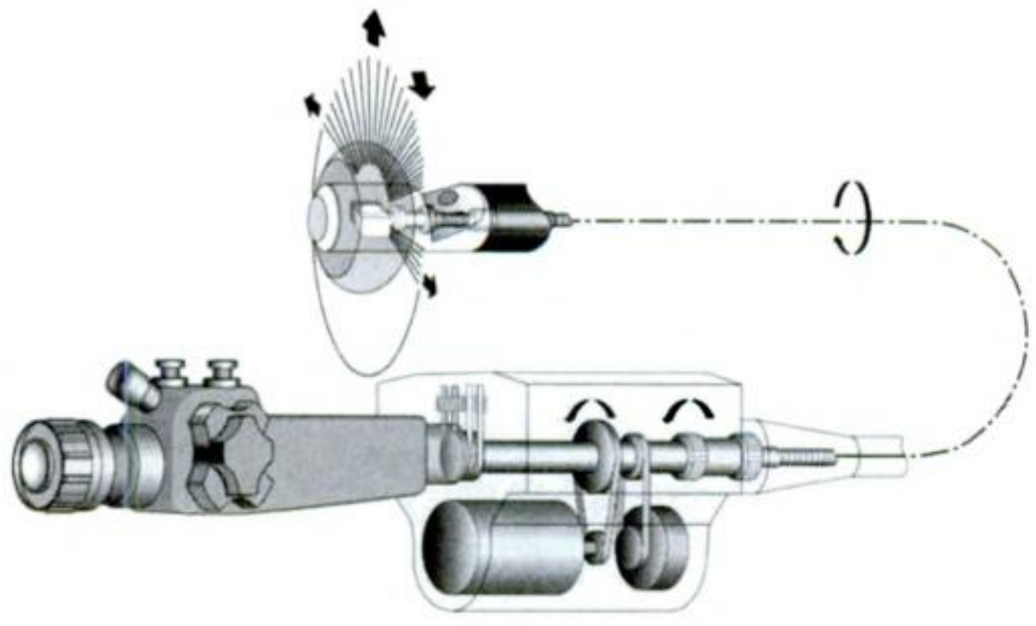


Figure 2-47. Ultrasound endoscopy radial scanning system.

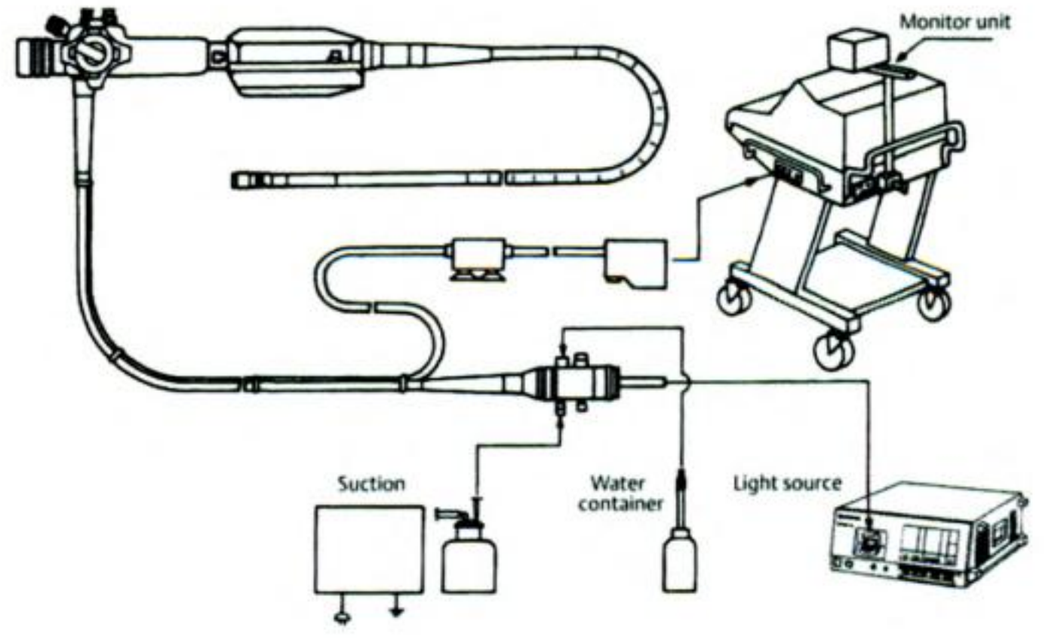


Figure 2-48. Ultrasound endoscopy unit.

Optical Coherence Tomography

The newly introduced technique of optical coherence tomography (OCT) using a low coherence light source provides two-dimensional cross-sectional images of the GI tract (Figure 2-49).[14] OCT is performed with near infrared light because the tissue is relatively transparent at these frequencies. Scanning depth is limited to 1 to 2 mm because of scattering of light in tissue. OCT is performed using catheters passed through the channel of the endoscope. Radial and linear scanning catheters have been employed, but linear systems have yielded better results. OCT can be performed through air.

Confocal Microscopy

The field of confocal microscopy is currently being explored for potential endoscopic application (Figures 2-50 to 2-53).[14]

Table 2-5A. Technical Features of Olympus Echoendoscopes and Ultrasonic Probes

	Insertion Tube OD mm	Channel ID mm	Bending Up/Down Right/Left	Working Length mm	Field of View	Depth of View mm	Frequency MHz	Scanning Mode	Comments
Ultrasonic videoscopes									
GF-UC 160P-AT8	11.8	2.8	130°/90° 90°/90°	1260	100°/55° forward	3–100	5–12	ECLA	Compatible Philips HDI 5000
GF-UC 160P-OL5	11.8	2.8	130°/90° 90°/90°	1250	100°/55° forward	3–100	7.5	ECLA	For EUS EXERA EU-C60
GF-UM160	10.5	2.2	130°/90° 90°/90°	1250	100°/55° forward	3–100	5, 7.5, 12, 20	MRS	For EUS EXERA EU-M60
GF-UL-140P ALS	11.8	2.8	130°/90° 90°/90°	1250	100°/55° forward	3–100	5, 6, 7, 5, 10	ECLA	Compatible ALOKA SSD-4000,5000, 5500, ALPHAI
Ultrasonic probe									
RU-75M-RI	12	Rigid	Rigid	150	—	—	7.5	MRS	Rigid rectal probe

ECLA = electrical curved-linear array; ID = inner diameter; MRS = mechanical radial scanning; OD = outer diameter.

Table 2-5B. Technical Features of Olympus Ultrasonic Miniature Probes

Ultrasonic Miniature Probes	Frequency MHz	Working Length mm	Compatible Balloon Sheath	Max OD Balloon Sheath	Compatible Biopsy Channel	Scanning Mode	Comments
UM-BS20-26R	20	2050	MAJ-643R	2.6	2.8	Mechanical radial	To be used only with balloon sheath
UM-DP20-25	20	2050	No	—	2.8	Mechanical helical for DPR	

OD = outer diameter.

Table 2-5C. Technical Features of Recent Echoendoscopes Pentax Used to Assess the Upper Gastrointestinal Tract

Pentax	**EG-3830-UT**	**EG-3630-UR**
Working length	1250 mm	1250 mm
Maximum diameter	12.8 mm	12 mm
Optic	50° oblique viewing	100°
Optical field of vision	120°	60°
Transducer	Electronic convex array	Electronic radial array
Sonographic field of vision	120°	270°
Axial resolution	5, 7.5 to 10 MHz	5, 7.5 to 10 MHz
Biopsy channel	Yes with Elevator	Yes

Table 2-5D. Technical Features of Endosonographic Miniprobes Fujinon

EVE 200/Mini sonde	**Frequency**	**Working Length**	**Diameter**	**Comments**
Endosonic Miniprobe	12 MHz	1900–2200 mm	2.6 mm 2.0 mm	Compatible with Toshiba Nemio and Hitachi
Endosonic Miniprobe	15 MHz	1900–2200 mm	2.6 mm 2.0 mm	
Endosonic Miniprobe	20 MHz	1900–2200 mm	2.6 mm 2.0 mm	

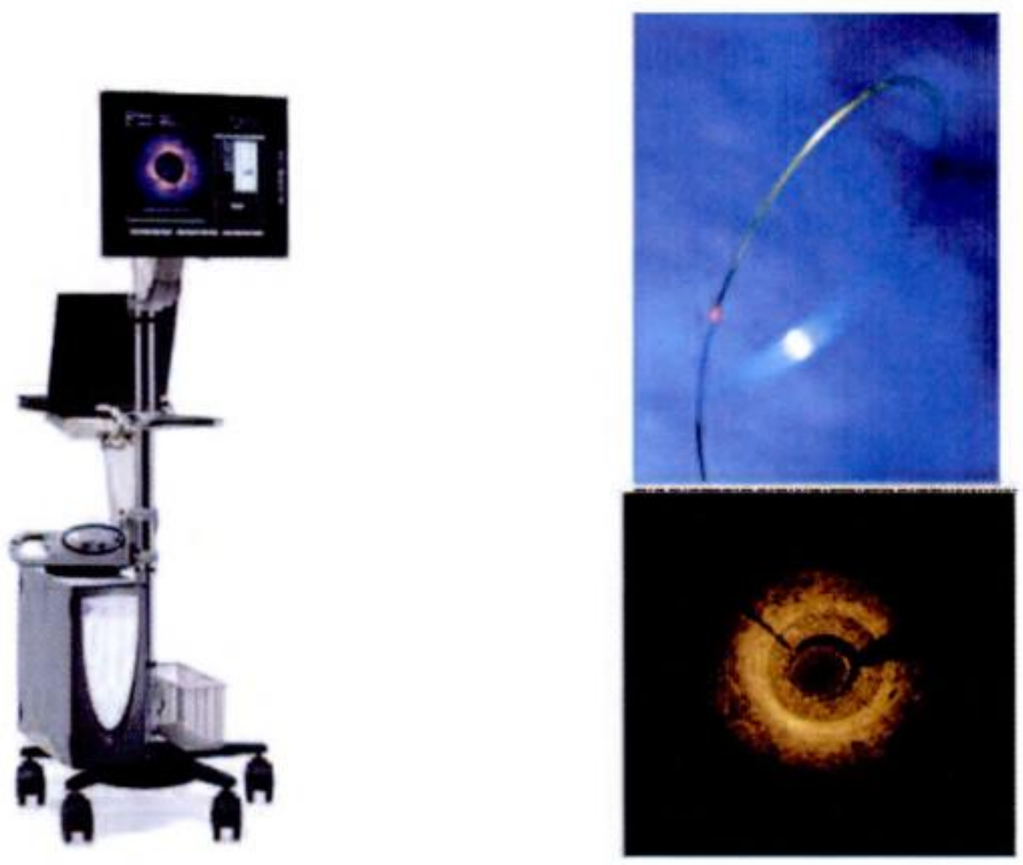


Figure 2-49. Optical coherence tomography Pentax system.

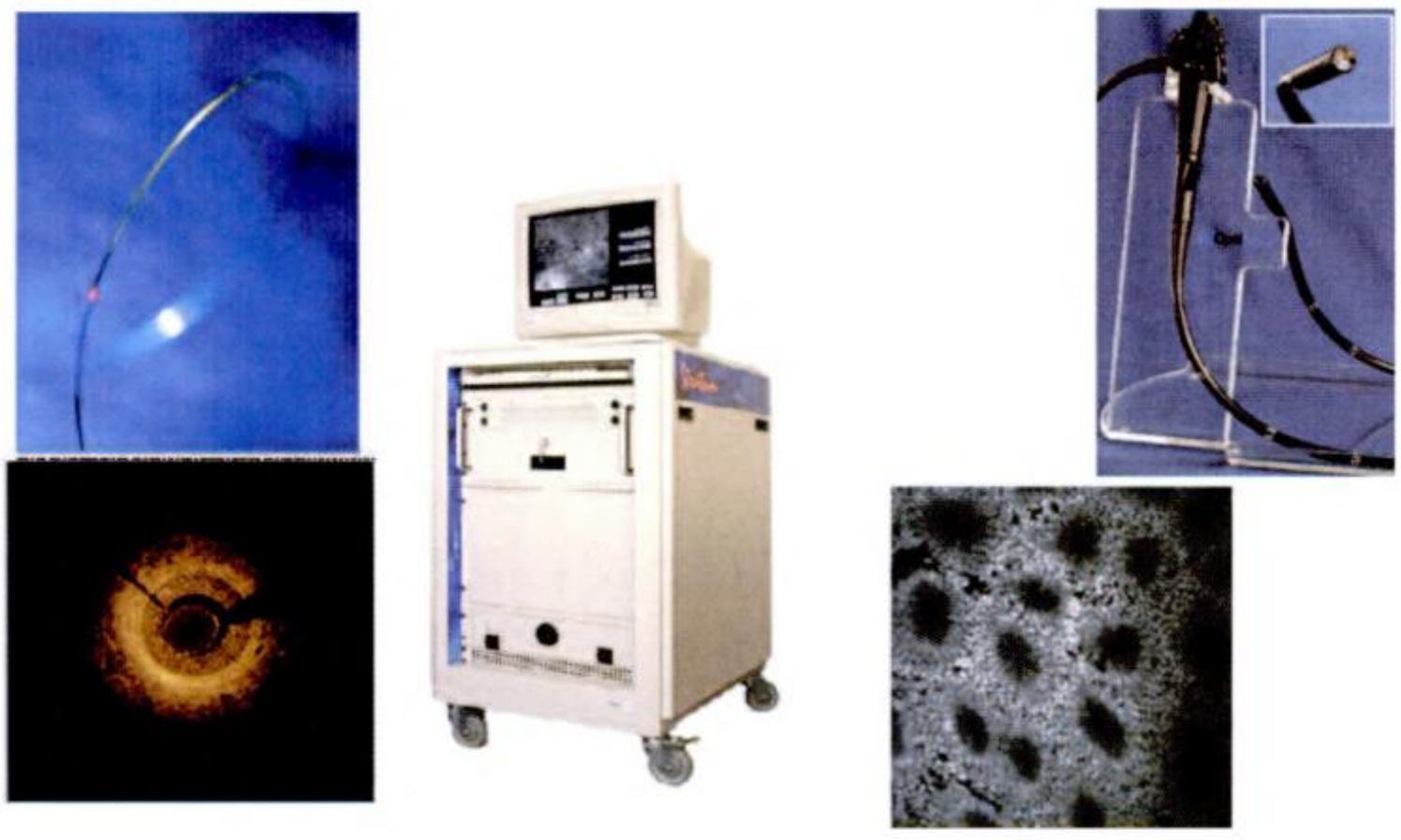


Figure 2-50. Pentax confocal endoscopy system.

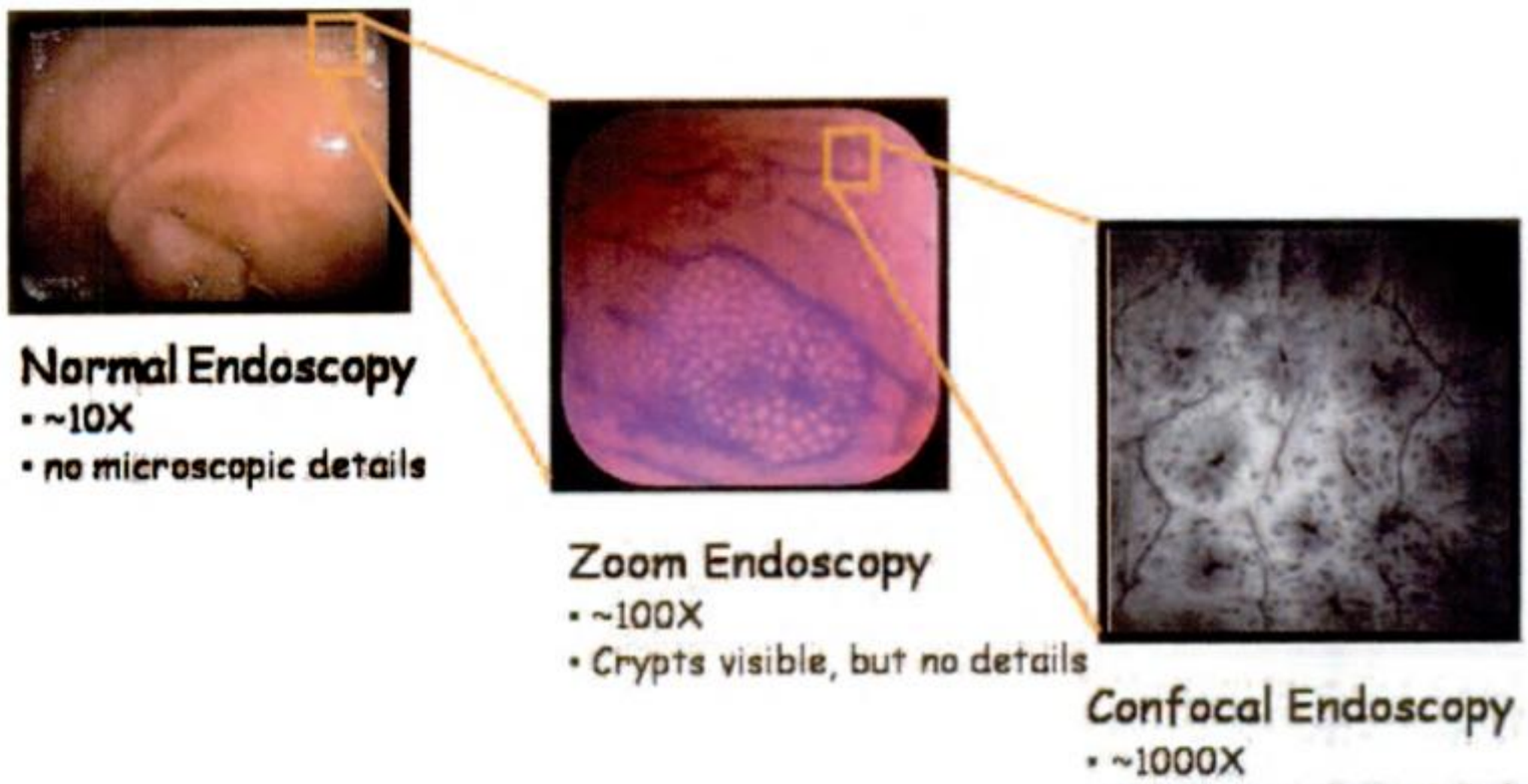


Figure 2-51. Pentax confocal endoscopy system: comparison of mucosal aspects through conventional endoscopy, magnifying endoscopy, and confocal endoscopy.

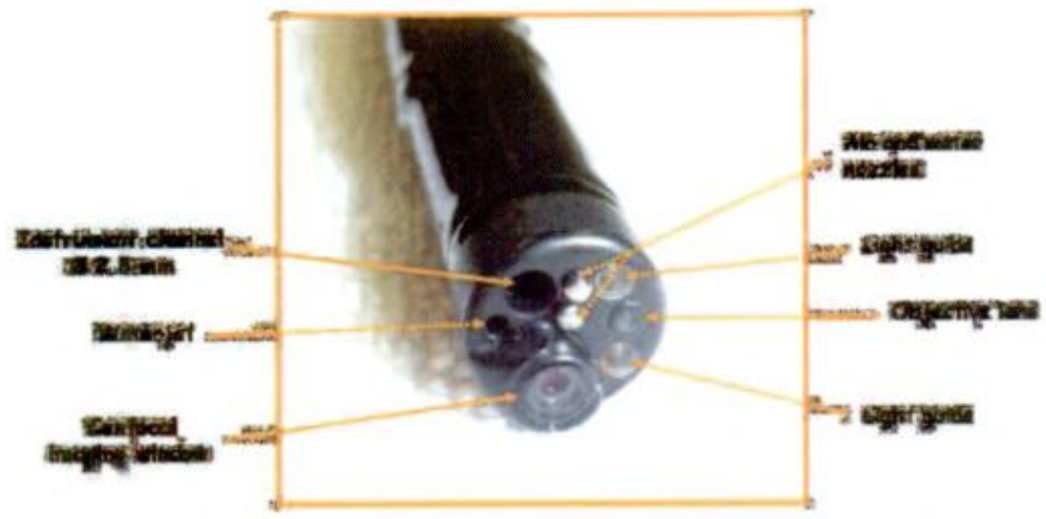


Figure 2-52. Distal end of Pentax confocal endoscope.

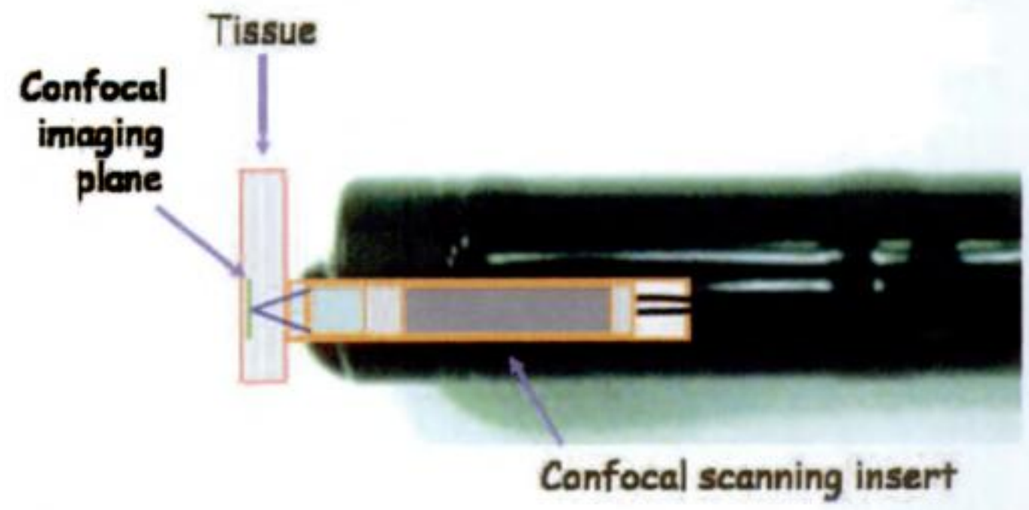


Figure 2-53. Section of distal end of Pentax confocal endoscope.

Endoscopic Accessories

Forceps

A range of biopsy forceps are available. "Crocodiles" with teeth on the forceps edge, and other models with a central spike (Figure 2-54) facilitate grasping mucosa.[15] The size and depth of the biopsy specimen are related to the diameter of the forceps.

Electrocautery Units

Electrocautery units produce continuous power output (cutting current), or an interrupted wave form (coagulation current).[16] Most (Figure 2-55) can deliver a "blended current" that combines the characteristics of both cutting and coagulating currents.

Snares

Snares are available in various sizes from 11 mm to 33 mm and in different shapes: oval, crescent-shaped, or hexagonal (Figures 2-56 to 2-58).[17,18] The diameter of the wire has to be considered when removing a polyp because thin snare wires cut faster than thick wires.

Hot Biopsy Forceps

A hot biopsy forceps is electrically insulated by a plastic outer sheath. Electrical current flowing through the forceps conducts electrical energy around the tissue held within the jaws. This permits cautery of a polyp base for example, while obtaining a biopsy for histological examination.[19]

Detachable Loops and Clips

A detachable loop (Figure 2-59) is a nylon ligature used to ensure hemostasis during or after polypectomy. It can be placed over a lesion like a wire snare, and tightened with a one-way silicon-rubber stopper, which prevents the loop from opening once it has been closed.[17] When extruded from the end of the delivery system, the loop is separated from the insertion tube. The loop is available in two sizes, 2.5 cm and 4.0 cm (Olympus). The loops spontaneously slough in 4 to 7 days.

Mucosal clips are small tweezer-like devices available in two lengths when fully opened (9 or 11 mm). They can be used for temporary marking of lesions, and more

Figure 2-54. Biopsy forceps with a central spike that facilitates grasping the mucosa.

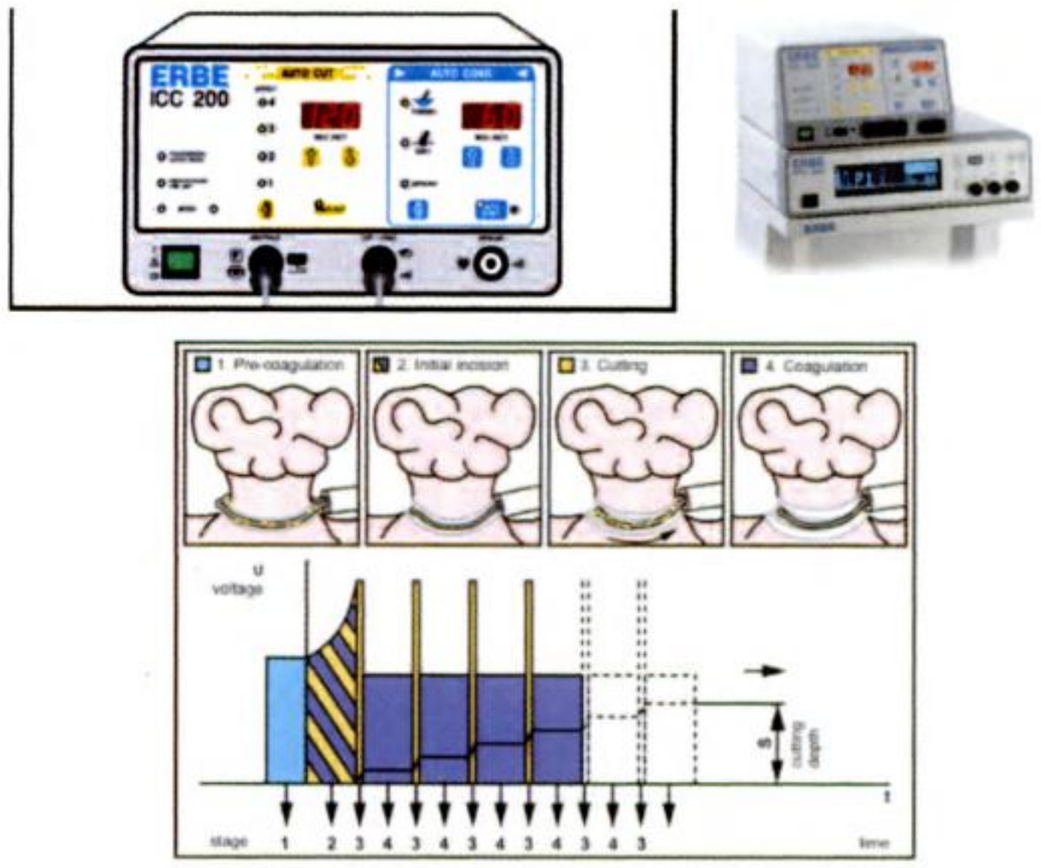


Figure 2-55. ERBE electrosurgical unit.

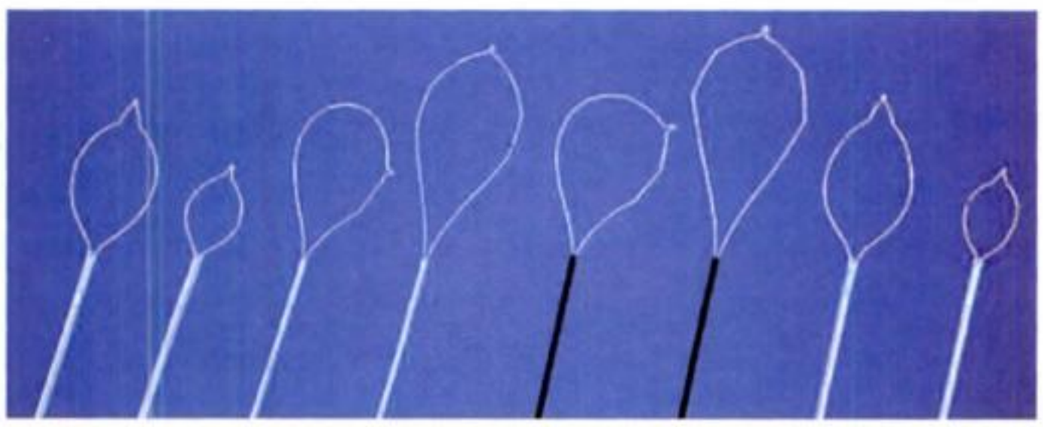


Figure 2-56. Polypectomy snares are available in various shapes and sizes.

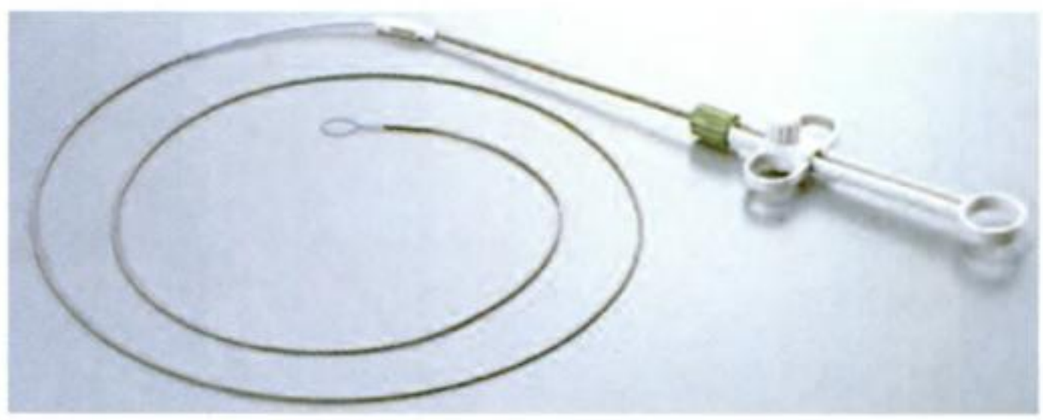


Figure 2-57. Plastic sheath of an Olympus polypectomy snare.

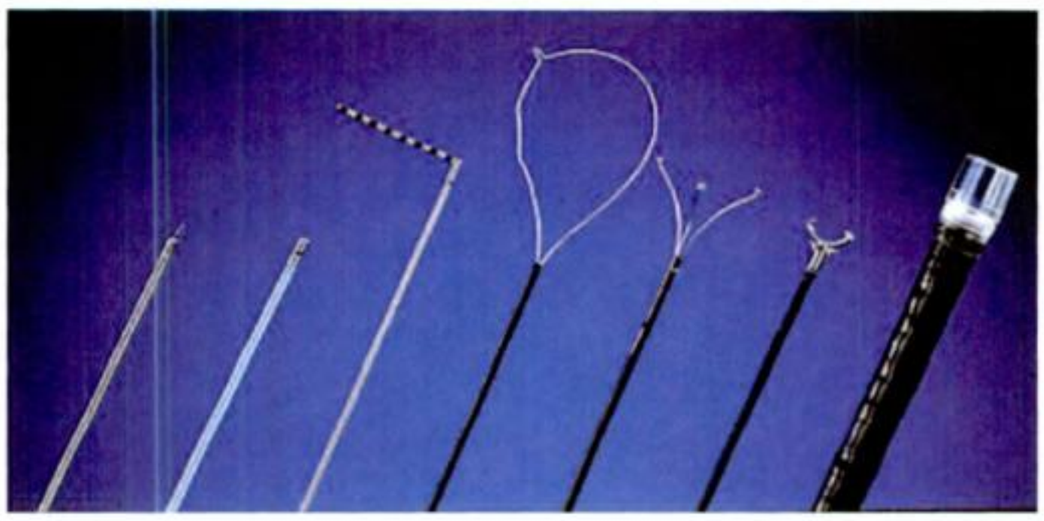
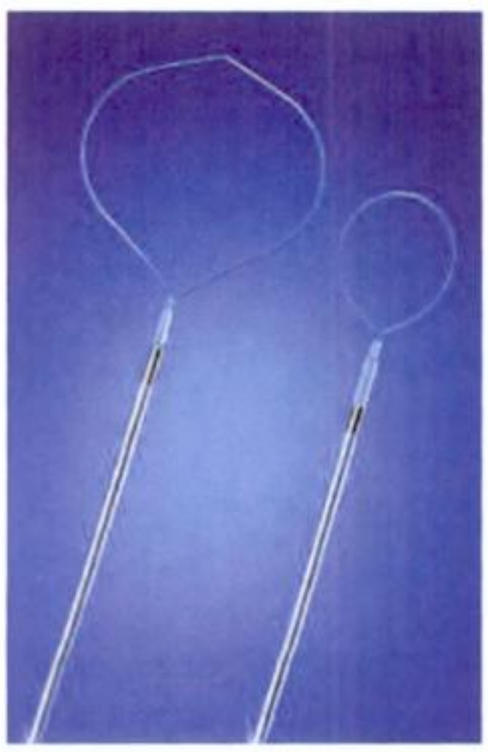


Figure 2-58. Olympus kit for endoscopic mucosal resection.

Figure 2-59. Olympus detachable snares.



frequently in pediatrics, for hemostasis.[17,18] Improvement in the application device has made it much easier to deploy clips. If it is necessary to apply a clip to the base of a pedunculated polyp and to snare the polyp above the clip, it is very important that the wire snare does not touch the metal clip in order to prevent an aberrant current pathway with potential risk of burning the colon wall.

Injector Needles

The injector needle (Figure 2-60) should be long enough to pass through the endoscope channel. An adapted sheath is necessary to prevent buckling when pressure is applied during the placement. The needle should lock in position when extended to prevent excess play of the needle when it is pushed into the mucosa.

Injector Needle for Mucosal Resection

Because the wall of the distended bowel has a total thickness of about 1.5 mm (each layer, mucosa, submucosa, and muscularis propria being about 0.5 mm thick), a precise submucosal injection is best achieved with an injector needle that has: (1) a rather obtusely angulated bevel; and (2) a small diameter, in order to avoid extravasation into the other layers of the GI wall.[18]

Injector Needle for Endoscopic Treatment of Esophageal and Gastric Varices

Injector needles are used for endoscopic sclerotherapy of esophageal varices. At present, the most common procedure is the intravariceal injection of polidocanol 1%.

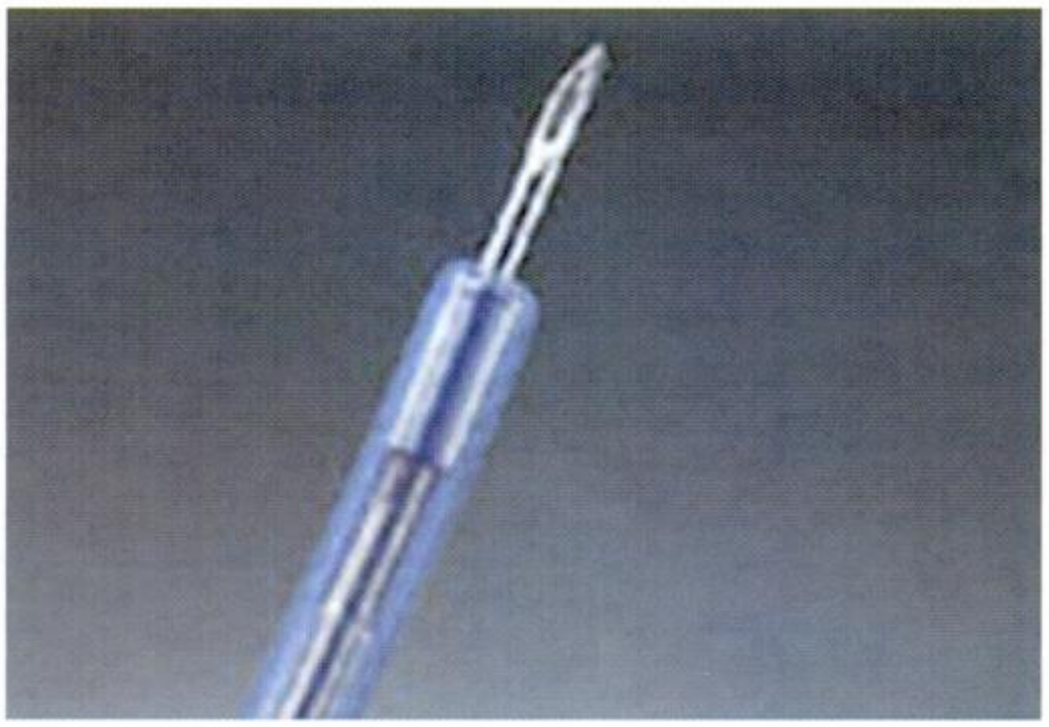


Figure 2-60. A retractable sclerotherapy needle.

A standard sclerotherapy needle is used to inject N-butyl-2-cyanoacrylate (Histoacryl) in gastric varices. Histoacryl is a watery substance that polymerizes and hardens instantaneously when it comes into contact with blood.[20,21] In order to avoid the risk of permanently obstructing the channels of the endoscope, the procedure must be performed as follows:

- Rinse the therapeutic channel of the endoscope with 2 mL of Lipiodol, an oil-based radiopaque contrast agent
- Fill the injection needle catheter with 2 mL of Lipiodol
- Puncture the varix and inject the Histoacryl-Lipiodol mixture
- Push the residual glue into the varix with a further 2 mL of Lipiodol
- Do not use suction before retracting the needle to avoid contact between the glue and the lens
- Rinse the needle catheter with water

Variceal Ligating Device

Endoscopic variceal ligation is limited in children by the size of the ligation device (Figure 2-61).[22] The device consists of a friction-fit adaptor attached to the end of the scope, an inner ligating cylinder with elastic "O" rings, and a tripwire. When the varix is aspirated into the inner cylinder, this produces a red-out appearance. The tripwire is pulled, releasing the "O" rubber ring, which strangulates the varix. The cylinder is made of transparent plastic to improve the field of vision. A number of multiple-shot band ligation devices are available (Six-Shooter by Wilson-Cook and Super 7 by Boston Scientific Microvasive). The latter device is made without latex.

Mini-Endoloops (Olympus) have been designed as an alternative to rubber bands for variceal ligation (Figure 2-62).

Figure 2-61. Super-7 variceal ligating device from Boston Scientific.

Figure 2-62. Mini-Endoloops Olympus for variceal ligation.

Argon Plasma Coagulator

Argon plasma coagulation (APC) is a method of coagulating tissue thermally using a monopolar high-frequency current conducted via ionized argon gas known as argon plasma (Figures 2-63 to 2-68). In APC, the probe does not need to be in direct contact with the target tissue because the monopolar circuit is completed by the flow of electrons through the ionized argon gas. This occurs when the distance from probe to tissue is optimal and when the electrical field strength exceeds a critical level (see Figures 2-67 and 2-68).[23,24] Electrical field strength of about 500V/mm is needed for ionization.

The delivery device for flexible endoscopy was developed in Germany (ERBE Inc. Germany). The equipment (see Figure 2-68) consists of an ultra-high-frequency electrosurgery generator ICC-350 or ICC-200, and an argon gas source, APC-300 (Erbe Elektromedizin, Germany).

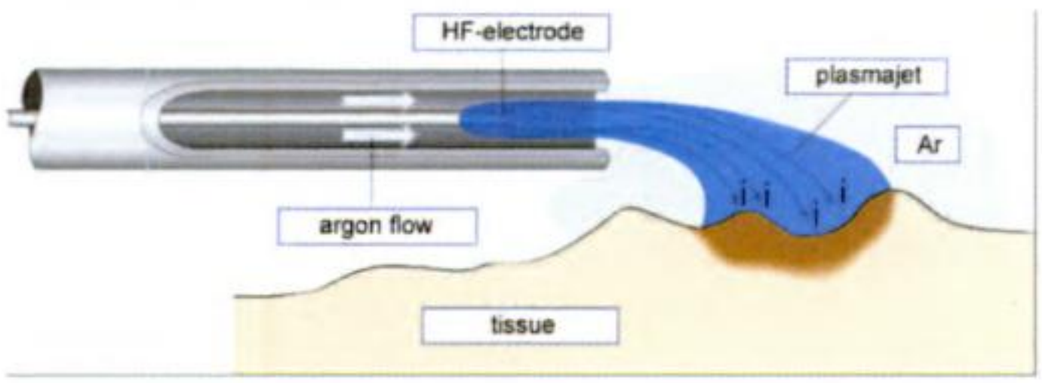


Figure 2-63. Tangential application of argon plasma coagulation to the target tissue. The electric voltaic arcs directed from the tip of the probe to the tissue surface are clearly visible.

The special APC probes for flexible endoscopy (see Figure 2-67) are composed of a heat-resistant ceramic nozzle at the tip of a flexible polytetrafluoroethylene tube, with a lumen to allow the flow of argon, and a wire to conduct a high-frequency current from the generator to an electrode within the distal part of the tube. In order to pre-

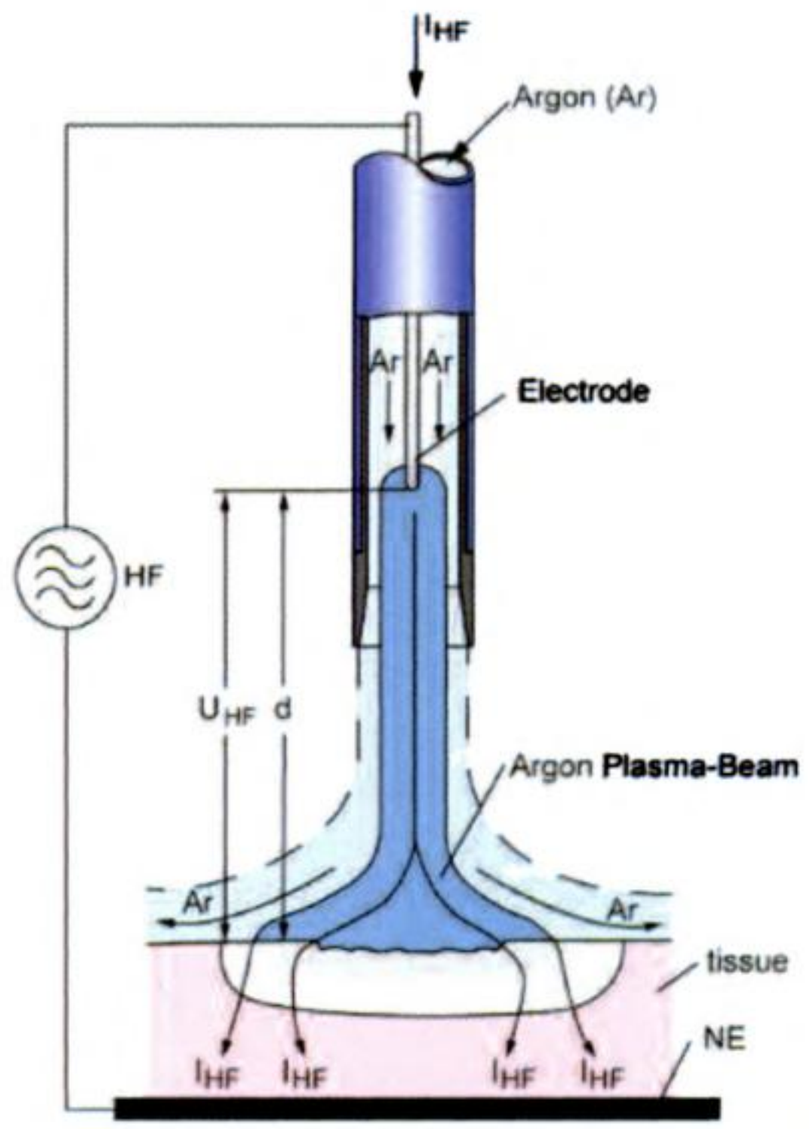


Figure 2-64. Principles on which argon plasma coagulation is based. Ar = argon; d = distance; HF = high-frequency source; IHF = high-frequency current; NE = neutral electrode; UHF = ultra-high-frequency current.

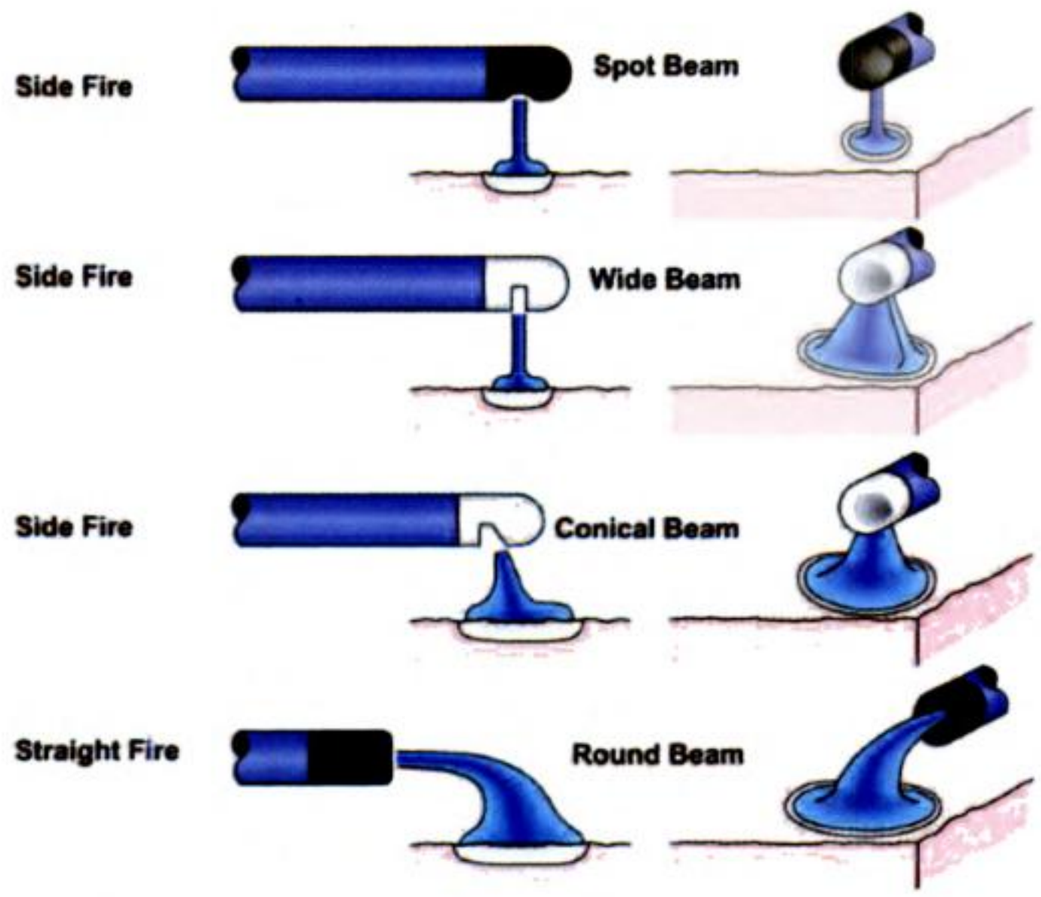


Figure 2-65. Different argon plasma coagulation probes for lateral application.

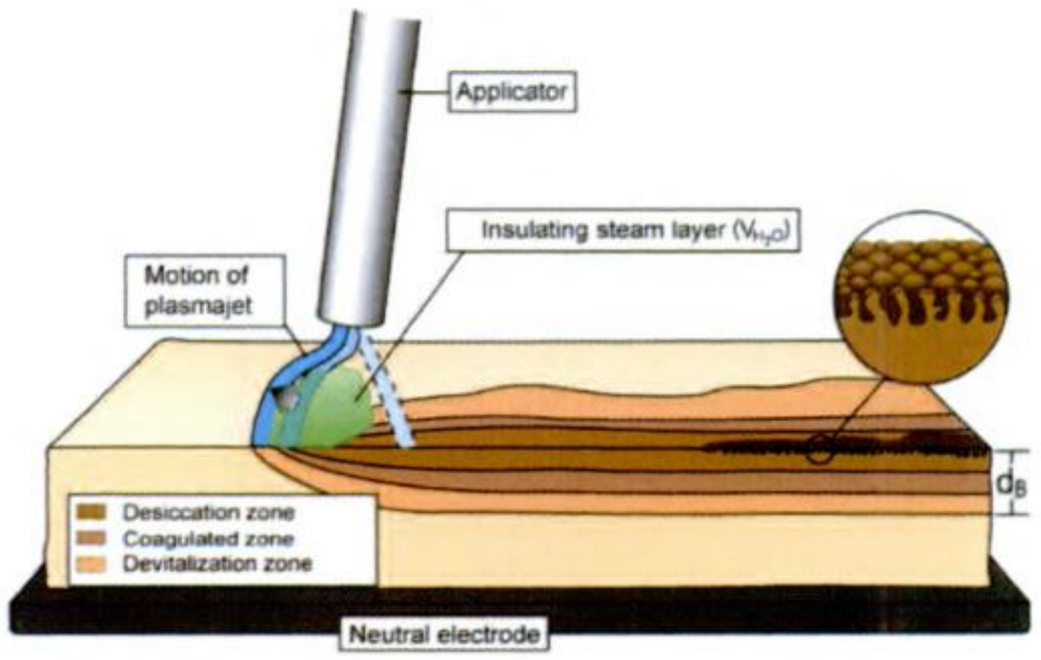


Figure 2-66. The thermal effects on tissue take place in three zones: devitalization, coagulation, and desiccation.

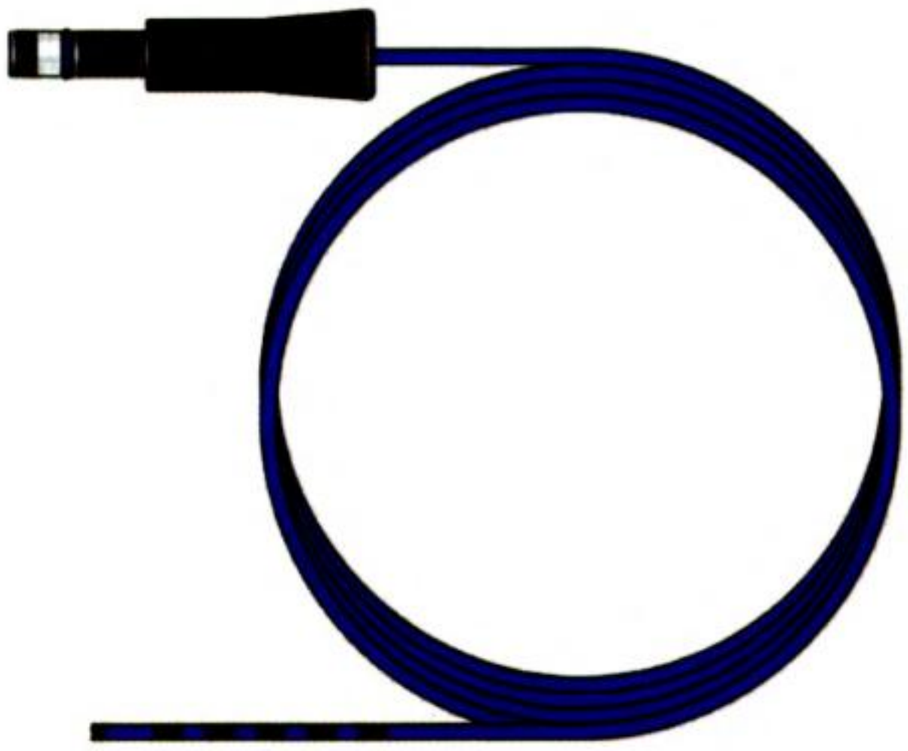


Figure 2-67. Argon plasma coagulation probe for endoscopic use.

Figure 2-68. Equipment for argon plasma coagulation: high-frequency electrosurgery generator VIO 200D and argon gas source APC-2 (Erbe Elektromedizin, Ltd, Tübingen, Germany).

vent direct contact with tissue, the electrode is placed a short, but safe, distance from the end of the tube. Two different types of APC probes are available for frontal or lateral application (see Figures 2-64 and 2-65). In pediatrics, the 2.3 mm diameter catheter only can be used.

At a critical distance between the probe and the target tissue, argon plasma beams can be seen as small flashes of lightning. The thermal effects of APC vary from the surface to the depth of the target tissue, as shown in Figure 2-66. Because of the inert character of argon, the tissue is neither burned nor vaporized.

The extent of thermal penetration of tissue can vary from less than 1 mm to 3 to 4 mm in response to the output power setting, motion of the probe tip, and duration of application. In the colon, the power output setting should usually be at 40 W, with a relatively low gas flow (0.8 L/mn).

APC may be applied not only axially, but also laterally and radially because the voltaic arc supported by the plasma beam depends on the electrical field, but is independent of the direction of the argon flow (see Figures 2-64 to 2-66). When the target tissue becomes desiccated, it loses its electrical conductivity, thus limiting the depth of thermal effect and the beam automatically moves toward nondesiccated areas.

Heater Probe

Available in two sizes (2.4 and 3.2 mm), the heater probe consists of a heat coil inside a Teflon-coated copper tip (Figure 2-69).[25] The probe is heated to 250° C, and can be programmed to deliver a fixed amount of energy. There are three side irrigation ports 1 cm from the probe tip.

Bipolar Coagulation Probe (BICAP)

The bipolar probe provides bipolar electrocoagulation, which is assumed to be safer than monopolar diathermy, which produces an unpredictable depth of damage.[25] The BICAP and the Gold Probe (Boston Scientific Microvasive) are available in two sizes (2.4 and 3.2 mm). The use of larger probes requires endoscopes with large channels (diameter 3.5 to 3.7 mm).

Figure 2-69. Teflon-coated tip of a heat probe with a water-jet opening.

Capsule Endoscope

The wireless capsule endoscope (Figure 2-70), recently produced by GIVEN (GastroIntestinal-VideoEndoscopy Imaging, Israel) resulted from technical advances in the area of complementary metal oxide silicon (CMOS), the application of specific integrated circuit and the development of white light emitted diode technologies.[26] The capsule, (11 × 26 mm; weight 3.4 g) houses a magnifying (1:8) color camera, four light sources, a radio transmitter and batteries (see Figure 2-70). The focal point of the lens is 1 mm; the viewing angle is 140°. The video images, taken twice per-second, are transmitted using a radio frequency signal to aerials placed on the body and captured on a portable recorder carried on a belt (Figure 2-71). The battery power is able to take 50,000 to 60,000 color images and lasts about 6 to 8 hours. These images are downloaded to a computer and viewed by the gastroenterologist. Image analysis requires special experience (Figure 2-72).

The benefit of this new technology is its noninvasive character, which avoids bowel cleansing, anesthesia, and air insufflation. Although the capsule is easily swallowed by fasting adolescents, it has to be endoscopically inserted in young children who are not able to swallow the device. Furthermore, an important limitation is the inability of the device to take biopsies and the fact that neither the velocity nor the direction can yet be controlled.

To prevent complications related to an unknown intestinal stricture, the manufacturer has proposed a preliminary procedure using a Patency Capsule likely to disintegrate with a Patency Scanner to permit localization (Figures 2-73 to 2-76).

Figure 2-70. Design of Wireless capsule endoscope.

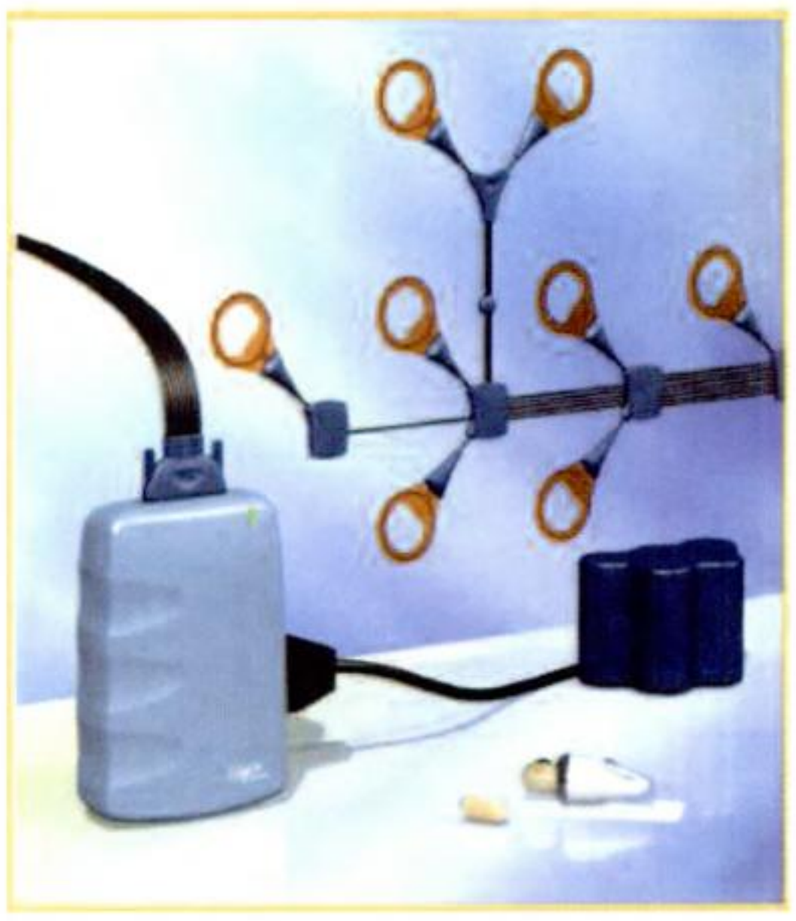


Figure 2-71. Given Data Recorder.

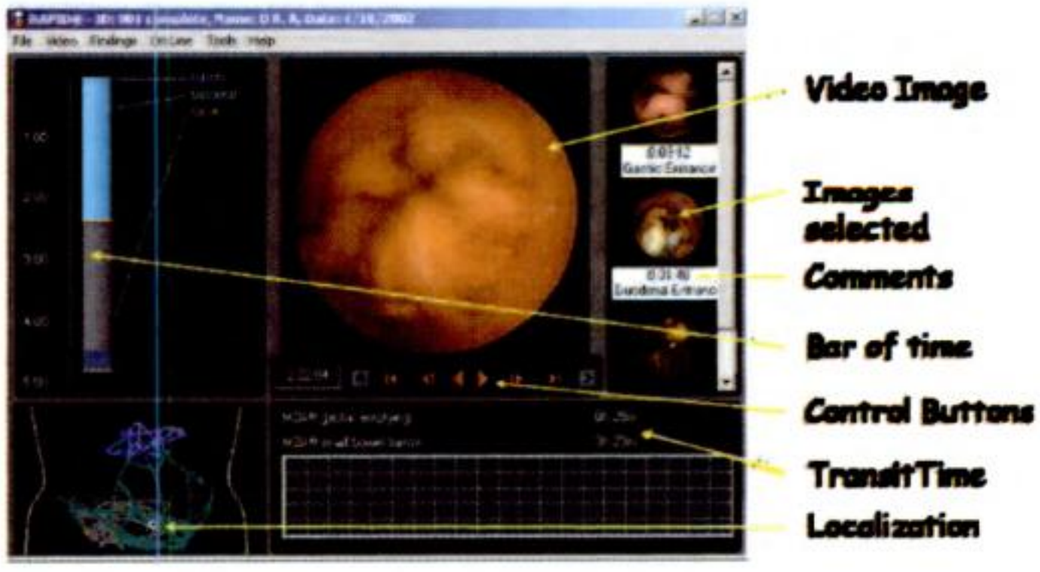


Figure 2-72. Working station for Given capsule.

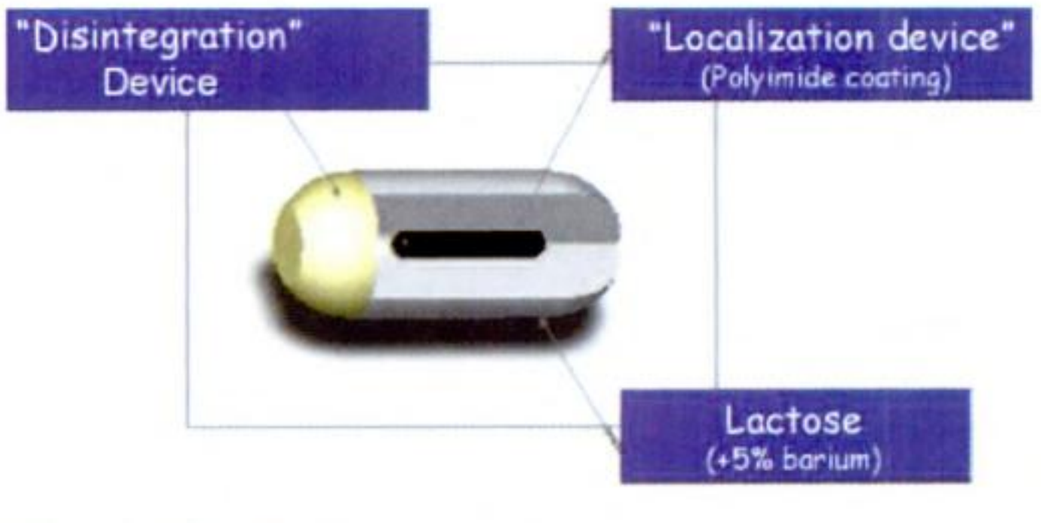


Figure 2-73. Patency capsule.

Figure 2-74. Inert composant of localization of Patency capsule.

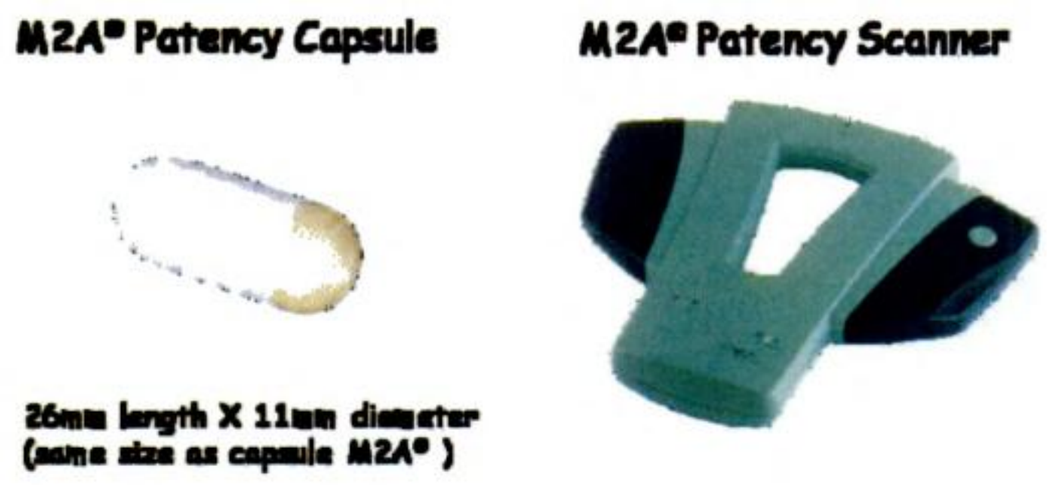


Figure 2-75. Patency scanner.

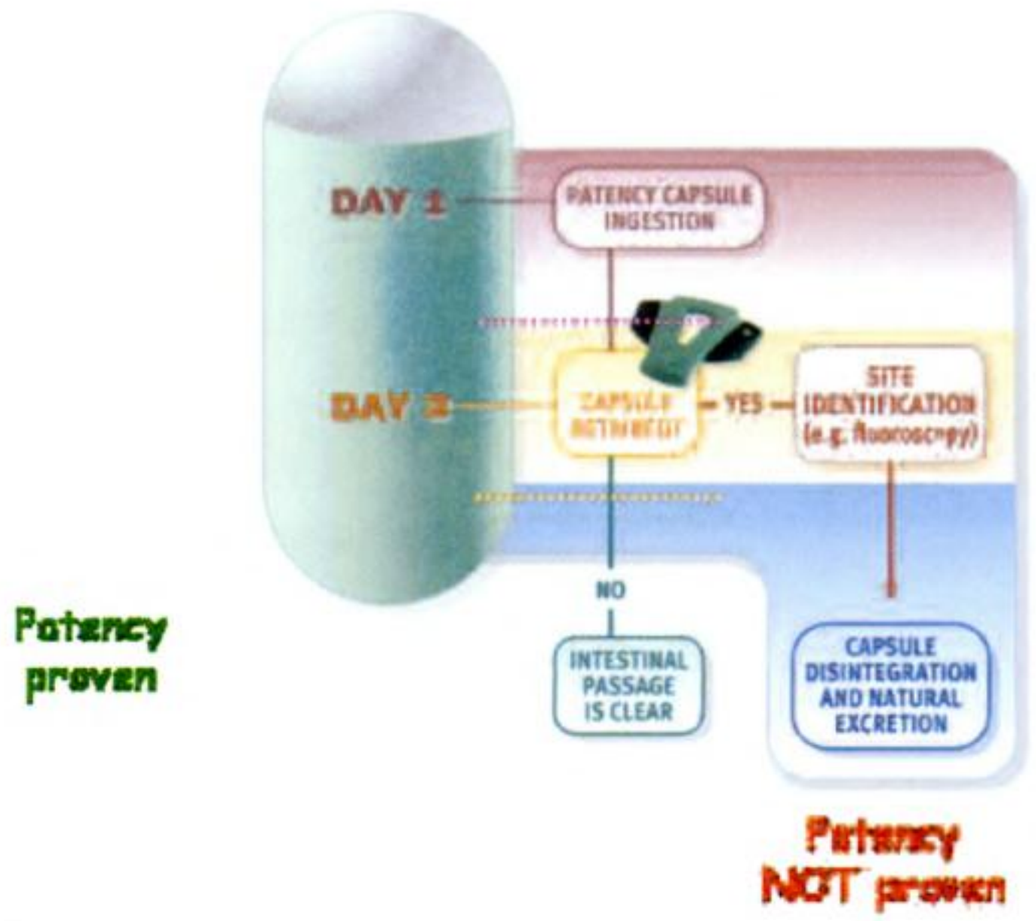


Figure 2-76. Patency procedure.

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Training in Pediatric Endoscopy 3

Mike Thomson

As with any practical procedure, the responsibility for acquiring and maintaining the skills in endoscopy rests primarily with the individual. However, to have qualified pediatric endoscopists, formalization of training and accreditation is necessary.[1–5] What constitutes adequate skill in endoscopy? How should competency be measured? How proficient should pediatric gastroenterologists be at the end of their period of training? These questions do not have simple answers and until recently information on training and rates of skill acquisition in both adult and pediatric endoscopy was limited.

Trainees learn the practical skills of endoscopy at very different rates. Potential explanations include individual variations in hand-eye coordination or three-dimensional spatial orientation or differences in the training experience. The cognitive knowledge needed to identify and recognize pathological lesions may also vary. For these reasons, specific guidelines may vary among training programs in pediatric endoscopy. To address this issue and provide objective evidence about parameters for training, a study in which trainee progress was prospectively documented by endoscopy trainers was conducted at the Royal Free Hospital in London. The data provide evidence for requiring both a minimum number of supervised procedures and for a formal assessment of individual proficiency.

Other relevant issues are also discussed. How much training in adults is relevant to the practice of pediatric gastroenterology? Are "virtual endoscopy" (computerized endoscopy simulators) and multimedia training devices of value? What is the role of the "log book" in documenting procedural experience and performance? Are training courses of value? Who should be trained in the various specific procedures and skills in pediatric endoscopy? Should concepts of "best practice" be established for endoscopy and for endoscopy training? Is it possible to standardize the way in which each procedure is performed, or to standardize the way in which procedures are taught or trainees assessed? What is required for trained endoscopists to maintain their skills? Should trained endoscopists be required to undergo periodic reassessment for accreditation? Is the training of trainers important? How can standards for accreditation be established for training centers?

Evidence and Recommendations

Much debate surrounds the question of the actual number of supervised procedures required to achieve competence during training. Guidelines issued by the North American Society for Pediatric Gastroenterology, Hepatology and Nutrition (NASPGHAN) in 1997 were based on expert opinion and recommended a minimum of 50 colonoscopies. In 1999 this recommendation was increased to at least 100.[6] The revised guidelines also specified minimum numbers for various therapeutic techniques, such as 20 snare polypectomies, 15 balloon dilations of strictures, and 20 injection therapy or electrocautery treatments for bleeding. Although standardized minimum levels of experience may provide guidance, assessment of an individual trainee's competence is also required. A procedure logbook with a trainer's assessment of performance for each procedure is a useful way to not only evaluate a trainee's competence, but also to monitor progress. Keeping such a record will shift the emphasis from "number counting" to skills assessment. Until a standardized assessment of endoscopic skills is validated, the minimum number of procedures required to achieve competence will probably continue as the standard of competency.

At a meeting of the World Congress of Pediatric Gastroenterology, Hepatology and Nutrition in 2000, a working group on endoscopy presented a report dealing with the question of training.[7] Three main areas were identified as requiring attention. Namely, the establishment and recognition of "centers of excellence in pediatric endoscopy," the role of training videos, and the value of practical courses in pediatric endoscopy. The working group's recommendations for training were similar to those stated by NASPGHAN in 1999. They included the following expectations and achievements:

1. To correctly recommend endoscopic procedures based on the findings in personal consultation and to recognize the indications and contraindications, and the diagnostic and therapeutic alternatives to endoscopic procedures.
2. To perform procedures safely, completely, and expeditiously.
3. To correctly identify most endoscopic findings and to perform endoscopic intervention when necessary.

4. To integrate endoscopic findings into a management plan.
5. To understand risk factors, and to recognize and manage complications.
6. To recognize personal and procedural limitations and to know when to seek help.
7. To be familiar with national organizational guidelines regarding sedation and monitoring for pediatric gastrointestinal (GI) procedures.
8. To identify age and indication appropriate endoscopic equipment.
9. To be familiar with the correct procedures for cleaning and maintenance of endoscopic equipment and infection control measures.

Quality assurance will undoubtedly receive increasing attention in the coming years. At the present time there are significant differences among various training centers in relation to technical standards and to the indications for endoscopic procedures. The challenge of quality improvement has been addressed by the American Society for Gastrointestinal Endoscopy and will need to be addressed by program directors training individuals in pediatric endoscopy.[5]

Rate of Skill Acquisition by Trainees

Adult studies have indicated that trainees need to participate in 100 to 180 colonoscopies before "competence" is achieved.[8] Those numbers are primarily based on the number of procedures the average trainee should expect to complete in order to gain sufficient proficiency to reach the cecum in a reasonable amount of time. Figure 3-1

Trainee Endoscopy Performance

Paediatric Endoscopy Study Group (Insert hospital)_____

Date_____ Patient age_____

Site: _____Endosc Unit _____Theatre _____Other_____

ENDOSCOPIST: Consultant_____SpR/Fellow_____

Number so far attempted by trainee: _____endoscopies _____colonoscopies

INTENDED GOAL OR EXTENT OF EXAM: _____duodenum _____caecum

_____ileum _____other

SEDATION: _____None _____IV/PO* _____G.A or deep sedation by anaesthetist

*Trainee required advice or assistance to adminster adequate sedation(IV/PO):____Yes____No

Trainee correctly indentified indications: _____few _____most_____all (score /10)

Trainee correctly identified lesions/findings: _____few _____most_____all (score /10)

Procedure induced endoscopic therapy: _____yes _____no

EXAMINATION

	Most distal unassisted (tick one)	Most distal completed (tick one)
Upper Endoscopy: oesophageal intubation examination of stomach pyloric intubation D2-3 intubation		
Technique	/10	/10
Colonoscopy: sigmoid colon intubate splenic flexure intubate caecum intubate ileum		
Technique	/10	/10

PROCEDURE TIMES: scope time only (minutes)

(Upper Endoscopy) Colonoscopy

To most distal site_____ To most distal site_____

Total_____ Total_____

OVERALL SUBJECTIVE SCORE (0-4)_____

0=no skills 1=few skills 2=modest skills, lacks control 3=good skills & control 4=excellent skills & control

Comments:_____

Signature:_____

Figure 3-1. Trainee Endoscopy Performance Record Sheet.

shows the record sheet, adapted from a proforma designed by Dr.Victor Fox at Boston Children's Hospital that has been used prospectively to assess trainees at the Royal Free Hospital, London. Using this document the rates of skill acquisition were assessed in ten trainees. "Skill acquisition curves" were then constructed for each individual for both upper GI endoscopy and colonoscopy.The rates at which each individual achieved competency in various relevant skills differed considerably. Examples relating to colonoscopy are shown in Figures 3-2A–E. One trainee may be competent at ileal intubation after 75 procedures, whereas another may require 150. Competence in lesion identification varied considerably among trainees. Those who were technically able were not necessarily proficient at recognizing abnormalities and vice versa. Based on these and other data, a pragmatic compromise regarding numbers of colonoscopies necessary for technical and cognitive proficiency might be in the order of 100. However, ongoing, prospective individual assessment is an essential part of training.

Recommendations for Training of Pediatric Endoscopists

In the United Kingdom the Royal Colleges' Joint Advisory Group (JAG) on endoscopic training includes representatives from all disciplines involved in endoscopy including pediatric gastroenterology. Their recommendations for professional guidelines as they relate to pediatric gastroenterology are outlined in Table 3-1 but can be viewed in detail on their Web site

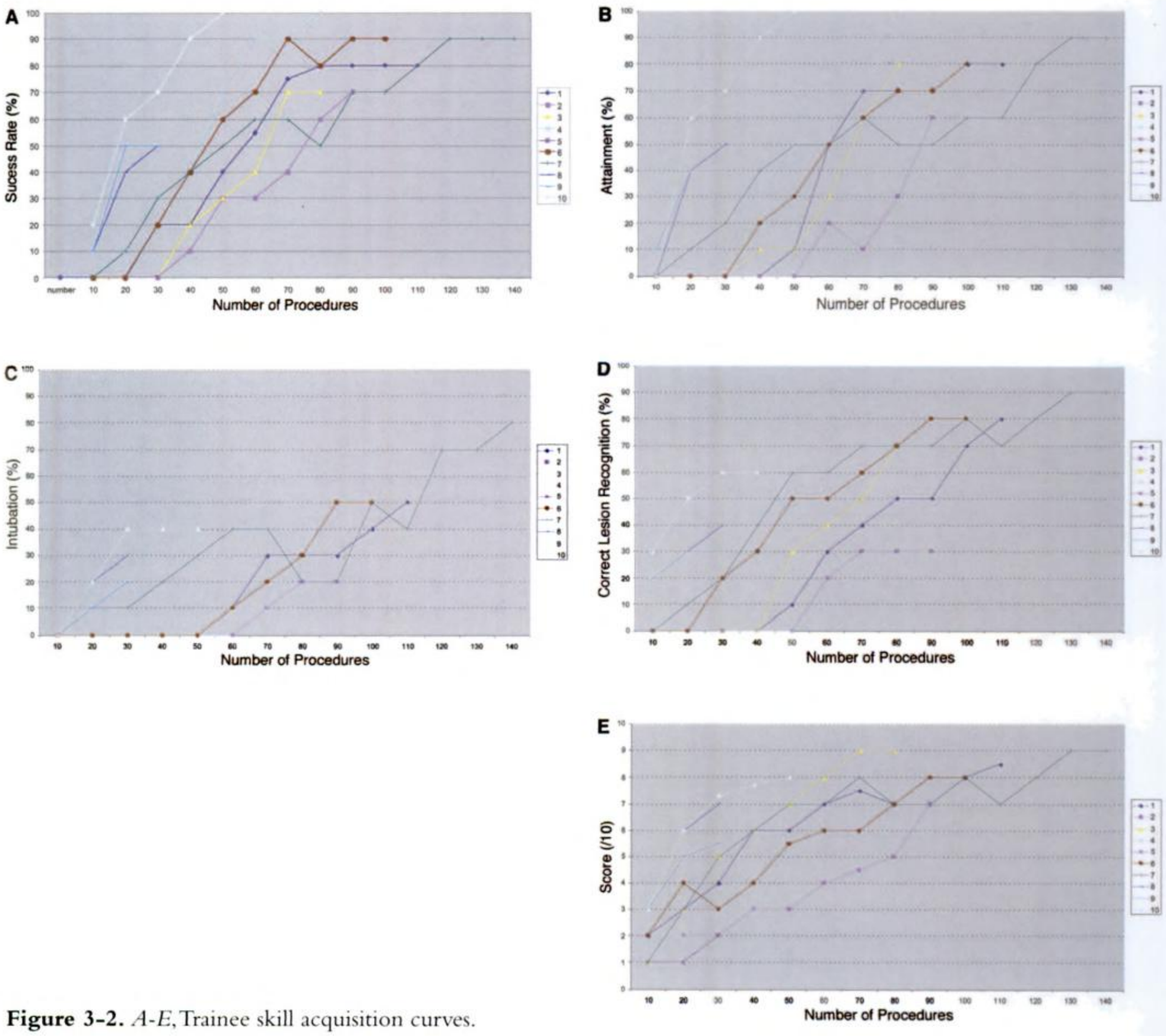

Figure 3-2. *A-E,* Trainee skill acquisition curves.

(www.thejag.org.uk). The guidelines emphasize that the training and experience required for pediatric GI endoscopy are different from adult endoscopy. Moreover, adult gastroenterologists who perform pediatric endoscopy should have appropriate and adequate training and experience.

Every trainee should achieve competence in ileal intubation because this is an important skill in colonoscopy. There are diseases for whom the diagnosis may only be made by inspecting and obtaining mucosal biopsies from the terminal ileum.[9-11] Examples of ileal pathology are illustrated in the relevant atlas section.

Logbooks

Figure 3-3A–E outline a possible model for an endoscopic logbook. The logbook forms a major part of the training portfolio of the trainee with contemporaneous comment from the trainer. All aspects of training are included.

Training Simulators

The use of endoscopy training stimulators may reduce the time needed to achieve competency. In one study, adult gastroenterology trainees beginning to learn colonoscopy were randomly assigned to receive train-

Table 3-1. Recommendations for Training in Pediatric Gastroenterology by the Royal Colleges' Joint Advisory Group (JAG)

1. Training should take place in units recognized by the Royal College of Paediatrics and Child Health (RCPCH) Speciality Advisory Committee on Pediatric Gastroenterology.
2. The training unit should be equipped with modern video-endoscopy equipment suitable for pediatric practice. There should be high quality televisual display and image recording facilities. There should be access to training videos and "JPEG" and "MPEG" files that are becoming available on Web sites such as those of the various pediatric gastroenterology societies.
3. Trainees should undertake at least 100 diagnostic upper gastrointestinal endoscopies and at least 100 diagnostic ileo-colonoscopies under supervision.
4. Trainees should have experience in the endoscopic removal of foreign bodies from the upper gastrointestinal tract and in colonoscopic polypectomy.
5. Having achieved competence at these procedures (Level 1 training) further training can lead to competence in a wider range of therapeutic procedures (Level 2). Throughout this training the emphasis should be on continuous assessment rather than numbers of procedures.
6. A written record of the number and variety of procedures carried out under supervision and subsequently independently should be kept for the trainee's "procedure experience record."
7. Trainees should attend courses in both diagnostic and therapeutic endoscopy.
8. Courses should be approved by BSPGHAN and should be provided on a regional or national basis.
9. Basic training courses on the principles of endoscopy should be attended. These could be specifically for pediatric trainees, or they might be basic theory courses such as those approved by JAG. Specific areas where practice differs from adult endoscopy will need to be addressed.

A

ENDOSCOPE CLEANING & DISINFECTION

NO.	Date	Type of Endoscope Cleaned & Disinfected	Signature (Supervisory Registered Nurse)

Figure 3-3. *A–E.* Proposal for logbook. *Continued on the next page.*

B **UPPER GASTROINTESTINAL ENDOSCOPY**

Trainee Supervisor Institution ..

No	Date	Patient UR	Age	[1] Indication	Successful Procedure Yes/No	Completed & Unassisted Yes/No	[2] Findings	Emergency Y/N	Therapeutic **S,A,F,NA	Complications (Specify)	Supervisor Signature
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

Unassisted —Trainee performs all procedure without hands on assistance from supervisor **Assisted** —Trainee attempts procedure but part of procedure is performed by supervisor

Indications [1]

B	Bleeding	NA No Active Symptoms
GU	Gastric Ulcer	B Banding
P	Pain/Dyspepsia	
I	IBD	D Dilation
A	Anaemia	
DA	Duodenitis	E Extraction
I	IBD Assessment	
DU	Duodenal Ulcer	L Lesion Removal
D	Dysphagia	
O	Specify	P PEG
M	Malabsorption	

Findings [2]

N	Normal
OS	Oesophageal Stricture
RO	Reflux Oesophagitis
V	Varices
FB	Foreign Body
GA	Gastritis

Therapeutic [3]

S
A
F
NA

R Removal Foreign Body

C **UPPER ENDOSCOPY SUMMARY SHEET**

Trainee Supervisor Institution ..

Completion Date	Total Attempted TA	Total Completed Unassisted TC	% Success TC/TA x100	Complications	No. of Therapeutic	No.of Emergency
	10					
	20					
	30					
	40					
	50					
	60					
	70					
	80					
	90					
	100					
DATES	TA	TC-Minimum	TC/TA x 100=	Complications	Therapeutic	Emergency

S-successful U-unassisted A-assisted, F-failed
TC-
TA

D COLONOSCOPY

Trainee *Supervisor* *Institution* ..

No	Date	Patient ID	Age	[1] Indication	Intact Colon Yes/No	Scope passed to eg. ileum, caecum, tv colon L colon Y/N	Completed & Unassisted Intact Colon/Ileum	[2] Findings	Time (mins) Anus to Anus	Snare Polypect -omy **S,A,F, NA	Reason for Non-Completion	Complications (Specify)	Supervisor Signature
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													

Unassisted —Trainee performs all procedure without hands on assistance from supervisor **Assisted** — Trainee attempts procedure but part of procedure is performed by supervisor

Indications [1]

A	Active Bleeding
NA	No Active Symptoms
O	Other
MB	Minor Red Bleeding
AN	Anemia
D	Diarrhoea
ABH	Altered Bowel Habit
P	Pain

Findings [2]

N	Normal
P	Polyp(s)
H	Hemangioma
AC	Allergic Colitis
CR	Crohn s
UC	Ulcerative Colitis

Figure 3-3. ***Continued*** *B–D,* Proposal for logbook. *Continued on the next page.*

E **COLONOSCOPY SUMMARY SHEET**

Trainee Supervisor Institution ..

Completion Date	Total No. Attempted Intact Colon plus Previous Colonic Resection	Total No. Intact Colons Attempted - TA	Total No. Intact Colons Completed Unassisted - TC	% Completed for Intact Colons TC/TA x 100	Mean Time for Complete Colonoscopy (intact colons)	Complications No.	Snare Polypectomies No.
	5						
	10						
	15						
	20						
	25						
	30						
	35						
	40						
	45						
	50						
	55						
	65						
	70						
	75						
	80						
	85						
	90						
	95						
	100						
TOTALS							

S-successful U-unassisted A-assisted, F-failed

Figure 3-3. ***Continued*** *E,* Proposal for logbook.

ing on a simulator (Symbionix GI-Mentor) or to proceed straight to conventional training with patients.[12] The two groups were subsequently reassessed on the endoscopy simulator (Figure 3-4) and there was a significant difference between the two groups. The colonoscopy trainee skill graphs from our unit (see Figure 3-2A–E) show that three individuals (8, 9, and 10) had steeper learning curves than the others. These three had undertaken a six-week program of training on the simulator prior to their first "live" colonoscopy. The trainees can log their performance on the simulator by saving it under an individual code. The trainer can examine the trainee's progress at any time by logging onto the simulator as a trainer. This approach is effective in teaching basic endoscopic techniques. As these simulators become more widely available they may become the standard first phase of training.

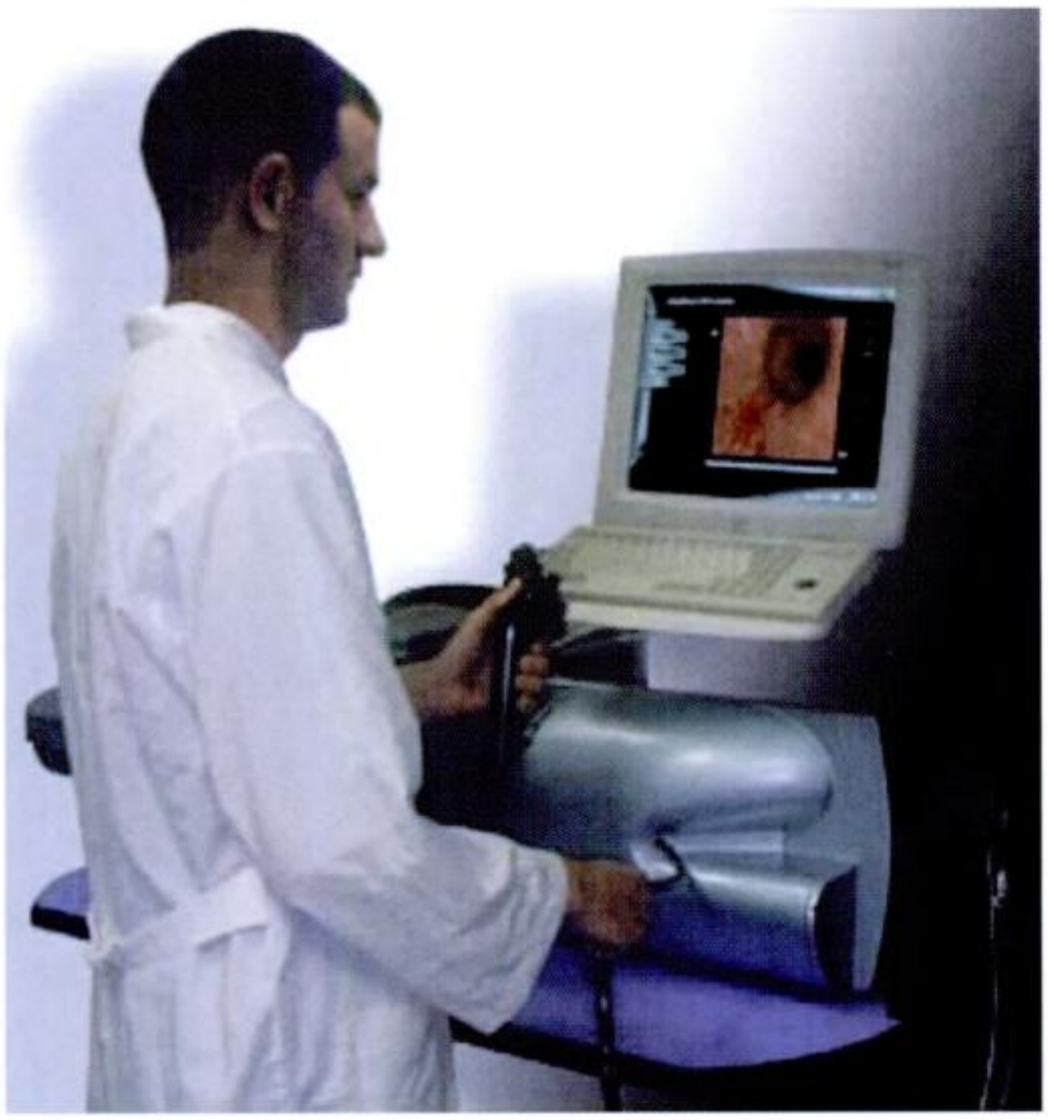

Figure 3-4. Symbionix GI-Mentor simulator being used for training in upper gastrointestinal endoscopy and colonoscopy.

Endoscopy Training Courses

Although there is no substitute for one-on-one teaching in a clinical environment with real patients, endoscopy training courses are of value. Watching procedures being performed by "experts" or gaining "hands-on" experience in an intensive training environment can increase the rate of learning. Many courses have evolved in the context of adult endoscopy, focussing on basic endoscopy skills and on the rudiments of endoscopic technique. The trainee is taught how the instruments work, how they are cleaned and maintained, and how an endoscopy unit is established and maintained. The safe use of sedation and general anaesthesia may be addressed. "Advanced" courses are also available, focussing on therapeutic techniques such as the removal of sessile polyps and the use of variceal banding, or on the recognition of unusual abnormalities, or the management of complications.

Training the Trainers

The ability to teach procedures such as endoscopy is an important skill that can be improved by expert coaching. Defining criteria and skills for trainers will establish uniform standards for teaching and will improve practice. The British Society of Gastroenterology runs "Train the Trainers" courses, which are mandatory for adult gastroenterology endoscopy trainers in the United Kingdom. Pediatric gastroenterology societies should consider providing similar courses.

Multimedia Training Tools

There is increasing potential for the use of multimedia tools to help the trainee in learning techniques and recognizing pathological abnormalities. Endoscopic manuals may illustrate a very wide range of lesions and may include video sequences on accompanying compact disks. These types of educational tools are useful resources to both trainer and trainee.

Training in Therapeutic Endoscopy

Opinions vary about who should receive formal training in the skills required for therapeutic procedures in pediatric endoscopy. Not all trainees need or should attempt to acquire each skill. Most pediatric colonoscopists are competent in the removal of simple polyps. Many endoscopists have attained proficiency in variceal banding and in the placement of percutaneous endoscopic gastrostomy tubes or buttons. However, endoscopic retrograde cholangiopancreatography (ERCP) requires specialized training and increasingly involves therapeutic intervention. Other techniques that may also fall into this category include endoscopic antireflux procedures, percutaneous endoscopic jejunostomy placement, complex polyp removal, enteroscopy, balloon dilation of strictures, laser or argon beam therapy, and endosonographic-assisted procedures such as transgastric pancreatic pseudocyst drainage. There are a limited number of pediatric patients who require these specialized procedures. For an endoscopist to maintain proficiency, patients should be referred to a restricted number of centers. Most training programs in pediatric endoscopy distinguish between basic endoscopic skills and complex therapeutic procedures. Clearly each complex therapeutic skill requires adequate training and demonstration of competence. Simulators now include special modules to help in learning techniques such as ERCP, polypectomy, and treatment of both variceal and nonvariceal bleeding (Figure 3-5).

Other Training Areas

There are many issues pertaining to training in endoscopy apart from technical competence in performing procedures. These include establishing and maintaining an endoscopy unit, patient management, obtaining informed consent, using sedation and general anaesthesia, discharge planning, and documenting and

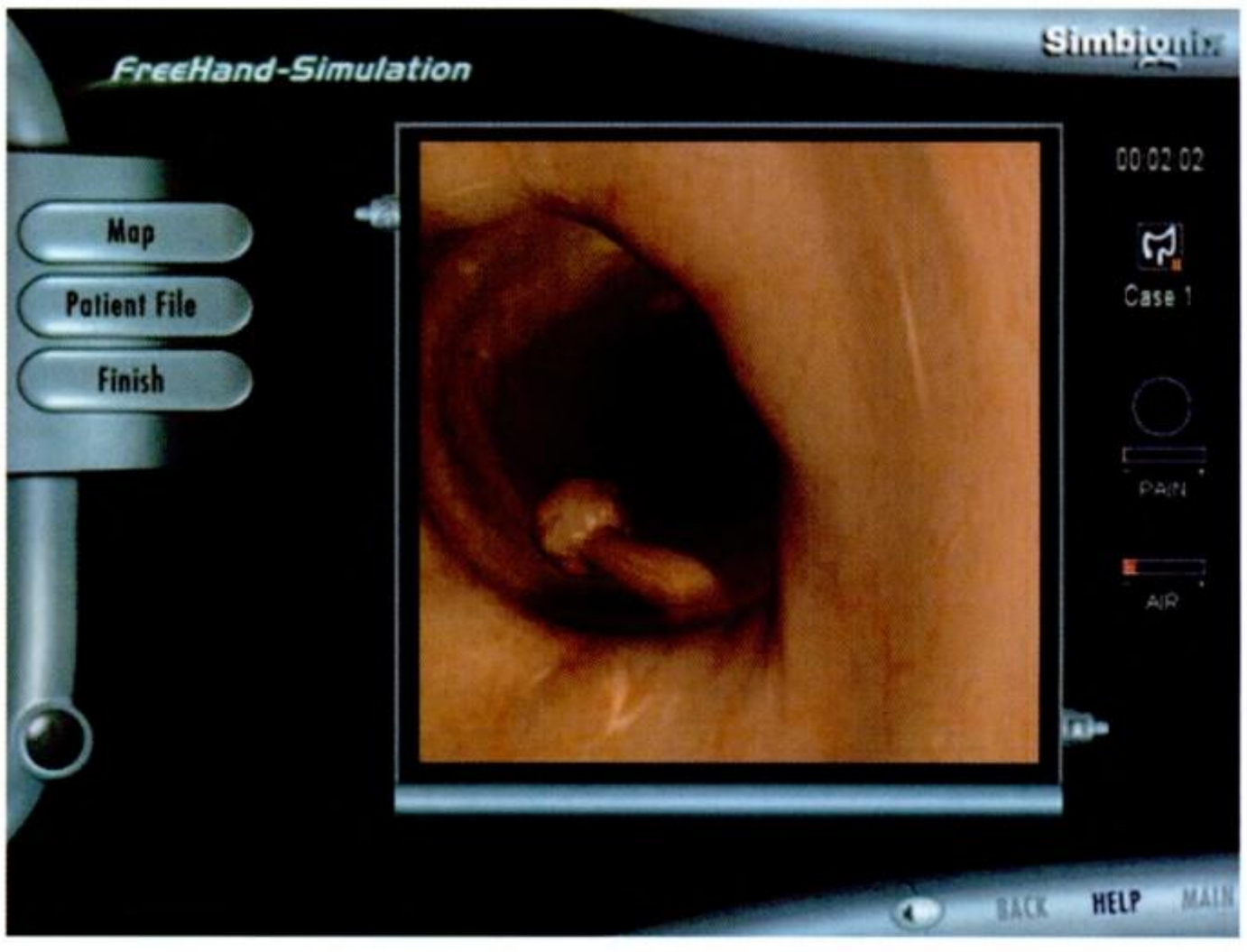

Figure 3-5. Symbionix GI-Mentor simulator being used for training in the technique of polypectomy.

reporting of procedures. Maintenance and repair of equipment requires that endoscopists are also knowledgeable in these areas. All staff involved with sedation should be appropriately accredited in pediatric resuscitation. Maintenance of licensure requires continuing medical education. Computerized programs currently exist to facilitate documentation of procedures and to facilitate communication of reports to primary care providers. All of these aspects should be addressed in a comprehensive training program.

Accreditation of Training Centers

Pediatric and pediatric gastroenterology training in the United States is monitored and accredited by various regionally-based boards. As well, a sub-board in adult liver transplantation has recently been established. This has generated interest in the development of an equivalent sub-board in pediatric liver transplantation. The knowledge necessary to care for children with these complex conditions requires highly specialized training. Similarly, children requiring therapeutic endoscopic intervention should be cared for by individuals trained and proficient in these complex procedures. Because relatively few children require this expertise, specialized training centers should be supported on a regional basis in which the endoscopist's skills are able to be maintained in the adult population. This strategy will enable individuals with the cognitive knowledge to care for children to be proficient in procedures that are commonly performed in adults, but rarely needed in the pediatric population. Accreditation of such centers will be required in order to promote high standards for training in pediatric endoscopy.

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The Endoscopy Unit

4

Liz McLean

The development of pediatric endoscopy has been of interest to both the medical and nursing professions and has resulted in advancement of the nursing role in pediatric gastroenterology. This chapter focuses first on the practical aspects of establishing a pediatric endoscopy unit and on its day-to-day management. Second, it discusses the training of the endoscopy nurse and role of this nurse in the running of the unit and the care of children undergoing endoscopy.

Planning the Unit

In planning the establishment of a pediatric endoscopy unit the likely workload must be carefully determined. It is crucial that there should be a sufficient number of patients to maintain stability of referral and to provide the critical mass necessary to maintain expertise and to support clinical effectiveness.[1] Demonstration that the number of patients is sufficient is also essential to making a credible financial case. Based on the anticipated workload a proposal can be developed using national and professional guidelines for such units.[2] This is necessary for accreditation with relevant national regulatory bodies.

A Child Friendly Environment

The endoscopy unit may be based in or close to the children's ward of a pediatric department or may be part of a larger general endoscopy unit that cares for both adults and children. The unit must of course provide a child and family friendly environment. A busy and technically orientated clinical environment will evoke anxiety in children. This can be avoided in various ways. Paintings of popular cartoon characters might be used to decorate the unit's walls. Medical equipment can often be disguised or hidden behind screens prior to sedation or induction of general anesthesia. Age appropriate music and video films can be provided. Child friendly medical accessories are commercially available, such as transparent or attractively colored anesthetic masks and patterned or colored dressings for use with intravenous cannulas. Most important, however, is that the staff adopt an age-appropriate style in their interactions with young patients.

The Endoscopy Room

The endoscopy room, where the procedures are performed, must be large enough to allow unconstrained use of endoscopic, monitoring, and anesthetic equipment. It must be large enough to allow for movement of the child during the procedure without compromising safe patient-handling techniques. The room and its doorways must be sufficiently large to allow the easy movement of patient trolleys and other equipment.

Excessive noise from adjacent rooms should be minimized so that children are not made anxious by overhearing other patients who may be upset while awaiting their procedure or while waking from sedation or general anesthesia in the nearby recovery area. It is also essential that the environment should be adequately enclosed to ensure privacy. A frequent concern for adolescents facing colonoscopy is the possibility that they may be embarrassed by a lack of privacy during the procedure. The ambient temperature of the room should be adjustable to appropriate levels to ensure that young children and small infants are not at risk of hypothermia. The lighting should be easily adjustable and blocking of natural light may be necessary sometimes. Reducing the lighting level can help children to relax and may also be important during the endoscopic procedures, when transillumination is needed to determine the position of the endoscope (Figure 4-1). Transillumination is especially important for procedures such as percutaneous endoscopic gastrostomy placement. In this enclosed

Figure 4-1. Transillumination at the hepatic flexure.

environment, frequent replacement of room air is required. There should be a negative air pressure within the room to prevent leakage of anesthetic gases to other areas, and a gas scavenging system should be in place that is capable of detecting excessive gas concentrations.

Location of the Endoscopy Unit

Ideally the endoscopy unit should be located close to the children's ward to which the patients will be admitted. However, this is not always possible. When designing a new unit, consideration should also be given to the proximity of the unit to other facilities in the hospital such as the radiology and anesthesiology departments and the operating room area.

The Recovery Area

The endoscopy unit requires a fully equipped and appropriately staffed recovery area for the initial recovery phase after sedation or anesthesia (see Chapter 5, "Patient Management"). Natural light is an advantage in the recovery area as in other patient areas.

Equipment Cleansing and Storage Areas

Another room separate from patient areas, but easily accessible to staff, is required to accommodate the endoscopes and the necessary cleaning equipment. This is best located adjacent to an exterior wall because high level ventilation and extraction of disinfectant fumes is essential. Disinfectant materials and solutions must be securely stored to avoid the risk of accidental patient or staff exposure. Space is required for cabinets to store endoscopic equipment and accessories near to the endoscopy room. Endoscopes should be hung vertically in storage cupboards (Figure 4-2). Secure lockable storage space must be available for drugs and anesthetic agents to fulfill national safety regulations. In all areas within the endoscopy unit, the walls, floors and other surfaces must be finished with flush junctions, and must be water-resistant and designed to withstand frequent cleaning. These areas should be clearly sign-posted as being environmentally hazardous given the presence of toxic and inflammable agents.

Office Accommodation, Computer Networking and Video Links

Ideally, the endoscopy room should be cable-linked to the hospital's computer network. If possible a video link to other viewing areas should be provided for training purposes. An office or clean-work area is required for completion of written records and to facilitate computer database entry.

Monitoring and Support Equipment

Essential equipment for pediatric cardiopulmonary resuscitation must be available and easily accessible at all times. Individual unit protocols must be compiled regarding the range of equipment and drugs required for sedation and general anesthesia, and for emergency resuscitation. Monitoring equipment is required both for the endoscopy room and the recovery area. Routine monitoring includes blood oxygenation (pulse oximetry),

Figure 4-2. Proper endoscope storage.

respiration, cardiac rate and rhythm, and blood pressure. A full range of equipment must be available for infants and children of all ages. Similarly, other items of equipment need to be available in a range of appropriate sizes, including face masks, nasal cannulas, endotracheal intubation equipment, and esophagogastroduodenoscopy (EGD) mouth guards (bite blocks). Both portable and central supplies of oxygen must be available to provide oxygen during procedures and during patient transfer.

Endoscopic Equipment and Accessories

The choice of endoscopic equipment to be obtained will depend on the number and variety of procedures likely to be performed, and on the age range of the patients. The strategy chosen may be influenced by hospital policy rather than being decided at service level. There may, for example, be an established adult endoscopy service in existence and the choice of compatible equipment may be important. Consideration must also be given to the strategy for regular servicing of endoscopic equipment and for the management of equipment failures. For some units, leasing equipment may be more cost effective than purchasing. A choice must be made between purchasing reusable or disposable accessories such as biopsy forceps. Disposable accessories should not be reused. If reusable accessories are employed, careful adherence to correct sterilization and disinfection techniques is essential. The cost and inconvenience of such infection control measures should be allowed for when considering the advantages and disadvantages of disposable equipment.

Purchasing of Equipment

Various regulations and guidelines exist regarding the cleaning and disinfection of endoscopic equipment.[3] It is necessary that the systems employed and the protocols followed should meet the requirements for the decontamination of medical devices laid down by relevant governmental authorities and professional bodies. It is essential to take account of these guidelines and regulations when purchasing cleaning and disinfecting equipment.

When purchasing equipment a service contract must be negotiated. Staff should ensure that routine maintenance takes place and should identify any delays with scheduled servicing. The endoscopy unit nursing staff should have a thorough knowledge of operating instructions and safety aspects of all equipment. This is particularly important with potentially hazardous equipment such as diathermy units.

Apart from legislative requirements, various other factors need to be considered when choosing a system for cleaning and disinfecting endoscopes. The service requirements are of importance. The type of chemical disinfectant to be used should be considered (see Cleaning and Disinfection of Equipment, below).

The Endoscopy Nurse

Minimum requirements for staffing a pediatric endoscopy unit may be specified in national guidelines for the care of children in a hospital. Such guidelines cover the requirements for training and the qualifications necessary to provide nursing care for children. The nurse working in pediatric endoscopy requires experience in patient observation and in assisting the endoscopist. These skills are an integral part of the endoscopy nurse's role. There should be a clear focus on safe and correct practice prior to, during, and after the procedure. The endoscopy nurse has an important role in communicating with the child and family. In units in which pediatric endoscopy is integrated into general endoscopy, some of the responsibilities described for the endoscopy nurse may be assumed by individuals with primary duties in those areas such as cleaning and maintaining instruments. In these units, the role of the endoscopy nurse may be focused on preprocedure preparation, performing the procedure, or recovery of the child. Different individuals may perform these duties.

Two nurses are normally required as a minimum level of staffing during pediatric endoscopy procedures. One assists the endoscopist; the other is primarily responsible for the child and family. The nurses have an essential role in maintaining documentation in the unit. This includes documentation of nursing care, and also recording of data relevant to quality improvement and risk assessment.

The nurse assisting the endoscopist must be familiar with the requirements for each procedure. Anticipation of the endoscopist's requirements greatly enhances the efficient performance of the procedure. Endoscopy nurses must be competent in the management of the endoscopic equipment. They should know how to clean, disinfect, and prepare the instruments. They should be able to select the appropriate type and size of endoscope for each procedure. They should be able to manage simple and common equipment failures, such as a loss of suction or of water supply to the

endoscope. They should be familiar with the requirements for equipment maintenance. Such skills and knowledge are acquired through training and experience gained from working in the endoscopy unit. There are various published practice guidelines of relevance to the endoscopy nurse. The Society of Gastroenterology Nurses and Associates has produced a set of standards of clinical nursing practice to be applied in the endoscopy setting, but these are primarily focused on patient care rather than addressing the specific skills required to assist the endoscopist.[4] Useful information on assisting at endoscopy may be gained from endoscopy training guidelines produced by various national societies such as the American Society of Gastrointestinal Endoscopy or the British Society of Gastroenterology.

Pediatric endoscopy nurses must have an appropriate nursing qualification. Training should provide an understanding of pediatric physiology and pharmacology, and of the emotional and psychosocial aspects of child care. They should have completed formal training in pediatric life support skills.

The Gastroenterological Nurses College of Australia has provided a view on the number of nurses needed to support an endoscopy service.[5] It has suggested that four whole-time equivalent nurses are required to staff an endoscopy service providing one patient list at any given time. Some units would require fewer staff, but for services undertaking complex therapeutic procedures, additional staff might be necessary.

The Nurse's Role with Child and Family

The endoscopy nurse may not be directly involved in the care of the child prior to the procedure. Close liaison with the nursing staff on the children's ward or the outpatient staff is therefore important. They must be aware of the preparation and safety requirements for these children. The child should be psychologically prepared for the procedure.

Practical preparation of the child before endoscopy includes the need to restrict oral intake according to an agreed protocol (see Chapter 5). This applies to procedures carried out under sedation and general anesthesia. The nurse should assess the child's state of hydration prior to the procedure. This is particularly important in infants and young children.

A bowel evacuation regimen is usually required prior to colonoscopy (see Chapter 5). The regimens employed vary widely, but the aim is to achieve complete cleansing of the bowel to facilitate safe advancement of the instrument and to permit unimpaired inspection of the mucosa. Often the child is restricted to a low residue diet for some days, and laxative treatment is then administered on the day before the procedure. With this treatment some passage of loose stools or diarrhea can be expected, and children may experience mild abdominal cramps. Such laxative regimens increase the risk of dehydration, and children should be encouraged to consume liberal amounts of fluid. In practice significant dehydration is uncommon, but care should be exercised.

The psychological care of the child (see Chapter 6, "Psychological Aspects of Endoscopy") is influenced by their age and development, their individual needs, and their previous experience of hospital investigations. Each child experiences the process in a unique way, and the nurse must adopt an individual approach. Theories of child development generally group children into wide age categories, but this is still of value in indicating how children may perceive and understand events.

Children under four years are largely dependent on their parents, although they are gradually gaining a sense of autonomy. For these children reducing parental anxiety can help the child to relax and cooperate. For children aged 4 to 7 years, fantasy and reality remain closely linked. The nurse's use of appropriate language and explanation and the avoidance of unfamiliar terminology are important. For those over 8 years, clear explanations of what is to be expected can be given early on in the process because the child's perception of time is enhanced. Older children may wish to explore issues in detail. Children of all ages benefit from clear, concrete explanations with the use of simple analogies and reference to their previous experiences for clarification. Strategies involving play or drawing may be helpful in improving the child's understanding. All children and adolescents may show signs of regression in stressful circumstances. They can be encouraged to personalize their experience by bringing along a favorite toy or music during their procedure. This may increase their sense of control and so reduce feelings of apprehension. The play specialist may have a useful role. The child could visit the endoscopy unit in advance and play can form a useful part of the preparation process. Play activities might also help some children afterwards in exploring their experience of endoscopy. This could be particularly important if a child's experience of sedation proved unsatisfactory.

Children understandably may wish their parent to remain with them during the endoscopy procedure. Current pediatric practice rightly encourages parents

to remain during induction of sedation or anesthesia (see Chapter 6). Some pediatric endoscopy units may wish to provide facilities for the parent to remain during the endoscopy. This policy has significant resource implications. It is arguable whether it is generally necessary, particularly if the child is to be examined under deep sedation or general anesthesia. Preparation and support for the parent are required if it is to be a positive experience. Before implementing such a policy a multidisciplinary approach should be established. There should be an agreed approach to providing information to parents before and during the procedure. The endoscopy nurse should discuss matters with the parents and child in advance and determine whether the parents do wish to remain during the procedure. Parents should understand that they can leave the endoscopy room at any time if they wish. The parent should be seated comfortably and should remain close to their child and to the nurse who is taking care of the child. Consideration should be given to strategy should a significant adverse event occur during the procedure. There should be prior agreement on the circumstances in which parents might be asked to leave the procedure room.

Informed consent is required for endoscopy (see Chapter 6). The endoscopy nurse or another designated member of staff should check as a matter of routine that the relevant written consent documentation is present in the child's records before commencing.

The Nurse's Role in the Endoscopy Room

Before the child's arrival in the endoscopy room, all equipment should be prepared and its function checked. The endoscopy nurse may prepare and label intravenous drugs required for sedation and its reversal. For reasons of safety and professional requirements, this should be done in conjunction with another specified member of staff. Children who are to receive sedation should have an intravenous canula inserted prior to arrival, whilst those receiving general anesthesia will more frequently have a canula inserted during anesthetic induction. Equipment that is not immediately required during induction should be stored out of sight, but within easy access if necessary.

On arrival in the endoscopy room the child and parent should be settled comfortably prior to induction of sedation or anesthesia. A calm and quiet environment is important. For young children, initial sedation may be carried out with the child sitting on the parent's lap. Physiological monitoring should commence prior to sedation or anesthesia. With general anesthesia, the endoscopy nurse's role is focused on assisting the endoscopist. With sedation, a designated nurse is primarily involved in monitoring the patient. Awareness of the child's physiological condition and of the potential risks of sedation, such as hypoventilation, apnea, or airway obstruction is paramount. The nurse is not only responsible for monitoring the child's condition, but for preparing equipment and drugs for intervention if required. Based on agreed protocols for sedation there should be a clear policy on the identification of signs of under-sedation and over-sedation. Both doctors and nurses responsible for the sedated patient should be proficient in managing life support. Essential equipment for resuscitation including appropriately sized face masks and intubation equipment and self-inflating ventilation bags should be available.

The endoscopy nurse shares responsibility with the endoscopist and, if present, the anesthesiologist for the documentation of patient care during the procedure. A time-based record of the patient's condition, state of sedation, and of the drugs administered should be maintained. Observations recorded should include the clinical assessment, oxygen saturation level based on pulse oximetry, respiratory rate, heart rate, and blood pressure. These should be recorded at 5-minute intervals. Airway patency should be closely monitored and maintained through appropriate positioning of the patient and, if necessary, the use of oral or nasal suctioning.

The role of the endoscopy nurse is changing with increasing direct involvement in procedures (see The Nurse Endoscopist, below). With appropriate training the nurse can assist in manipulation of the endoscope, and may have an active role to play in performing procedures such as percutaneous endoscopic gastrostomy insertion.

The Nurse's Role following the Procedure

When the procedure is completed the child should be prepared for transfer to the recovery area. The intravenous canula should be adequately secured. Care should be taken that there is no residual anesthetic or sedative agent remaining in the lumen of the canula. Children should be washed if necessary and covered appropriately. It is essential that the child and their coverings are both clean and dry. A final assessment of the child's physiological status should be made to confirm that transfer can safely take place.

The endoscopy nurse should communicate with both the recovery area staff and, if necessary, the children's

ward staff to ensure that continuity of care is maintained. A written and verbal report of the child's condition throughout the endoscopy, the administration of drugs, other interventions, and any adverse events occurring should be provided. Parents should, of course, be informed of any significant events.

The nurses providing care in the recovery area should also be appropriately trained in pediatric life support skills. Monitoring continues as described above until the child is alert and able to communicate as usual. The nursing staff should be aware that if a benzodiazepine or opiate reversal agent has been administered the level of sedation could deepen during the recovery phase because these agents have a shorter action than the sedative agents. If an oropharyngeal local anesthetic agent has been used it may be necessary to delay the first oral intake.

A set of recovery area discharge criteria have been proposed by the American Academy of Pediatrics.[6] Physiological observations should be satisfactory and stable. The child should be easily aroused and should be able to sit up and talk in a manner appropriate to their developmental stage. The child's state of hydration should be satisfactory. If the child is being transferred to another unit in the hospital, the care provided in the recovery area should be documented and discussed with the nursing staff on the children's ward at the time of transfer.

The Nurse Endoscopist

Successful development of role of the nurse endoscopist has taken place in adult endoscopy units. These nurses, usually employed as gastroenterology nurse practitioners, complete the same training and accreditation as doctors training in endoscopy. Generally nurse endoscopists have undertaken EGD and sigmoidoscopy, but some have provided a full diagnostic endoscopy service using conscious sedation.[7] In time the nurse endoscopist may find a role in pediatric endoscopy. However the issues surrounding endoscopic sedation for children are complex because children may require deeper levels of sedation than adults.

Cleaning and Disinfection of Equipment

Infection control, including cleaning and disinfection of equipment may be the responsibility of the endoscopy nurse. Although technicians or assistants sometimes undertake these tasks, the nurse must be fully acquainted with the requirements for good practice. Guidance on infection control and cleaning and disinfection procedures are provided by various professional bodies.[8,9]

Preliminary Cleaning Process

Immediately after the endoscopic procedure is completed, the air/water channel is flushed through for 10 to 15 seconds and water and detergent are suctioned through the biopsy channel to remove gross debris. This irrigation should be performed first with cold water because heat coagulates protein and may cause adherence of organic material. This can lead to blockage of the channel lumen.

The endoscope is then leak-tested prior to submersion in cleaning fluid to ensure that there is no surface damage (Figure 4-3). If the endoscope should be found to have a leak it will require repair. The external surface is wiped clean and the endoscope is packed in an appropriate clinical bag to indicate that it remains contaminated. The absence of a leak is demonstrated by showing that an increased residual air pressure can be maintained within the endoscope channels as specified in the manufacturer's criteria.

Regardless of the technique used, the most important step in the process is the initial manual cleansing with an enzymatic detergent in order to remove all secretions, blood, and other organic material. The endoscope is immersed in warm water containing an enzymatic detergent (Figure 4-4). Video endoscopes and fiberoptic endoscopes require the sealing of electrical connections prior to immersion of the instrument in cleaning fluid. Manual cleaning includes thorough brushing

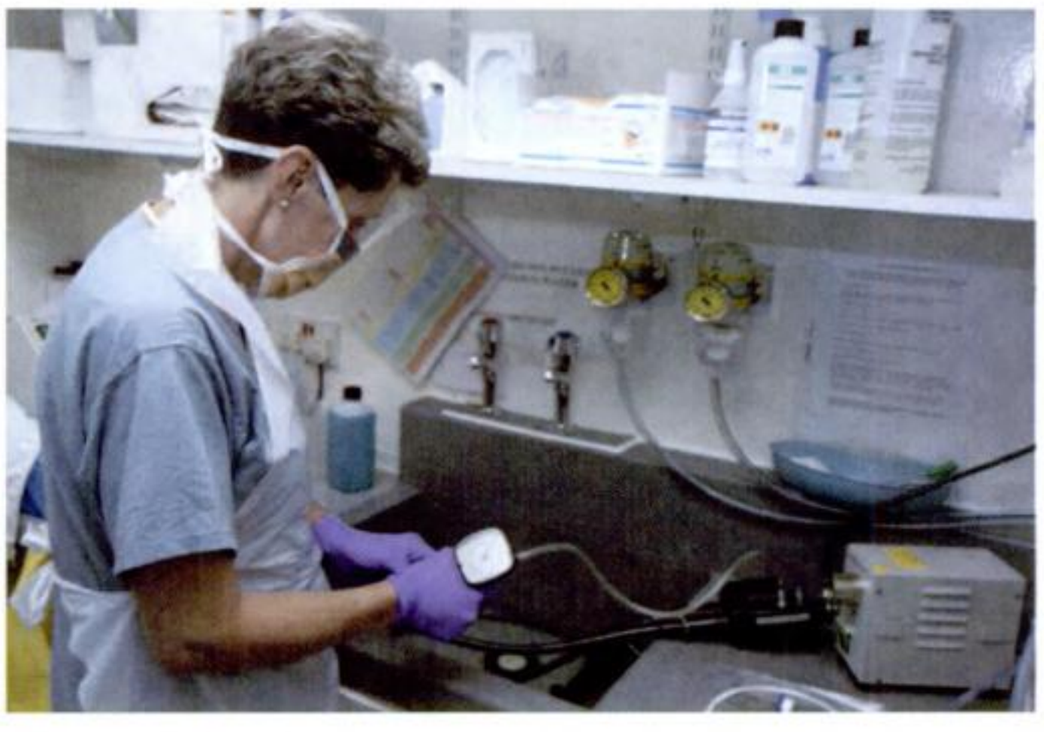


Figure 4-3. Leak testing of endoscope prior to submersion.

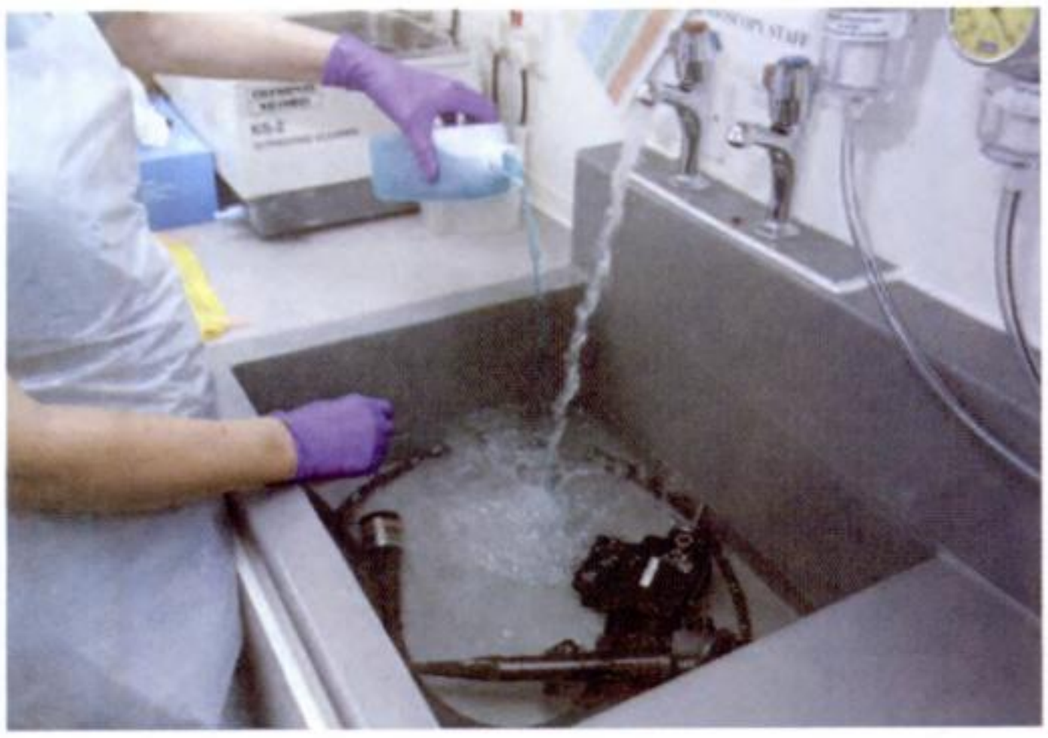


Figure 4-4. Washing the endoscope in enzymatic cleaning solution.

Figure 4-5. Cleaning the suction, biopsy and air/water channels with a brush removes particulate debris.

Figure 4-6. Cleaning the head and dials of the endoscope.

through of the suction/biopsy channel (Figure 4-5). The brush must be of appropriate diameter and cleaned between each passage until it emerges clean from the channel. Channel valves and ports are brushed to remove debris. The outer surface of the instrument, including the endoscope shaft and control unit, the angulation controls, and the umbilical connection, are cleaned (Figure 4-6). A soft toothbrush may be useful for cleaning grooves, particularly around the angulation controls (Figures 4-7A,B). Finally, the instrument is rinsed with water to remove the detergent (Figure 4-8). Some manufacturers indicate that this final rinse phase is not necessary.

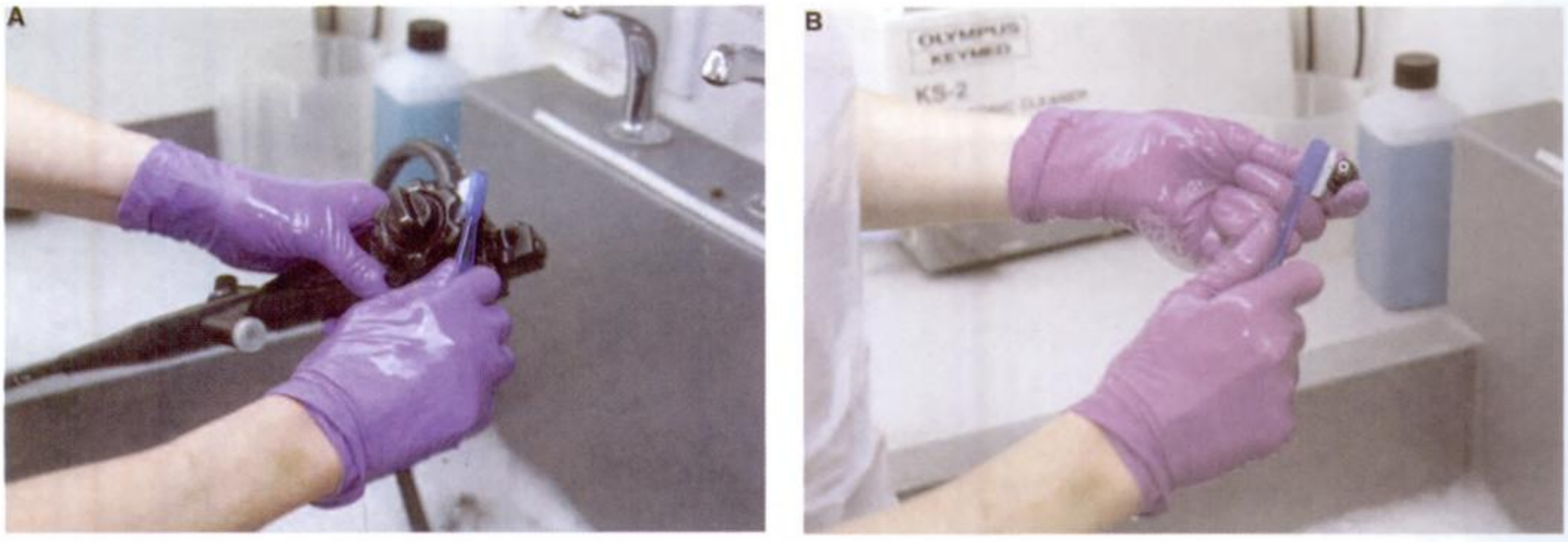


Figure 4-7. Using a soft brush to clean valves and grooves.

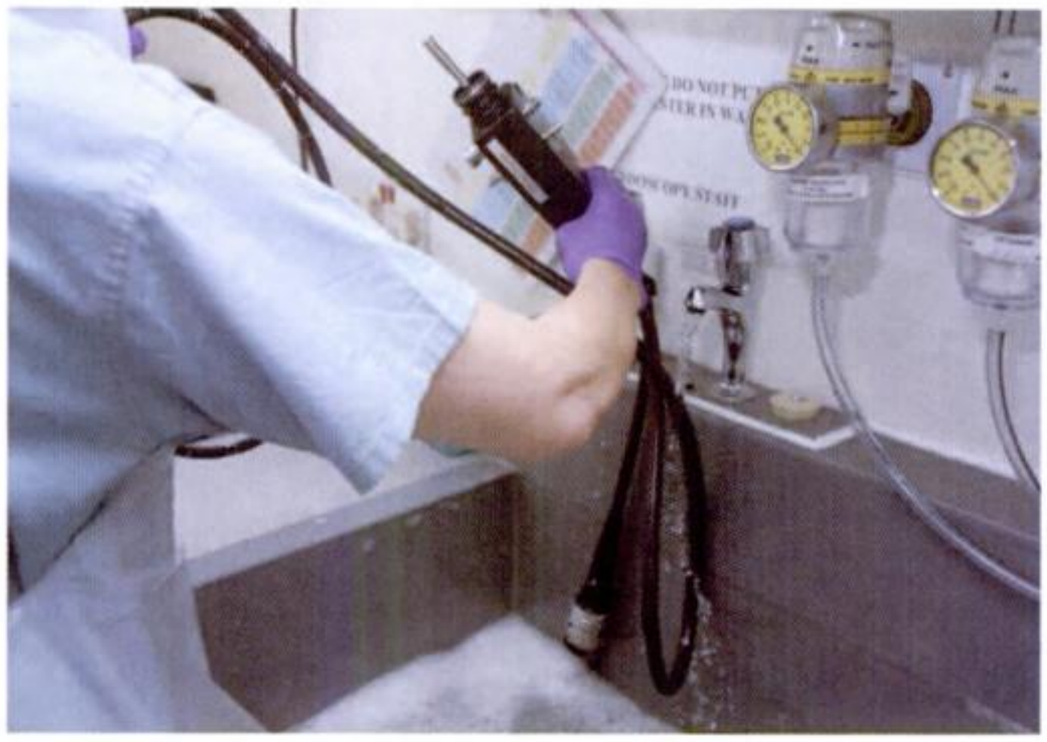
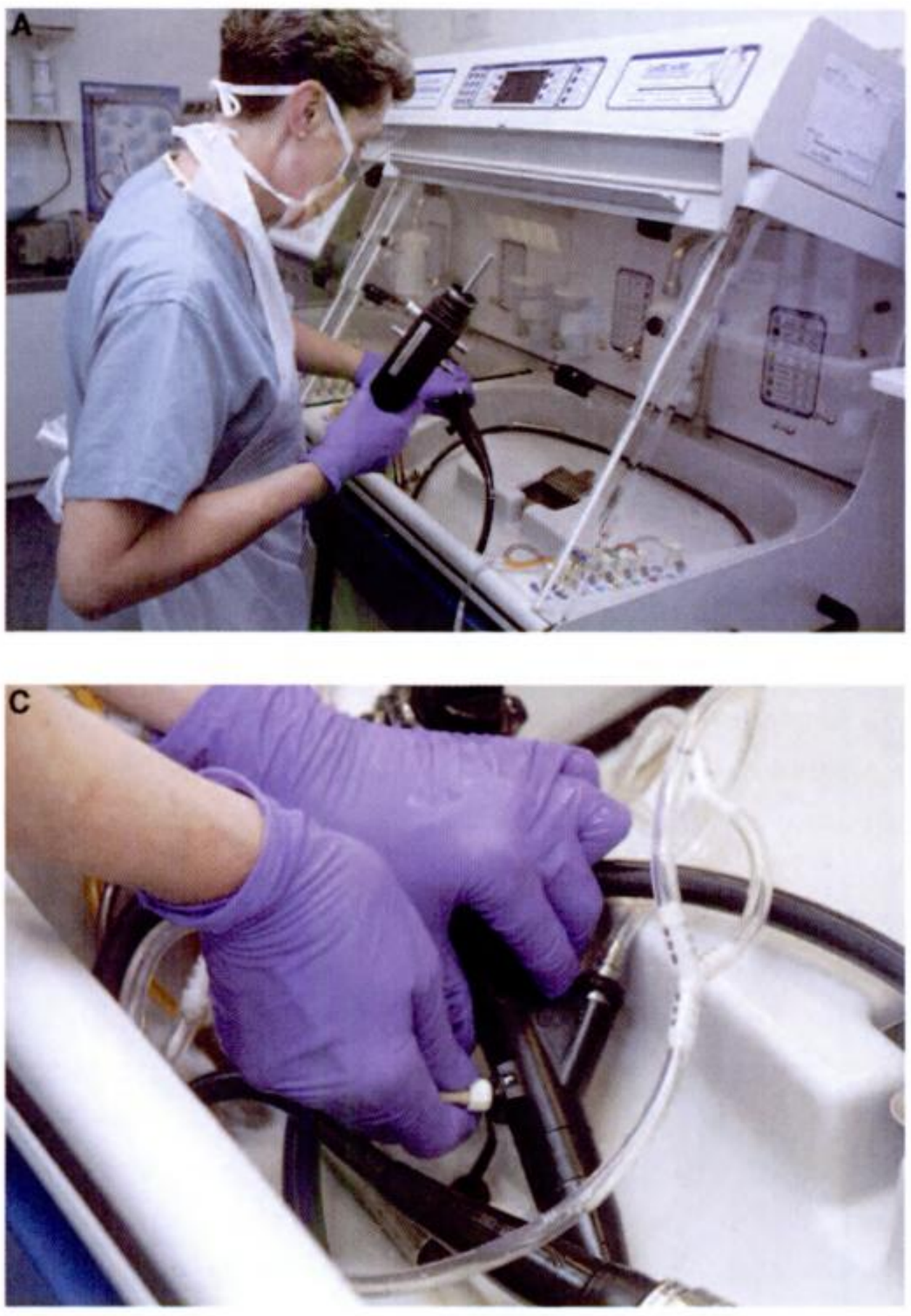


Figure 4-8. Thorough washing of cleaning solution from the endoscope.

Disinfection Process

The disinfection process then follows. This may be based on a manual technique or the use of an automated endoscope washer disinfector. It is generally agreed that the latter is more reliable. Unfortunately, automated systems are not universally available, and currently many units continue to rely on manual techniques.[8] The reliability of manual techniques may vary unless meticulous care is taken. The installation of an automated washer disinfector should therefore be considered an important priority.

If an automated process is not available, a manual disinfection process is carefully undertaken. With the automated process, the endoscope is connected to the washer disinfector following the manufacturer's instructions (Figures 4-9 A–F). Some of these provide a clean-



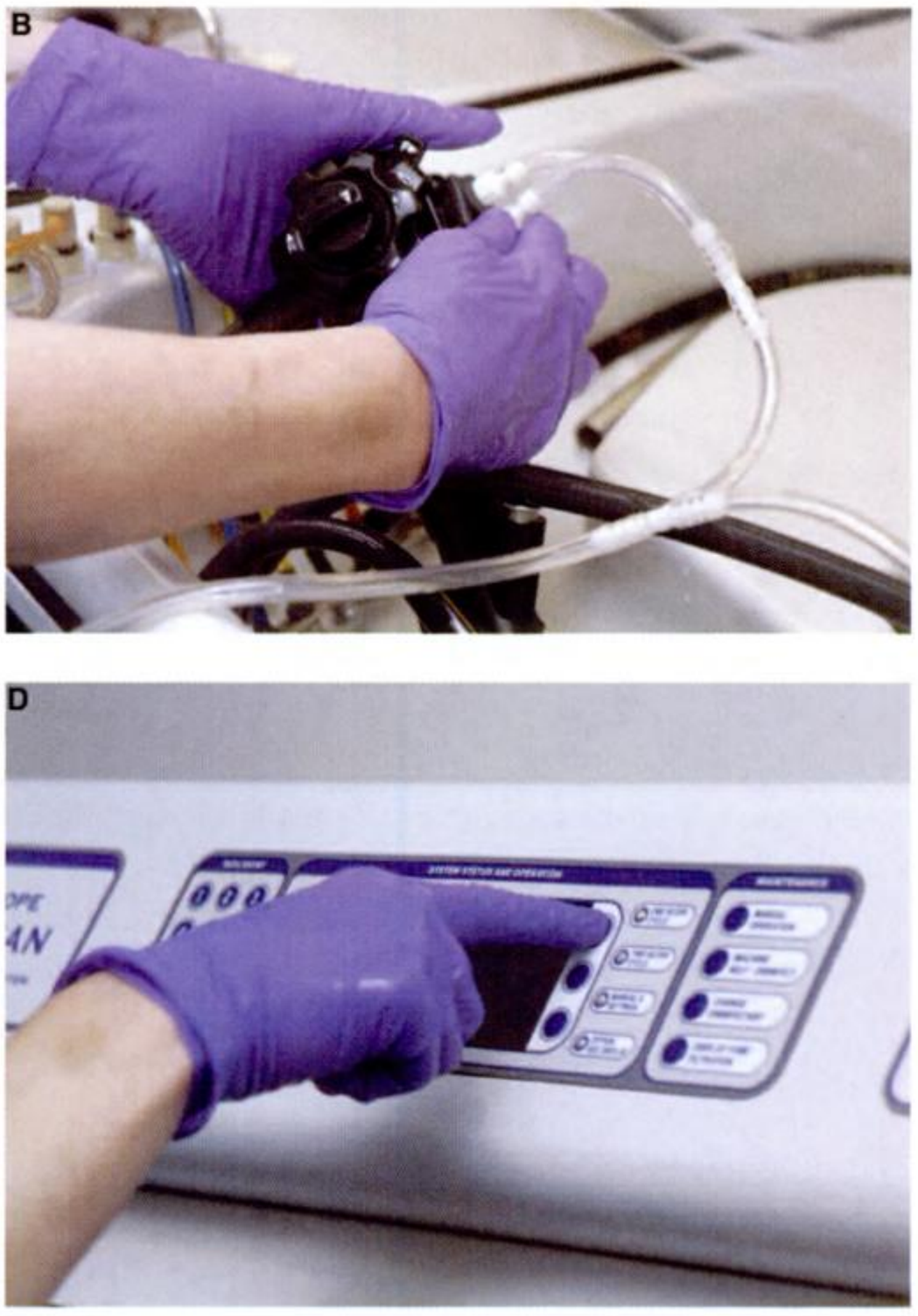


Figure 4-9. Using the automated washer disinfector to clean the endoscope. *Continued on the next page.*

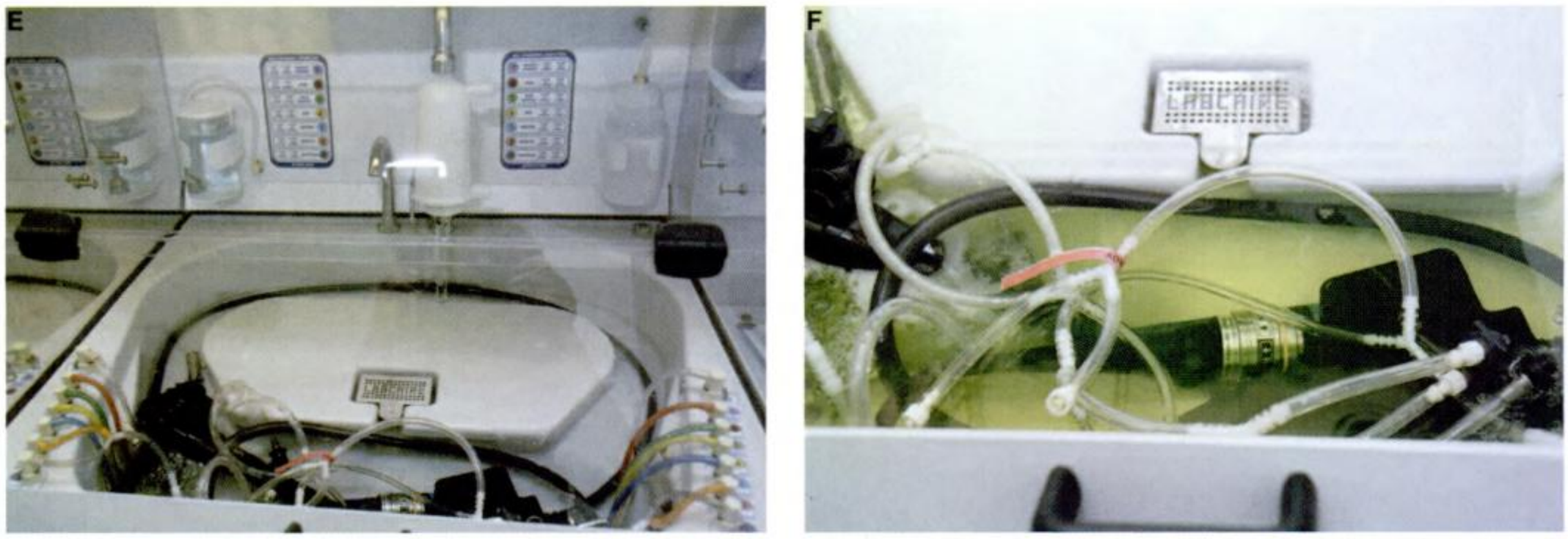


Figure 4-9. *Continued* Using the automated washer disinfector to clean the endoscope.

ing cycle prior to disinfection, but the initial process of manual cleaning described above remains essential.

In terms of risk, endoscopy is technically classified as a "noninvasive" procedure, meaning that it does not involve entry into sterile body spaces. However, the endoscope is in contact with mucous membranes and body fluids, and endoscopy is therefore classified as "intermediate risk." It is this classification that determines the disinfection requirements. "Intermediate risk" procedures require either sterilization or "high-level disinfection." Endoscopes cannot tolerate the high temperatures necessary for sterilization. High-level disinfection is therefore employed, based on the removal or destruction of vegetative organisms using chemical disinfectants.

Local disinfection policies are generally established in collaboration with the institution's infection control team. These policies are usually based on national guidelines or regulations produced by professional or governmental bodies. In devising disinfection policies various factors are important, including the range of antimicrobial activity required, disinfectant contact time, stability, toxicity, and inactivation, and the cost and corrosiveness of the disinfectants employed. Policies vary in terms of disinfectant concentrations, use of multiple disinfectants, and disinfectant immersion time. National licensing requirements and manufacturer's instructions must be followed. The following general comments are based on the views of a range of international professional and governmental bodies.[9–11]

Glutaraldehyde 2% is widely employed as a chemical disinfectant for endoscopic equipment. However its use is prohibited in some European countries. It has a wide range of antimicrobial activity and is effective against bacteria, spores, fungi, and viruses. Although it is relatively noncorrosive, it vaporizes easily and is highly irritating. Direct contact with skin and mucus membranes must be avoided through the use of protective clothing and effective ventilation. Peracetic acid (0.2–0.35%) is now a recognized alternative. It is thought to be less irritating but more expensive. Automated washer disinfectors either using glutaraldehyde or peracetic acid require provision for containment and extraction of fumes. Levels of atmospheric contamination must be monitored and records must be maintained. Other oxidizing agents have been used as alternative disinfectants. Chlorine dioxide is a strong irritant and not compatible with all types of equipment. Superoxidized water (Sterilox) appears to be relatively nontoxic and is an effective antimicrobial provided that the equipment has first been cleaned thoroughly.

To prevent patient exposure to disinfectants a thorough rinse cycle is necessary. The rinse water should either be free of bacteria, or sterilized and passed through a bacteria-retaining filter (0.22 micron) before use. A lack of care with manual disinfection techniques could also result in unacceptable levels of patient exposure to disinfectant.

The temperature at which disinfection is carried out is important. Some automated systems achieve disinfection with reduced concentrations of glutaraldehyde by heating formulations to 45°–55°C. In general, higher temperatures permit a reduced disinfection time; however, increased vapour production is likely, potentially increasing the risk of environmental contamination. If the disinfectant solution is to be reused, heating may reduce its reliability. Most in vitro testing of chemical disinfectants has been carried out at 20°C. If lower temperatures are used antimicrobial activity may be reduced.

Disinfection of endoscopes is performed before each session and between procedures. Disinfection immersion times may vary, but immersion for 10 minutes with glutaraldehyde, or 5 minutes with peracetic acid (0.35%) or chlorine dioxide destroys most vegetative bacteria and viruses including human immunodeficiency virus, as well as hepatitis B and C. Doubling of these immersion times inactivates *Mycobacterium tuberculosis* and atypical mycobacteria. The extended immersion time is applied at the end of the endoscopy session, and also prior to endoscopic retrograde cholangiopancreatography procedures. Some recommend a much longer period of immersion (45 minutes) with glutaraldehyde, and some have even suggested that total inactivation of bacterial spores might take more than 3 hours. However, most protocols suggest that if the initial cleaning process is thorough, prolonged exposure to disinfectants is not necessary.

Isopropyl alcohol and 70% ethyl alcohol are rapidly effective disinfectants, which evaporate so that rinsing is not required. Endoscope lens systems should not be exposed to alcohol for more than 5 minutes. Alcohols are often used to complete the disinfection cycle with forced air employed to dry endoscope channel lumens. This may reduce the likelihood of microbial proliferation within the instruments during storage. Endoscopes should hang vertically in a ventilated cupboard during storage. Valves should be dried and stored separately.

Valves are lubricated with silicone oil immediately before use or according to the manufacturer's instructions. The use of silicone oil with reusable biopsy forceps may prolong their life span.

Biopsy forceps and other accessories, such as water bottles, should be sterilized by autoclaving if possible. Defective accessories, such as biopsy forceps with kinking of the shaft, should be discarded as they may malfunction or damage the endoscopic channels. Ultrasonic cleaning of endoscopic equipment such as valves prior to disinfection (Figure 4-10) is valuable. This is particularly useful with biopsy forceps because their spiral construction makes manual cleaning difficult. Brushes used during the cleaning process should be disinfected with the endoscope and inspected carefully for signs of damage.

Automated washer disinfectors must have facilities for self-disinfection of their immersion and storage tanks, fluid pathways, and filters. This reduces the risk of biofilm development and equipment contamination. This cycle is undertaken according to manufacturer's guidelines, but is usually carried out before each endoscopy session. Various pathogens including *Pseudomonas aeruginosa*, other gram-negative bacilli and mycobacteria have been isolated from disinfectors and rinse water. Some mycobacteria, such as *Mycobacterium chelonae* have a high level of resistance to glutaraldehyde. Disinfection with an alternative such as peracetic acid may sometimes be required.

To reduce risk of contamination and to prevent dilution of disinfectants, most automated washer disinfectors use the disinfectant and rinse water just once before disposal. Assessment of rinse water endotoxin levels is part of the standard safety monitoring process. There is controversy about the need for microbiological monitoring of endoscopic equipment, but it could confirm the efficacy of cleaning and disinfection processes and might reveal problems with the structural integrity of the endoscope. If disinfectant solutions are reused the concentrations must be monitored. They should not be reused beyond the manufacturer's recommended life span. Washer disinfectors should be subject to regular programs of maintenance, testing, and calibration to demonstrate continued satisfactory performance. The maintenance requirements must be clearly detailed in service contracts.

Maintenance of Records

It is essential that there are accurate and detailed records to allow tracking of each endoscope through the processes of decontamination and usage. The traceability of reusable accessories is not considered essential.[11] The use of an endoscope in a patient found to have Creutzfeldt-Jacob disease would require that the instrument be removed permanently from use because prion

Figure 4-10. Ultrasonic cleaning of endoscopic equipment prior to disinfection.

proteins are resistant to disinfection. It must therefore be possible to identify the patients in whom a particular endoscope has been used in the event of exposure to a potential risk. The precise regulations regarding these important requirements are to be found in national health and safety directives.

Health and Safety Considerations

Nursing and other staff involved in the cleaning and disinfection process are usually subject to mandatory health surveillance. There should be a pre-employment assessment with regard to relevant conditions such as skin or mucosal sensitivities and asthma. Lung function may be assessed by spirometry. Annual monitoring, including completion of questionnaires on symptoms are usually required. Regulations usually require that such occupational health records be retained for many years. Endoscopy staff should be immune to hepatitis B and vaccinated if necessary. Staff should use protective clothing including gloves, aprons, and preferably eye protection with face shields during endoscopic procedures and during the cleaning and disinfection process (Figure 4-11). Protocols for dealing with disinfectant spillage should be available, along with appropriate supplementary protective clothing such as nitrile gloves, overshoes, and respiratory protective equipment.

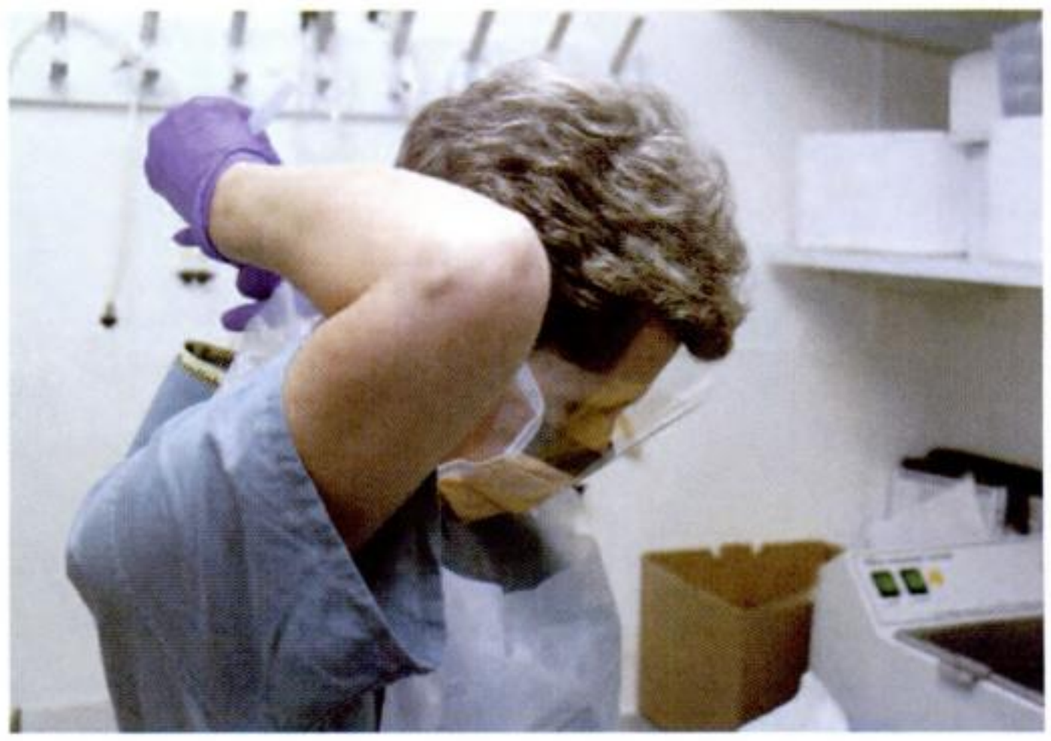


Figure 4-11. Proper placement of mask.

Quality and Outcomes Assessment

Proper documentation is essential to the process of monitoring and improving quality and outcomes in pediatric gastroenterology. Several guidelines for documentation have been developed.[12,13] Such guidelines emphasize the need to record data on both process and outcome. Items such as procedure indication, complications, and patient satisfaction are important. Inclusion of such items in routine endoscopy reports can assist with audit and/or research activities. Obviously the way in which data are recorded will affect the ability to measure and compare outcomes. Standardization may facilitate cross-unit comparisons. The European Society for Gastrointestinal Endoscopy has produced guidelines on a "minimal standard terminology" for gastrointestinal endoscopy.[14]

There are a number of computer software programs that assist in documentation of quality indicators and outcomes facilitating subsequent data analysis. The sophistication of such programs varies. Some are "text only" systems; others may allow direct data entry on patient observations or vital signs, or permit downloading of images including video recordings. Such databases can potentially facilitate the collection and analysis of complex data sets. Such analyses may be valuable in terms of research, audit, and practice accountability and in examining the cost-effectiveness of practice.

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Patient Management

M. Stephen Murphy

Many children and adolescents are anxious at the prospect of diagnostic investigations. Most children are quite unfamiliar with the idea of gastrointestinal (GI) endoscopy, and have little understanding of what it entails. Sometimes a parent or other adult known to the family may have undergone an endoscopic examination and they are likely to assume that the child's experience will be similar. For various reasons it should be quite different. Pediatric endoscopy should take place in a child-friendly setting. Adult endoscopy is often performed using little or no sedation, but in children adequate sedation or general anesthesia should be employed.

Preparing Patient and Family

Much can be done to alleviate the child's natural apprehension about endoscopy. It is an invasive technique, and a mere description of the process is likely to heighten rather than reduce anxiety. Sensitive explanation appropriate to the child's age and understanding is required. The patient and family should have ample opportunity to discuss the process, and they should be given a realistic idea as to what can be expected. Most pediatric endoscopy does not require overnight admission to the hospital. The first explanations about the procedure come from the pediatric gastroenterologist who can best explain the medical context and discuss the details of the procedure. Additional information from other members of the team, such as the endoscopy or gastroenterology nurse and an advance visit to the endoscopy unit to meet with the nursing staff and to take a look at the facilities may also be helpful. Adequate explanation and the opportunity to ask questions are of course essential to the process of obtaining informed consent.

Both child and family should understand the various steps to be followed prior to the procedure. Some children may require special preparation such as a bowel evacuation regimen prior to colonoscopy. The need to fast prior to the procedure should be explained. For those attending as "day cases," the booking and admission procedures should be explained. The process of sedation and general anesthesia should be discussed. The procedure itself requires careful discussion (see section on Informed Consent). Crude explanations and demonstrations of equipment are more likely to cause anxiety than to reduce it. Describing the endoscope as a "camera" or "telescope" is common practice, but such descriptions are visually inaccurate and quite possibly alarming. It is better described as a flexible tube through which the lining of the stomach and intestine can be examined. Finally the recovery and discharge process should be explained. Although direct discussion of these matters is essential, it is also useful to provide a written summary of the key points.

Informed Consent

Informed consent for GI endoscopy is necessary but differs from one country to another in terms of medical practice and legal interpretation. Moreover societal views on patient autonomy and on the rights of children are changing. Certain fundamental principles underlie the concept of "informed consent." First, to give consent the individual must be "competent." This means that they must be sufficiently mature and intelligent to appreciate the medical issues, the risks of the procedure, and the possible consequences of giving or withholding consent. Second, they must be adequately informed about the procedure, its potential value, and the risks associated with it. Thus they need to know that the information obtained from the procedure could be important in establishing a diagnosis or in guiding clinical management. If an alternative investigation is of roughly equal merit this might also require discussion.

It is difficult to make precise recommendations regarding informed consent for GI endoscopy. Nevertheless, some general comments can be made. There is a growing recognition of the right of the competent child to give or withhold consent. Legal views regarding age and competence vary. There is inevitable ambiguity about the specific risks that require discussion for "informed" consent. Discussion of all conceivable risks is neither appropriate nor possible, but certain principles should be considered. Common adverse events and less common but serious complications usually require discussion. A useful test is simply whether you believe the information you provide could reasonably influence the decision to give consent. For this reason, the context in which the procedure is

undertaken can influence the discussion of risk. If a procedure is urgent and life saving, the obligation to discuss lesser risks may be reduced. Those who ask questions are making clear a desire for information, and this places additional responsibility to address any concerns with special care.

When obtaining consent for GI endoscopy it should be possible to tell the child and parents that the procedure is not expected to cause serious discomfort and to reassure young people undergoing colonoscopy that care will be taken to avoid embarrassment to them. If the procedure is to be undertaken using sedation this should be explained. They should know that sedation is sometimes unsuccessful and in such cases the procedure would have to be deferred. The safety issues surrounding sedation or general anesthesia should be discussed. They should know that the procedure will be performed in a safe environment with trained staff, and will be supervised or performed by a competent endoscopist. While acknowledging the existence of potential complications it is also important to discuss safety measures and reassure the child and family that serious complications are uncommon. Specifically the possibility of perforation should be discussed, as this is a well-recognized and serious risk even in the hands of a competent endoscopist. The consequences of perforation, including need for laparotomy, should be discussed. Although the most reliable published figures on the risk of perforation apply to adult patients, it is probably helpful to provide some estimate of the incidence. It is also relevant to point out that the risk may be increased for children with severe colitis or malnutrition and hypoalbuminemia.

Written consent for endoscopy is a standard of practice in most countries. Consent forms generally indicate the nature of the proposed procedure and the person giving consent is asked to confirm that they are satisfied with the information they have received and that they agree to the procedure. The person obtaining consent may also sign a statement to the effect that they have provided an appropriate explanation of the procedure. For children over the age of 7 years informed assent may be required in some settings.

Bowel Preparation for Colonoscopy

A bowel cleansing regimen is usually necessary prior to colonoscopy. This is important if the endoscopist is to have an unimpaired view of the bowel lumen throughout the procedure, thus facilitating safe and efficient progress in advancing the colonoscope. Poor visibility could increase the risk of bowel perforation. In addition, the presence of feces may increase the risk of injury due to ignition of combustible gases during electrocautery or laser therapy. Bowel cleansing is essential for proper examination of the colonic mucosa. The objective is to clear the colon of all feces, and to reduce coating of the bowel surface. Many different regimens have been advocated, but none is completely satisfactory.

Bowel Cleansing Regimens

In young infants, a period of clear fluid administration alone may be sufficient preparation, and laxatives may not be required. A saline enema (5 mL/kg) could be administered just before the procedure.

In older infants and children a liquid or low-residue diet is often prescribed for two or three days. Some form of pharmacological bowel evacuation regimen follows this. Many pharmacological agents have been employed including stimulant and osmotic laxatives and gut lavage solutions. Many of these agents are quite effective, achieving good bowel cleansing in about 80% of cases. Important considerations in choosing between regimens include patient safety, comfort, and convenience.

Commonly used stimulant laxatives include bisacodyl, senna, and sodium picosulphate. These are usually given in relatively high doses to produce an effective bowel clear-out. Osmotic agents that have been widely used include mannitol, magnesium citrate, sodium phosphate, and polyethylene glycol-based electrolyte lavage solutions. Osmotic and stimulant laxatives are often used in combination. In some regimens phosphate enemas or large volume saline enemas are administered shortly before the procedure.

Lactulose, mannitol, and sorbitol are poorly absorbed sugars or sugar alcohols that act by retaining water in the gut lumen through an osmotic action. There are two concerns with these agents. First, in large dose they can potentially cause significant loss of fluid and electrolytes, an important consideration in young patients. Second, bacterial fermentation of the unabsorbed sugar may lead to increased colonic hydrogen production—a risk for patients undergoing electrocautery or laser therapy. These agents are not currently in widespread use. Magnesium salts are often used in bowel cleansing regimens for adults, either alone or in conjunction with other laxatives. They are less widely used in pediatric practice. Oral sodium phosphate in hypertonic

solution has been widely used in recent years, and studies suggest that this may be a palatable, effective, and generally safe agent in adults. However, fatal overdoses have been reported, and hyperphosphatemia and hypocalcemia may occur. Because phosphate absorption may be increased in patients with obstruction, impaction, or paralytic ileus, these agents should not be used in those circumstances. Neither should they be used in patients with renal, cardiac, or hepatic disease.

In 1980 an osmotically balanced polyethylene glycol-based electrolyte gut lavage solution (PEG-ELS) was introduced. The PEG in these solutions (molecular weight 3350) is poorly absorbed and acts as an osmotic agent retaining water in the bowel lumen. Lavage with this solution causes little net water and electrolyte secretion or absorption and PEG is not subject to bacterial fermentation. Several clinical trials have demonstrated its efficacy. The main difficulty with PEG-ELS is its rather poor acceptability, especially in the young. The patient must consume a large volume (typically several liters) and this can cause nausea, vomiting, and abdominal distention and discomfort. To enhance gastric emptying, a prokinetic agent such as metoclopramide may be given before starting the solution. Despite attempts to improve its taste and odor by introducing sulphate-free products and by adding flavorings, PEG-ELS is somewhat unpalatable. Children usually require nasogastric tube administration. This requires close supervision because there have been reports of life-threatening pulmonary aspiration—during the infusion, probably because the tube may become displaced into the esophagus as a result of retching or vomiting. Despite these problems, PEG-ELS is generally tolerated, and provides a rapid and effective cleanout. PEG3350 without electrolytes has been studied in children 2–18 years of age with good efficacy and safety at a dose of 1.5 g/kg/day for 4 days prior to colonoscopy.[1] There are relatively few randomized controlled trials of bowel cleansing regimens in children. Two studies have compared sodium phosphate-based regimens with nasogastric PEG-ELS in children.[2,3] One reported that sodium phosphate was more effective, while the second found no difference. The sodium phosphate regimen was preferred to PEG-ELS by the patients, but in both studies it caused transient hyperphosphatemia. Another pediatric study compared three different regimens: combined magnesium citrate and senna, bisacodyl followed by a phosphate enema, and PEG-ELS.[4] The bisacodyl-based regimen was least effective and the PEG-ELS regimen was least acceptable. In a randomized controlled trial comparing a regimen of clear fluids followed by Picolax (a combination of sodium picosulphate and magnesium citrate), versus unrestricted diet and bisacodyl followed by a phosphate enema, the Picolax-based regimen was more effective.[5]

Laxative regimens are easy to administer, and although they sometimes cause mild abdominal cramps and diarrhea, these are indications that the treatment is working. Following bowel evacuation, ileal effluent will continue to enter the colon and because the colon absorbs water, coating of the mucosa with stool may quickly recur. The time to response with laxatives is unpredictable, but generally occurs within 2 to 8 hours. Because children will often be traveling to the hospital several hours before the procedure, the timing of the bowel preparation is important. An example of an effective laxative regimen, administered after 2 days on a low-residue diet, is outlined in Table 5-1. In that regimen laxatives are administered in the morning and evening the day before the procedure, the final dose being taken 12 hours before arrival at the hospital.

Enemas

In some children a limited examination of the distal colon is all that is required, and in such cases a phosphate enema administered 30 minutes before the procedure may be an adequate preparation. Mucosal changes related to bowel preparations, especially from oral phosphate or phosphate enemas may have an appearance suggestive of inflammatory bowel disease. Consideration of the preparation used should be a factor in interpreting mucosal abnormalities observed during colonoscopy.

Bowel Preparation in Special Circumstances

Whatever regimen is normally preferred, modification may be necessary. A child who presents with diarrhea

Table 5-1. Example of an Effective Laxative Regimen Taken on the Day Prior to Colonoscopy.

Age (yr)	Senokot Syrup Evening Dose (mL)	Sodium Picosulphate Morning and Evening (mg)
2–5	30	2.5
5–8	40	2.5
8–12	50	5
> 12	60	10

may require a less vigorous preparation than one with chronic constipation. Patients with severe constipation may benefit from a more sustained period of laxative therapy prior to colonoscopy. If colonoscopy is performed in a patient with active GI bleeding, a vigorous preparation is often unnecessary because blood has a purgative action. In patients with partial obstruction, standard oral preparations could be dangerous. In such cases adequate bowel cleansing may be achievable with large volume water or isotonic saline enemas 2 hours before the procedure. In an older child, for example, 1 L enemas can be administered repeatedly until the fluid drains free of solid residue.

Contraindications to Bowel Evacuation

In children with severe colitis a standard bowel preparation may be dangerous. It could exacerbate the condition risking progression to toxic megacolon and bowel perforation. In such cases a limited examination is usually all that is intended, and this can be performed without bowel preparation.

Preprocedure Fast

As a general guideline children should fast for at least 6 hours prior to sedation or general anesthesia. Clear fluids and breast milk may be taken up to 2 hours before the procedure. Special care should be taken in children in whom delayed gastric emptying is suspected. In such cases the risk of vomiting and aspiration may be very high.

Antimicrobial Prophylaxis

Various guidelines have been produced regarding the use of antibiotic prophylaxis in GI endoscopy.[6–9] Overall, although it is known that bacteremia may occur with endoscopy, it appears that the risk of clinically significant infection is relatively small. Most data come from adult studies, and detailed studies are lacking in children. Recommendations have been produced and have varied in the degree of caution advised.

The American Heart Association has produced recommendations on the prevention of bacterial endocarditis.[7] According to these guidelines, the risk of endocarditis following GI endoscopic procedures is considered to be small. Although transient bacteremia might occur in 2 to 5% of patients, the organisms usually identified were not considered to pose a high risk for endocarditis. Minor endoscopic procedures such as mucosal biopsy and polypectomy are not thought to increase the risk of bacteremia significantly. Antimicrobial prophylaxis is therefore not recommended for such procedures. Some procedures are associated with an increased risk of bacteremia. In several studies a high rate of bacteremia (average 45%) has been reported with esophageal stricture dilatation, and the rate with injection sclerotherapy for esophageal varices may be about 30%. Although endoscopic retrograde cholangiopancreatography is not normally associated with a significant risk, the risk of bacteremia with biliary obstruction is much higher. For these procedures antimicrobial prophylaxis is recommended, particularly in patients who are at risk of developing endocarditis. Patients whose cardiac conditions are considered high risk include those with prosthetic heart valves, a previous history of endocarditis (even without other heart disease), cyanotic congenital heart disease, or surgically constructed systemic pulmonary shunts or conduits. Patients at moderate risk are those with uncorrected congenital cardiac abnormalities including patent ductus arteriosus, ventricular septal defect, primum atrial septal defect, coarctation of the aorta and bicuspid aortic valve. Acquired valve dysfunction and hypertrophic cardiomyopathy are conditions for which there is a moderate risk.

The European Society of Gastrointestinal Endoscopy also recommends that antimicrobial prophylaxis be given to individuals at risk of endocarditis who are undergoing esophageal stricture dilatation, variceal sclerotherapy, or endoscopic laser therapy. In addition, it recommends prophylaxis for those undergoing percutaneous endoscopic gastrostomy in view of the risk of local infection.[10]

The British Society of Gastroenterology has taken a relatively cautious stance recommending that all patients undergoing endoscopic procedures should receive antimicrobial prophylaxis if they are in a high-risk category for endocarditis or if they are at risk of septicemia due to immunosuppression or neutropenia.[8]

Prophylaxis is only effective if given in doses sufficient to assure adequate serum concentrations during and shortly after the procedure. Expert advice should be sought on the appropriate choice of antimicrobial agents, and in particular cases the duration of administration may be altered. Generally, however, antimicrobial treatment is started shortly before the procedure and is not continued for more than 6 hours. For esophageal procedures the most likely risk for endocarditis is from *Streptococcus viridans* (α-hemolytic streptococci). A single dose of amoxicillin (50 mg/kg, maximum 2.0 g) given 1 hour before the procedure is recommended. For colonoscopic

procedures, endocarditis is most often caused by *Enterococcus faecalis* (enterococci). Although gram-negative bacteremia may occur, these organisms rarely cause endocarditis. In moderate risk cases amoxicillin alone (or vancomycin) may be sufficient, while in high-risk patients gentamicin should also be given. If the patient is at risk from neutropenia, metronidazole should be included in the prophylaxis regimen.

Hospital Admission and Initial Preparations

Following admission a final assessment takes place to ensure that the child is fit for the procedure and that the procedure is still necessary. If it is to be performed under sedation an intravenous cannula is inserted. The insertion site may be numbed using a local anesthetic cream. It is helpful to insert the cannula before the child arrives in the endoscopy room. This can reduce the risk of the child becoming upset just prior to the procedure. Distressed children often fail to respond well to sedation.

Arrival in the Endoscopy Room

Parents should be encouraged to accompany their child to the endoscopy room. On arrival the child and family are welcomed and appropriate reassurance and explanation is provided. The necessary monitoring equipment is then set up. It is helpful if older children are placed in the appropriate examination position prior to commencing sedation. For upper endoscopy under sedation, the mouth-guard should be inserted while the child is still able to understand and cooperate. Parents may remain with their child while sedation or general anesthesia is induced. Some departments actively encourage parents to remain during the procedure if it is carried out under sedation, and some parents may express a wish to stay with their child (see Chapter 4, "The Endoscopy Unit"); others prefer that parents remain in the waiting area until the procedure is completed. Parents may themselves require support and this situation may have significant staffing implications during a complicated procedure. Whatever the departmental policy in this matter, a flexible approach to the presence of parents may be desirable, but the practical implications must also be taken into account.

Sedation and General Anesthesia

GI endoscopy is a highly invasive procedure and in almost all children has the potential to cause great distress if performed without adequate sedation or general anesthesia. Unfortunately for some children, pediatric endoscopy is still sometimes performed without any sedation. Surprisingly, a major textbook on endoscopy has suggested that sedation may be unnecessary for infants. This advice is reminiscent of outdated views on pain management in children. In the past, and without evidence, it was suggested that young infants have a reduced capacity to feel pain. Although there is an obvious need to alleviate distress in infants and children undergoing endoscopic procedures, there is no consensus on the best approach. The choice is between sedation and general anesthesia.

The ideal sedative regimen would be effective for every patient, act rapidly, induce an adequate but safe level of sedation for the duration of the procedure, wear off immediately afterwards, and have no adverse effects. No such regimen exists. For this reason many advocate the use of general anesthesia for pediatric endoscopy. Others disagree, arguing that sedation has an essential role in pediatric practice, and that for GI endoscopy it can be both safe and effective. The logistic and financial implications of relying on general anesthesia must also be considered. The true morbidity and mortality rates associated with pediatric endoscopy, whether performed under general anesthesia or sedation, are unknown.

Principals and Definitions

The level of central nervous system (CNS) depression produced by a sedative depends on the specific agent, the dose given, and the rate of administration. The individual response to sedation is also somewhat unpredictable. Whatever the intended level of sedation, the end result may vary along a continuum from minimal sedation to general anesthesia. During the process of sedation it is sometimes difficult to be certain of the precise point that has been reached along that continuum of CNS depression. From a practical point of view it is generally considered possible to distinguish between two distinct levels of CNS depression, referred to as "conscious sedation" and "deep sedation." The distinction between these states is central to the debate about safety and efficacy.

The term conscious sedation implies a level of CNS depression in which communication is maintained so that the patient can respond to verbal command. At this level it is expected that the protective reflexes are preserved, and the patient can maintain a patent airway independently. The term deep sedation implies a level of CNS depression in which the patient is essentially unconscious and does not respond to verbal command.

Deeply sedated patients are expected to continue breathing spontaneously, but the protective reflexes may be impaired or even lost, and so the patient's ability to maintain a patent airway is not assured. Patients under general anesthesia are unconscious and the protective reflexes are usually lost; therefore, they may be unable to maintain a patent airway independently.

Several important considerations arise regarding these different states of CNS depression. First, there is considerable variation in the degree of CNS depression that may occur within the definitions of conscious and deep sedation. Second, sedated patients may pass unexpectedly from a state of conscious sedation to deep sedation. Third, there is an overlap between the level of CNS depression that can occur with deep sedation and general anesthesia, and some hold the view that, from the safety perspective, no distinction should be made between these two states. There is therefore controversy about the use of sedation for invasive procedures in pediatrics.

Patient Selection and Contraindications to Sedation

Patient selection is a crucially important consideration for safe sedation. The endoscopist must identify any special risk factors, and in such cases general anesthesia may be required. General anesthesia may be preferred if it is likely that the procedure will be especially difficult or prolonged, and if certain types of therapeutic endoscopy are planned. General anesthesia provides a greater chance of successfully completing such procedures. Sometimes, often inexplicably, children fail to achieve adequate sedation despite the use of a usually reliable regimen. In such cases, with increasing doses of sedation, the child becomes gradually more confused and agitated and resists the examination. This appears to occur much more frequently in children who are anxious and distressed prior to commencing sedation. Even though experience shows that a failure of sedation does not reliably predict future failures, it is often difficult to take this risk, and so general anesthesia may be preferred.

Sedation for GI Endoscopy

Esophagogastroduodenoscopy (EGD) is a relatively short procedure and is usually completed in 5 to 10 minutes. However, esophageal intubation elicits powerful pharyngeal protective reflexes. If sedation is inadequate this phase of the procedure is potentially very distressing. In contrast, colonoscopy may be less acutely distressing, but a complete examination of the colon and terminal ileum may take 40 minutes or longer, and children can experience episodes of discomfort. It follows that ideal sedative regimens for these very different procedures would not be identical. Nevertheless identical regimens are often employed.

In adult practice, significant complications are said to occur in about 1 per 1,000 EGD procedures, and the associated mortality rate is between 5 and 30 per 100,000. Many of these complications are due to cardiorespiratory events, and consequently there is concern about the potentially important role of sedation as a contributing factor. Even though most adult patients may prefer sedation, this has led some to a view that the routine use of sedation should be abandoned in adults in the interest of safety.

The risk profile for young patients is of course quite different to that in adult patients. Published data on the risks associated with pediatric endoscopy and sedation are limited, but it could be expected that the risk of death from cardiorespiratory complications might be much lower. Experience shows that children are usually more distressed than adults when undergoing EGD. Although this may sometimes reflect psychological differences, it is clear there must be a physiological basis, there being a very vigorous reflex response to intubation in young people. Conscious sedation may alleviate anxiety and induce amnesia, yet a significant minority of children becomes agitated and combative during EGD. In such circumstances there may be risks to the patient and to the endoscopic equipment. Inadequate sedation can also result in an incomplete or hurried and unsatisfactory examination. There are also ethical and legal concerns. It could be argued that a combative patient, although sedated, is in fact withdrawing consent.

For these reasons, most pediatric endoscopists induce a significantly deeper level of sedation than is customary in adult practice. In fact, most children are deeply sedated (Figure 5-1A–C). Many pediatric regimens use a combination of intravenous benzodiazepines and opiates, derived from practice in adult GI endoscopy. Commonly midazolam and meperidine are used together. The doses used in pediatric endoscopic practice are often relatively greater than in adults because deeper levels of sedation are required. Consequently, recovery may be delayed. Certain other agents have been employed, such as intravenous ketamine.[11] This has the advantage of potency and a short duration of action, but some consider it best considered as a general anesthetic agent. An alternative to conventional

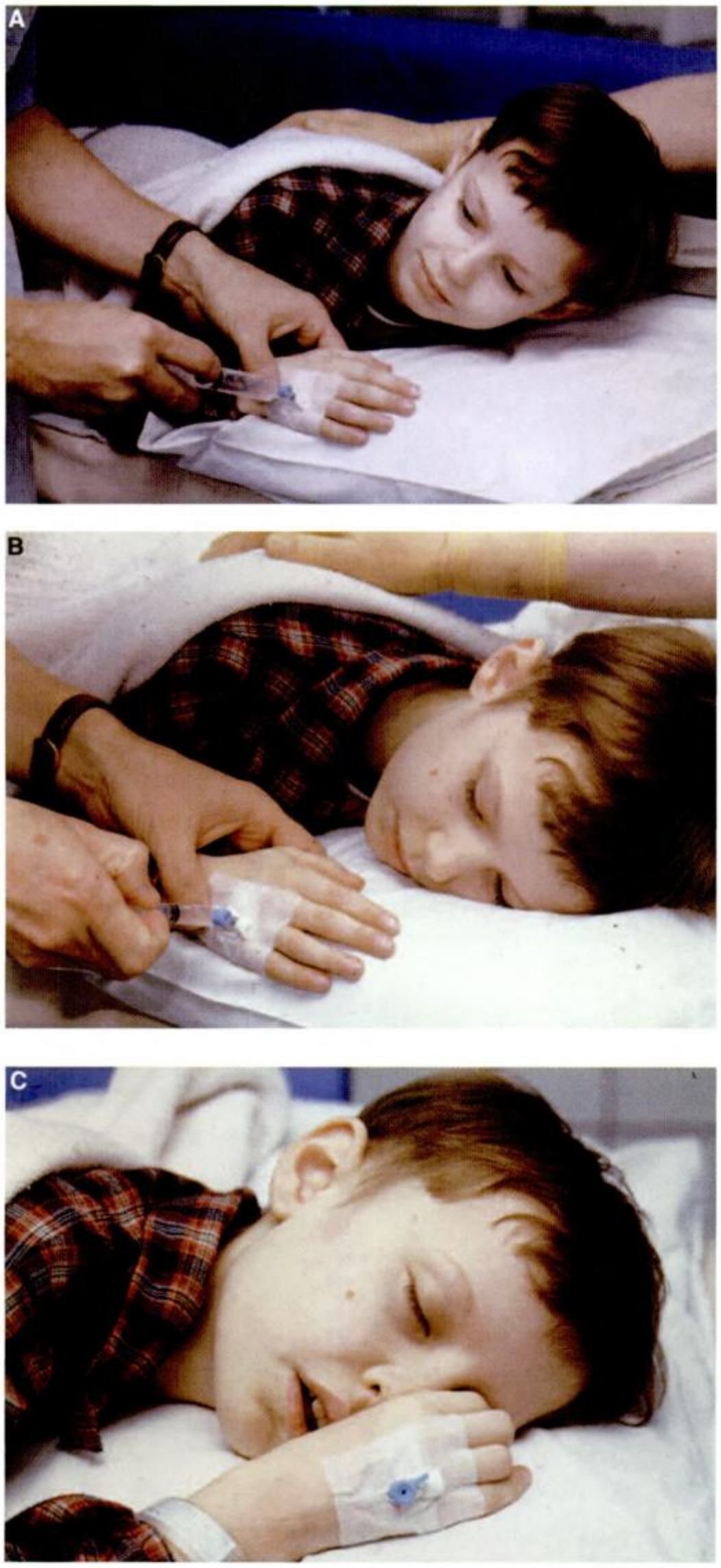

Figure 5-1. *A–C,* Intravenous sedation of a child. Progression through conscious sedation to deep sedation.

intravenous sedation is the use of nitrous oxide/ oxygen inhalation, although this requires further evaluation.[12]

Whatever sedatives are used, the intended sedation end-point must be one in which a thorough and unhurried examination can be carried out without persistent patient distress and with minimal physical restraint required. In our unit, in the past, we used a regimen

Table 5-2. Example of a Moderately Effective Sedative Regimen Based on a Combination of Intravenous Meperidine and Midazolam.

Midazolam	administered in 0.1 mg/kg boluses maximum dose of 0.75 mg/kg or 15 mg (whichever is smaller)
and	
Meperidine	administered in 0.5 mg/kg boluses maximum dose of 2.5 mg/kg

based on midazolam and meperidine (Table 5-2). These agents were titrated to produce the necessary level of sedation required by the child for the procedure. Using this protocol, procedures were completed in 90% of cases and sedation was highly satisfactory in 70%. As a matter of policy oxygen supplementation was given if the oxygen saturation fell below 94%. Mild hypoxemia requiring oxygen occurred in 14% but all responded promptly. In practice the children received an average of 0.3mg/kg of midazolam (maximum 0.6mg/kg) and 1.5mg/kg of meperidine (maximum 2.5mg/kg).

In effect, many children received doses likely to induce deep sedation, and this was indeed the case. In recent years we have changed to a policy of using general anesthesia routinely.

The American Academy of Pediatrics has produced guidelines on the use of sedation that may provide a basis for safe practice in the pediatric endoscopy unit.[13,14] These guidelines suggest that both conscious and deep sedation are acceptable endpoints, depending on the clinical requirement. Although conscious and deep sedation may demand different levels of monitoring, the eventual level of sedation is not completely predictable and so it is necessary to be prepared to upgrade the level of monitoring whenever necessary. Some authorities have insisted that there can be no distinction between deep sedation and general anesthesia, and that deep sedation should therefore be supervised by an anesthesiologist.[15] The American Academy of Pediatrics' guidelines considered that this was not essential, but practitioners supervising deep sedation should be trained in pediatric life support. Monitoring of children under deep sedation should be identical to that required for general anesthesia. The personnel, facilities, and equipment necessary for the resuscitation of infants and children should be at hand. A trained

member of the team should monitor the patient's condition, and in the case of deep sedation, this should be their sole responsibility. For endoscopic sedation it is best to assume that the child will be deeply sedated. Continuous monitoring of heart rate and oxygen saturation is therefore advised, and an anesthetic-type time-based record of the patient's condition should be maintained. In any endoscopy unit it is essential that clear polices should be established on the use of sedation or general anesthesia, and that written protocols be produced and adhered to. In developing such protocols it is advisable to take account of local as well as international opinion.

Recovery and Discharge Policies

A significant disadvantage to benzodiazepine and opiate sedation is that these agents have a prolonged effect with slow patient recovery. It is essential that following sedation monitoring should continue in an appropriately equipped recovery area until specifically agreed recovery criteria are met. Oxygen saturation should be normal and the child should be fully conscious and capable of responding to command.

After this initial recovery period children are often transferred from the recovery area to a children's ward. There they should remain under observation until they are fully awake, tolerating oral fluids, and mobile if appropriate. Parents should be cautioned that despite appearances the sedatives may not wear off completely for many hours. Caution should be exercised for 24 hours, and physical activities in which a lack of coordination could be hazardous should be avoided.

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Psychological Aspects of Endoscopy 6

Silvia Amendola

When a child requires an invasive medical procedure such as gastrointestinal endoscopy, he or she and the entire family may experience feelings of anxiety. Anxiety may be heightened by a lack of information, by misinformation, or by preconceived and erroneous ideas. Very few studies have been undertaken to investigate and to understand the best means of reducing anxiety in patients undergoing endoscopy.

Studies have been carried out in adults to examine the process of patient preparation and to evaluate their experience with esophagogastroduodenoscopy (EGD).[1] One pediatric study has shown that EGD, colonoscopy, and bronchoscopy induce similar preprocedure anxiety, a complex sequence of cognitive, affective, and behavioral events evoked by stress.[2] As an emotional state, anxiety is characterized by subjective, consciously perceived feelings of tension, apprehension, and nervousness, accompanied by activation of the autonomic nervous system.

Provision of information about procedural events and likely experiences is a standard preparatory intervention for those about to undergo procedures such as EGD.[3] Preparatory information is intended to reduce anxiety by providing patients and their families with realistic expectations, thus diminishing fear of the unknown.[4] Studies have shown that children who are educated about the procedure are significantly less anxious both in the admission unit and in the procedure area.[5,6] The details of the preparation should be based on the cognitive level of the child and must be entirely truthful.[7,8] Clear explanations of the procedure, being able in advance to see the equipment that will be used, and having adequate opportunities for both child and parents to ask questions are important in alleviating anxiety.

Although the benefits of such preparation are well documented, the mechanisms that underlie their efficacy are not well understood.[9] Janis' theory postulates that the purpose of preparatory information is to first increase anxiety thus encouraging patients to worry, so that eventually at the time of the procedure they experience less anxiety.[10] Others propose a direct relationship between preparation and anxiety.[11,12] In contrast to Janis' theory, others hypothesize that preparation in fact reduces anxiety by providing the patient with realistic expectations.[13]

Lazarus and Folkman described "the appraisal model," a more explicit framework for understanding the effect of preparation on anxiety.[14] This model accounts for individual differences in response to medical procedures. Claar and colleagues examined an appraisal-based model of children's experiences with EGD.[15] The study demonstrated that children who underwent an intervention to decrease threatening appraisals of the forthcoming procedure experienced less anticipatory anxiety, less procedural distress, and less pain than those given information based on simple routine preparation. In one study, children who received preparatory intervention experienced significantly less anxiety and distress than those who did not receive any special preparation.[16] In addition to procedural information, children were provided with a demonstration of the equipment to be used during the procedure; there were opportunities to practice with a doll; to see a book showing photographs of a child entering the clinic, undergoing the EGD, and resting in the recovery area. Time was allotted with a specialist to answer questions. These interventions may help patients formulate less threatening appraisals of the EGD by providing them with more information about what to expect. Those who received psychological preparation just before endoscopy had significantly less self-reported anxiety before and during the procedure than did those patients in the control group. In addition, patients who underwent psychological preparation before the endoscopy had significantly less autonomic nervous system stimulation, as measured by heart rate and systolic blood pressure, than the control group. Children, in particular, need information to help them distinguish reality from fantasy. If enough information is not provided, the child may become emotionally overwhelmed. Strong emotions such as anxiety, fear, and anger may render the child unable to cooperate and have the unwanted effect of increasing the amount of sedation required to complete the examination.

Shapira and Tamir evaluated 206 patients (mean age 45.1 years) undergoing EGD and examined the effects of a family member remaining with them throughout the entire procedure.[17] Eighty-nine percent of patients found this helpful. Sixty-three percent of the accompanying relatives reported that being present reduced

their own fear whereas 7.6% reported that their fear had actually been increased.

In children, diagnostic EGD is often performed as an outpatient procedure sometimes using conscious sedation.[18] The purpose of sedation and analgesia is to relieve anxiety, discomfort, and pain, and to diminish the patient's recollection of the event. The level of sedation that is required to perform the procedure may range from minimal sedation to deep sedation that may be indistinguishable from general anaesthesia. Diagnostic endoscopy and some therapeutic endoscopic procedures can be performed using conscious sedation. It is not known which patients would choose sedation on receiving detailed information about the advantages and disadvantages compared with general anesthesia.[19] General anaesthesia may be required in patients unable to cooperate, or if lengthy, uncomfortable or technically difficult procedures are anticipated.[20] In many pediatric endoscopy units general anesthesia is routinely employed, especially for younger patients.

In a study intended to identify independent predictors of a comfortable, technically adequate, unsedated diagnostic EGD, the number able to comfortably tolerate the procedure and complete a satisfactory examination was small.[21] One study evaluated the influence of personality traits on patient reaction to EGD and suggested that a version of the Eysenck personality inventory could be used to assess patients' neurotic phenotype and hence predict the need for premedication.

Conscious sedation successfully induced amnesia for EGD in close to 100% of adults[22]; however, a study of pediatric patients found that only 14 of 20 children given midazolam experienced significant amnesia.[23] The aspects of the procedure that children are likely to recall are not known. Furthermore, it needs to be determined whether patient recall diminishes over time, and whether procedural and psychosocial variables (such as anxiety) are associated with different levels of recall. Claar and colleagues evaluated distress experienced during EGD and the effects of conscious sedation on patient memories and attitudes regarding future procedures.[24] They reported that preparation before EGD in those receiving conscious sedation reduced distress. Those children who had more information about the procedure exhibited less distress and reported less anxiety in subsequent EGD examinations. Children who experienced less distress during intravenous cannula insertion were also less distressed during EGD. This observation raises the possibility that alleviation of distress with cannula placement by using topical anesthesia could actually reduce distress during the EGD. Patients who had more detailed recall of the procedure had a more negative view of the procedure and of potential future EGD examinations.

Providing children undergoing gastrointestinal endoscopic procedures with a better and more positive experience by reducing stress has important implications not only for the immediate procedure but also in future medical management.

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Diagnostic Upper Gastrointestinal Endoscopy

7

M. Stephen Murphy

Upper gastrointestinal (GI) endoscopy or esophagogastroduodenoscopy (EGD) is a powerful diagnostic technique first introduced into pediatric practice about 30 years ago.[1] It has contributed greatly to our knowledge of pediatric GI disease. It allows us to inspect the upper GI tract and to identify various abnormalities, but more importantly, mucosal biopsies can be obtained from the esophagus, stomach, and duodenum. Even when the macroscopic appearances are normal, mucosal histology may prove diagnostic. When appropriate, other diagnostic samples such as mucosal surface brushings or luminal fluid aspirates can also be collected.

Indications

There are numerous conditions that can be identified using EGD (Table 7-1). The Atlas section following this chapter illustrates the normal endoscopic appearances of the upper gastrointestinal tract and also shows many of the disorders which may be identified with EGD.

Abdominal Pain

Recurrent abdominal pain is one of the most common clinical problems encountered by pediatricians and pediatric gastroenterologists.[2] In most cases there is no identifiable underlying GI pathology and only a small proportion of cases require investigation by EGD. The decision to perform EGD is influenced by the clinical presentation and to some extent by the severity of the problem. If the pain is associated with other features suggestive of organic disease in the proximal GI tract, the decision to perform an EGD is straightforward. Retrosternal pain or epigastric pain, especially if accompanied by reflux symptoms, would suggest the likely presence of organic disease. A history of pain-induced nocturnal wakening is suggestive of peptic ulcer disease, and is a clear indication for EGD.[3] Epigastric pain associated with other symptoms such as vomiting, GI bleeding (occult or overt), or weight loss would point to organic pathology and an EGD

Table 7-1. Disorders in Which Diagnostic EGD May Play a Primary Role

Esophagitis
- Reflux esophagitis (including Barrett's esophagus)
- Infectious esophagitis (eg, Candida, herpes simplex,
- Eosinophilic esophagitis)

Gastroesophageal injury
- Caustic agents
- Drugs
- Mallory-Weiss syndrome

Mucosal ulceration
- Acute (stress) erosions
- Peptic ulcer disease

Gastropathies
- *Helicobacter pylori* associated gastritis
- Menetrier's disease (hypertrophic gastritis)
- Varioliform gastritis

Portal hypertension
- Varices (esophageal, gastric, duodenal)
- Portal hypertensive gastropathy

Enteropathies
- Celiac disease
- Allergic enteropathy (milk and other foods)
- Eosinophilic gastroenteropathy
- Infectious – eg, giardiasis, CMV
- Graft-versus-host disease

Protracted diarrhea of Infancy
- Microvillus inclusion disease
- Various other "epithelial abnormalities"

"Inflammatory (autoimmune) enteropathies"

Miscellaneous conditions affecting the small intestine
- Congenital and acquired lymphangectasia
- Agammaglobulinemia and hypogammaglobulinemia
- Primary and secondary dissacharidase deficiencies

Abetalipoproteinemia

Andersen's disease

Space-occupying lesions
- Bezoars
- Pancreatic rest
- Adenomatous polyps (Gardiner's syndrome)
- Hamartomatous polyps (Peutz-Jeghers syndrome)
- Gastric lymphoma
- Gastric leiomyoma and leiomyosarcoma
- Gastroesophageal carcinomas

Crohn's Disease

CMV = cytomegalovirus; EGD = esophagogastroduodenoscopy

may be diagnostic. Some children present with nonspecific but apparently disabling abdominal pain. In such cases the decision regarding EGD may be difficult, but even though the examination may well prove normal, it may be considered appropriate. In such cases, the examination should, however, be seen as part of an overall strategy of investigation and management.

Investigation of Diarrhea and Malabsorption

EGD provides an efficient means for obtaining duodenal mucosal biopsies, and consequently has an important role in the investigation of infants and children with diarrhea. In young infants with protracted diarrhea, endoscopic biopsy has helped expand our knowledge of the pathophysiology of various conditions that may be responsible for this disorder.[4] The introduction of small pediatric endoscopes suitable for use even in the neonate has been helpful in delineating these disorders. In addition to routine histological examination of biopsy specimens, specific studies are sometimes required. Disaccharidase activities can be measured using biopsy specimens from the second part of the duodenum in order to reveal deficiency states such as congenital sucrase-isomaltase deficiency. Electron microscopy is required to establish the diagnosis of microvillus inclusion disease. Fat stains can demonstrate the characteristic accumulation of lipid in the enterocyte in fat transport disorders such as abetalipoproteinemia or Andersen's disease.

In the western world, celiac disease is the most common enteropathy causing malabsorption. Prior to the availability of EGD in children, to diagnose celiac disease a jejunal biopsy was obtained using a spring-loaded biopsy capsule. Because of the advantages of endoscopic duodenal biopsy, it is now the preferred technique. Although endoscopic biopsies are generally smaller than capsule biopsies, if properly oriented they are quite adequate for diagnosis. Endoscopy has the additional advantage in that several biopsies can be obtained without removing the instrument. Capsule biopsy is a potentially time consuming and troublesome process with a significant failure rate. Children first require adequate sedation. The capsule can be advanced using a push-technique assisted by radiologic guidance. Alternatively it may be advanced to the stomach and then allowed to migrate distally by peristaltic action. The latter approach may take a considerable amount of time. The final position of the capsule in the jejunum must be checked radiologically. If, for technical reasons, the capsule fails to capture a biopsy specimen, the procedure must be repeated after removing and resetting the capsule. Such failures are frequent. In contrast, endoscopic biopsy is usually completed within five minutes, the failure rate is exceptionally low, and there is no exposure to radiation. Endoscopy is performed in a dedicated unit with trained support staff and arrangements for appropriate patient monitoring. Capsule biopsy should be performed under similar circumstances, but this may not always be the case. Units that carry out capsule biopsy infrequently may lack expertise, and may not have established appropriate and safe management protocols.

GI Bleeding

In children presenting with acute or chronic GI bleeding, EGD may have an important role in diagnosis. Disorders including Mallory-Weiss syndrome, varices or portal hypertensive gastropathy, stress erosions, peptic ulcer disease, vascular abnormalities, and rarely neoplasia can be identified.

Investigation of Anatomical Anomalies

Although certain abnormalities may be readily apparent on endoscopy, structural or anatomical anomalies are often better visualized radiologically. For example, because of the difficulty of traversing an esophageal stricture with an endoscope, its length and severity may be more easily assessed using barium contrast radiology. Similarly, contrast radiology may more easily demonstrate the characteristic beaked appearance of achalasia in the distal esophagus. In those children who present with vomiting as their major symptom, a barium contrast study may be the initial investigation of choice. Occasionally imaging studies reveal a real or apparent space-occupying lesion or other abnormality that requires EGD for clarification.

Inflammatory Bowel Diseases

Increasingly EGD is recognized as a valuable technique in the investigation of children with suspected inflammatory bowel disease, and many clinicians now consider upper endoscopy to be part of the initial routine investigation.[5] In some patients, the diagnosis of Crohn's disease is established, when without EGD they might have been thought to have ulcerative colitis or indeterminate colitis.

Technique

The anatomical structures of the proximal GI tract have a relatively constant configuration, and so the techniques employed in EGD are relatively straightforward. The difficulties encountered by the novice endoscopist are generally quite predictable, and with proper technique they are readily overcome. With practice, passage of the instrument and examination of the esophagus, stomach, and duodenum should rarely prove difficult.

Choice of Instrument

Care should be taken to select an appropriately sized endoscope. The use of a small diameter instrument tends to reduce the size of the biopsy forceps channel and hence the size of the biopsies than can be obtained (see Chapter 2, "Endoscopic Equipment"). The mechanical properties of larger diameter endoscopes are such that many find them easier to use. However, the use of an unduly large endoscope may be associated with various problems. Compression of the airway may cause respiratory compromise, especially if the procedure is performed under sedation. There may also be difficulties in passing a large instrument through the pyloric canal or from the duodenal bulb into the second part of the duodenum. Such difficulties may increase the risk of perforation, particularly if excessive force is applied.

Patient Position and Initial Preparations

The correct positioning of the child during EGD can greatly facilitate the examination. This is particularly important for those first learning the technique, because changes in patient position inevitably require alterations to the basic maneuvers employed in advancing the instrument. Such variation in anatomic relationships adds an unnecessary layer of complexity to the learning process.

The child should rest in the left lateral position, with the head flexed slightly forward from the vertical (Figure 7-1). Excessive flexion of the neck increases the endoscopic angulation necessary for successful esophageal intubation, and attempts to advance the endoscope in this position may cause discomfort because pressure is applied to the posterior oropharynx rather than in the direction of advancement. Excessive neck extension tends to facilitate tracheal rather than esophageal intubation and should be avoided. The head should be supported with an appropriate headrest to avoid lateral flexion of the neck because this greatly increases the difficulty of esophageal intubation. With lateral flexion the endoscope will predictably deviate sideways in the oropharynx or hypopharynx, again increasing patient discomfort and risking injury.

Maintaining the patient in the correct position is important during passage of the instrument to the pylorus, and then into and beyond the duodenal bulb. There is a common tendency for the patient to roll slightly onto the back during the examination, and this changes the visual orientation of the gastroduodenal structures. The endoscopist must then compensate, which may complicate the examination. The assistant engaged in holding the patient may find it helpful to position an appropriately sized supporting "sandbag" or pillow at the patient's back.

Whether the examination is carried out using conscious or deep sedation, a modest degree of restraint will be necessary from time to time. Infants may be swaddled, and older children may be wrapped in a blanket.

The patient holds a mouth guard (bite-block) between the teeth. This has a central aperture through which the endoscope is passed (Figure 7-2). The guard should be large enough to accommodate the endoscope, but not so large as to cause discomfort. Even young infants without teeth may damage the instrument unless a mouth guard is used. In cooperative children it is often advisable to insert the guard prior to sedation, allowing them to become accustomed to its presence. Deeply sedated and hence noncooperative children may sometimes involuntarily clench the teeth, so that insertion of the guard becomes difficult. Nevertheless, in young and anxious children it may be better to defer placement until after sedation.

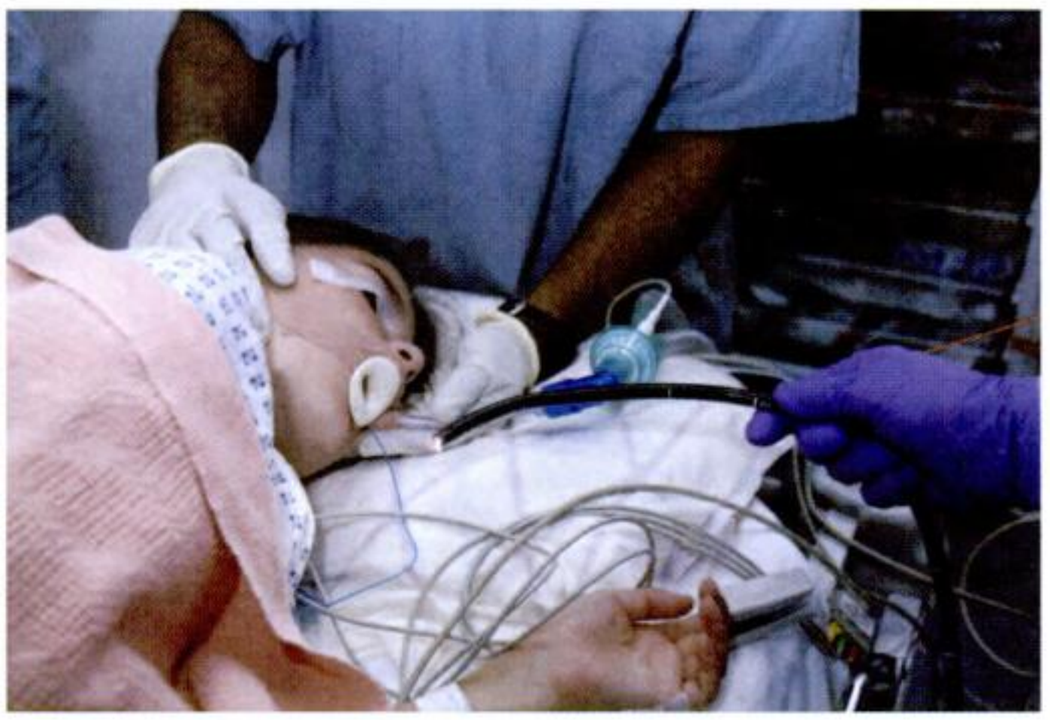

Figure 7-1. Patient positioning prior to endoscopic intubation.

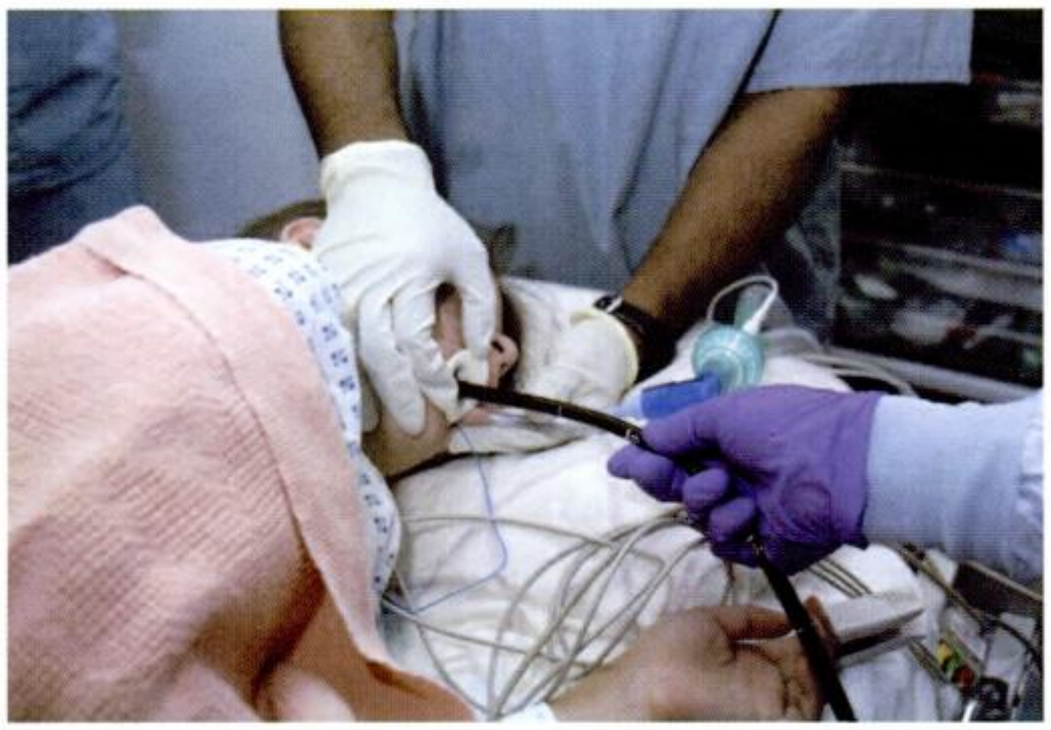

Figure 7-2. Passage of endoscope through bite-block.

Commencing the Examination

Before commencing the examination the endoscopist checks that the instrument is fully functional. The up/down and right/left angulation controls are unlocked, and the angulation movements are checked. The suction and air insufflation functions are checked with the endoscope tip immersed in water. Evidence of effective suctioning can be obtained by observing the transparent suction tubing. Air insufflation should produce a brisk train of bubbles in the water (Figure 7-3). The lens washing facility should produce a strong laterally directed jet of water across the tip of the instrument (Figure 7-4). Lastly, the instrument should be directed towards a suitable object and focused if necessary.

Intubation and Examination of the Esophagus

The endoscopist stands facing the patient with the control unit of the instrument in the left hand and the distal end of the endoscope in the right hand. With the fingers of the left hand encircling the control section, the tips of the fingers reach round to adjust the angulation controls. The thumb and index finger can adjust the up/down control, and the thumb and middle finger the left/right control. The final element in directional control is provided by rotational movements of the endoscope achieved either by direct rotation using the right hand, or by a change in the endoscopist's body position, turning to left or right.

Intubation of the esophagus is the first potential challenge for the novice endoscopist. Passage of the instrument through the pharynx frequently evokes powerful local protective reflexes, and patients are most likely to become agitated and combative at this phase of the procedure even when apparently well sedated. A clumsy intubation technique is one of the most common causes of difficulty with EGD. If the endoscopist completes this phase of the examination quickly and with minimal pharyngeal stimulation, any problems of patient discomfort are transient and slight.

Immediately before inserting the instrument it is helpful to rehearse the tip flexion required to pass the endoscope down over the tongue into the hypopharynx (see Figure 7-1). If the child is under general anesthesia, requesting the anesthetist to lift the jaw by pulling up the angle of the mandible can enhance the view of the inlet to the esophagus. The instrument should remain in the midline as it passes down through the pharynx

Figure 7-3. Checking that air insufflation is satisfactory.

Figure 7-4. Checking the lens washing waterjet.

to the esophageal inlet. If the endoscopist encounters difficulty, the midline position may be confirmed by identifying the point of transillumination in the neck. The endoscope may be advanced into the esophagus either blindly or with visual guidance. Although some advocate the latter, careful blind intubation is safe and is commonly performed. A slight feeling of resistance may be encountered at the level of the cricopharyngeal muscle in the proximal esophagus. At this point, a consciously sedated patient can be asked to swallow in order to relax the cricopharyngeus and so ease passage of the instrument. Although many children will not be able to swallow on request, with a gentle application of pressure the endoscope will readily pass through the cricopharyngeus. Once in the esophagus the characteristic tubular appearance is immediately obvious.

The instrument will pass down the narrow confines of the esophagus without difficulty. It is important to make any necessary adjustments to keep the esophageal lumen at the center of view. Insufflation of air from time to time will maintain a clear view. The gastroesophageal junction is identified using a number of anatomical features. First, the z-line of the gastroesophageal mucosal junction may be visible, the esophageal mucosa appearing pale compared with the salmon-pink gastric mucosa. Second, the gastric rugae may be seen immediately distal to the esophageal mucosa. Last, there may be an area of relative luminal narrowing at the level of the diaphragm—the "diaphragmatic pinch." In the conscious patient this feature can be accentuated by asking the patient to inhale briefly or to "sniff." Each of these indicators should be evaluated because in individual patients some may be more reliable than others. A sliding hiatus hernia can be confirmed by noting that the z-line and gastric rugae lie above the diaphragmatic pinch. Similarly, in patients with Barrett's esophagus the z-line may be proximally displaced. Finally, before advancing through the gastroesophageal junction, aspiration of air reduces the intraesophageal pressure and may reveal small esophageal varices that might not otherwise be obvious.

Examination of the Stomach

The endoscope moves easily through the gastroesophageal junction, but immediately upon entering the stomach the forward view may be obscured by gastric mucosal folds in the cardia. At this point adequate insufflation of the stomach is necessary to gain a clear view. Aspiration of pooled gastric secretions is critical prior to full distention of the stomach to minimize the risk of aspiration. As air is insufflated the gastric lumen and the gastric rugae are evident, but with further distention the rugae gradually flatten. As the endoscope is advanced it readily slides down along the greater curvature of the stomach to the gastric antrum. Very often as the endoscope reaches the antrum the pylorus comes into view. However, in infants and small children the pylorus is often located very close to the angulus incisura and the angle of approach is necessarily somewhat acute. In this case it can be very helpful to perform a so-called "J-maneuvre" of the endoscope. The endoscope is retroflexed so as to look back up the stomach (thus adopting a "J" configuration). Then with some minor adjustments, it is usually easy to look face-on at the edge of the angulus incisura. The pylorus lies a few centimeters distal to the angulus. Once visualized with this maneuver the line of approach is clear. The J-maneuver can also be very helpful in performing a thorough examination of the gastric cardia. The gastric body lies proximal to the angulus and further proximally is the fundus and the gastroesophageal junction through which the shaft of the endoscope is to be seen passing downwards. If the endoscope is carefully withdrawn in the retroflexed position, and some lateral and rotational adjustments are made, thorough examination of the entire gastric mucosa is possible.

Intubation of the Pylorus and Examination of the Duodenal Bulb

Once the entrance to the pyloric canal is visualized, intubation is usually straightforward. If the pylorus is closed it appears as a series of mucosal folds radiating from a central point. With gentle pressure, sometimes assisted by a brief puff of air, the endoscope will usually pass easily into the pylorus. Once the tip is within the pyloric canal the endoscopist should hesitate briefly to examine the duodenal bulb. Gentle movements of the angulation controls enable inspection of all surfaces of the bulb from this position.

Passage of the Endoscope Beyond the Duodenal Bulb

The endoscope is now advanced into the duodenal bulb. Passage into the second part of the duodenum is sometimes quite direct and easy, but frequently it requires negotiation of a series of bends. The duodenum turns posteriorly and inferiorly at this point. If passage to the second part is not direct, a specific maneuver will usually prove effective. The angulation controls are rotated in opposite directions turning the

endoscope tip upwards and to the right, and at the same time the endoscopist makes a 45 degree body turn to the right, thus causing the endoscope to rotate clockwise. These three adjustments are performed simultaneously while the endoscope is gently advanced. The second part of the duodenum is recognized by the presence of the circular duodenal folds. Quite often forward pressure on the endoscope may by now have produced a loop in the stomach resulting in lateral pressure on the greater curvature. While observing to ensure that the tip of the endoscope does not move backwards, withdrawal of the endoscope at this point relieves any discomfort that the patient may be expe-riencing from gastric distention and, in addition, may result in paradoxical forward movement of the endoscope down into the duodenum. Straightening the endoscope in this way improves directional control and facilitates subsequent passage of the biopsy forceps.

The magnification facility available with many video endoscopes can be usefully employed to examine the duodenal villi. If water is injected through the endoscope channel to the area being inspected, the villi float upwards making them easier to visualize. In patients with celiac disease the absence of normal villi is usually obvious.

Mucosal Biopsies

Usually multiple biopsies are required. In order to complete procedures efficiently, proficiency at obtaining biopsies speedily is essential. The endoscopy nurse closes the jaws of the biopsy forceps and the endoscopist then passes the forceps down the biopsy channel (Figure 7-5). Passage is easier if the nurse supports the forceps cable vertically above the instrument channel. Continuous observation of the area to be biopsied will prevent injury to the mucosa when the forceps emerge from the channel. As an added precaution the forceps cable should be held lightly between the fingers while advancing, so that any unintended contact with the mucosal surface will result in its sliding through the fingers reducing the risk of injury.

Biopsies tend to be more satisfactory if obtained using a direct rather than tangential approach to the mucosa. This direct approach is slightly more difficult in the tubular esophagus, but can be readily achieved as follows. The forceps are advanced until they come into view and are then opened. The endoscopist then withdraws the forceps gently so that they are held close to the tip of the endoscope. The endoscope is angulated to face the mucosa directly. The forceps can then be advanced directly towards the mucosa and the biopsy obtained. Aspiration of air in the esophagus prior to obtaining the biopsy will also help by collapsing the mucosa around the open forceps, drawing the mucosa into the biopsy cups. This maneuver can be especially helpful in cases where the mucosa is thickened and noncompliant.

Sometimes difficulties are encountered in passing the biopsy forceps from the distal end of the forceps channel. This may happen when attempting to obtain duodenal biopsies because the endoscope may be markedly angulated. Straightening the endoscope as described earlier can greatly reduce this problem. The assistant should avoid inadvertently applying positive pressure to the control handle that closes the forceps because this has the effect of making the shaft of the forceps more rigid. Increased resistance to the passage of the forceps from the tip of the endoscope suggests that the channel is damaged, and using force may cause further harm to the instrument.

The number and site of mucosal biopsies obtained will vary, depending on the clinical indication, endoscopic findings, and local practice. The biopsies from each site may be placed on an individual paper square and then immersed in formaldehyde or other appropriate solution (Figure 7-6). Care should be taken to

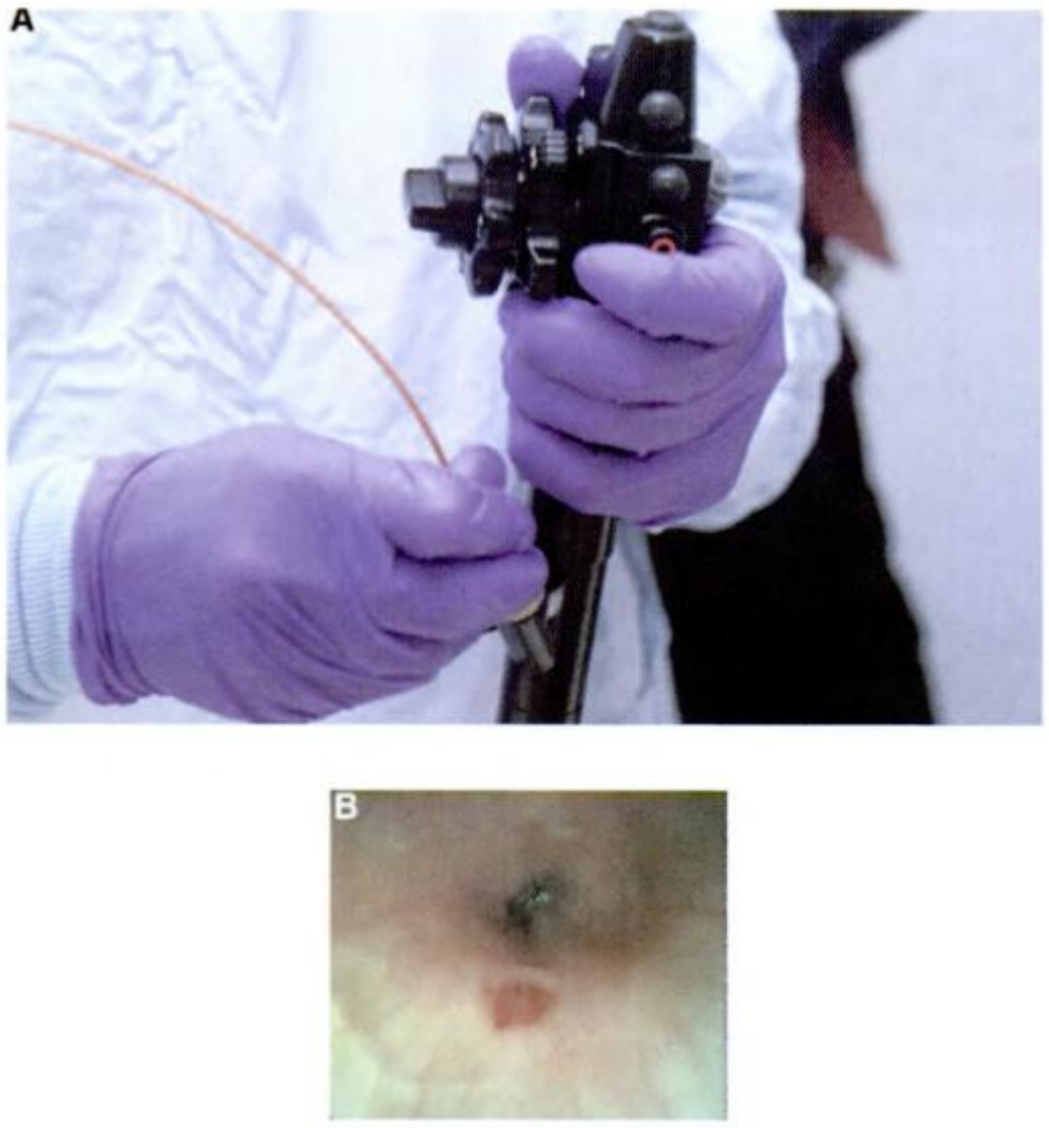

Figure 7-5. *A*, Passing the forceps down the instrument canal. *B*, Biopsy site demonstrating crater caused by biopsy.

avoid mechanical damage to the biopsy specimens during this process. Routine biopsies are most often obtained from the distal esophagus, the gastric antrum, and the second part of the duodenum, but additional biopsies may be taken from the gastric cardia and corpus, and from the mid-esophagus. Taking biopsies from the esophagus immediately adjacent to the z-line is usually avoided because of difficulties arising in the interpretation of regional histological features, such as basal hyperplasia. In addition to the routine biopsy of macroscopically normal mucosa, direct biopsy of abnormal areas or lesions is performed. Such targeted biopsies are usually best taken from the margins of lesions such as ulcers.

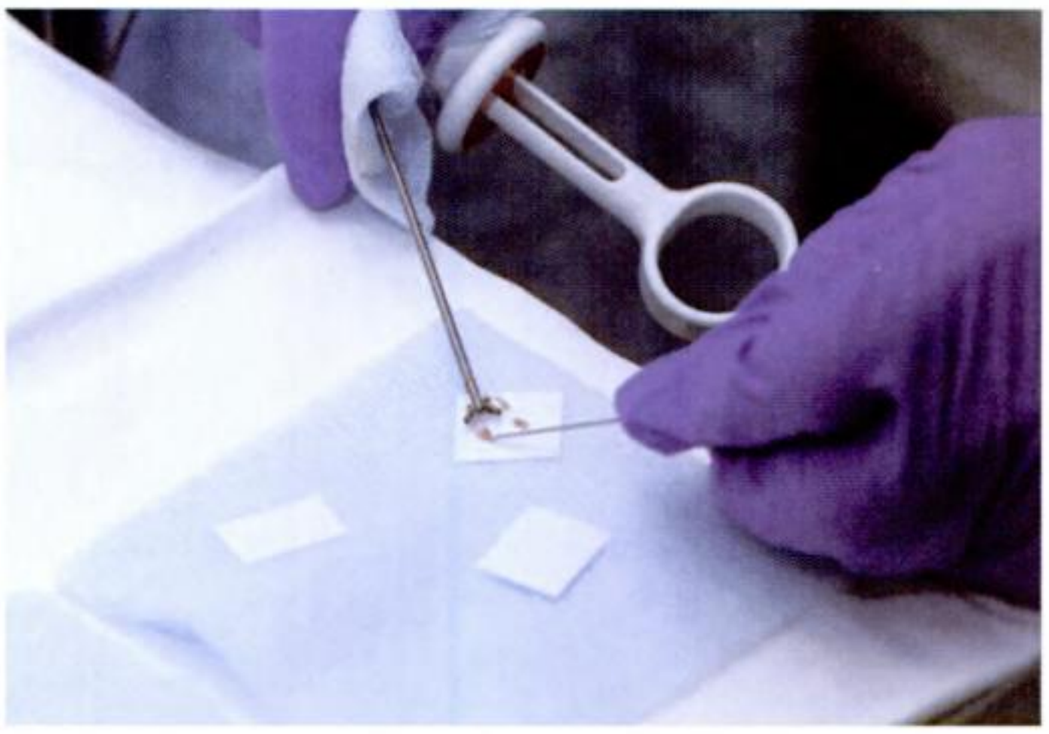

Figure 7-6. Mucosal biopsies placed on filter paper prior to immersion in fixative.

Completion of the Examination

Examination of the upper GI tract continues as the endoscopist withdraws the instrument. Particular attention is paid to areas that may not have been adequately inspected previously while advancing the instrument. If the stomach is still distended with air, complete aspiration will enhance patient comfort. The proximal esophagus is better visualized during the removal of the instrument and may permit identification of unusual lesions such as a patch of ectopic gastric mucosa at the esophageal inlet.

Complications

For the experienced endoscopist, diagnostic EGD is a safe procedure and should rarely result in significant complications. The risks are minimized by appropriate patient selection and careful patient management (see Chapter 5, "Patient Management"), and by ensuring that the procedure is carried out or supervised by a skilled endoscopist. The complications directly associated with EGD most often arise due to mechanical trauma to the soft tissues of the mouth and upper GI tract.

Attention should be paid to the presence of loose teeth because they can easily be dislodged and pose a risk of inhalation. Care should be taken during the placement of the mouth guard to ensure that the soft tissues of the mouth do not become trapped between the guard and the teeth.

Although gentle pressure is obviously necessary in order to advance the endoscope from mouth to duodenum, the application of excessive force may risk causing a perforation. If the endoscope will not advance with gentle pressure this is a clear indication of faulty technique or of some structural abnormality. Particular care should be taken in patients with significant esophageal or gastroduodenal disease and in malnourished patients. Abnormal anatomy (eg, due to strictures) can make the procedure difficult or impossible. Disorders such as Crohn's disease may render the tissues more vulnerable to mechanical injury.

Significant bleeding is not an expected complication of EGD, although caution should be exercised in those with severe disorders of hemostasis or coagulation. A large duodenal hematoma may result from endoscope trauma or submucosal bleeding following a biopsy. Luminal obstruction from a hematoma is an uncommon complication of EGD. The risk may be reduced if the endoscopist avoids excessive "tenting" of the mucosa by bringing the tip of the instrument close to the duodenal mucosa before taking biopsies.

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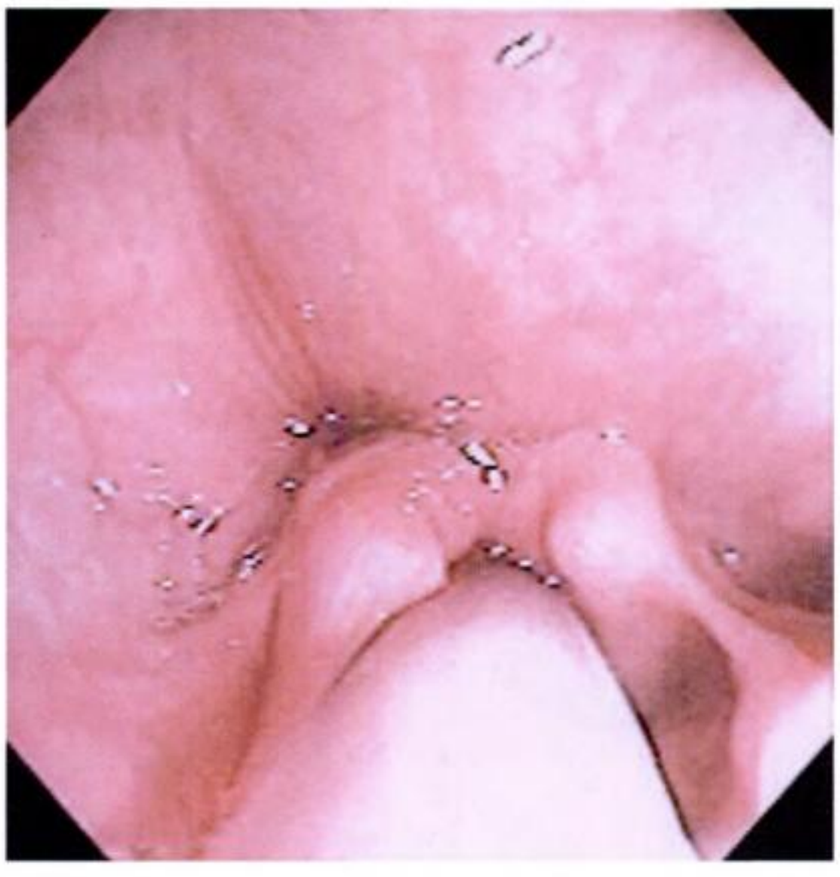
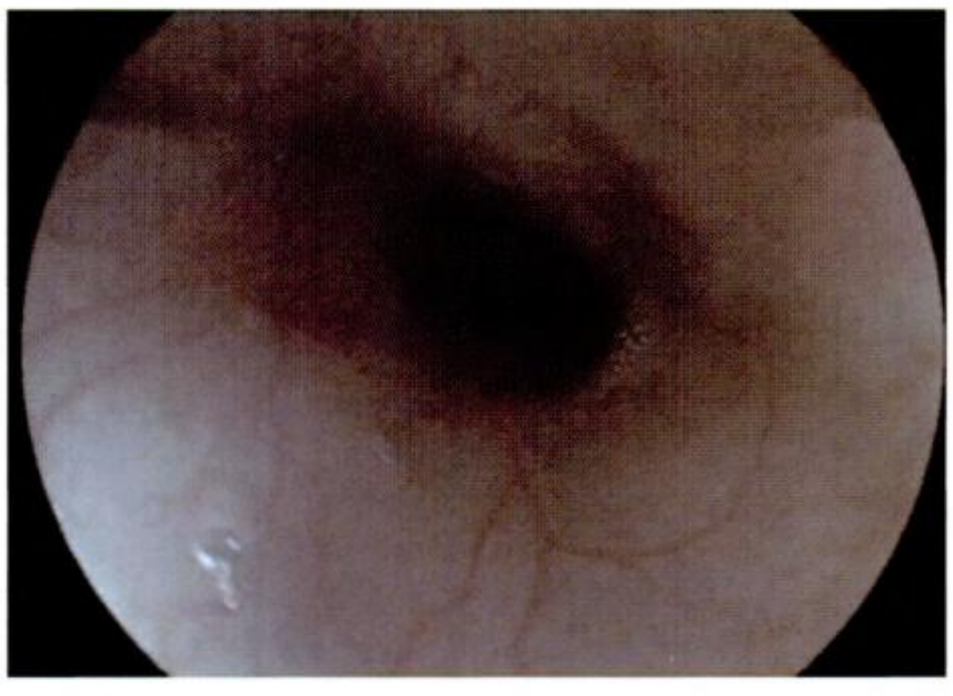
Atlas Part I

Esophagus

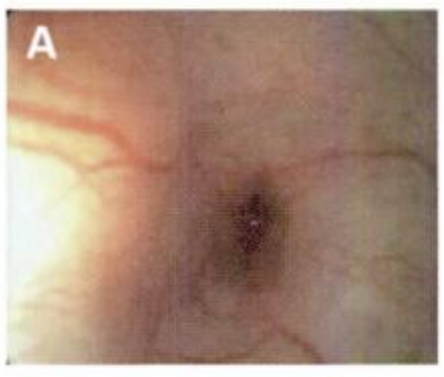
Normal Esophagus

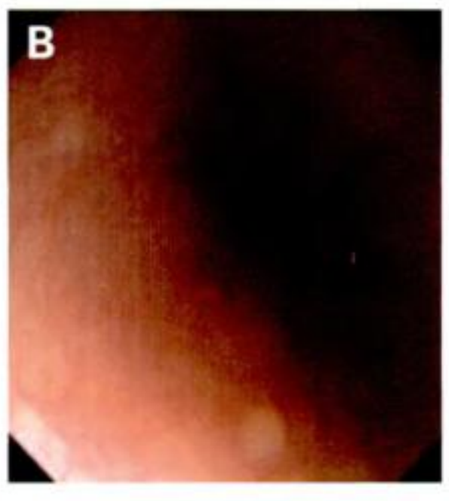


1. Endotracheal tube visualised during endoscopic intubation.

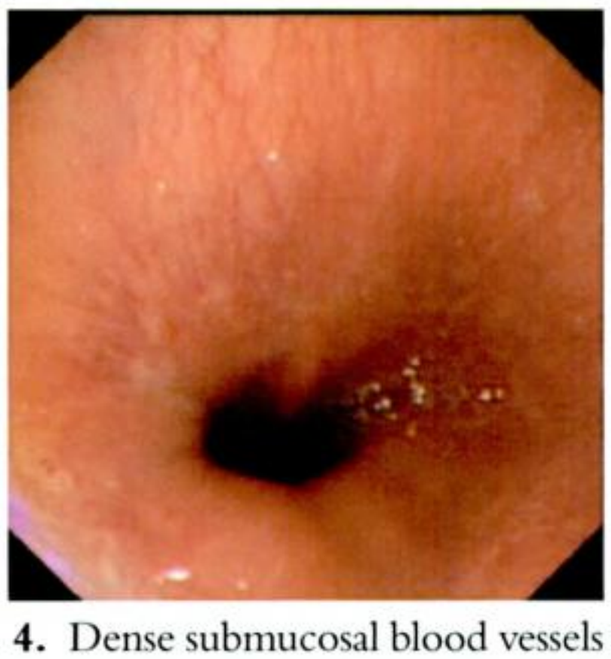


2. Mid esophagus.

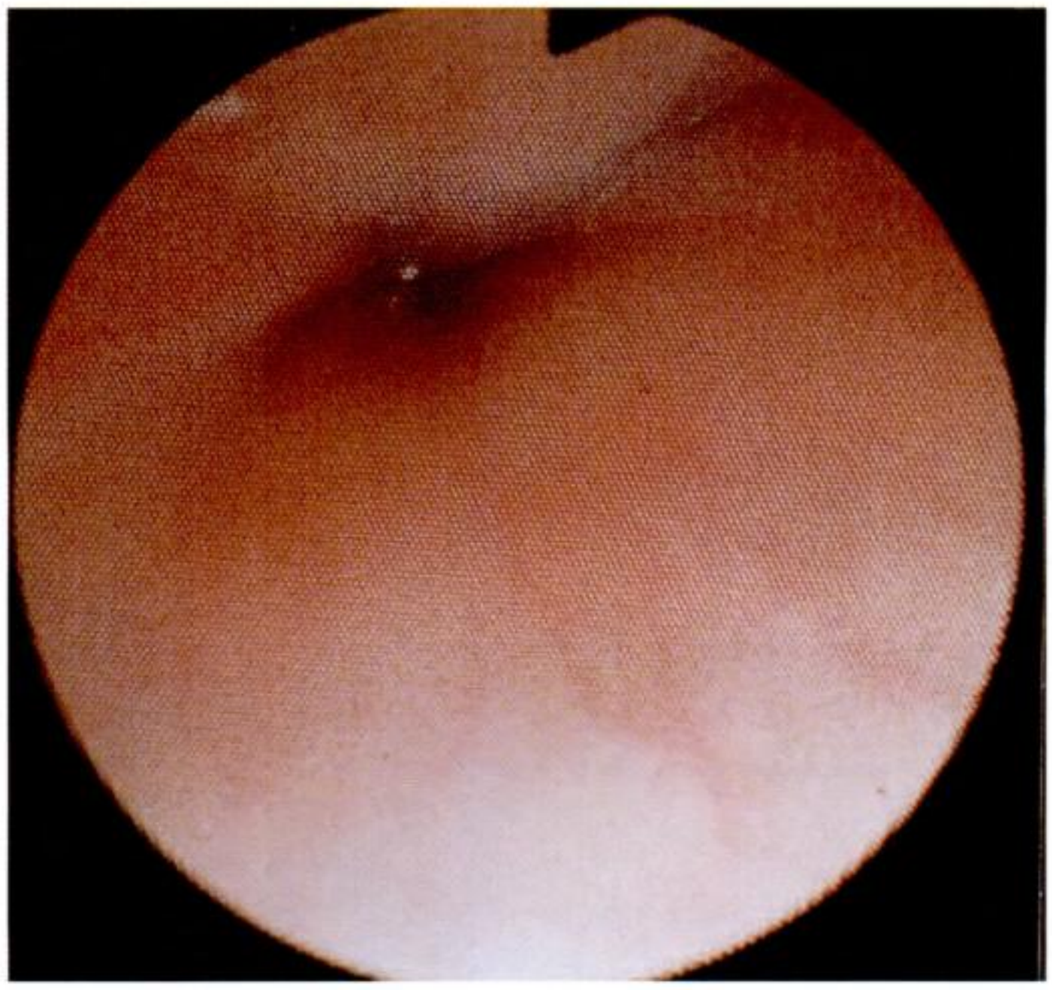




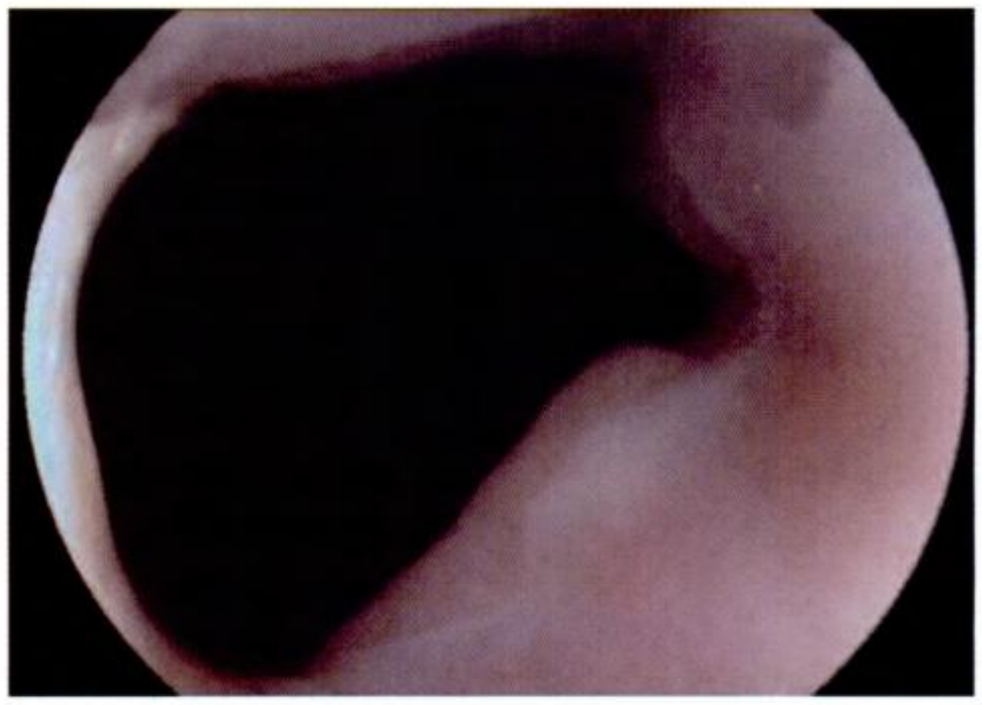
3. *A*, One year old infant with a prominent vascular pattern. *B*, Epithelial pearls in distal esophagus.



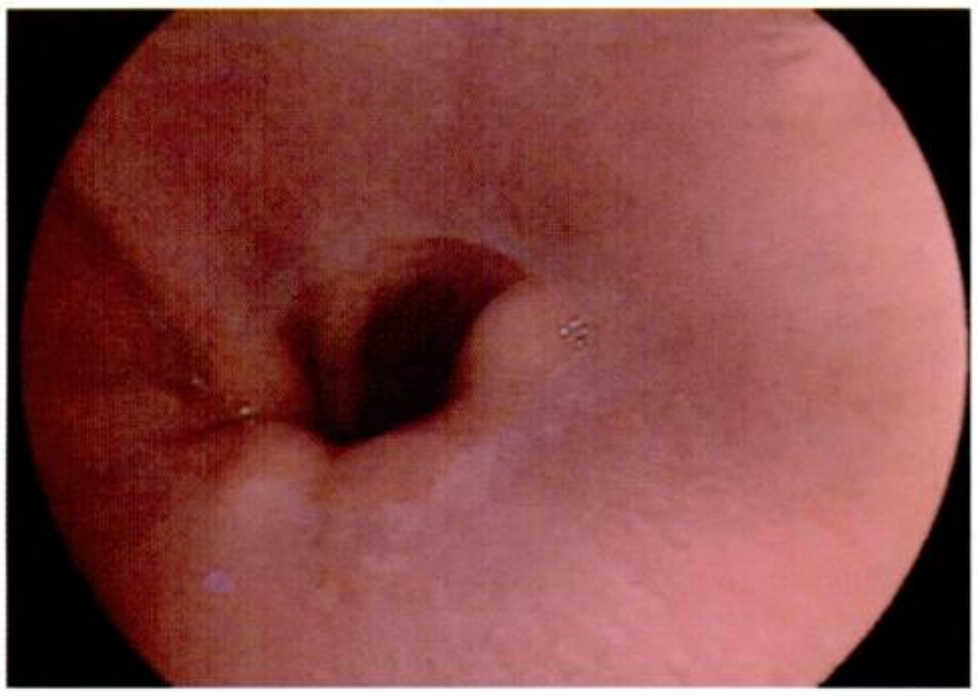
4. Dense submucosal blood vessels in distal esophagus giving the false impression of abnormal hyperemia.



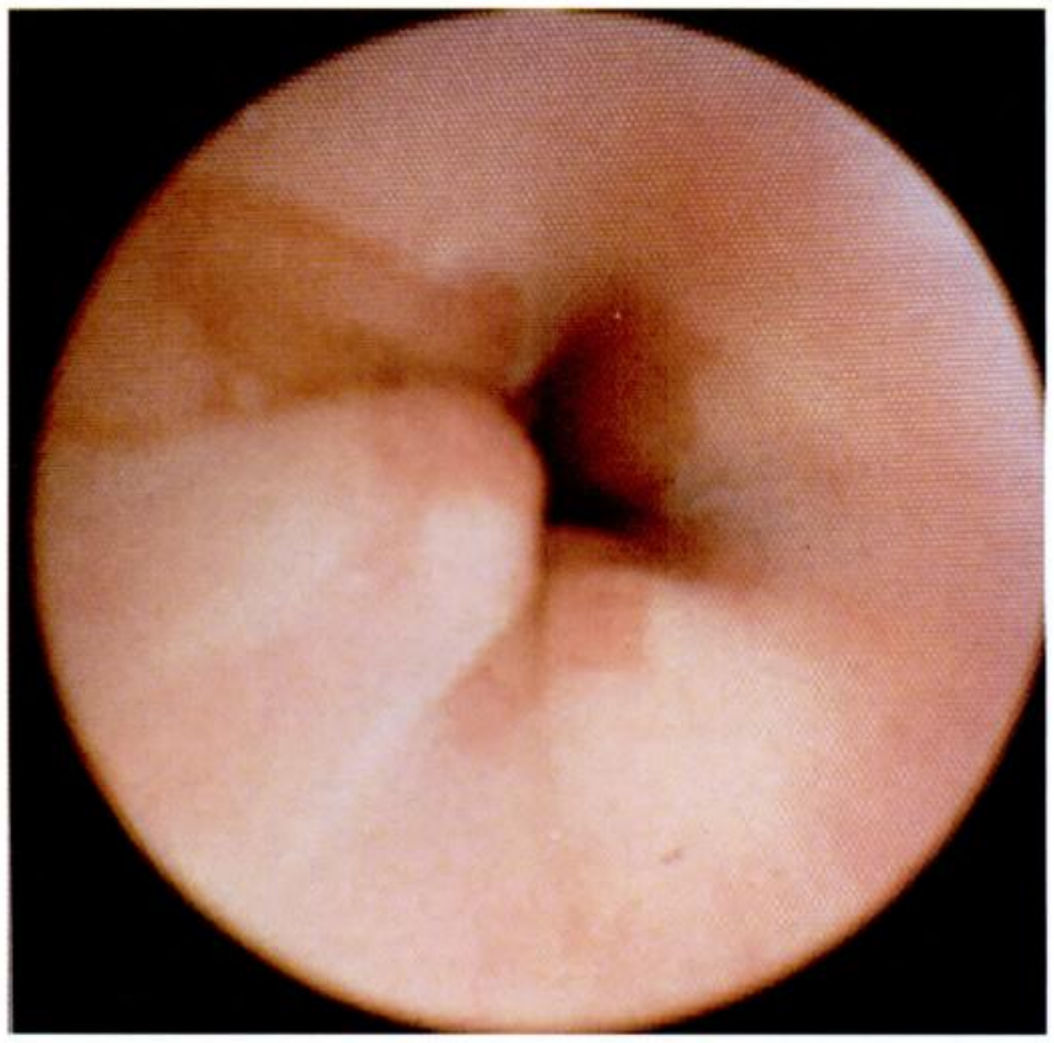
5. Normal appearance of distal esophagus in a neonate, with less prominent blood vessels.



6. Z-line at the gastroesophageal junction.

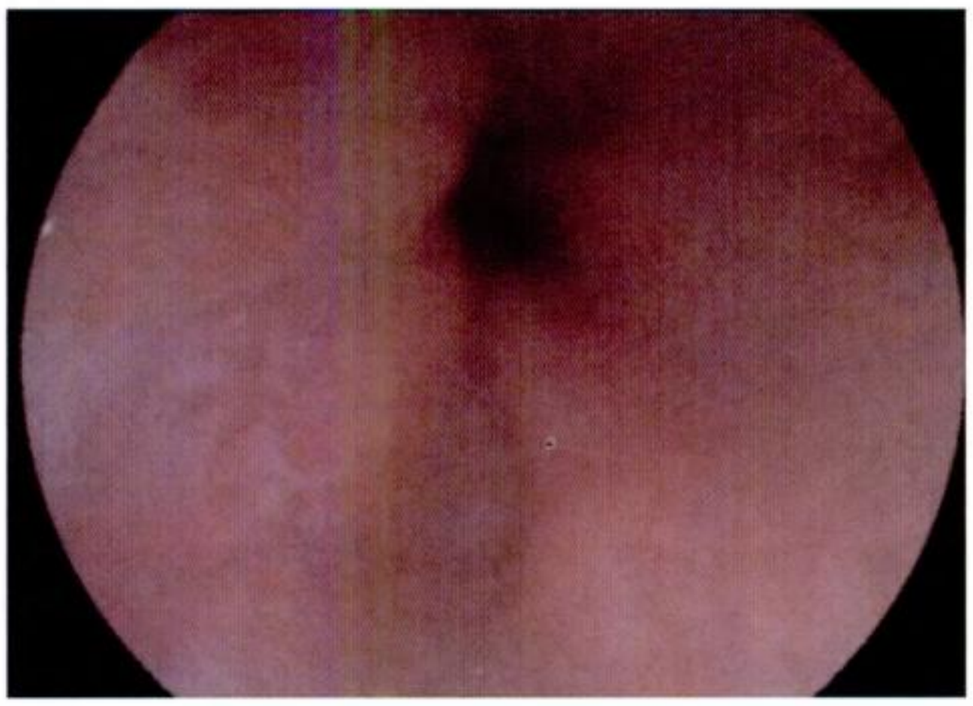


7. Normal variations in appearance of Z-line.

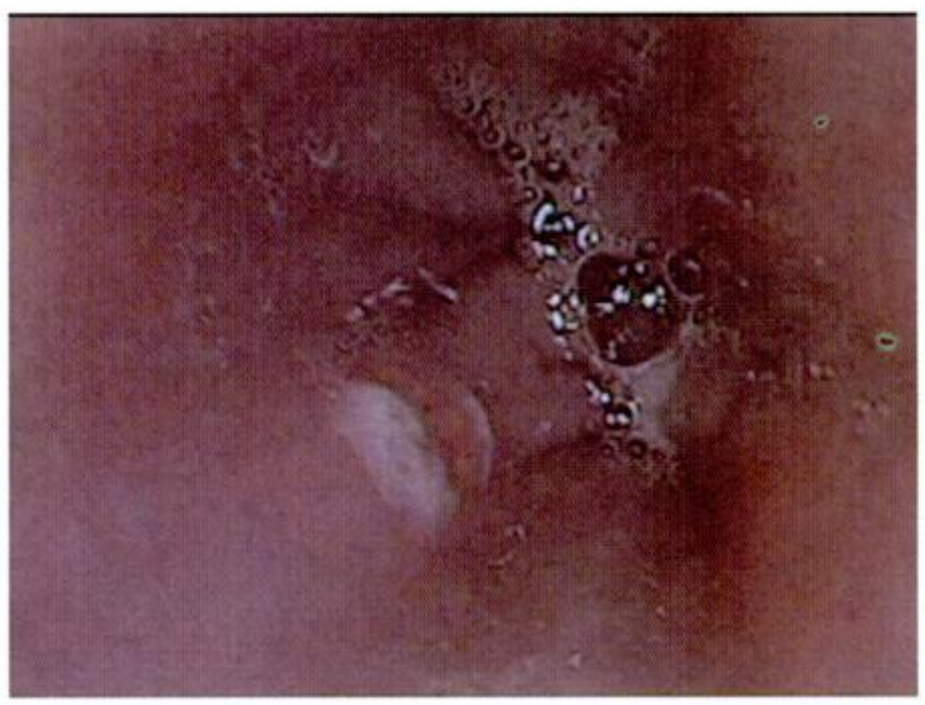


8. Normal variations in gastroesophageal Z-line. This normal variation should not be confused with Barrett's esophagus.

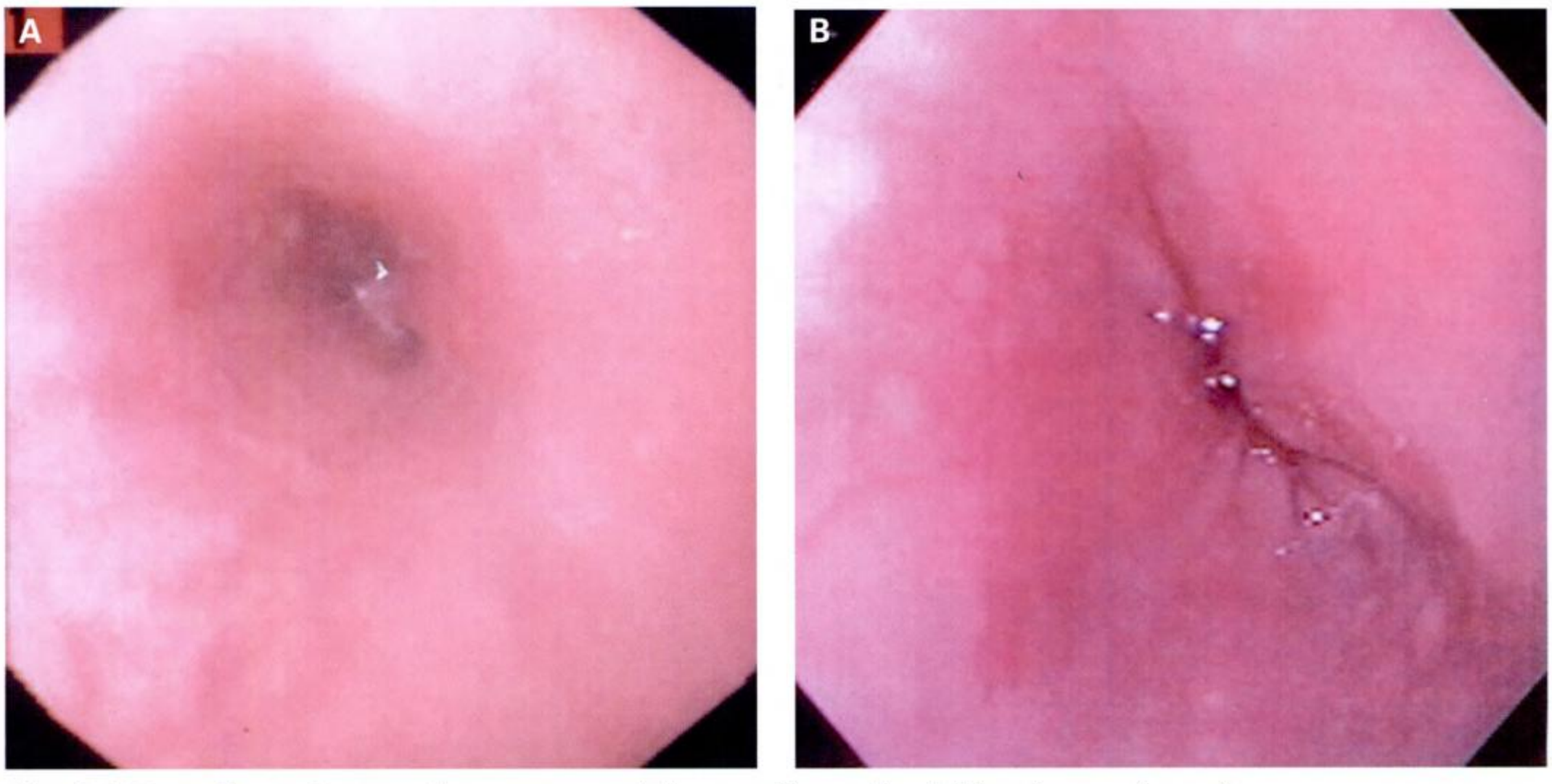
Peptic Esophagitis



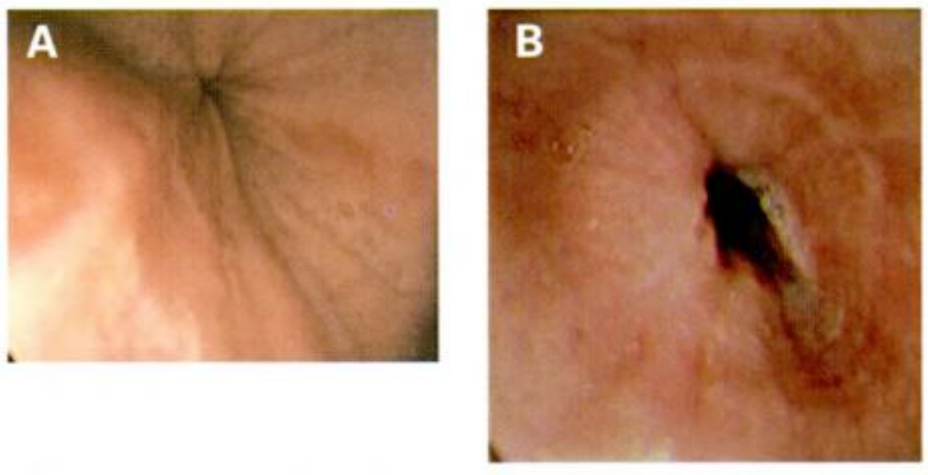
9. Mild esophagitis characterized by distal erythema.



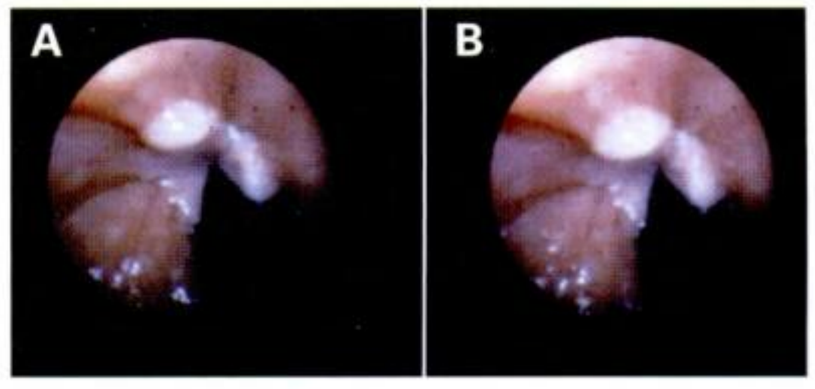
10. Peptic esophagitis with small focal ulceration at the Z-line.



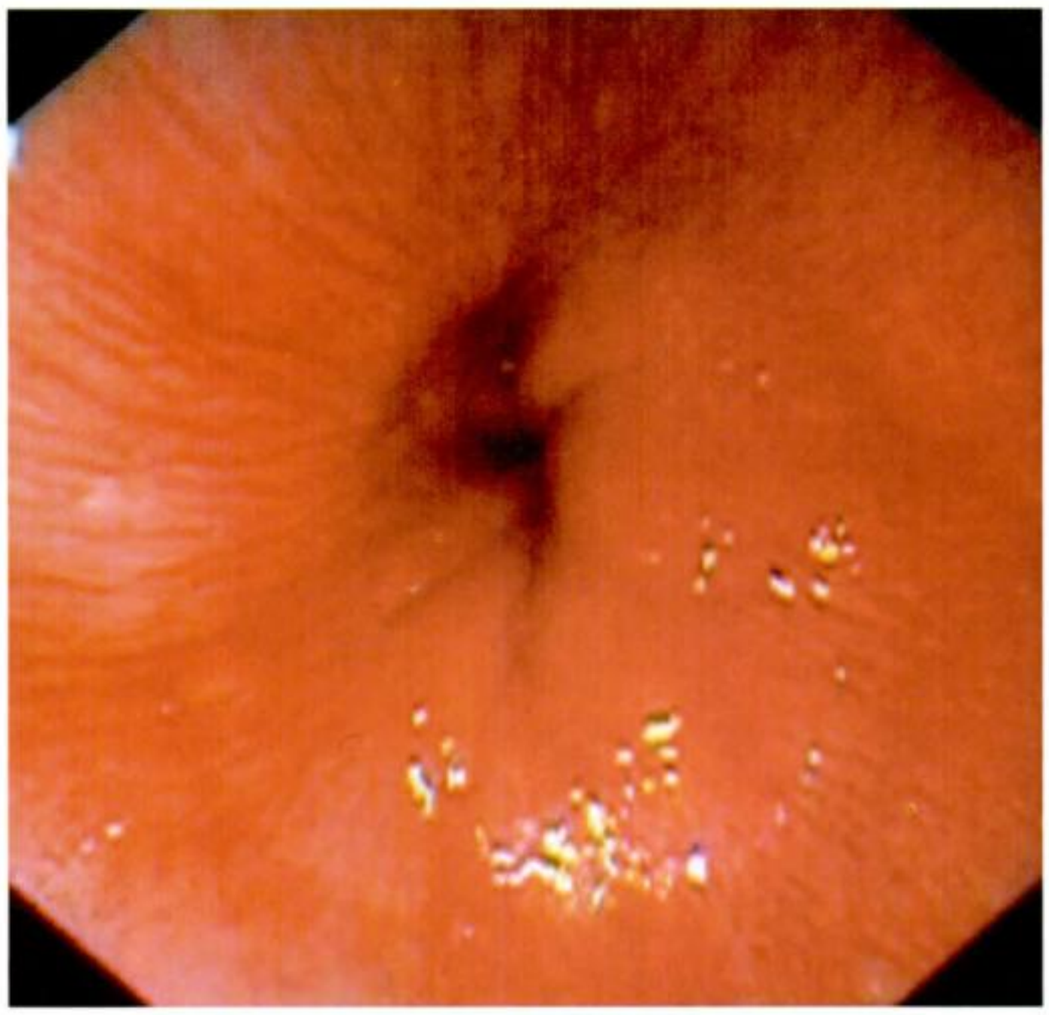
11. *A, B,* Loss of smooth mucosal appearance and absence of normally visible submucosal vessels.



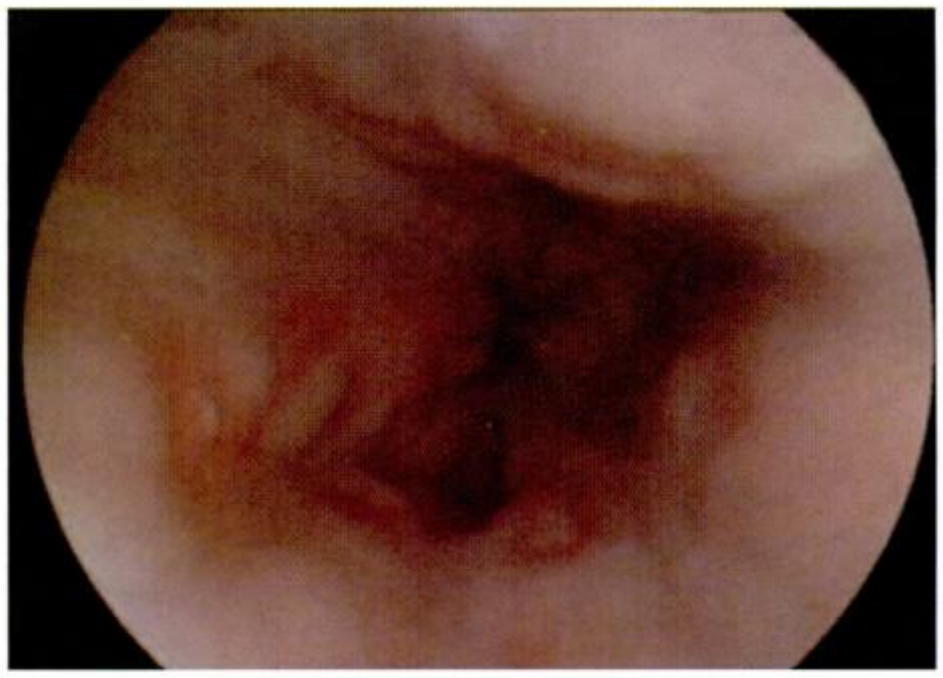
12. Erythema in the distal esophagus.



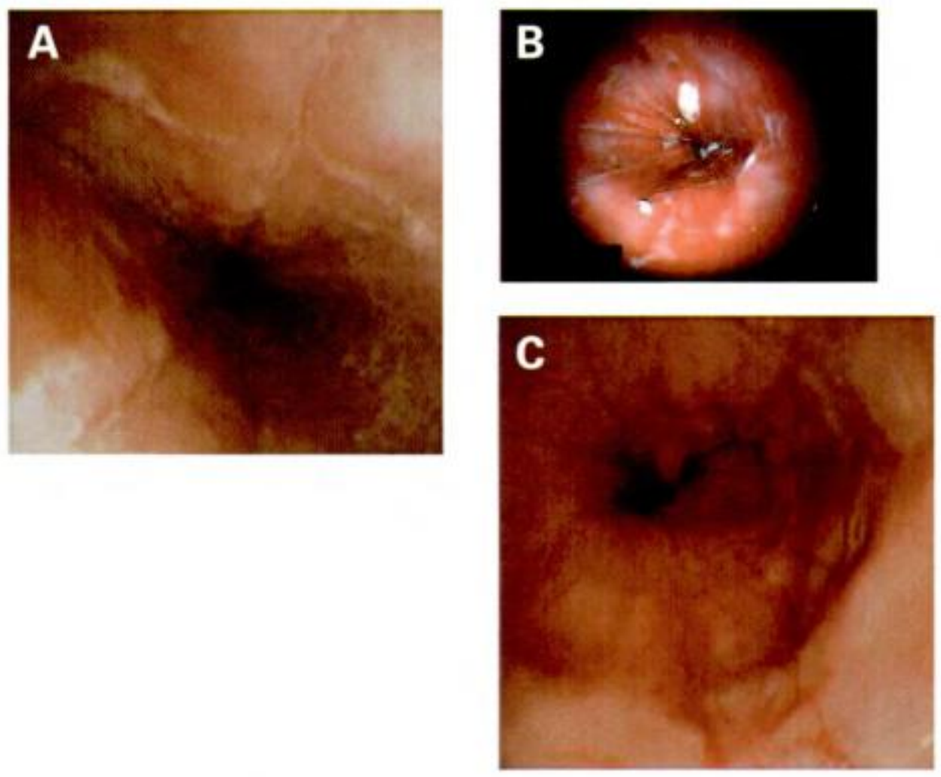
13. Ulceration at the Z-line.



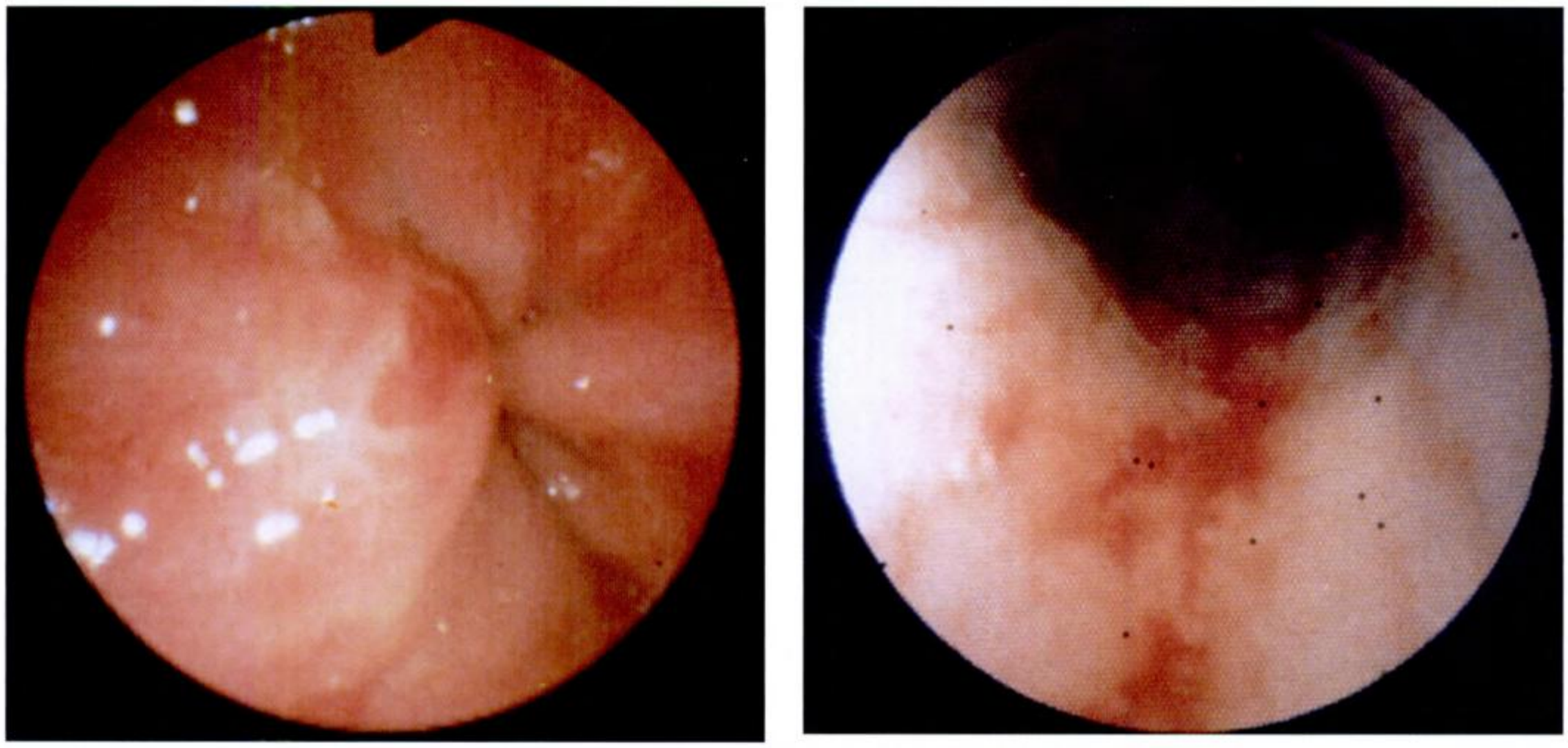
14. Erythema due to esophagitis in a patient with scleroderma.



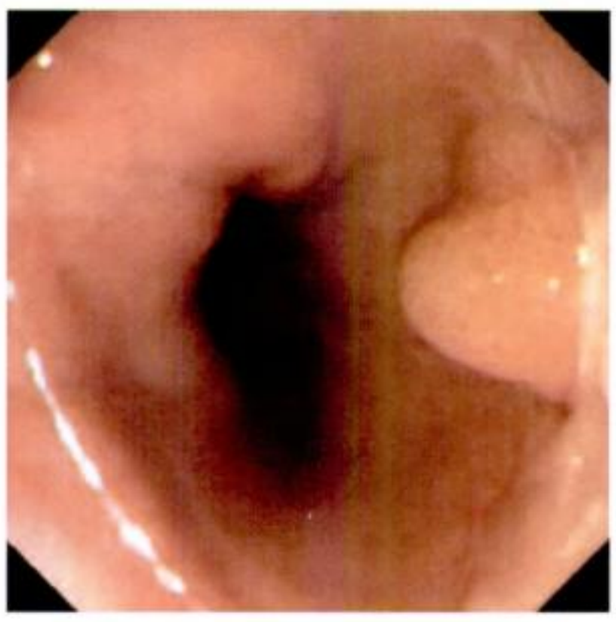
15. Erosive esophagitis with multiple ulcers.



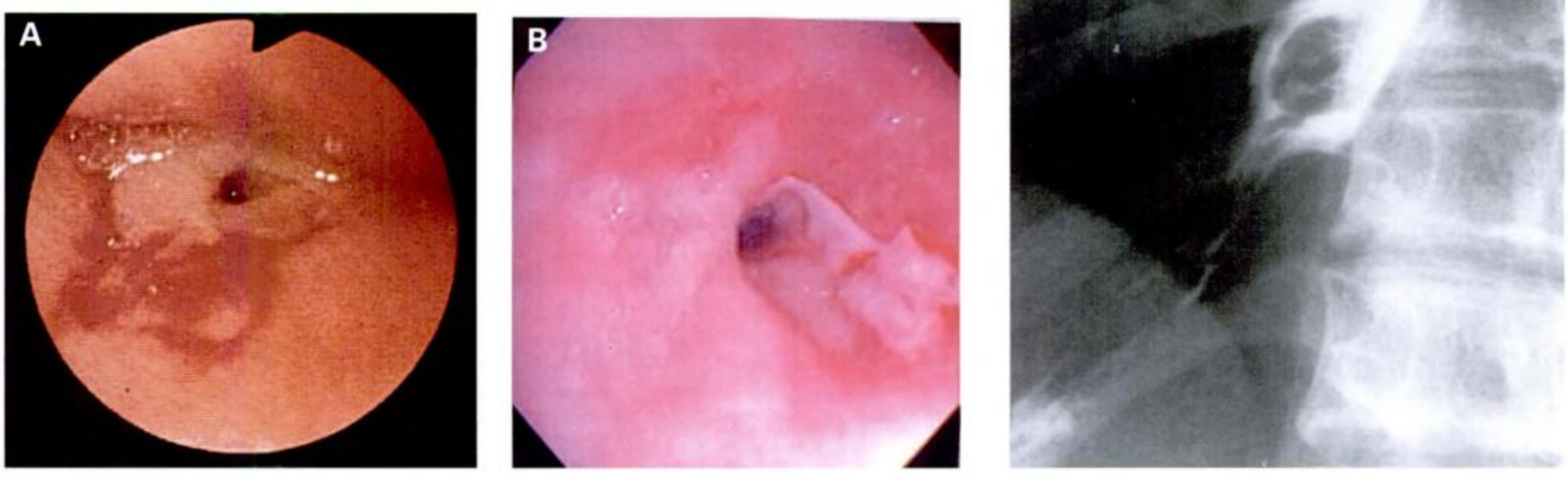
16. Severe distal peptic esophagitis.



17. Peptic esophagitis with erythema, loss of normal vascular pattern and distal ulceration.

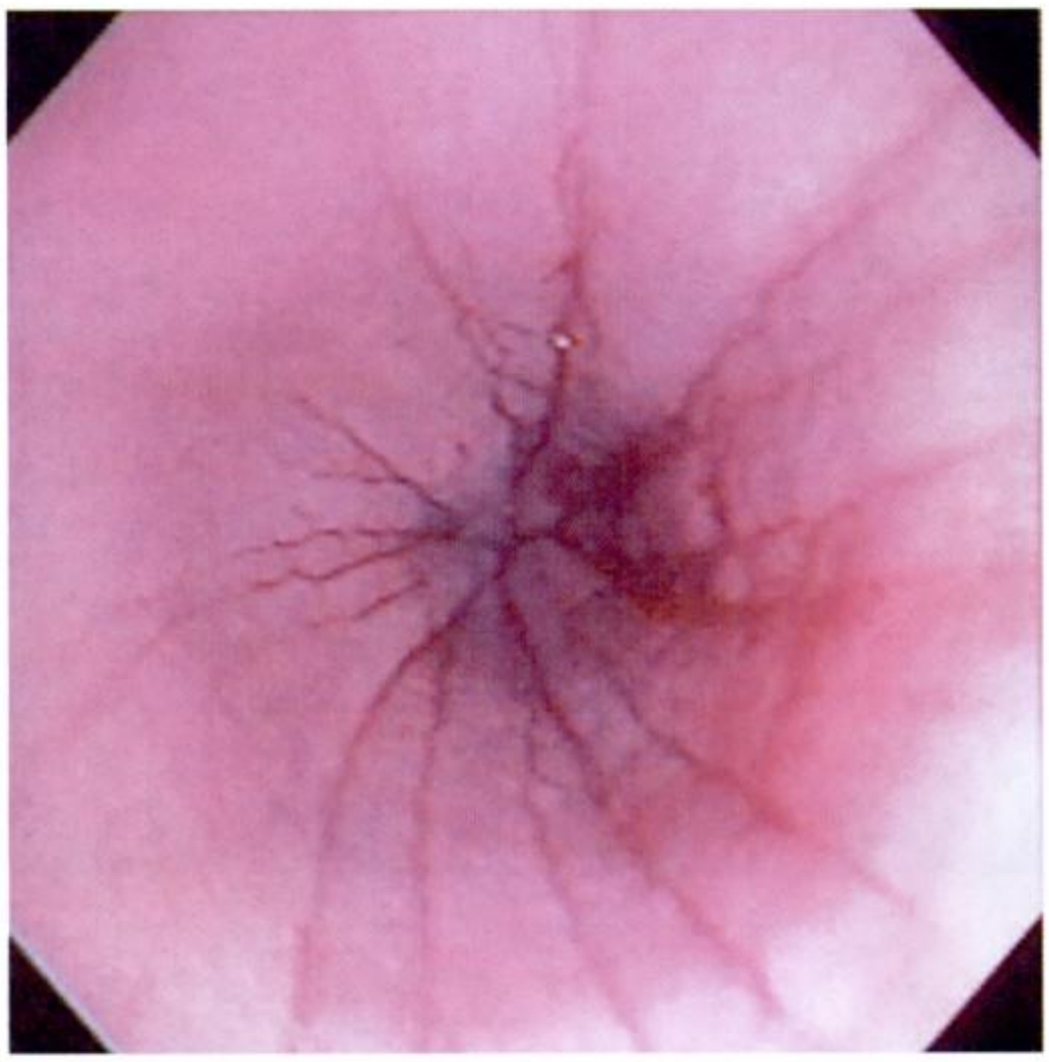


18. Reactionary polypoid lesion at the GE junction in a child with GERD.

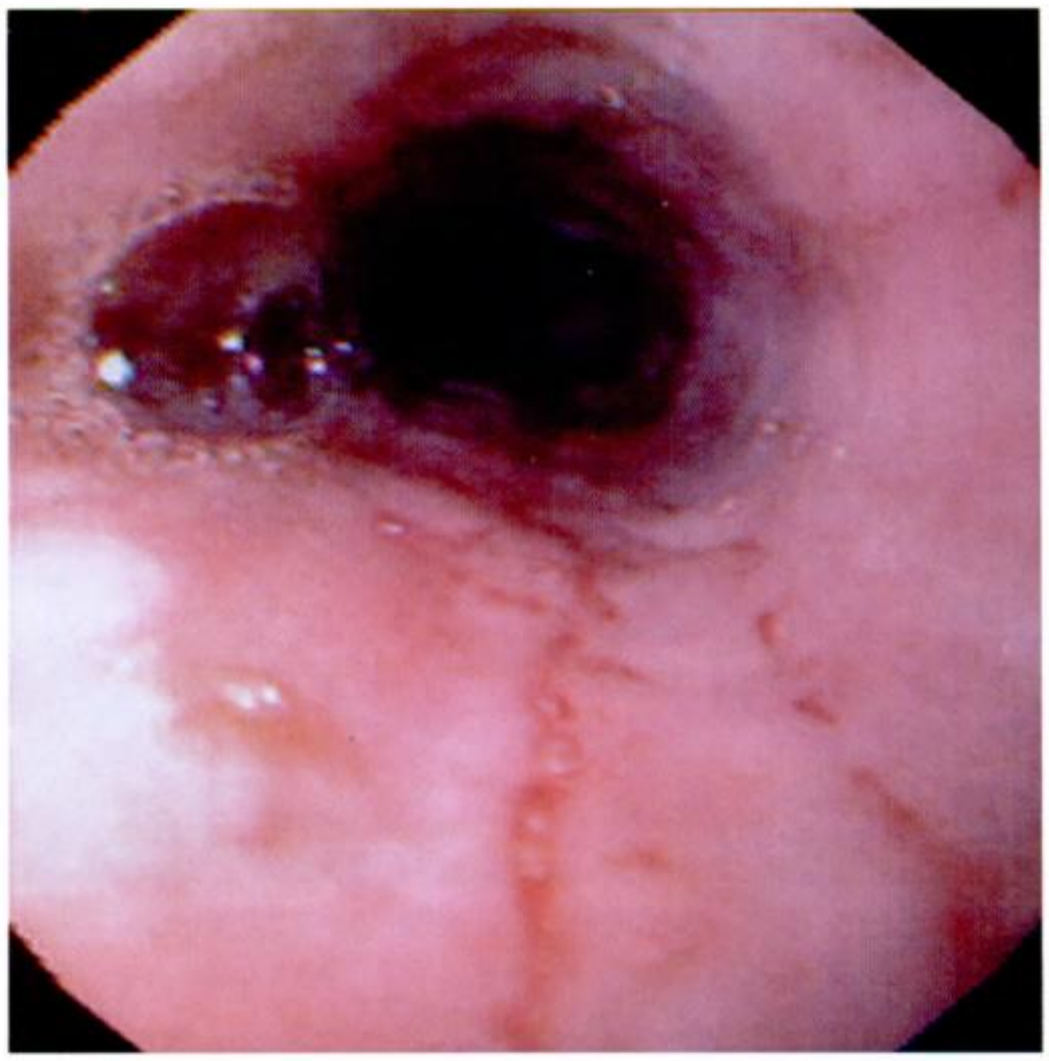


19. *A*, Strictures due to peptic esophagitis, some showing adjacent ulceration. The accompanying barium contrast study reveals the anatomy of the stricture. *B*, Stricture with adjacent ulcer. *C*, Barium contrast study showing residual food above a long peptic stricture.

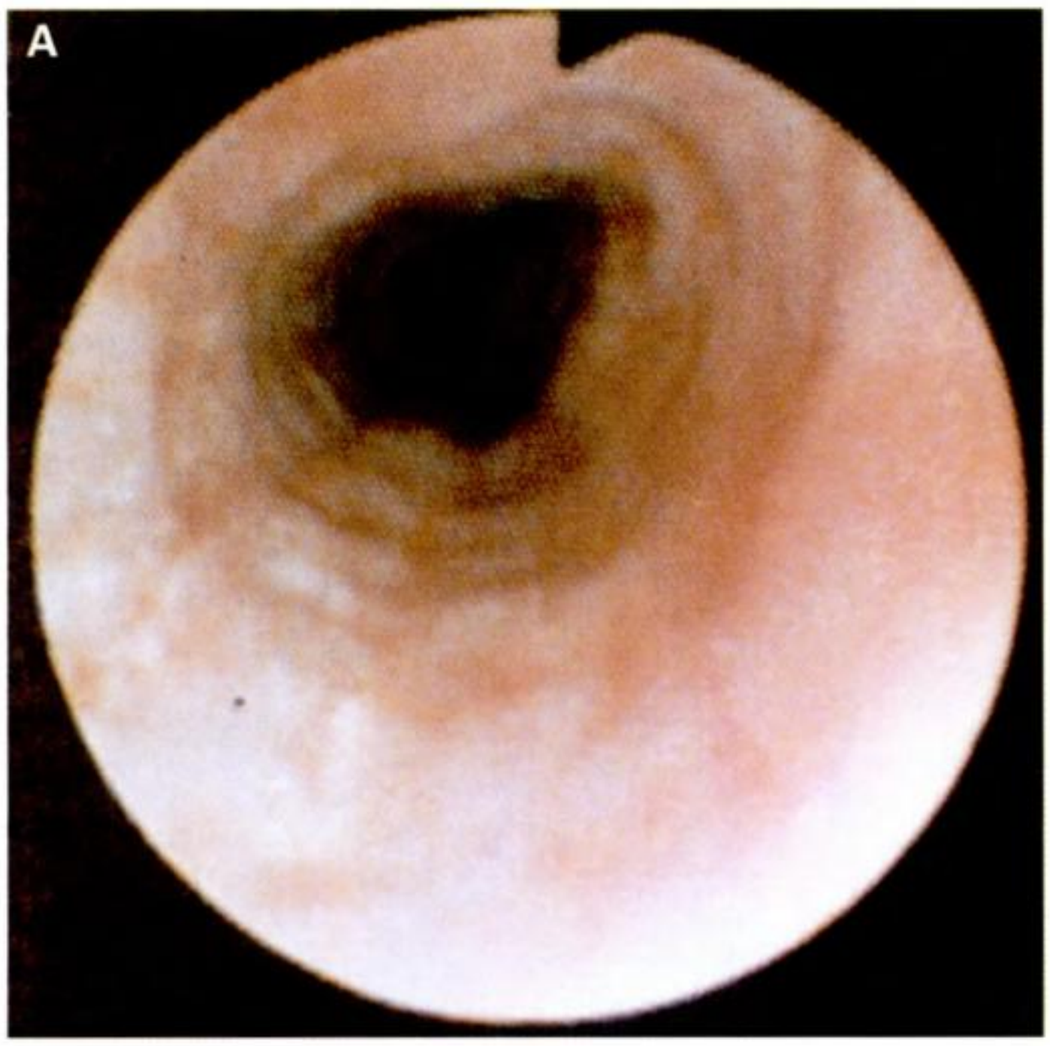
Eosinophilic Esophagitis

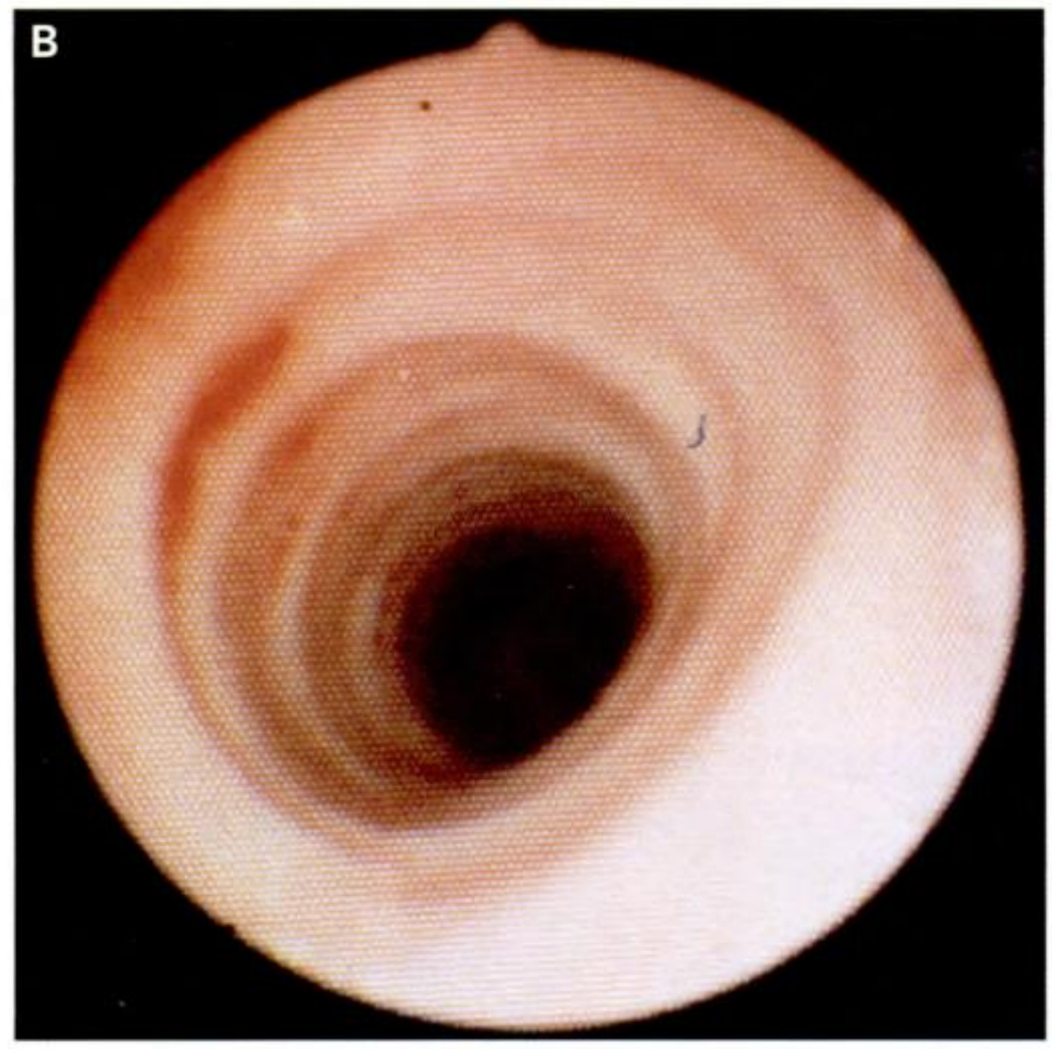


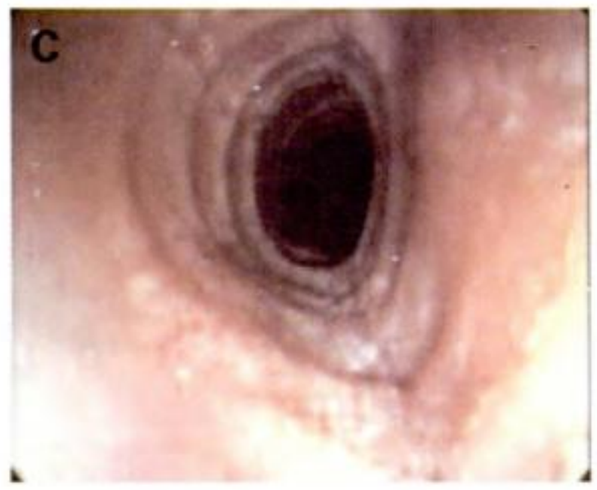
20. Loss of smooth mucosal appearance, absence of normal visible vessels and characteristic pattern of linear furrowing.



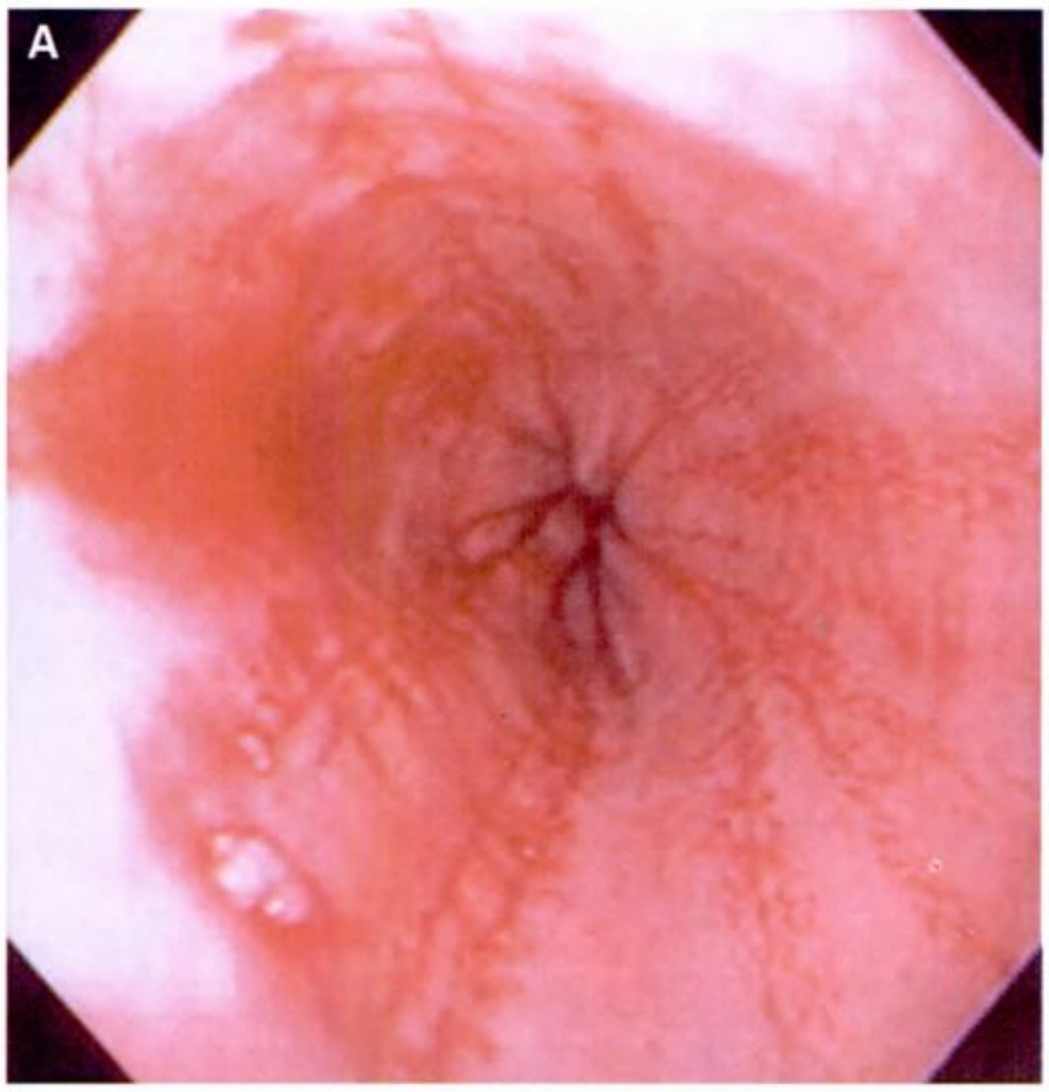
21. Linear 'furrowing' in mid-esophagus.

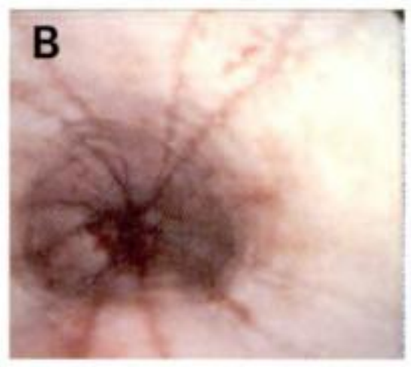


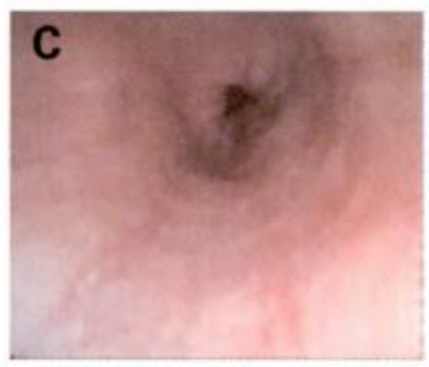




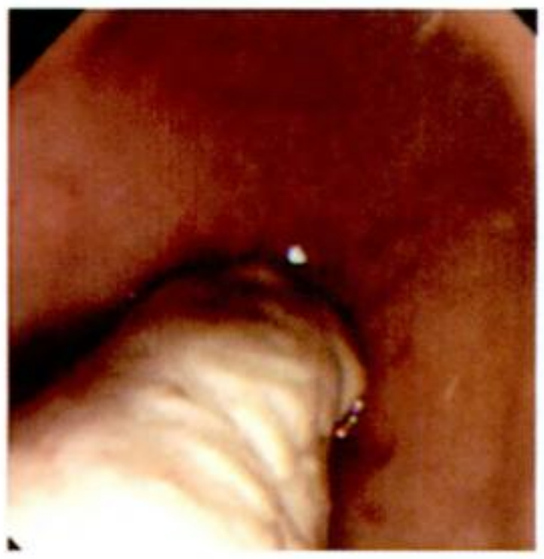
22. Typical ringed appearance of eosinophilic esophagitis.



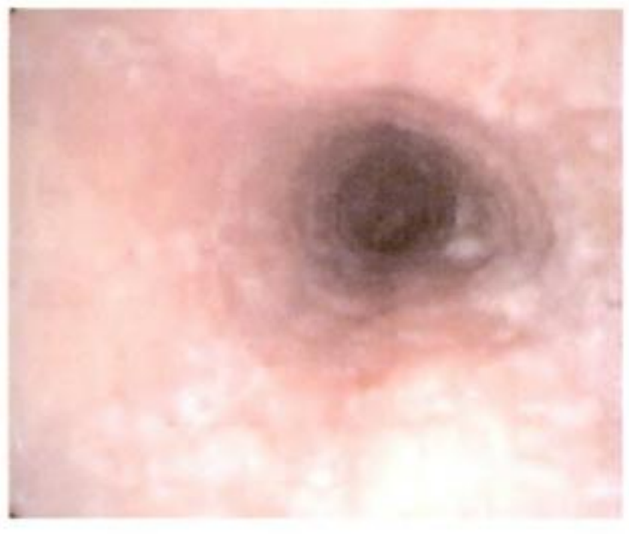




23. Ringed appearance together with characteristic pattern of linear furrowing.

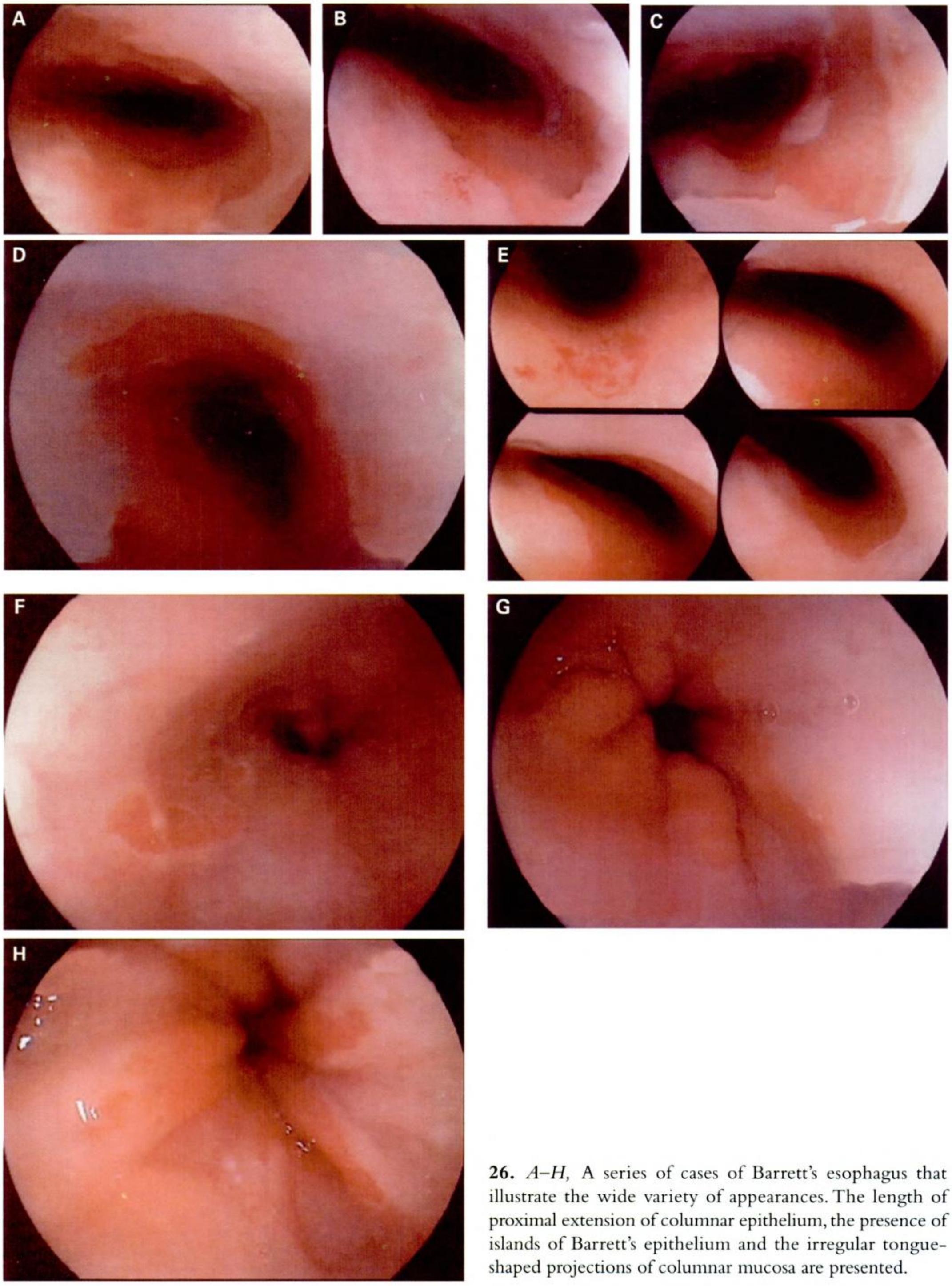


24. Large food impaction molded to the shape of the esophagus in a child with eosinophilic esophagitis.

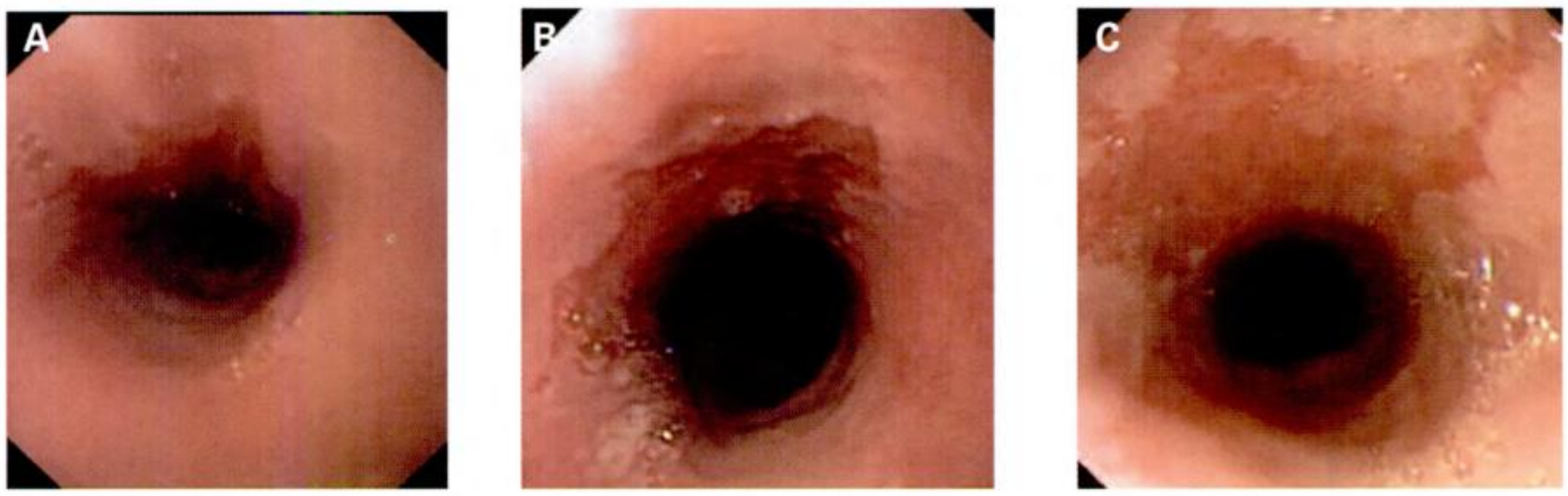


25. Eosinophilic esophagitis with white eosinophilic exudate.

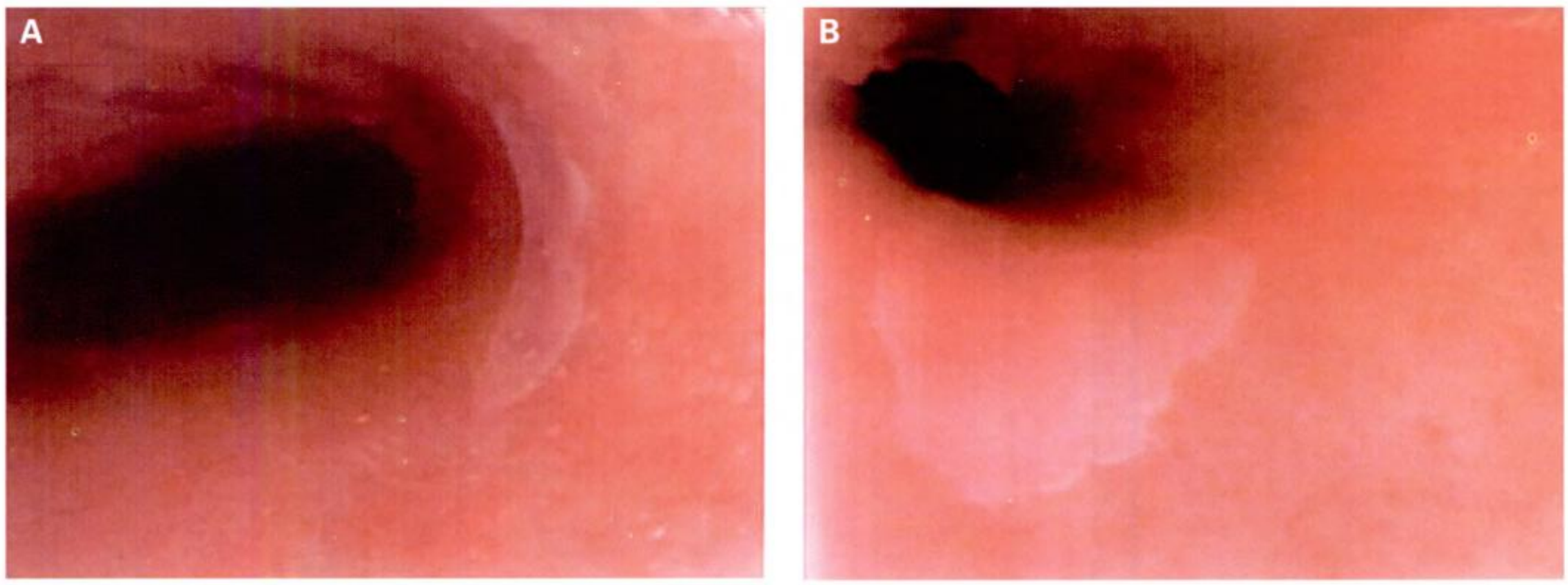
BARRETT'S ESOPHAGUS



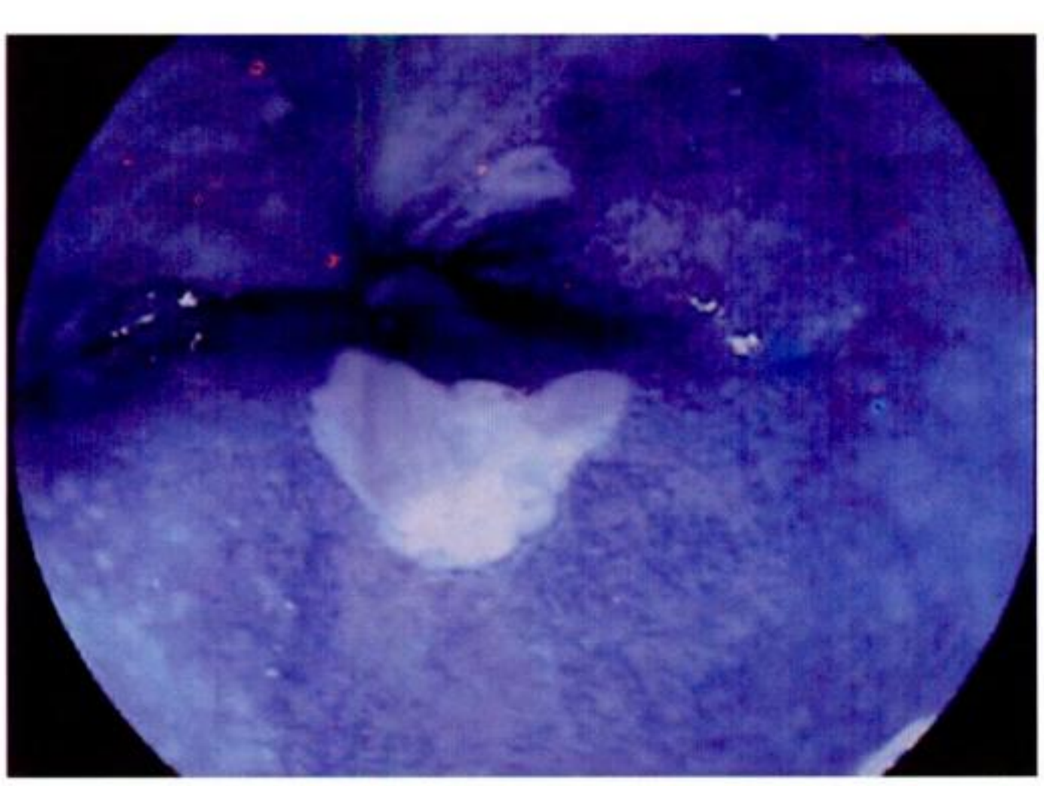
26. *A–H,* A series of cases of Barrett's esophagus that illustrate the wide variety of appearances. The length of proximal extension of columnar epithelium, the presence of islands of Barrett's epithelium and the irregular tongue-shaped projections of columnar mucosa are presented.



27. Barrett's esophagus in child with cystic fibrosis.

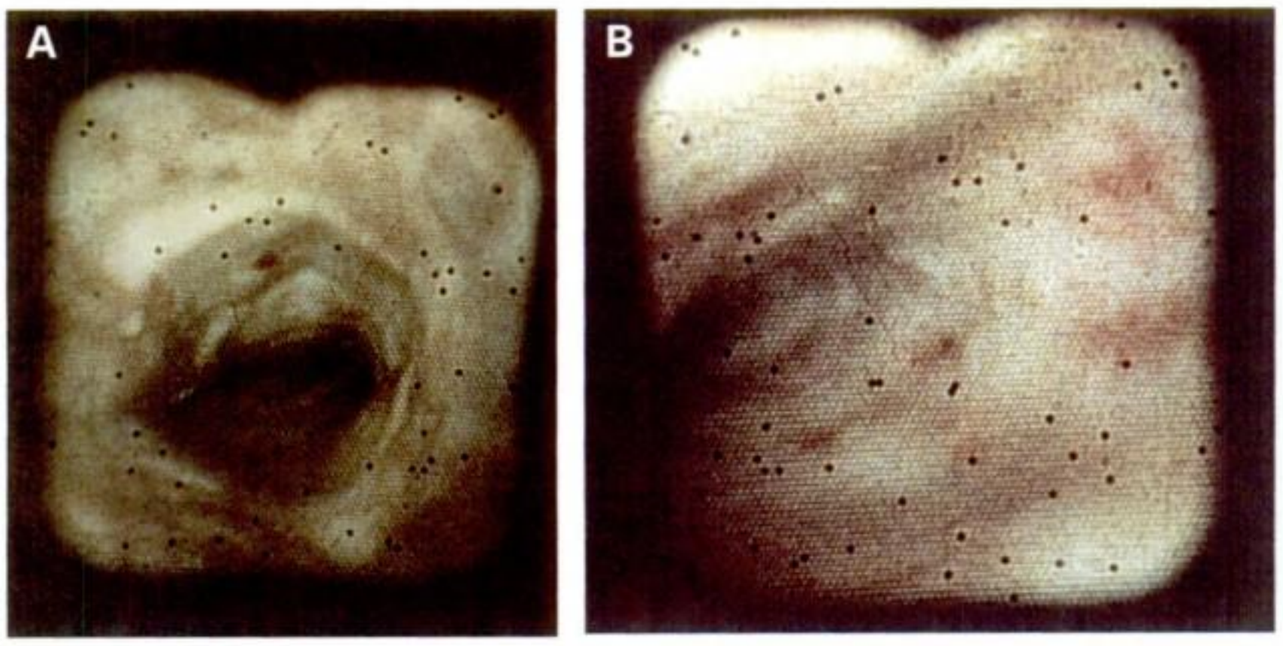


28. Digital zoom magnification of residual squamous island surrounded by columnar epithelium.

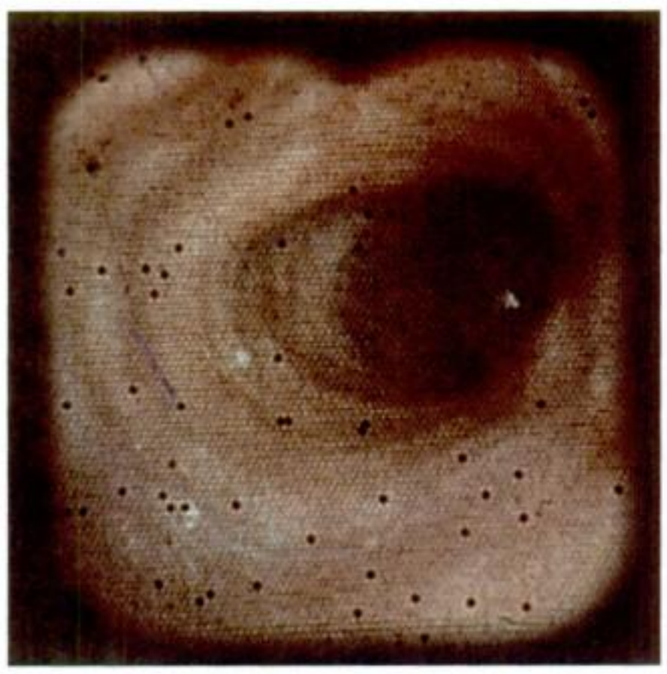


29. Squamous islands are surrounded by columnar epithelium which is stained by methylene blue.

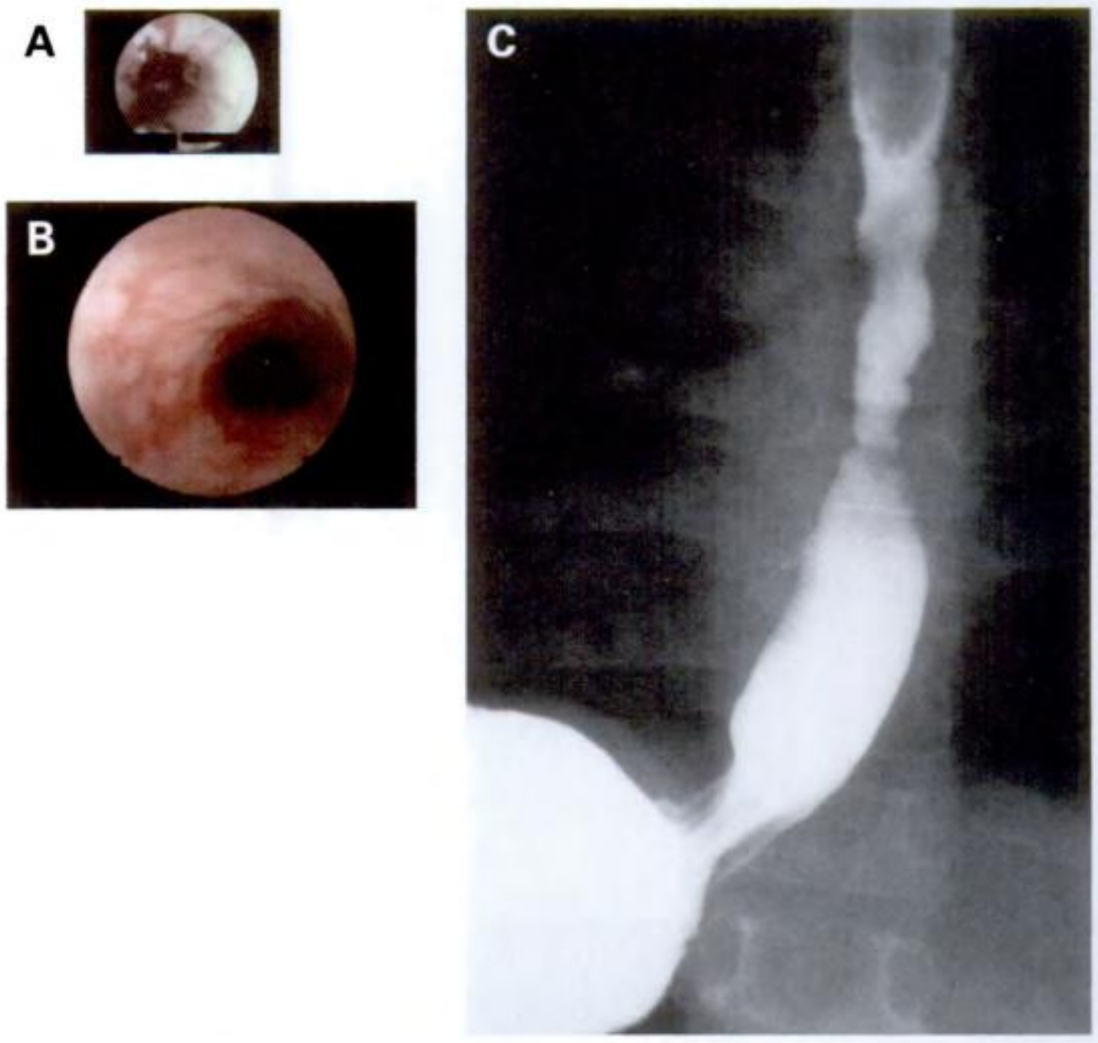
Caustic Esophagitis



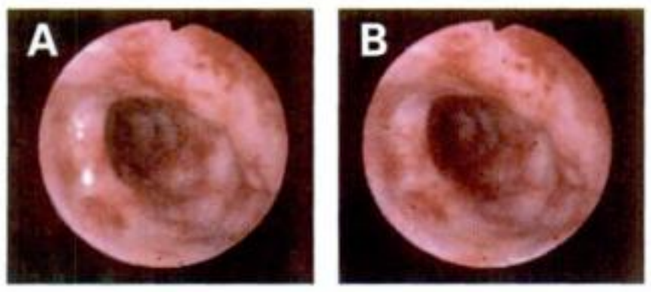
30. Recent caustic ingestion. Appearance at day 1.



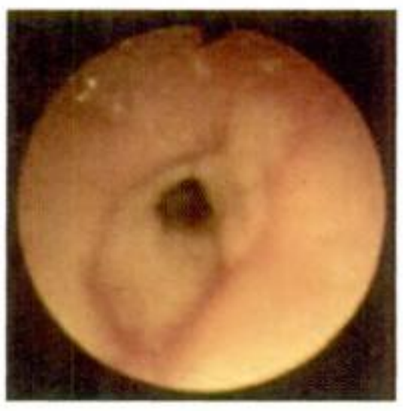
31. Caustic ingestion on day 7. Evolving appearance between days 2 and 7.



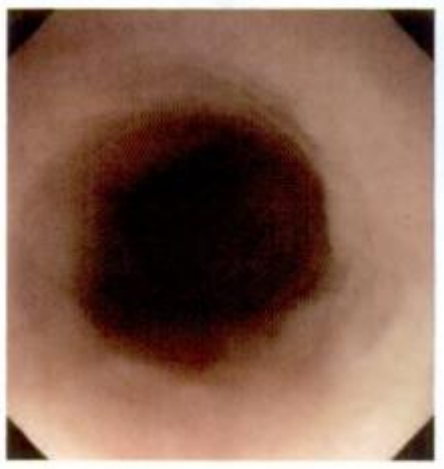
32. *A*, Severe esophagitis due to caustic ingestion day 1. *B*, Healing esophagitis 8 days following caustic ingestion. *C*, Stricturing resulting from caustic ingestion. (Image courtesy of Ahmed Maherzi, MD.)



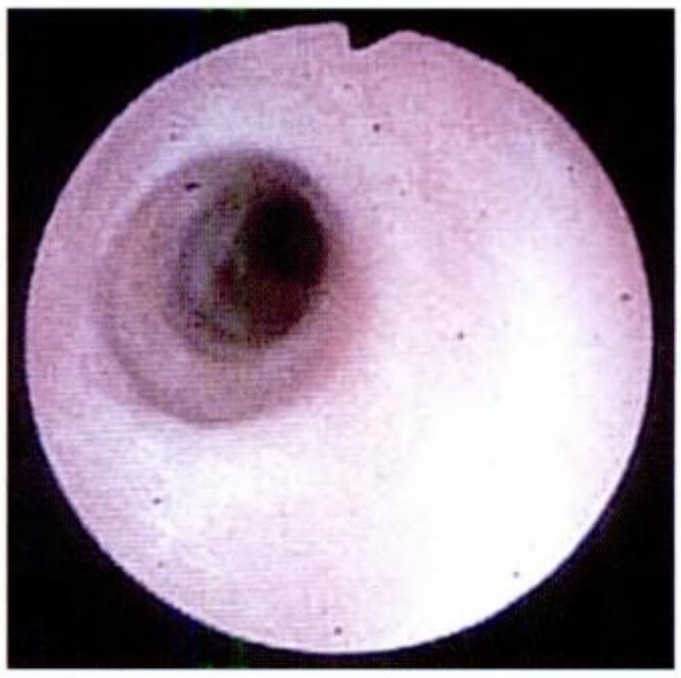
33. Hemorrhagic exudate.



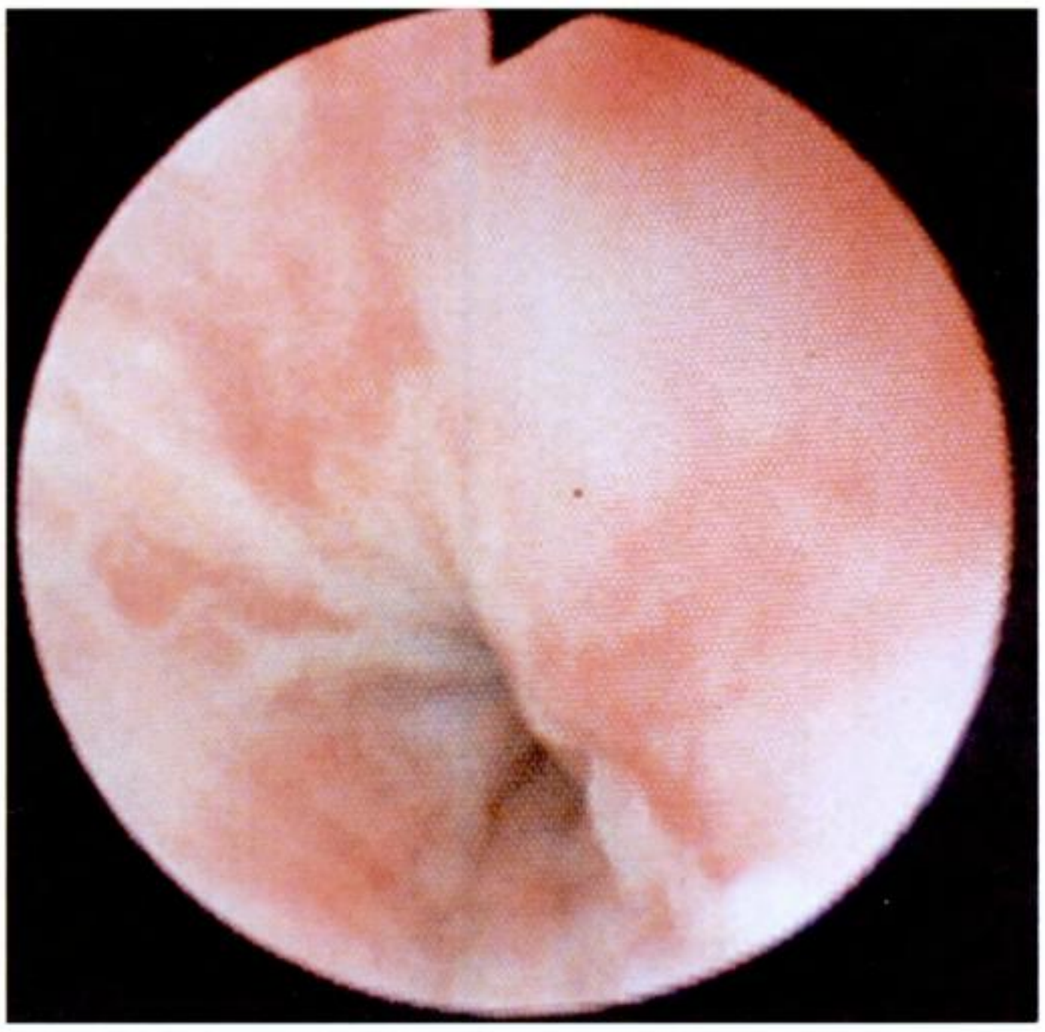
34. Esophageal ulceration and stenosis. (Image courtesy of Adolfo Bautista Casasnovas, MD.)



35. Pale tubular esophagus three years after caustic ingestion.

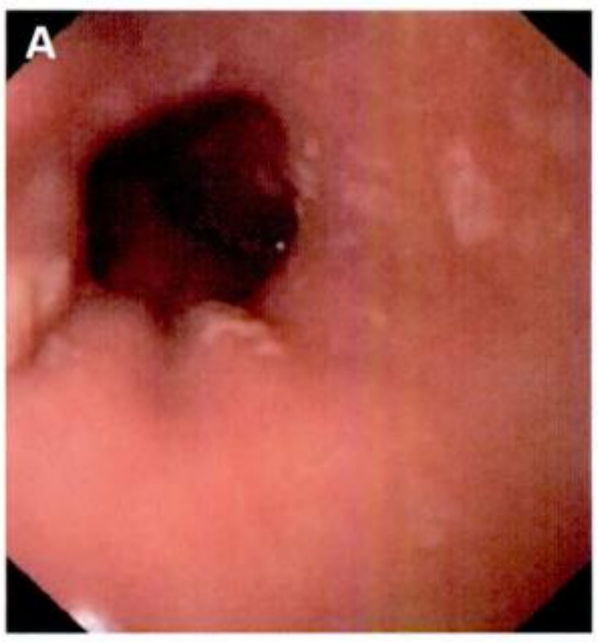


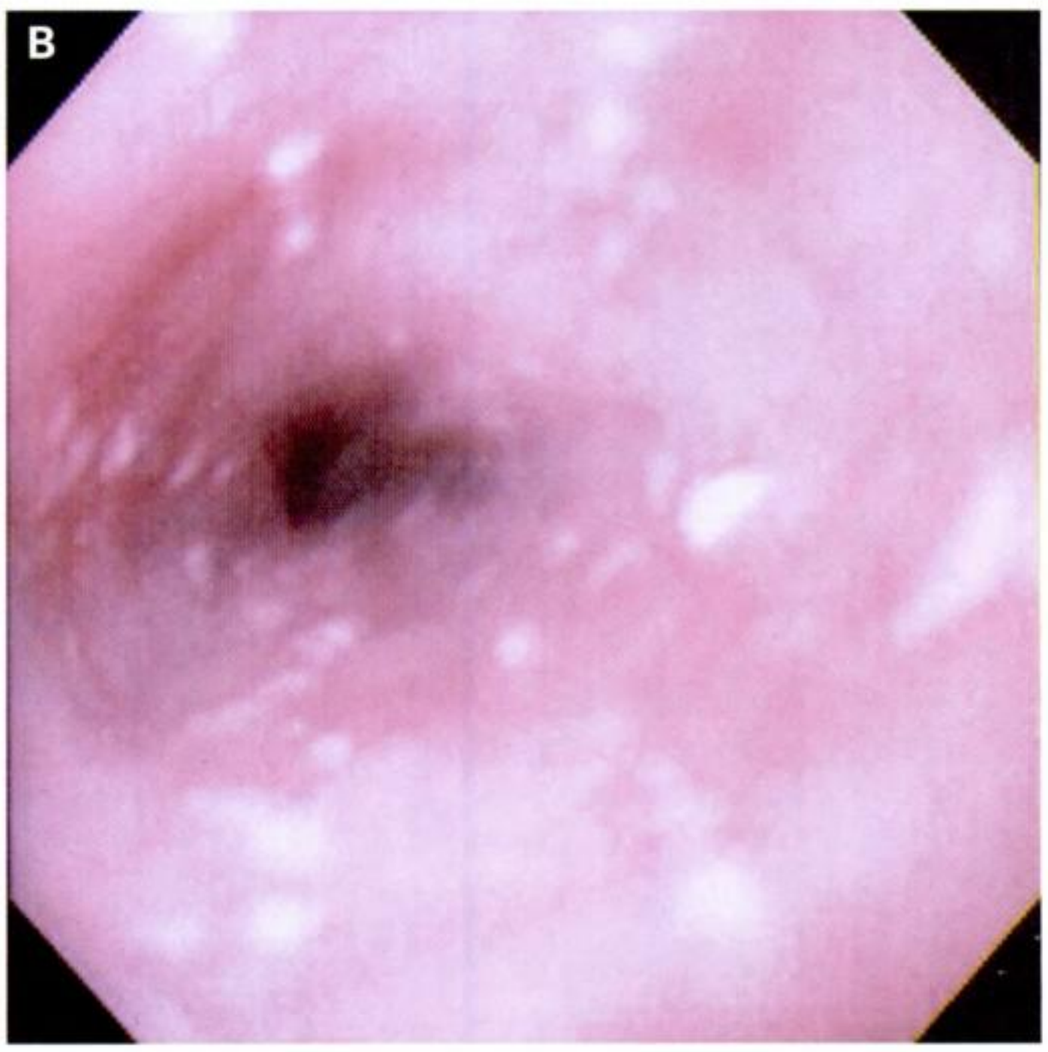
36. Stenosis six weeks following caustic injury.

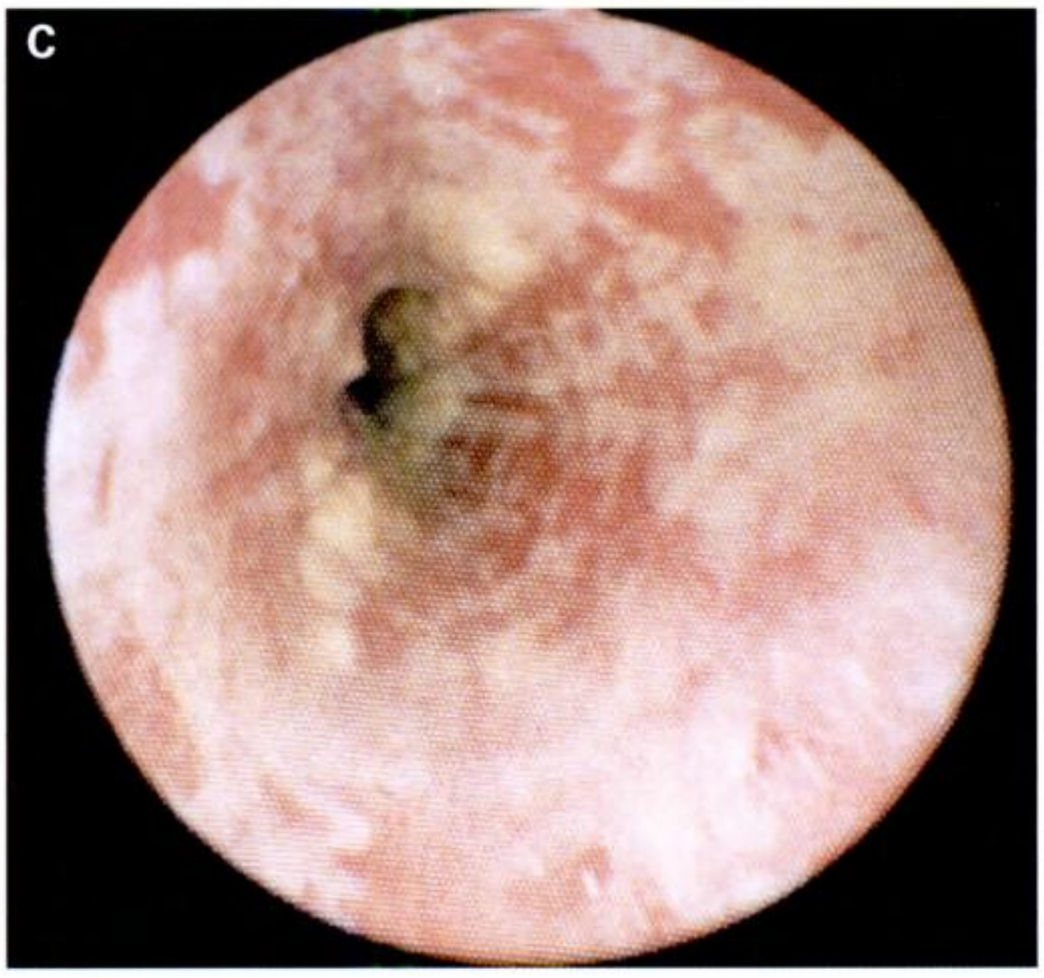


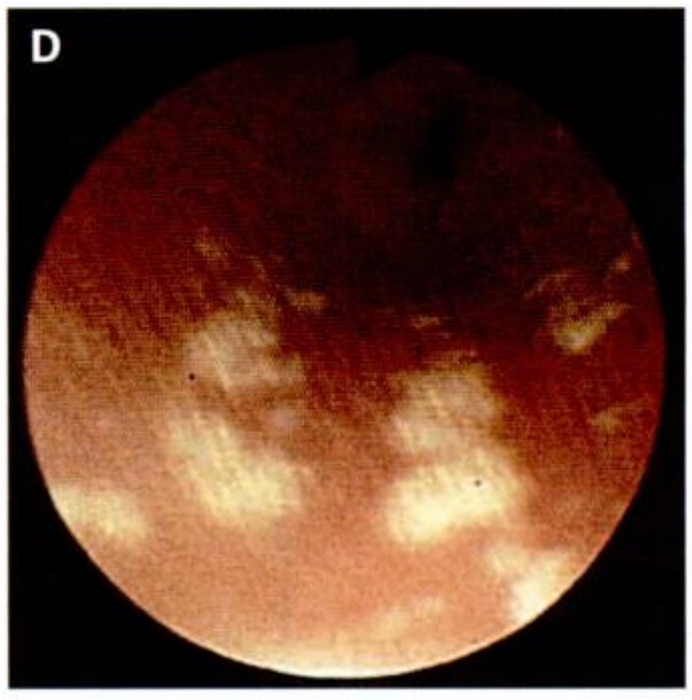
37. Caustic esophagitis with stricture.

Infectious Esophagitis



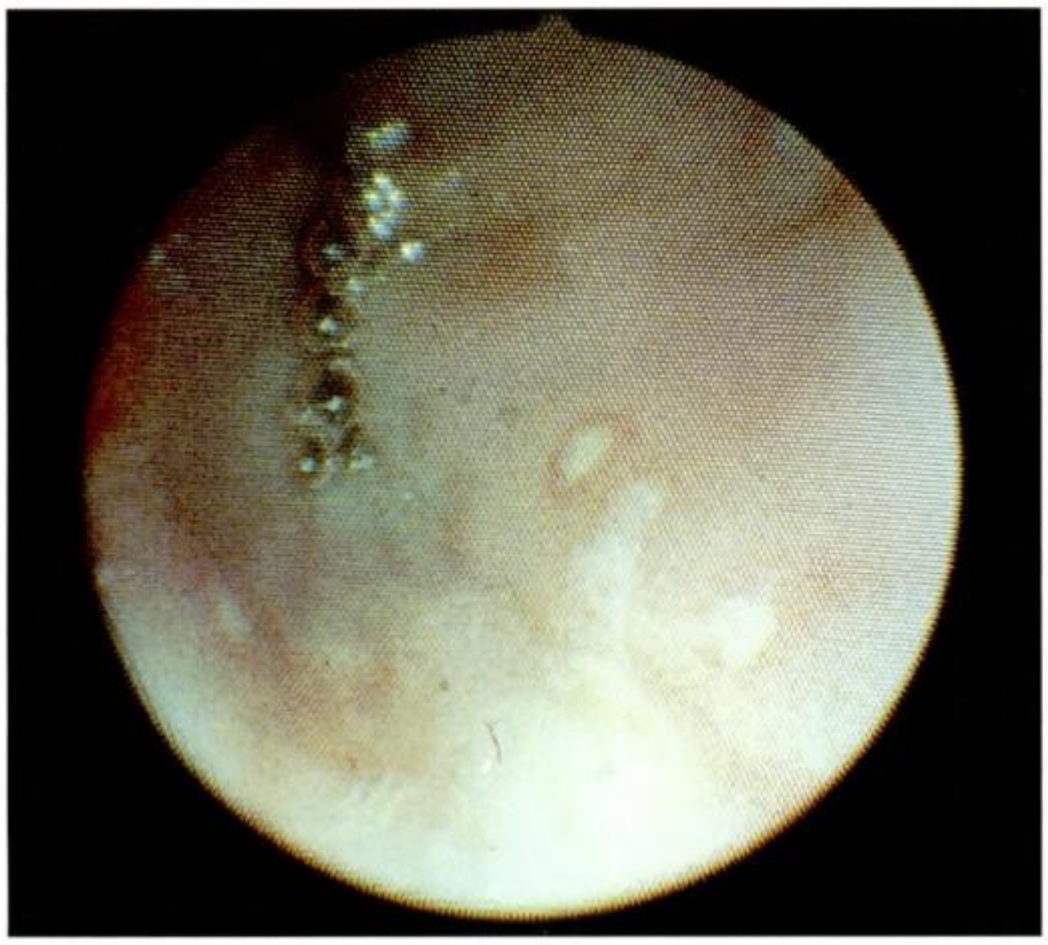




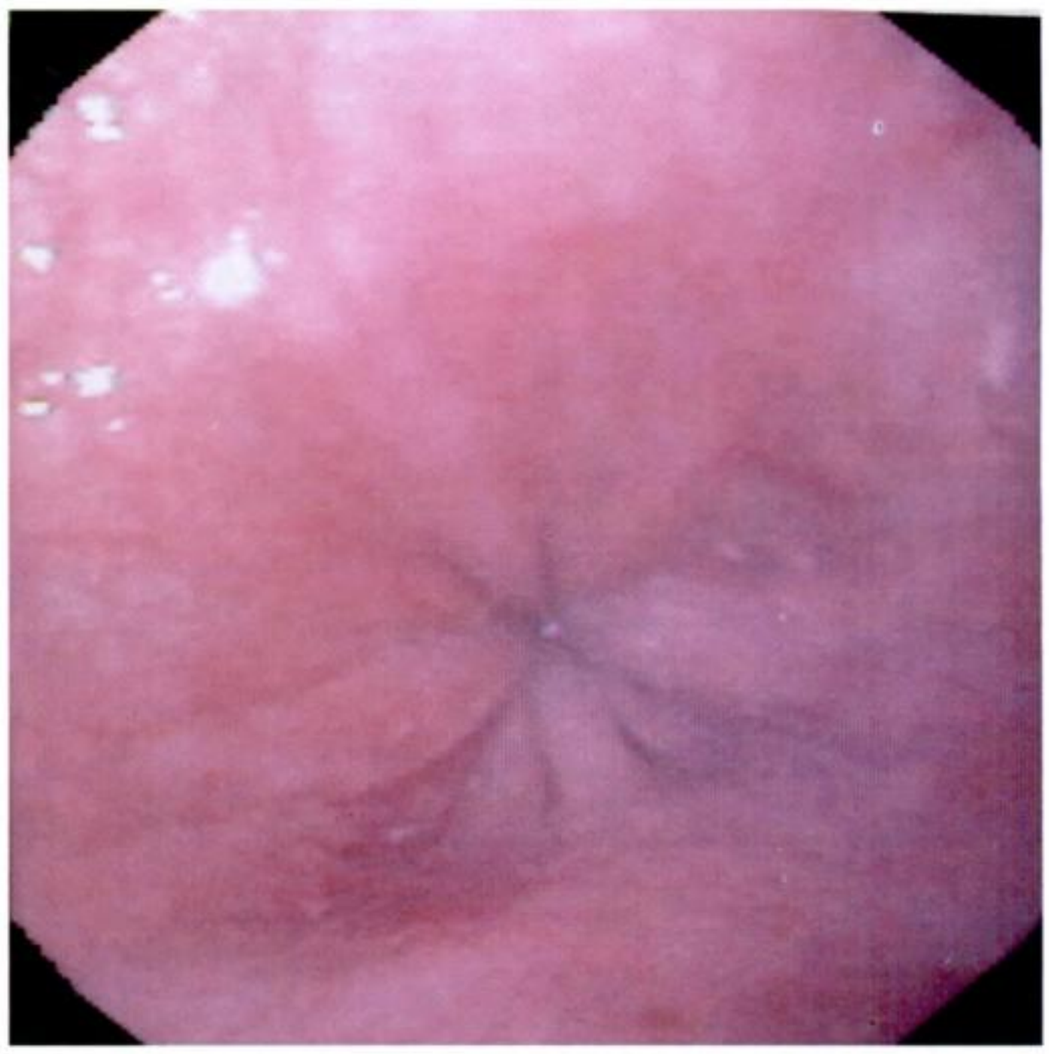


38. *A–D*, Varied appearance of candidiasis. (38C, Image courtesy of Stanley A. Cohen, MD; 38D, Image courtesy of Yves Vannerom, MD.)

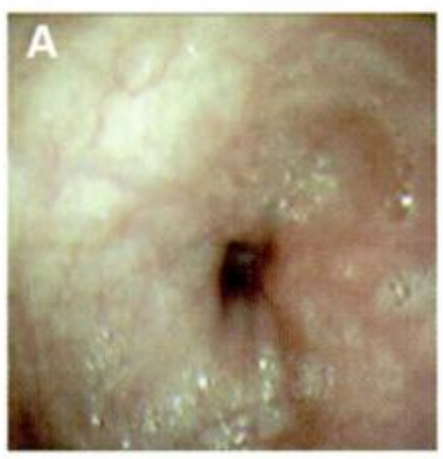
Achalasia

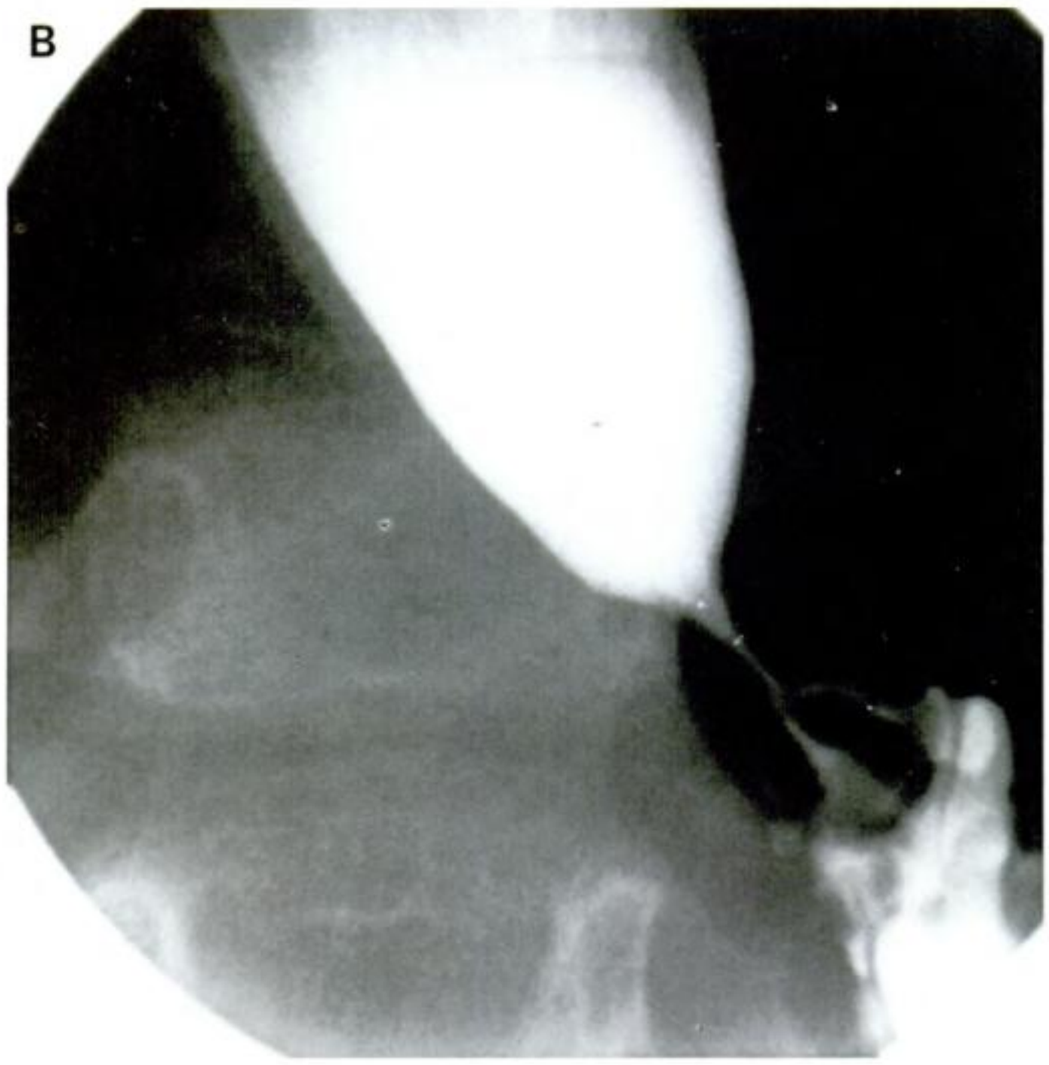


39. Herpetic esophagitis with focal ulceration.

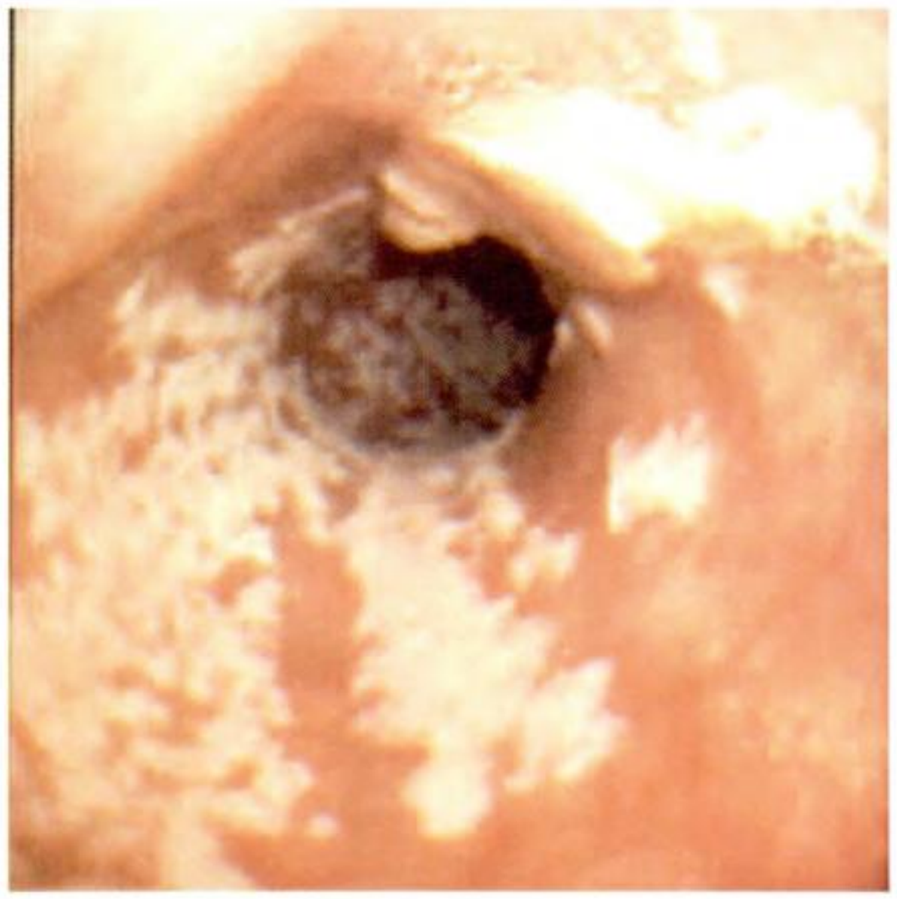


40. Prominent circumferential folds at the gastroesophageal junction.

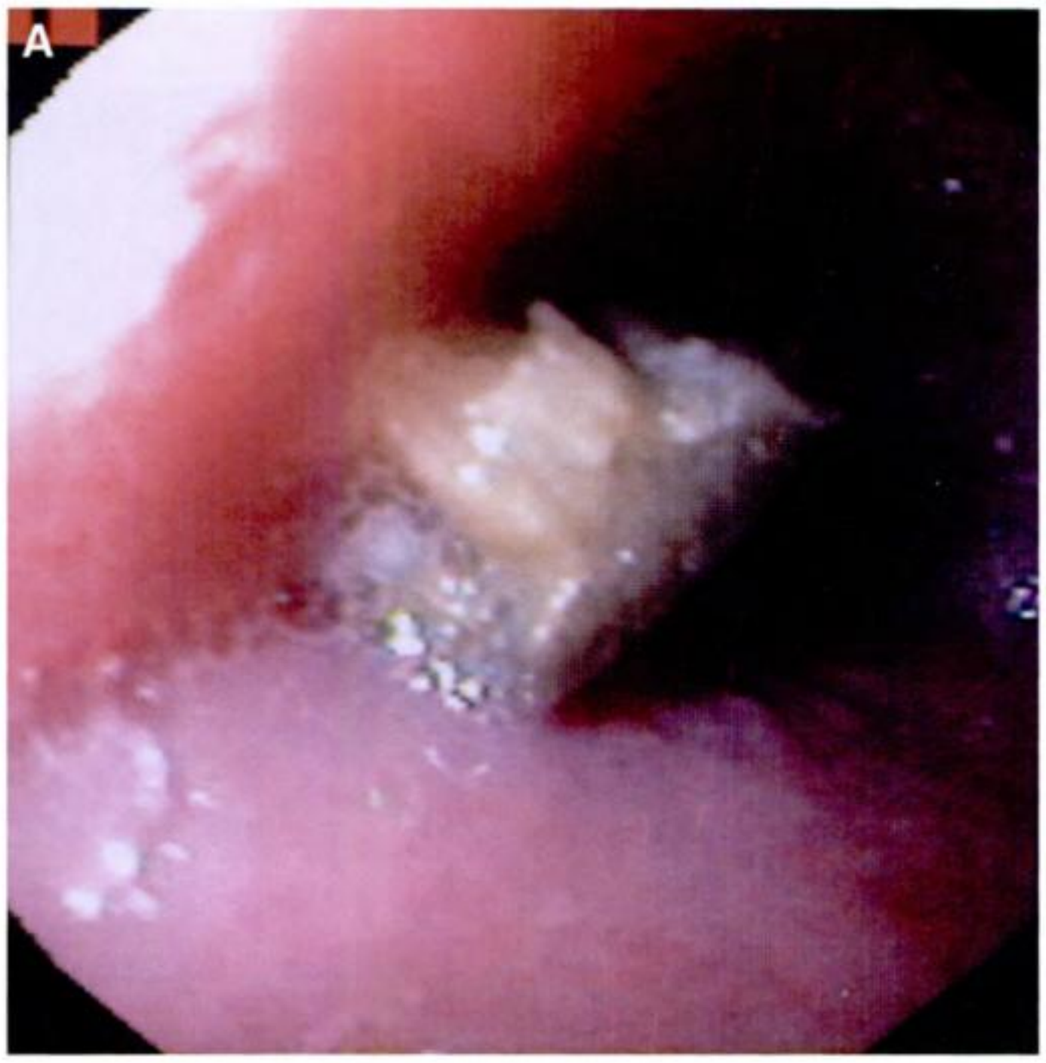




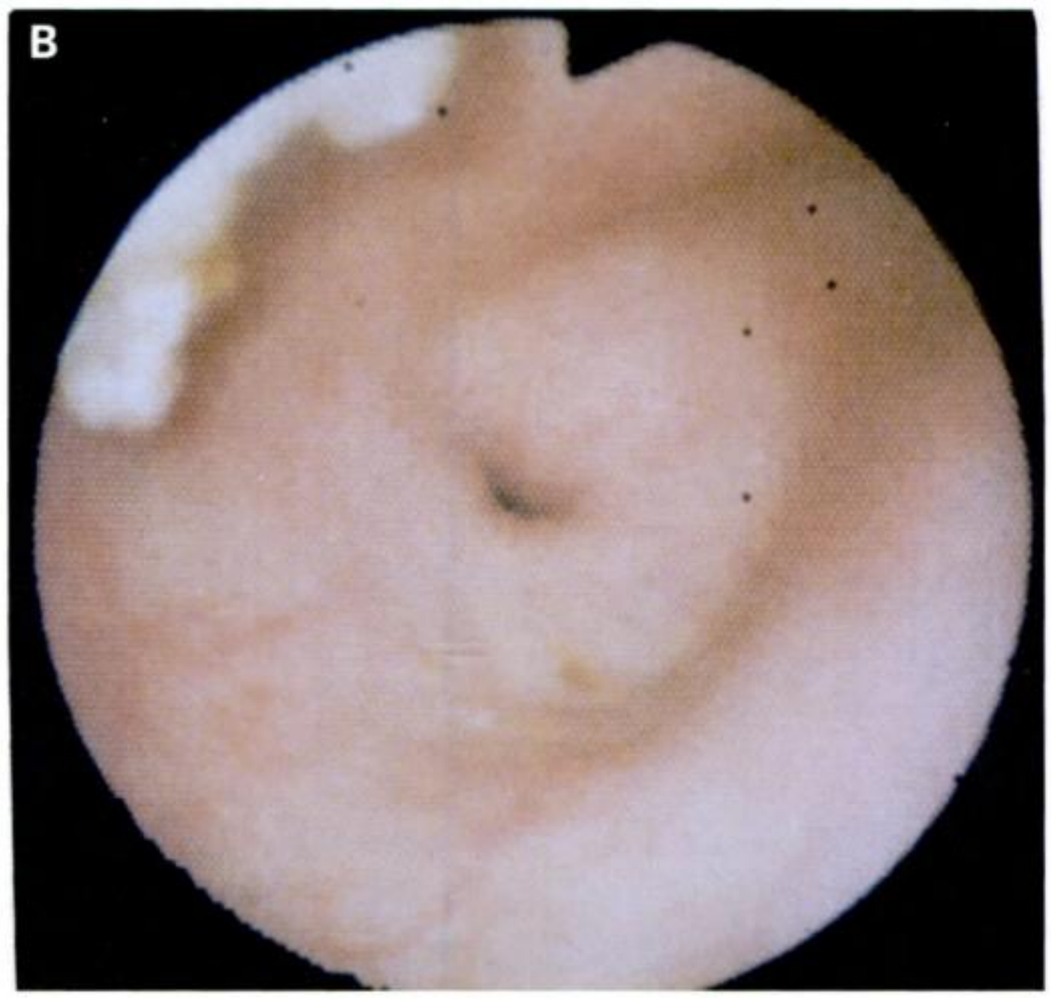
41. *A*, Achalasia with esophageal narrowing. *B*, Barium contrast study showing beaked appearance typical of achalasia.

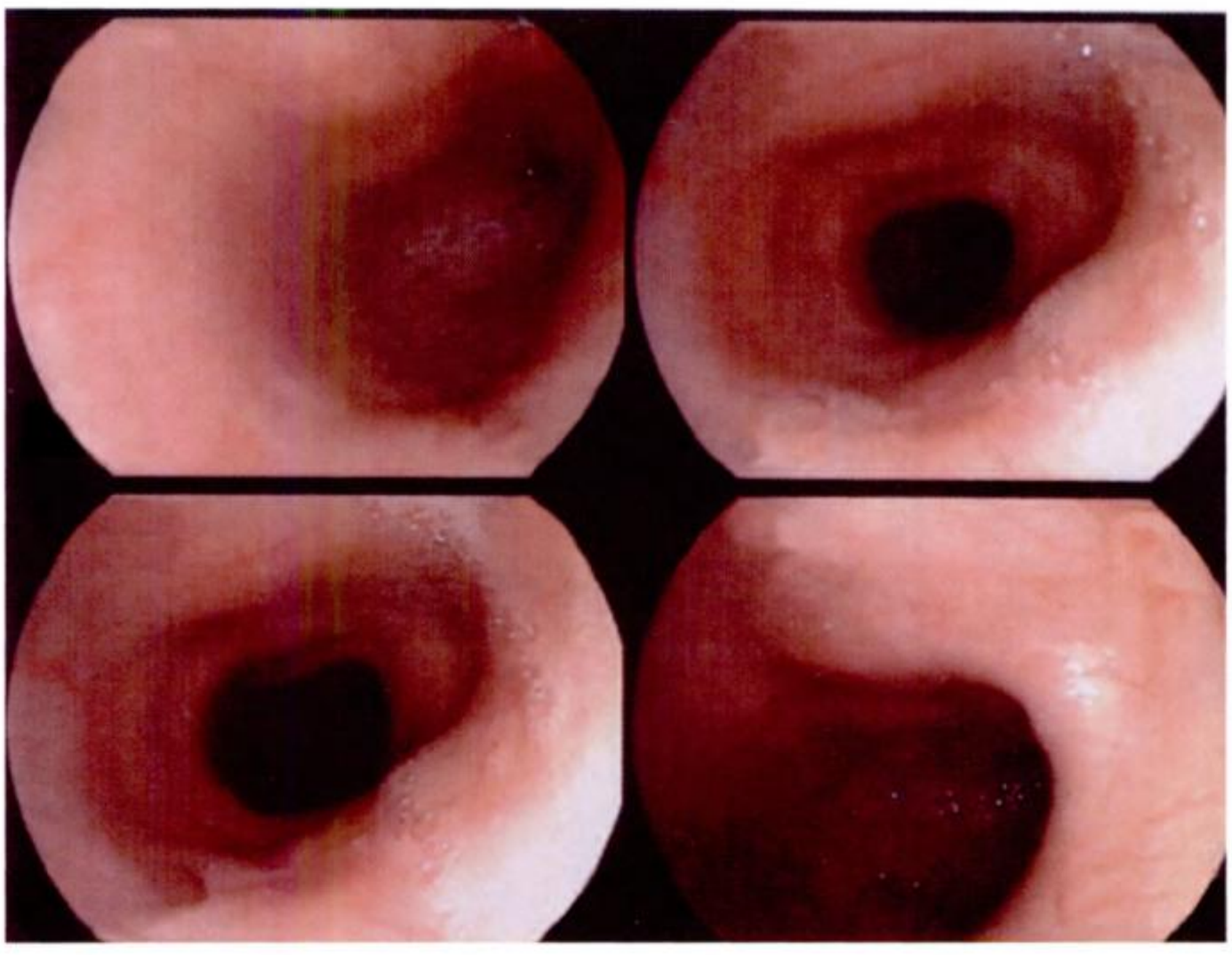


42. Milk formula residue in the esophagus.



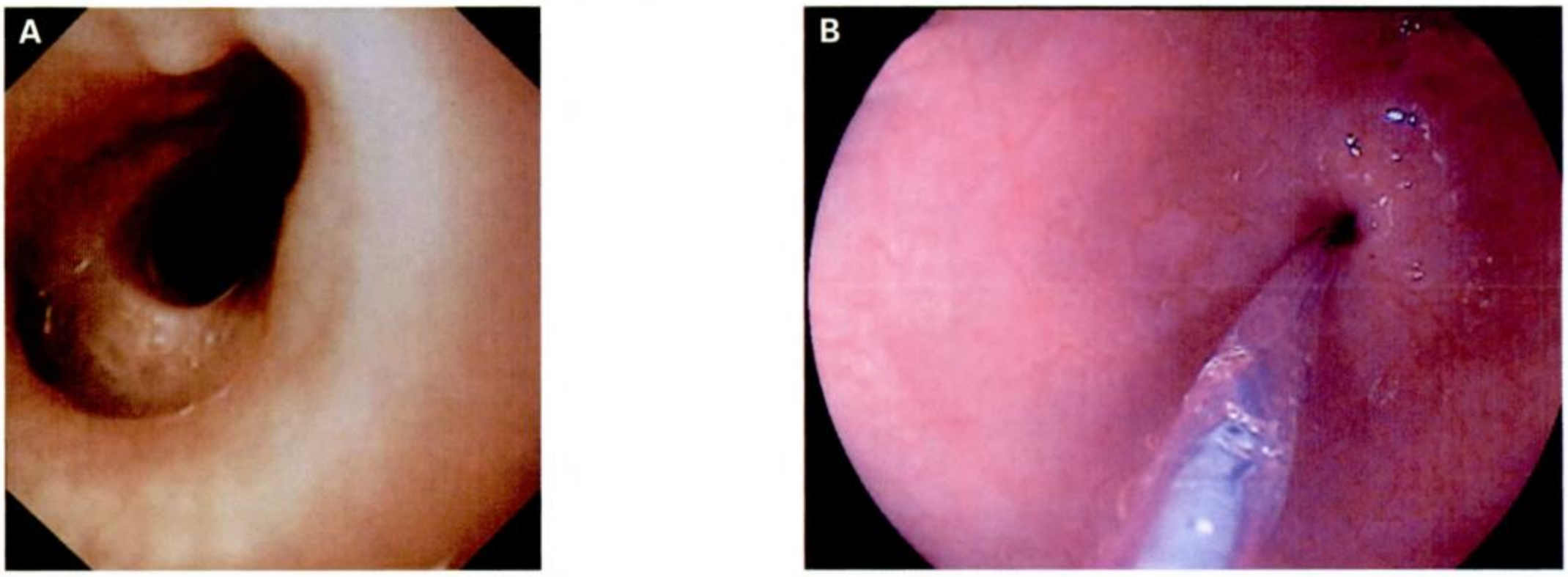
43. Solid food residue in the esophagus.



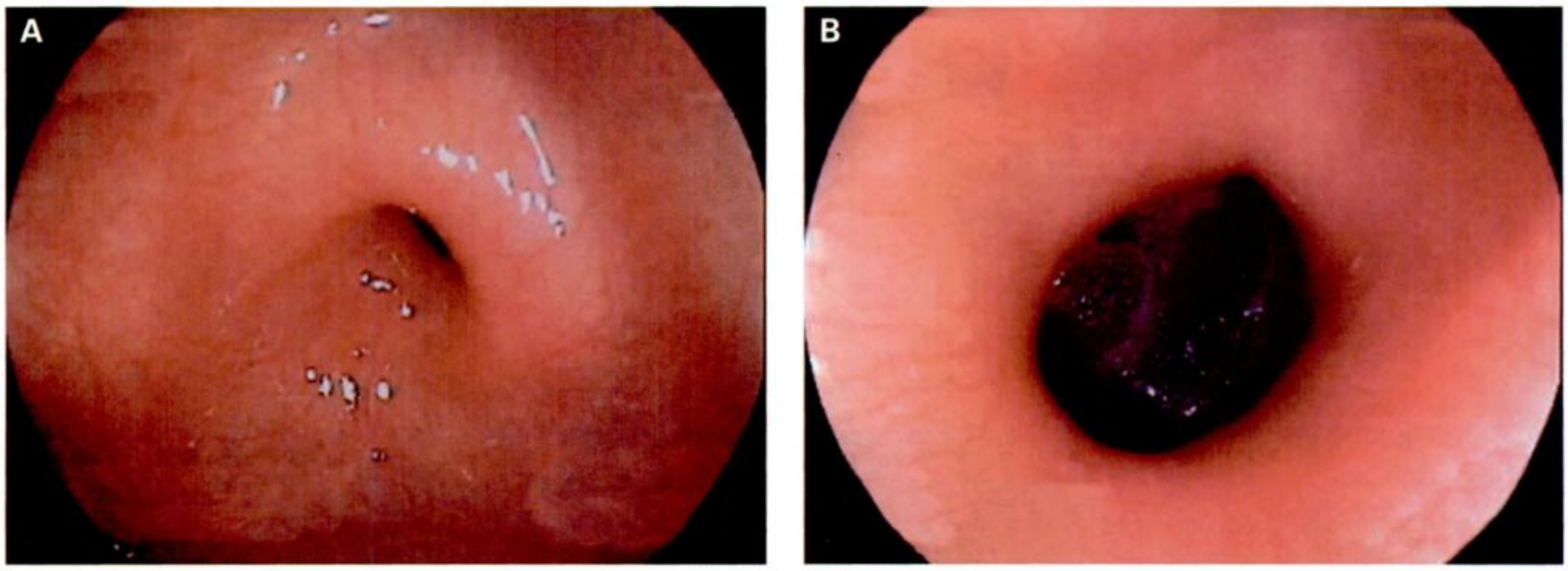


44. Dilated esophagus with absence of peristaltic contractions and closure of the cardia.

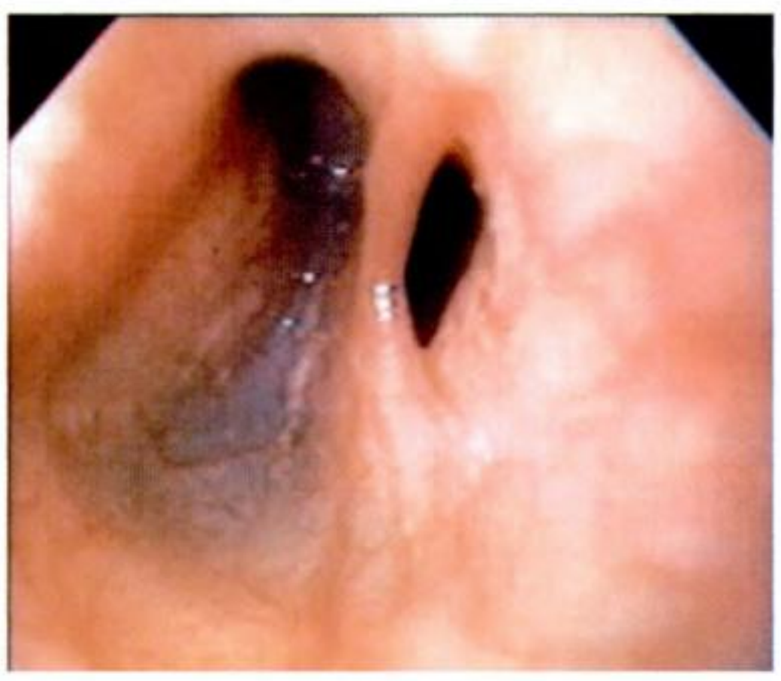
Congenital Esophageal Anomalies



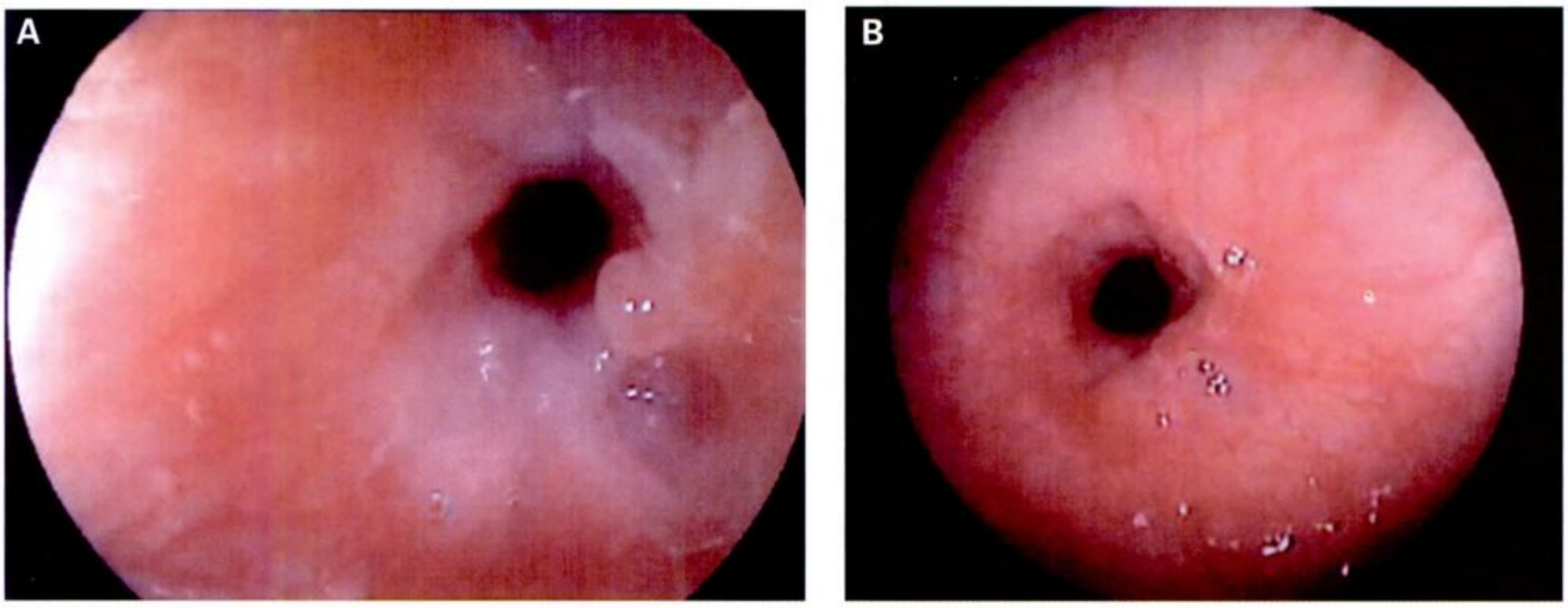
45. *A*, Congenital esophageal stenosis. (Image courtesy of Ahmed Maherzi, MD and Frederic Gottrand, MD.) *B*, Hydrostatic balloon dilatation.



46. *A*, Esophageal congenital web. *B*, Congenital web with retained food.

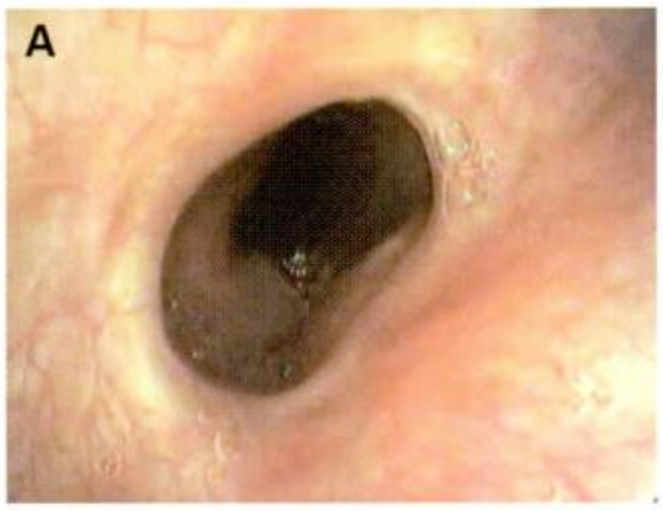


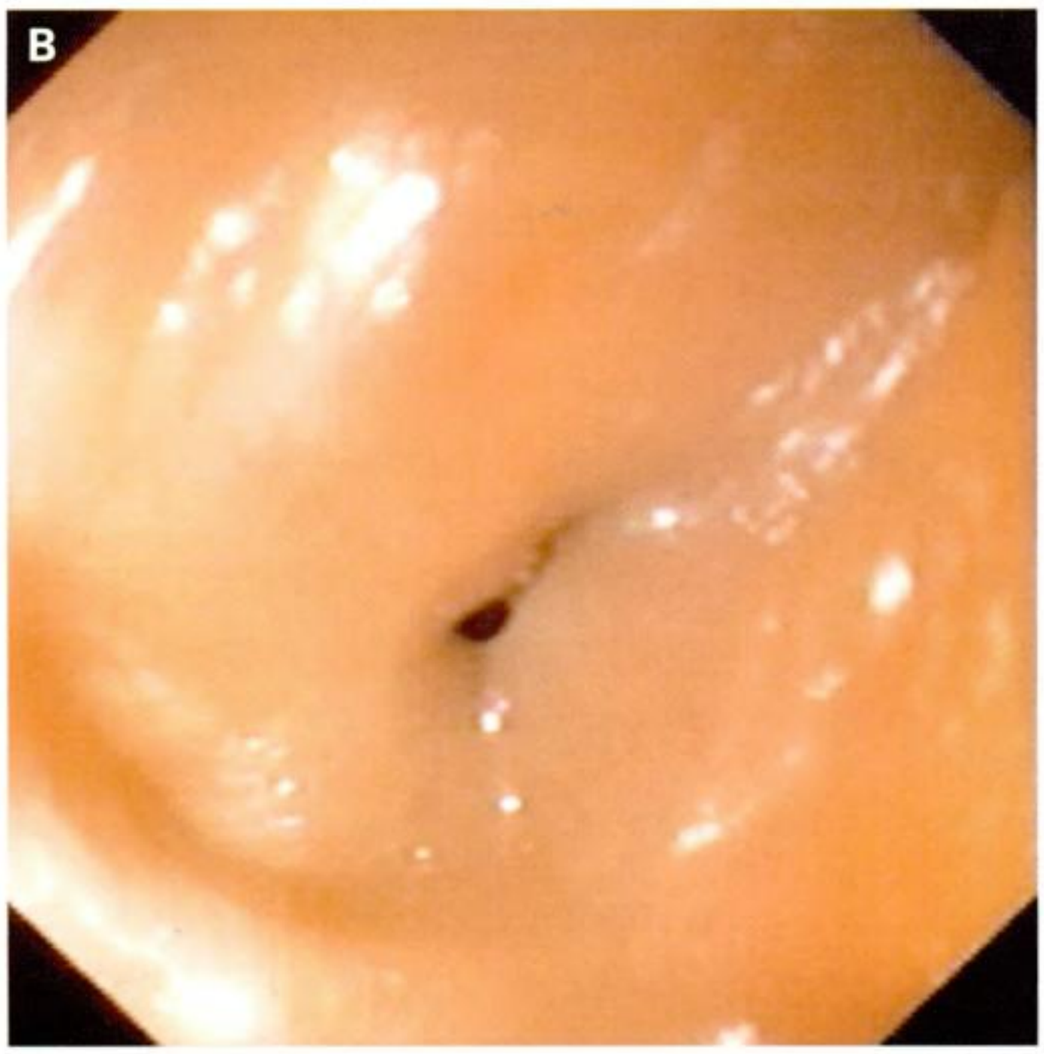
47. Communicating esophageal duplication. (Image courtesy of Manoel Ernesto Gonçalves, MD.)

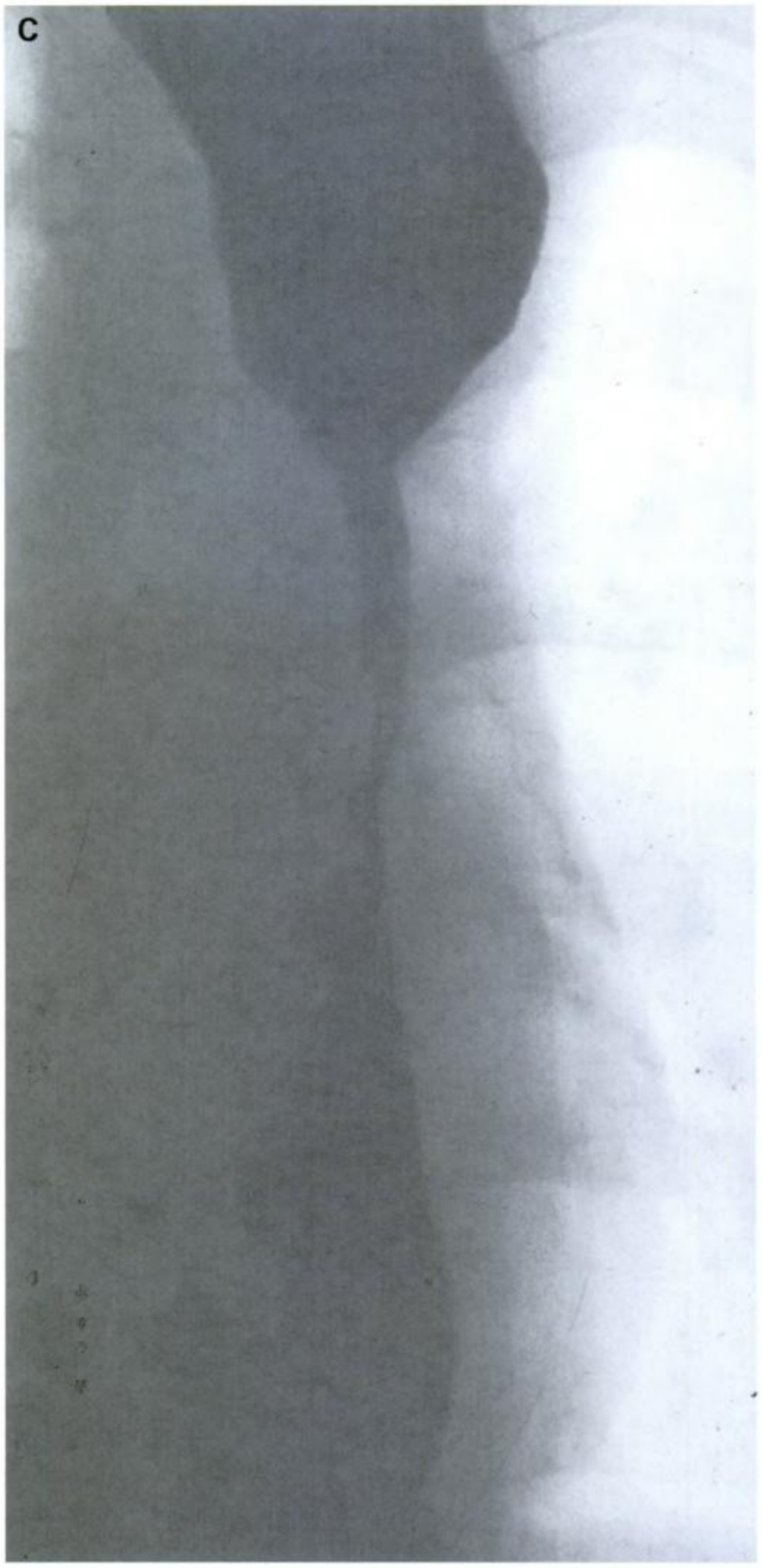


48. Anastomotic stricture with scarring following surgical repair of congenital esophageal atresia.

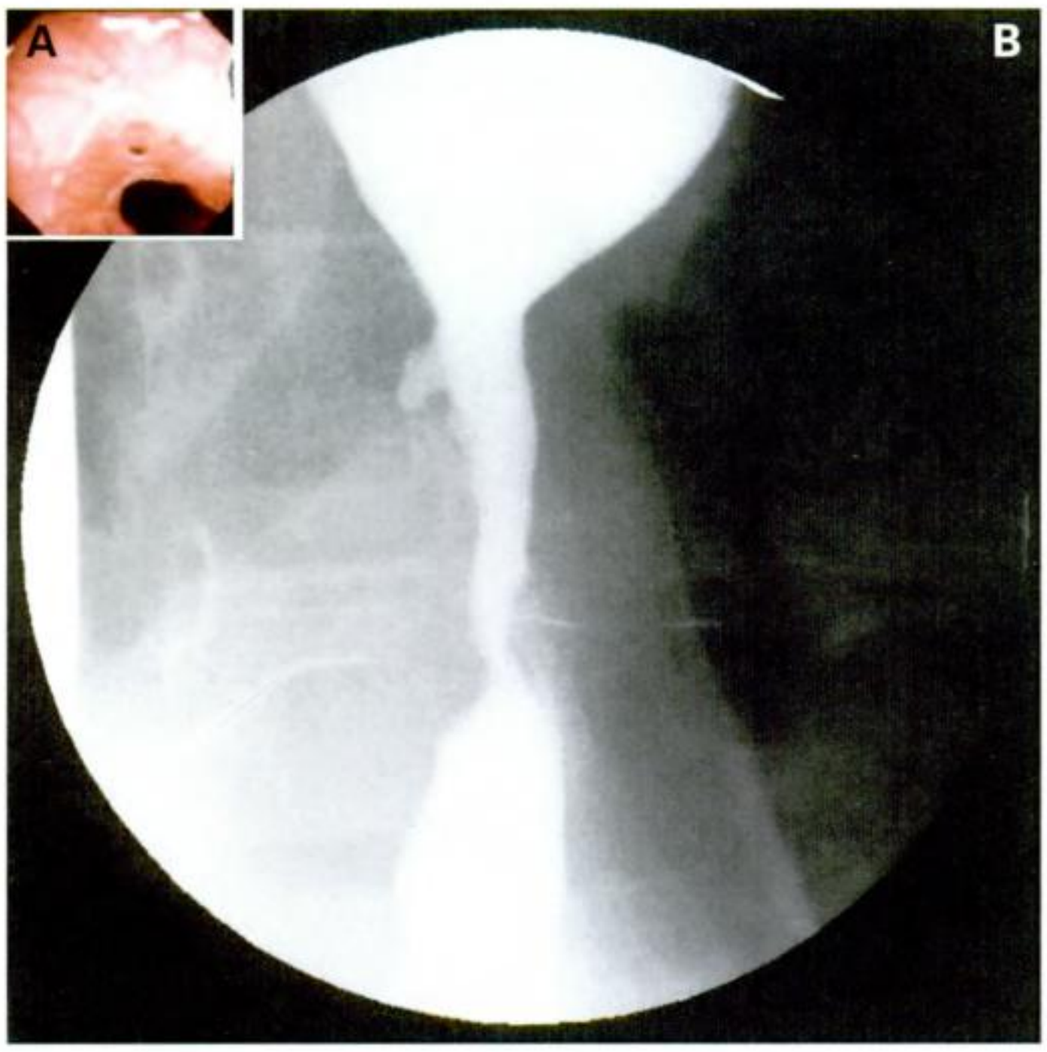
49. *A*, Residual blind-ended diverticulum following tracheoesophageal fistula repair. *B*, Barium contrast study demonstrating a fistula. (Images courtesy of Luigi Dall'Oglio, MD and Joseph F. Fitzgerald, MD.)



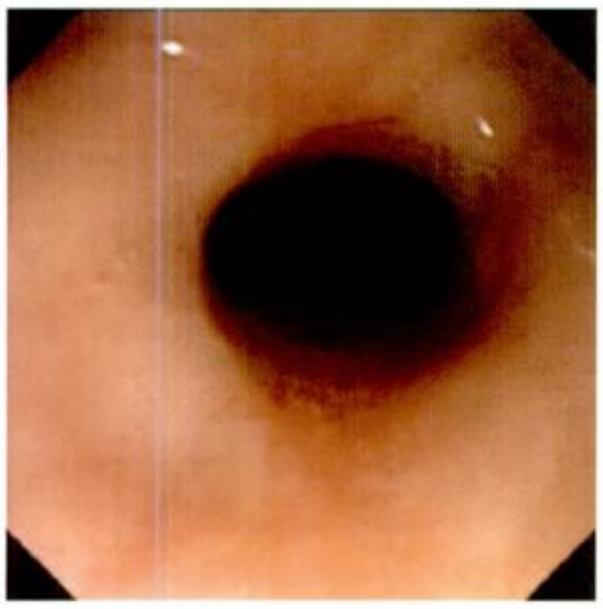




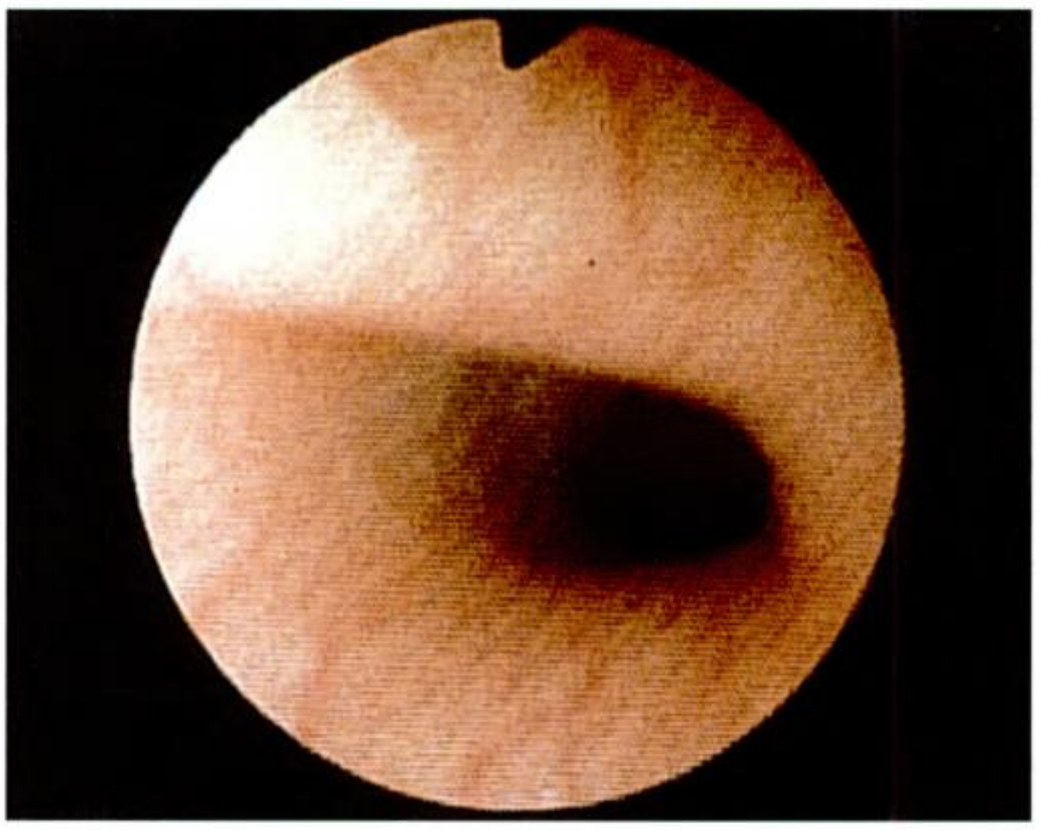
50. *A–C,* Variations in anastomotic and peptic strictures following surgical repair of esophageal atresia.



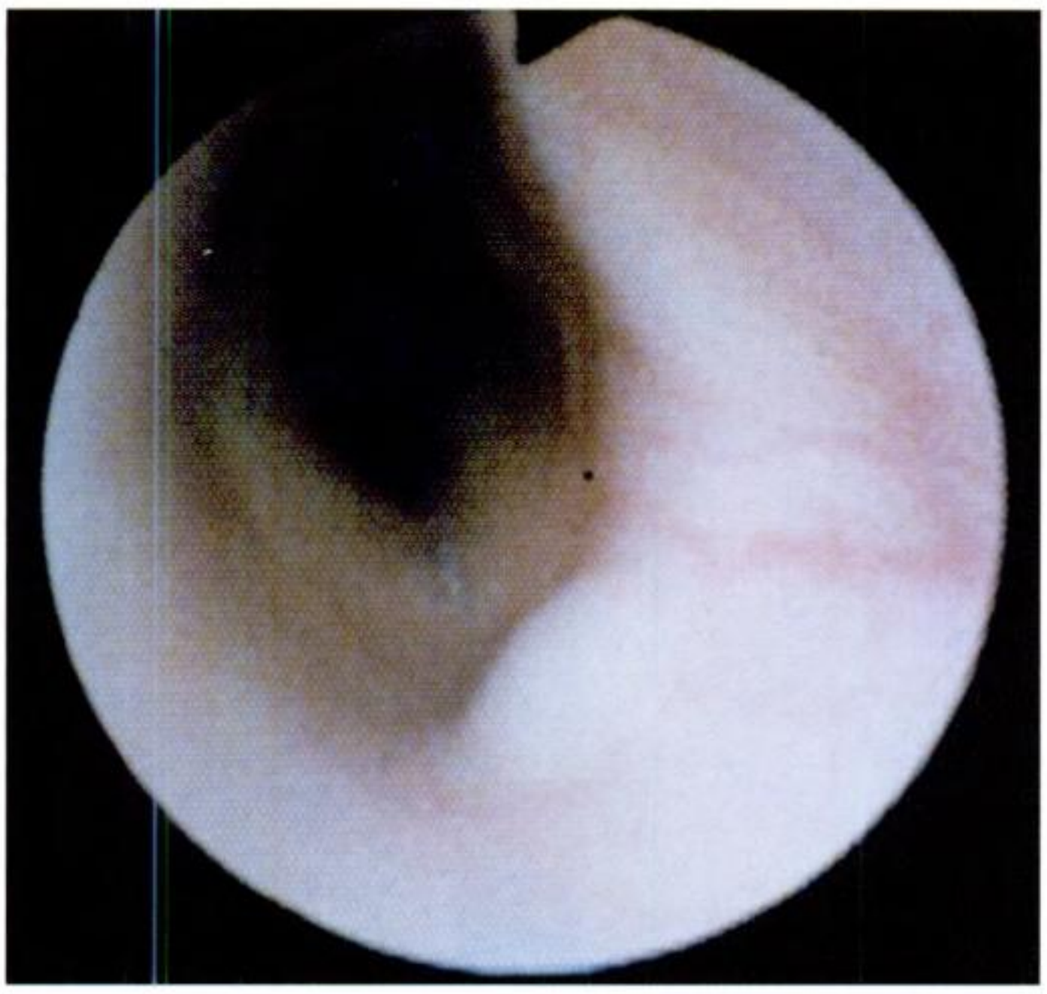
51. Residual esophageal diverticulum following repair of esophageal atresia.



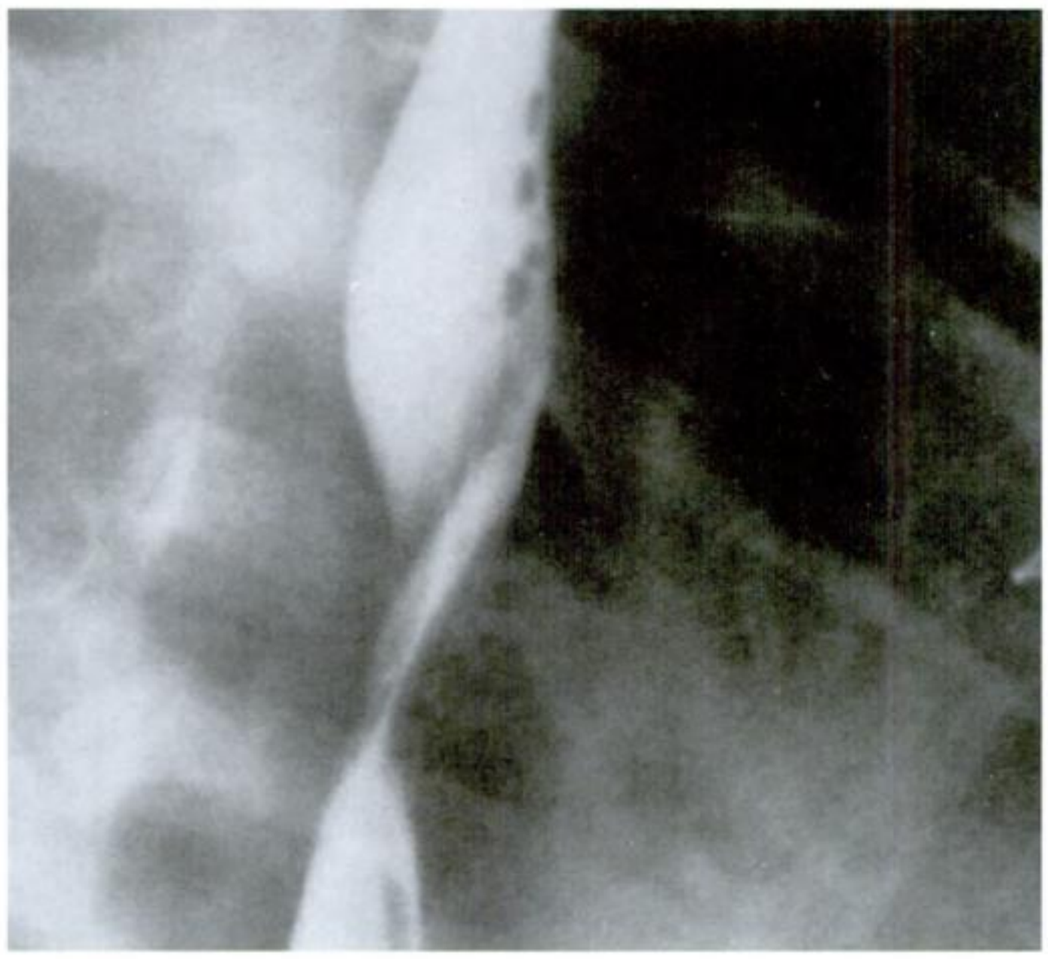
52. Ulcers at anastomosis between esophageal remnant and gastric tube after repair of esophageal atresia.



53. Vascular ring.

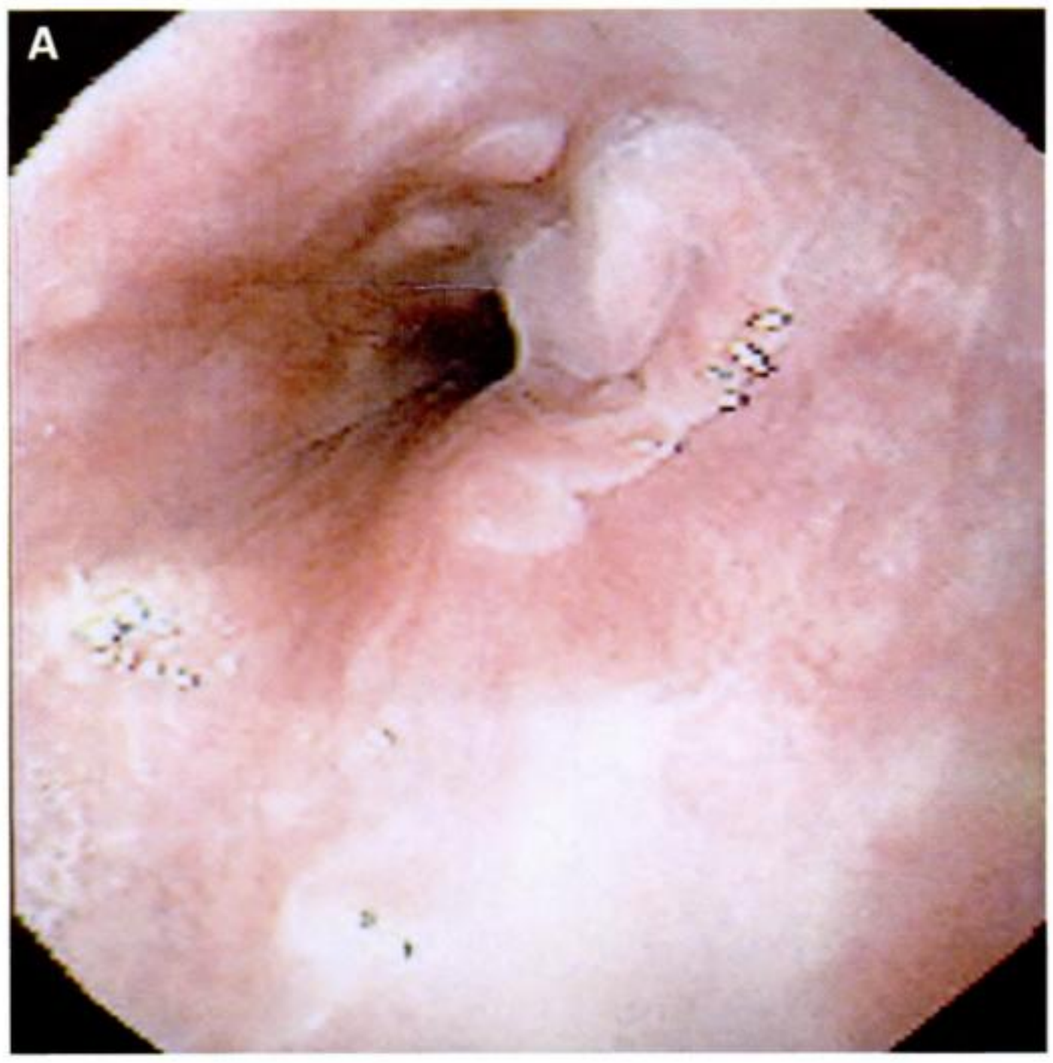


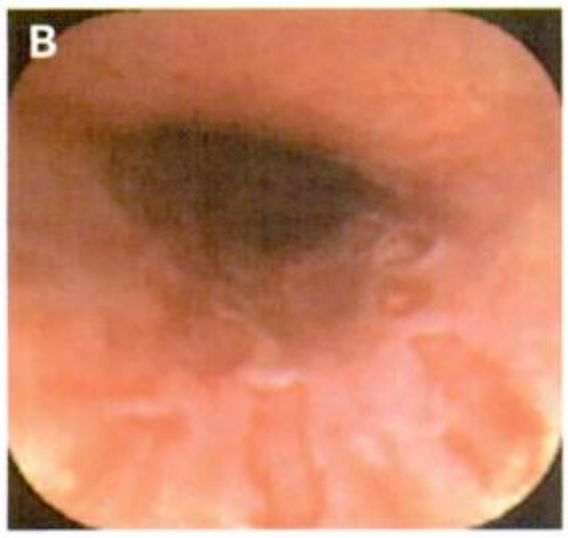
54. Marked esophageal indentation due to vascular ring.

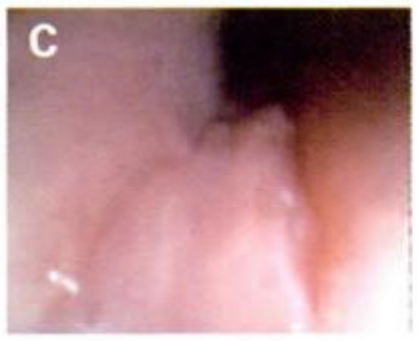


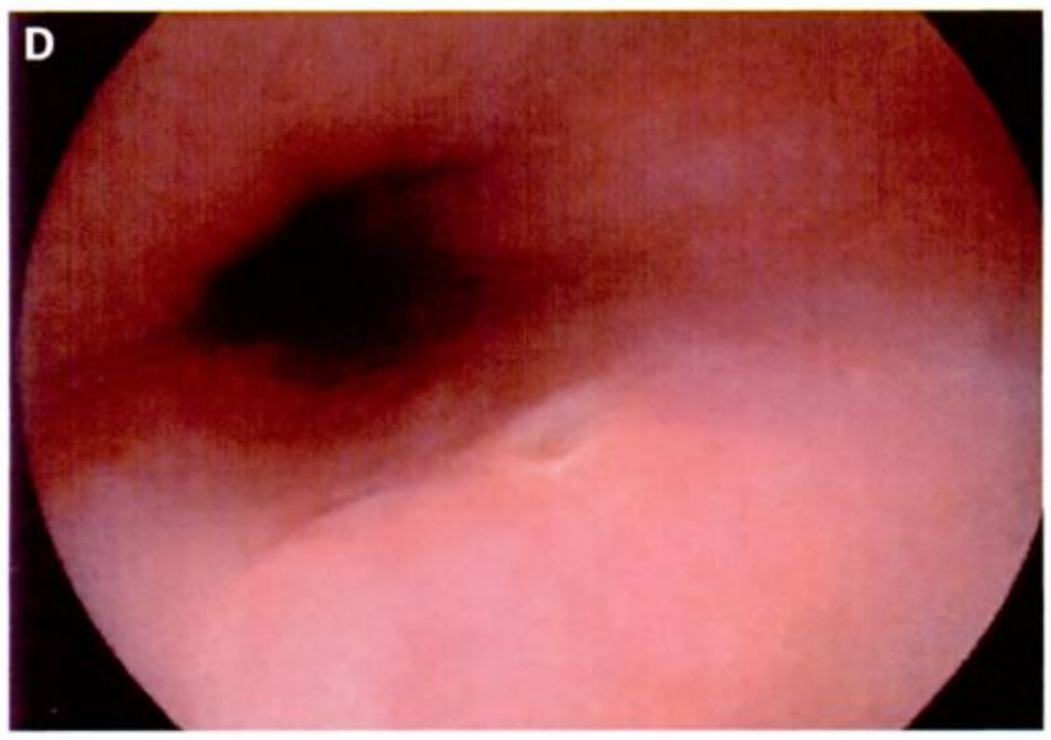
55. Pulsatile indentation in proximal esophagus due to aberrant left subclavian artery as shown in barium x-ray.

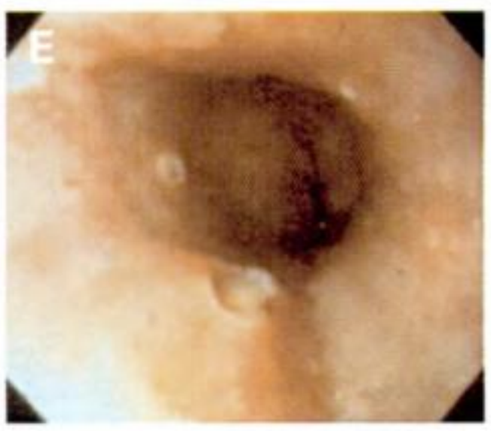
Esophageal Crohn's Disease





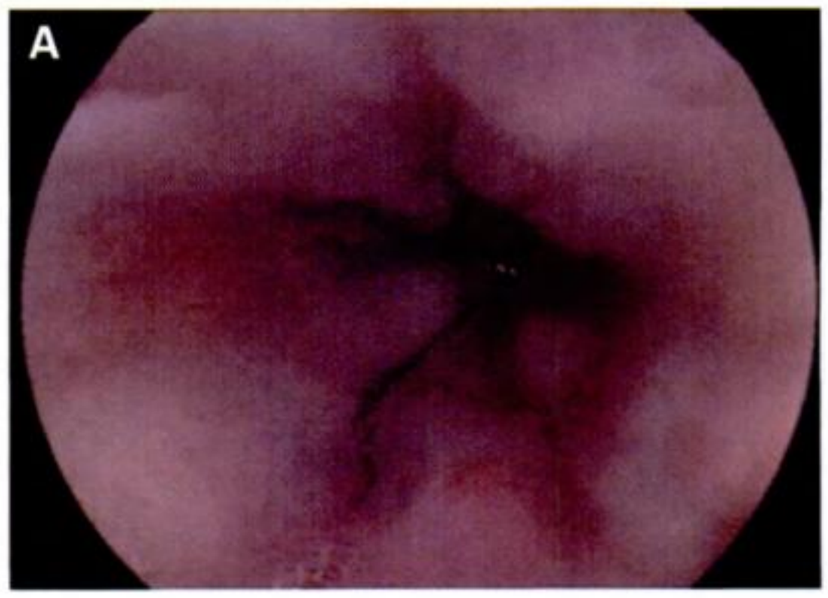


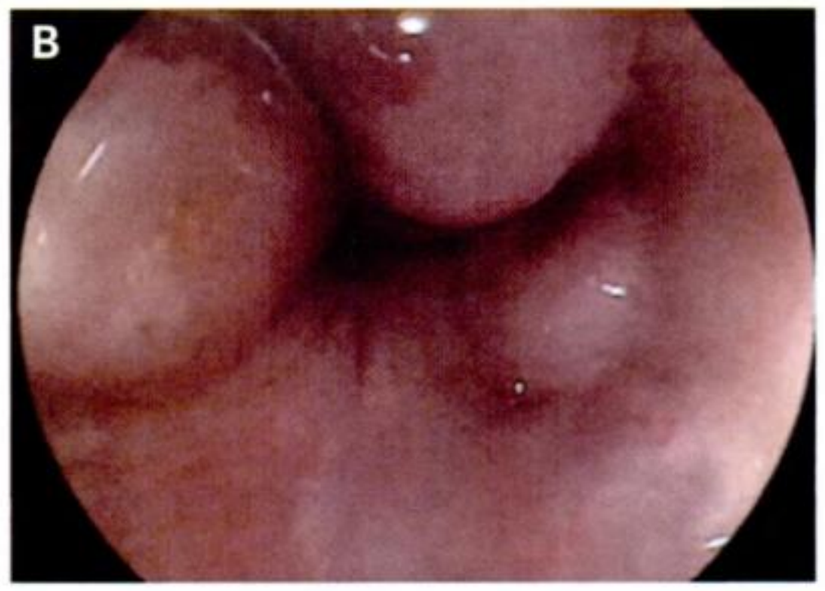


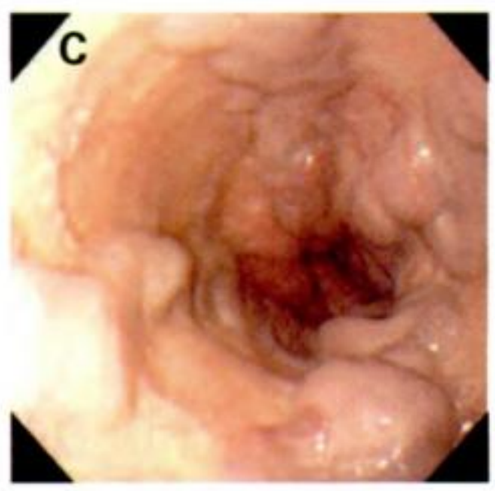


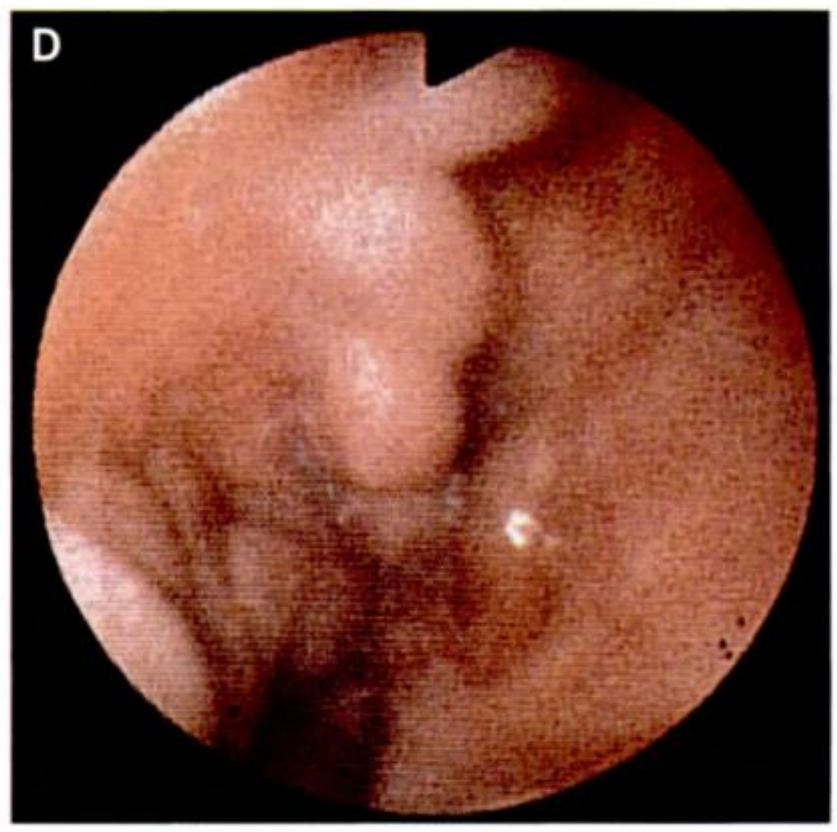
56. Varying degrees of esophageal ulcerations found in children with Crohn's disease. (56E, Image courtesy of Marie-Elisabeth Samson-Bouma, MD,)

Esophageal Varices

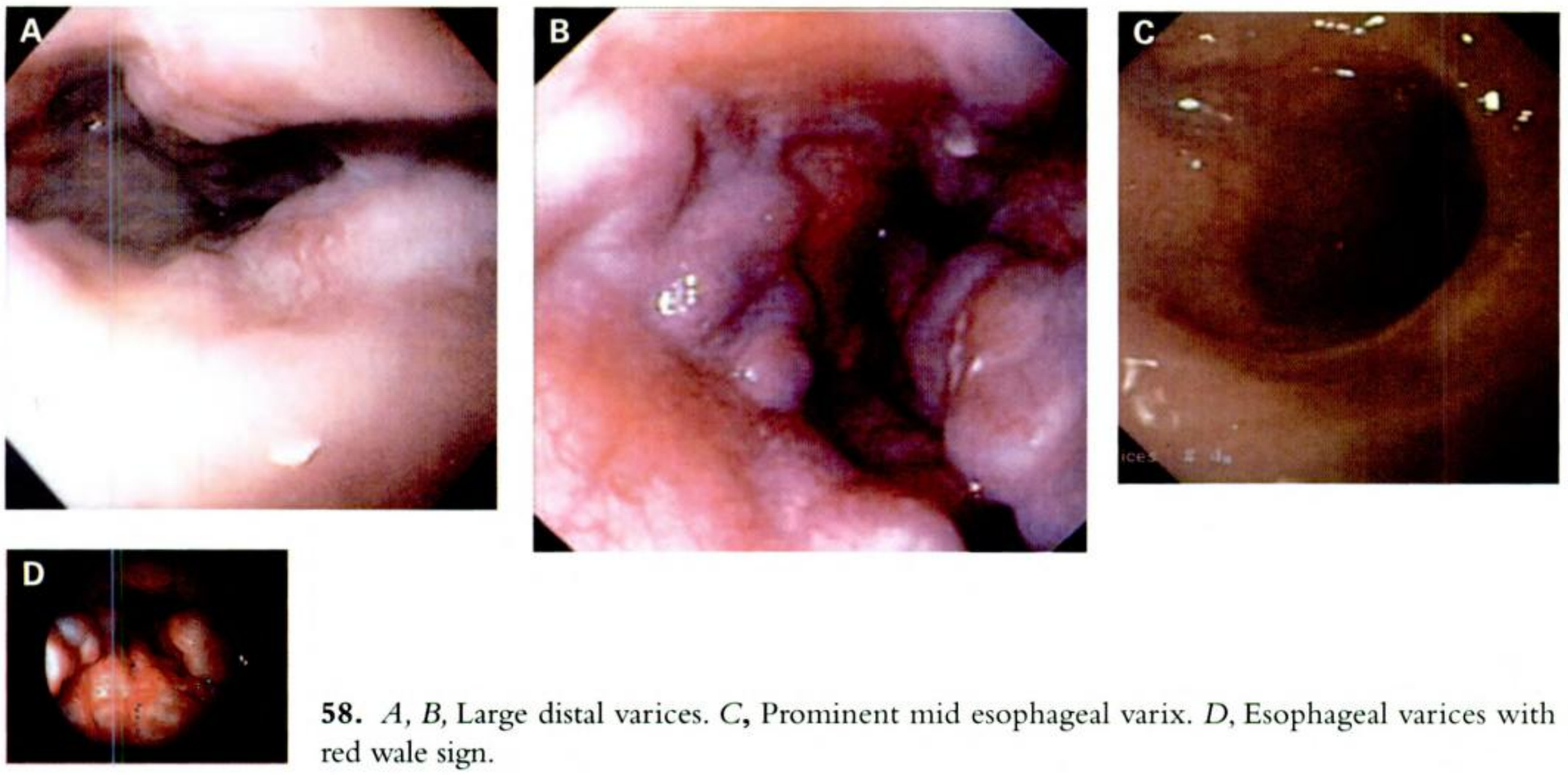






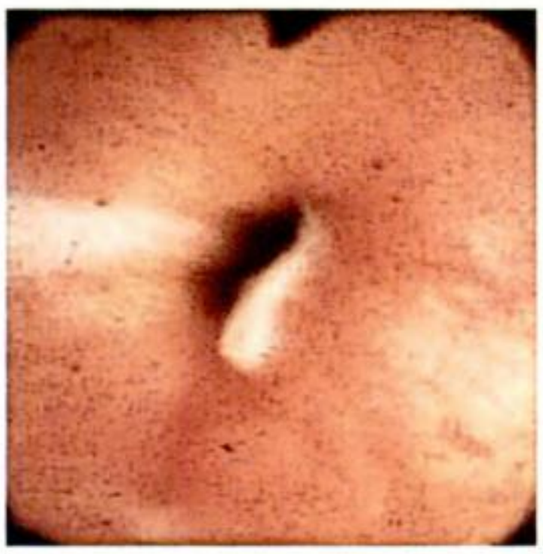


57. *A, B,* Multiple lower esophageal varices. *C,* Variations in the appearance of esophageal varices. (Image courtesy of Jeong Kee Seo, MD.) *D,* Varix appears to be white because of the thickness of the overlying mucosa.

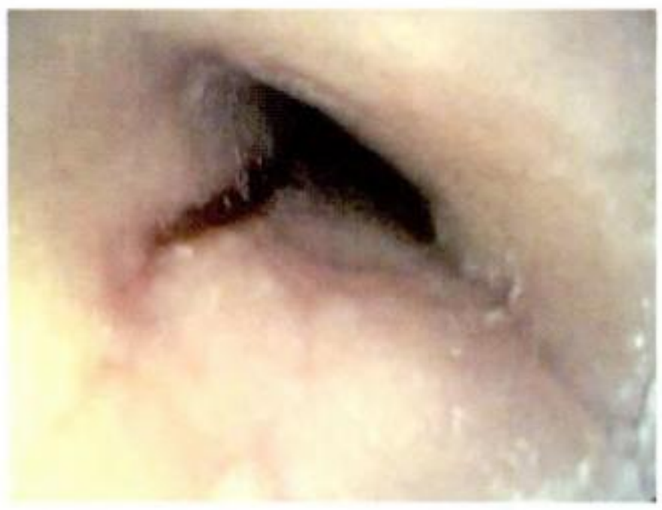


58. *A, B,* Large distal varices. *C,* Prominent mid esophageal varix. *D,* Esophageal varices with red wale sign.

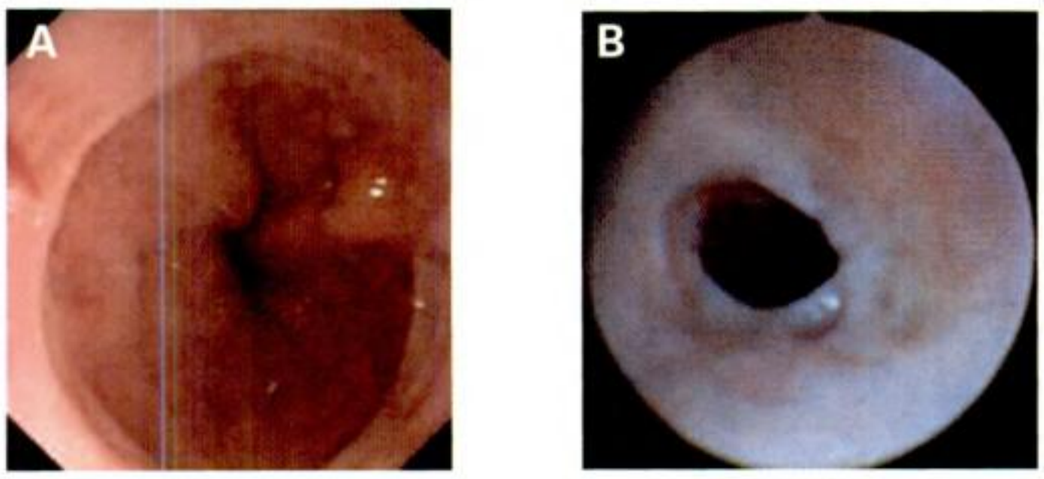
Other Esophageal Abnormalities



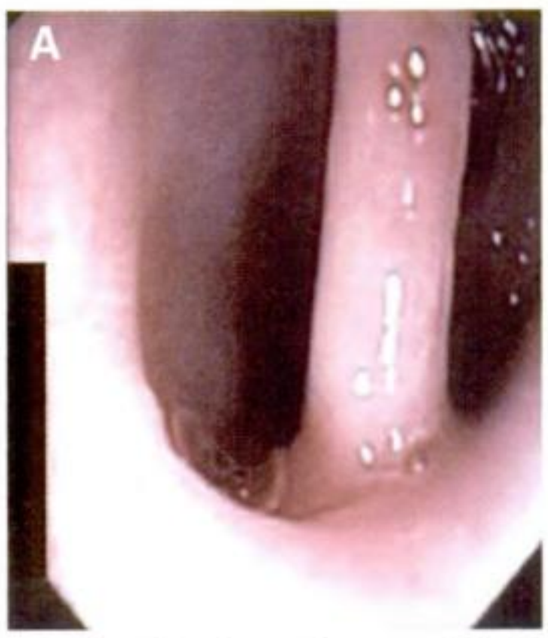
59. Hemorrhagic esophagitis in one-day old infant.

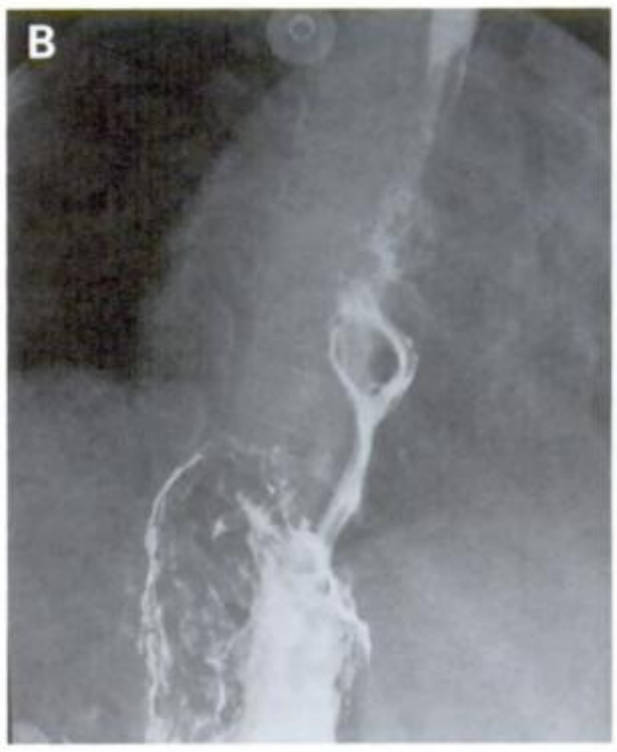


60. Mallory-Weiss tear.

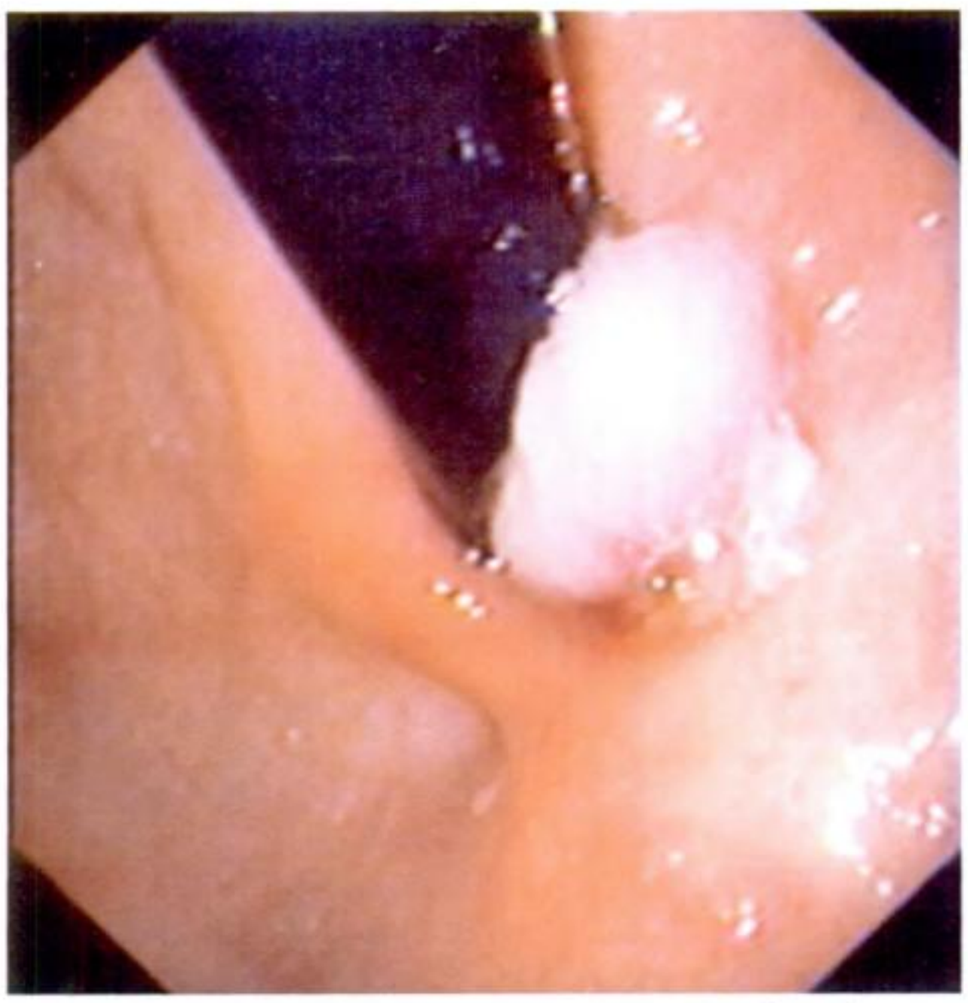


61. Schatzki ring. Persistent indentation in the distal esophagus.

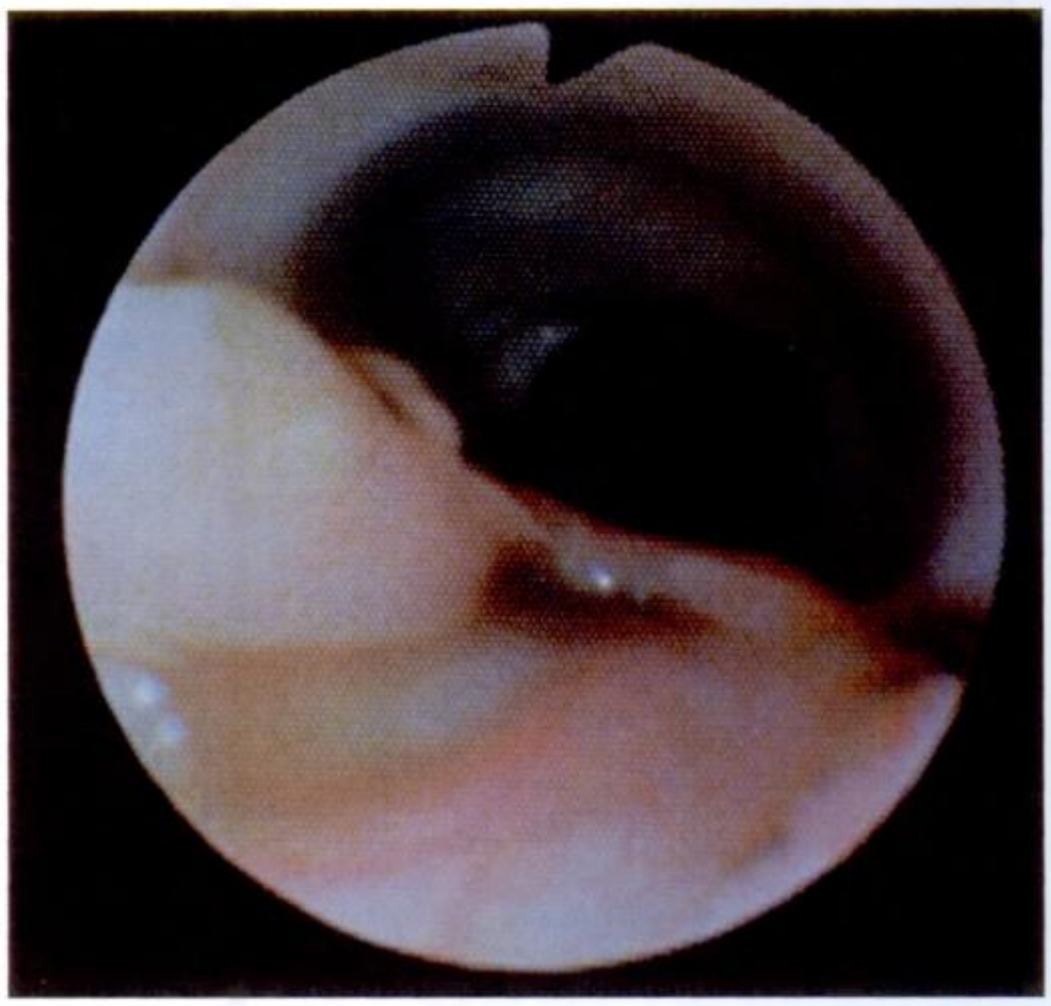




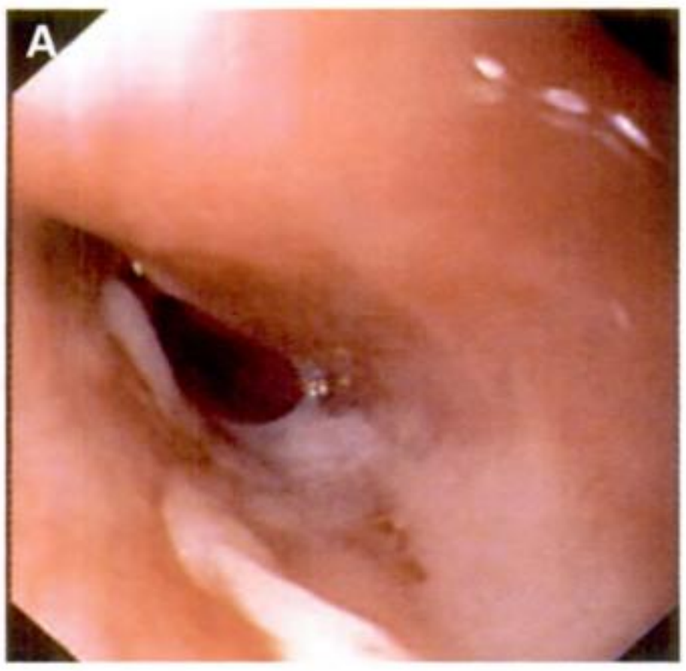
62. *A*, Septum in the distal esophagus with *B*, accompanying barium x-ray. (Images courtesy of Yoram Elitsur, MD.)

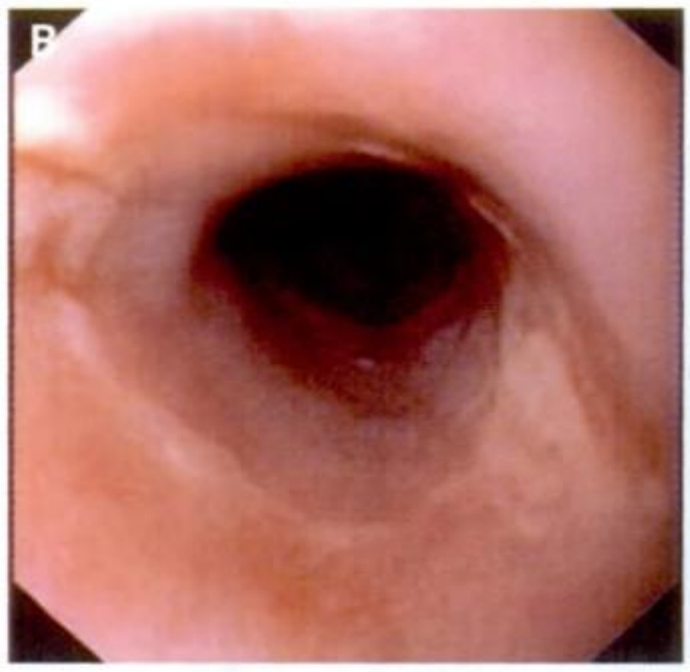


63. Esophageal pseudopolyp viewed on retroflexed view of sentinel fold in a patient with Wiscott Aldrich syndrome.

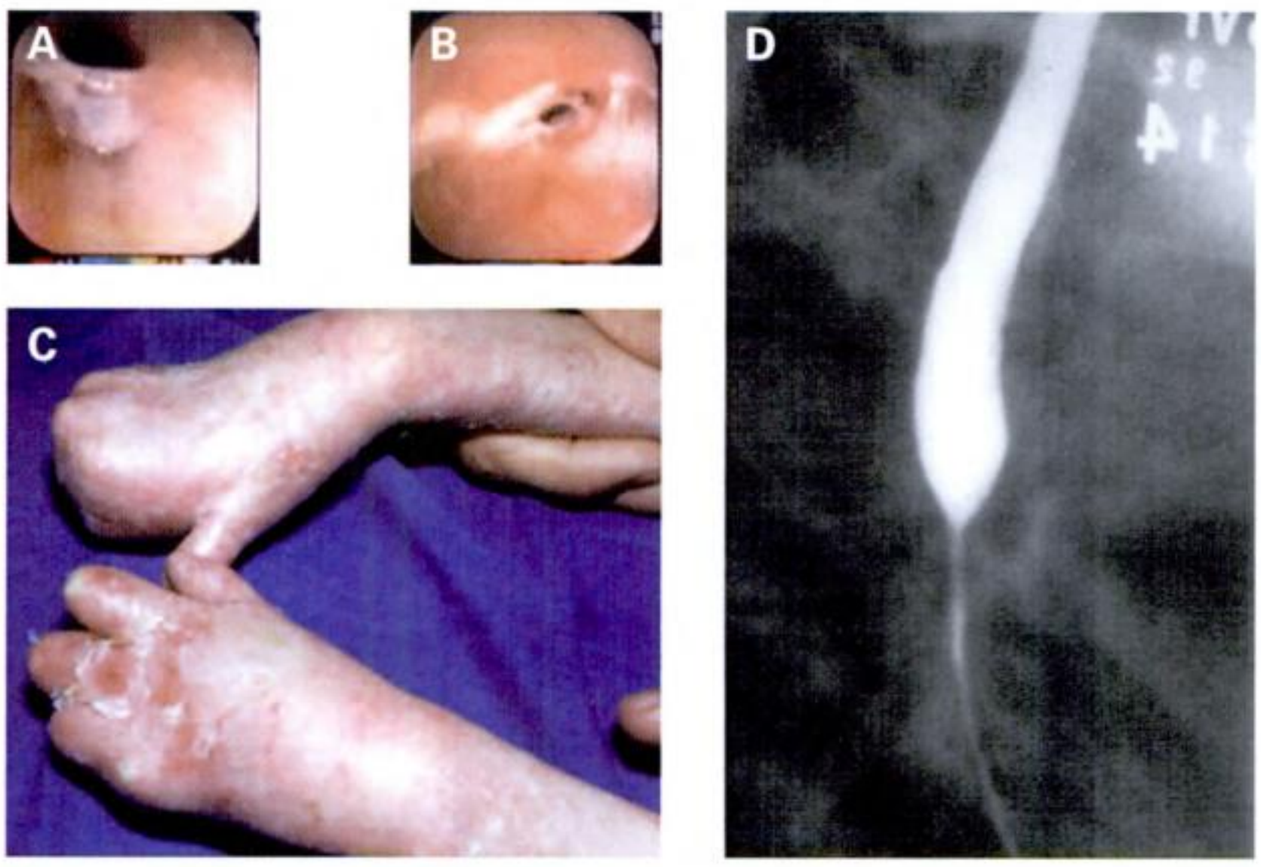


64. Mucosal bridge following healing of esophageal ulceration in association with a primary immune deficiency.

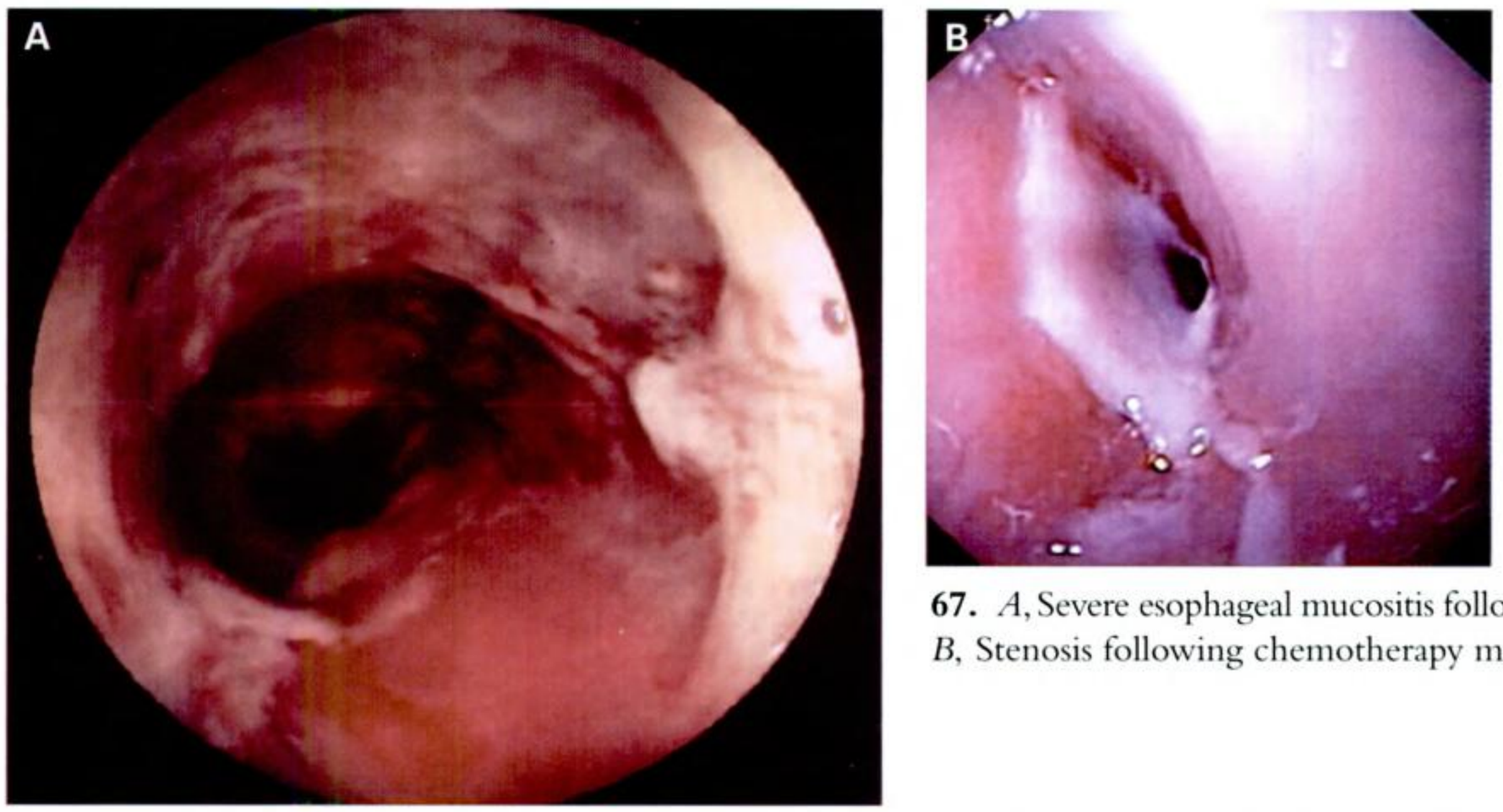




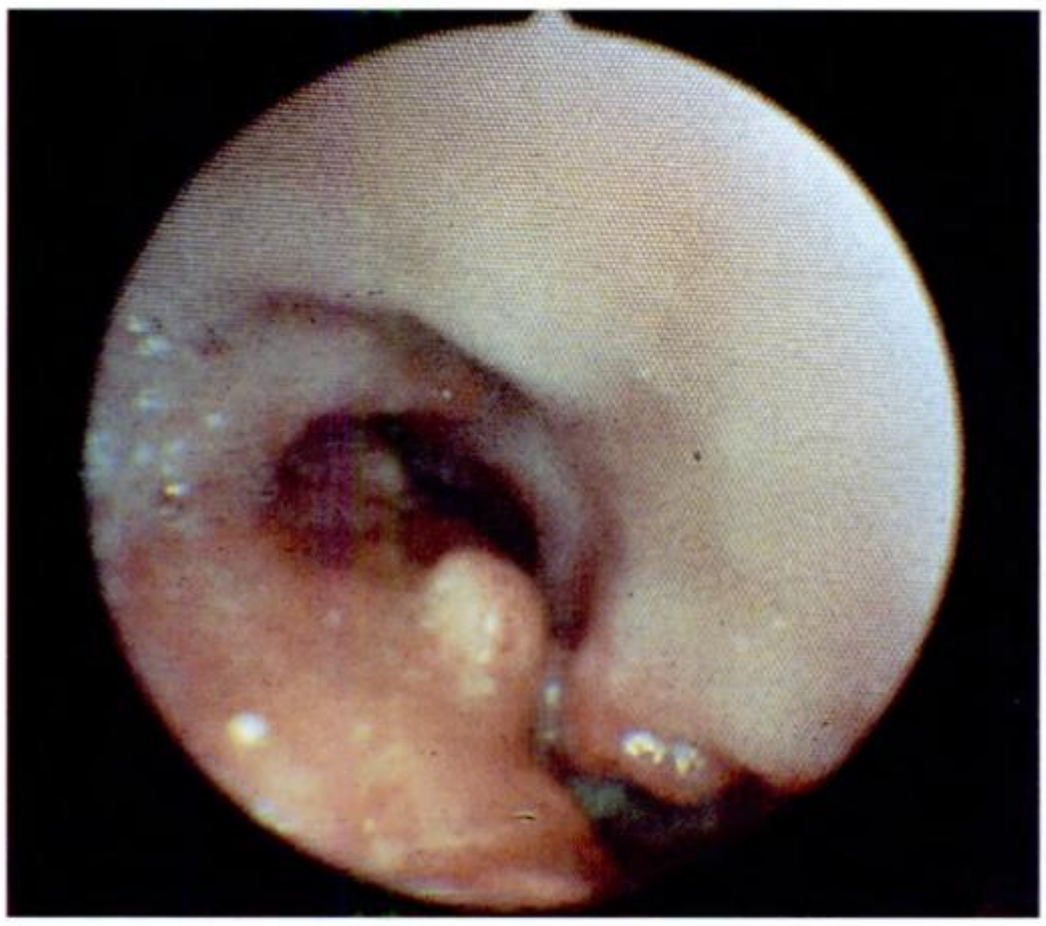
65. *A*, Cervical esophageal stricture prior to dilatation in a 10 year old boy with congenital dyskeratosis and immunodeficiency. *B*, Cervical esophageal stricture following dilatation.



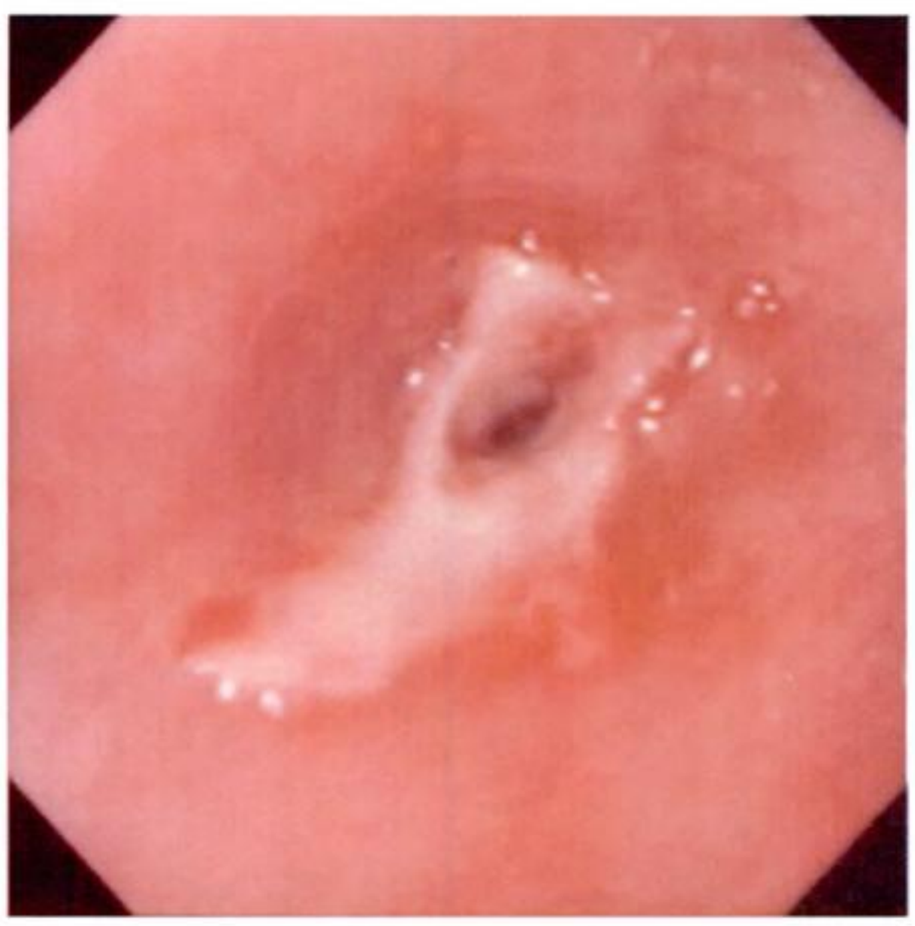
66. Epidermolysis bullosa. *A,B,* Esophageal stricture. *C,* Hand deformities. *D,* Long stricture in the mid and distal esophagus. (Images courtesy of Manoel Ernesto Gonçalves, MD.)



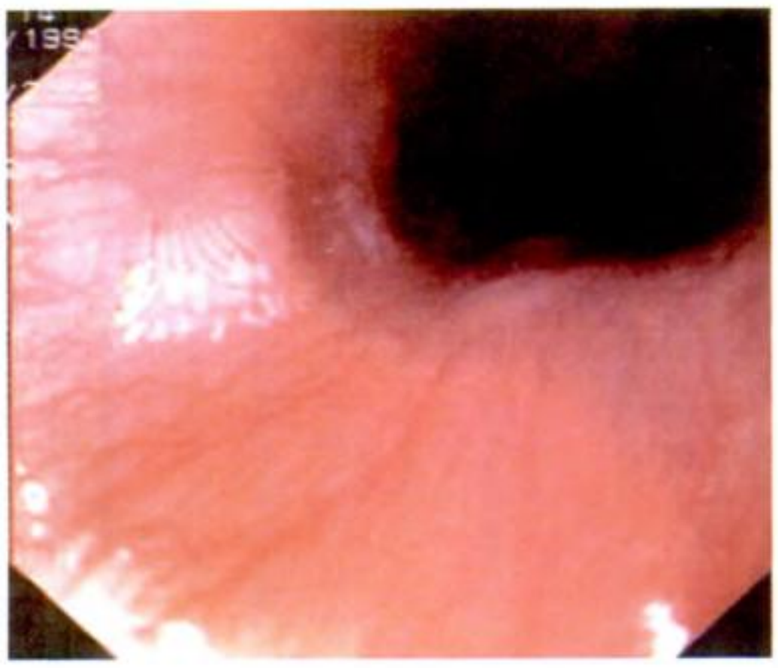
67. *A,* Severe esophageal mucositis following chemotherapy. *B,* Stenosis following chemotherapy mucositis.



68. Adenocarcinoma in the esophagus of an adolescent girl who had congenital tracheo-esophageal fistula.

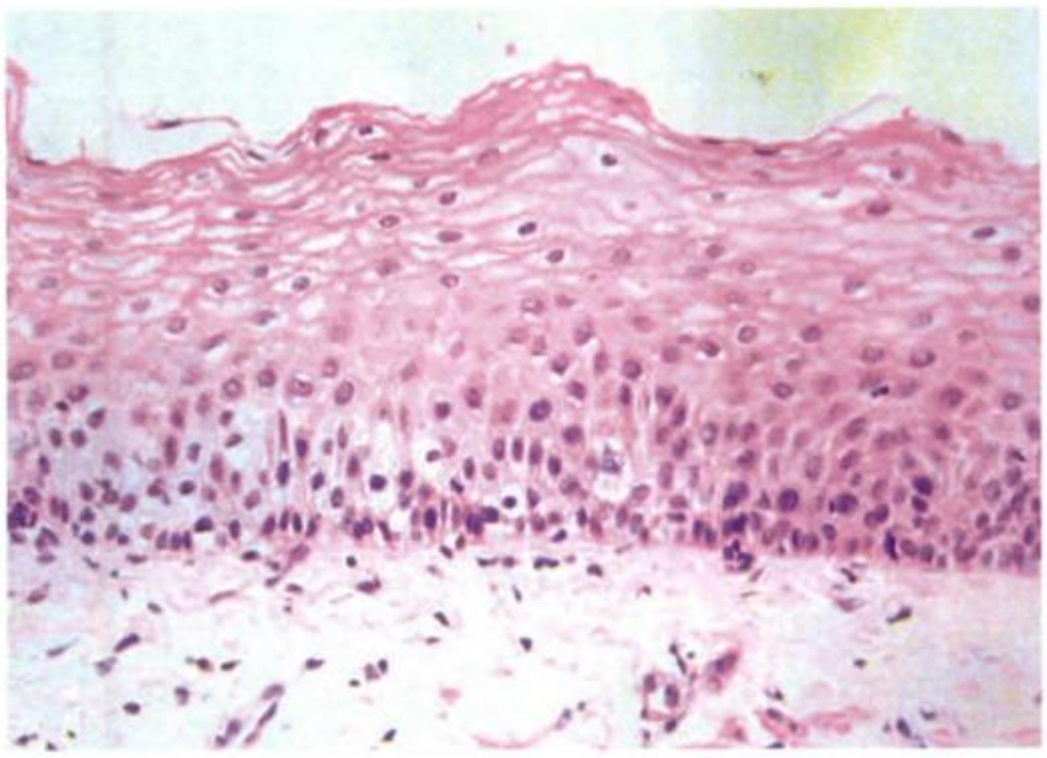


69. Ulcerated esophageal stenosis due to graft versus host disease following allogenic bone marrow transplantation.

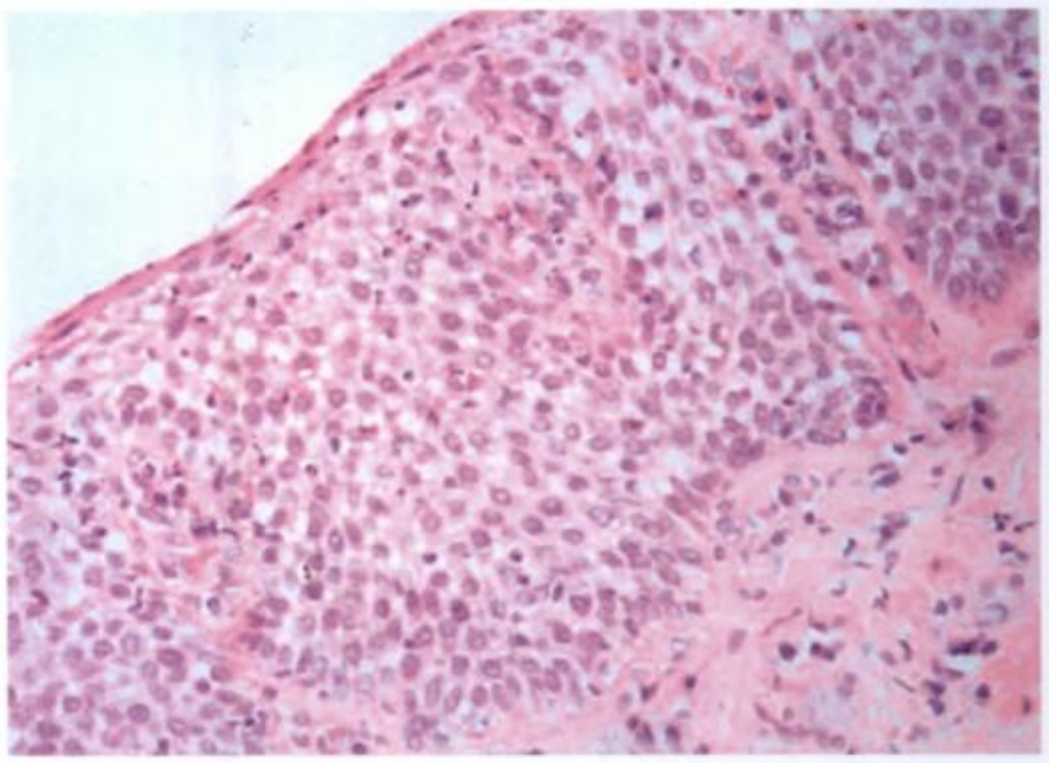


70. Jelly-fish appearance is a unique esophageal lesion in Cowden's syndrome observed in children over 10 years of age.

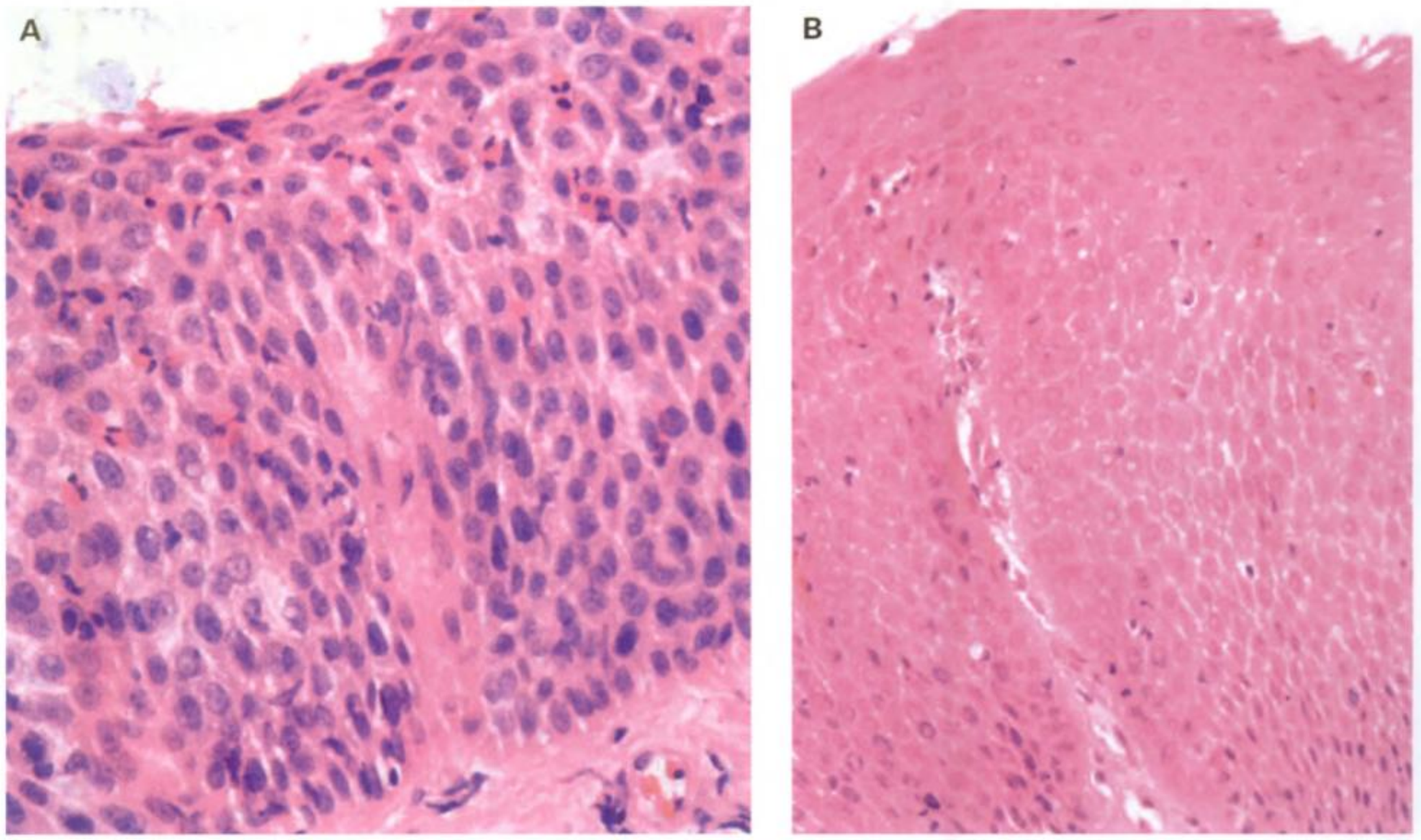
Esophageal Histology



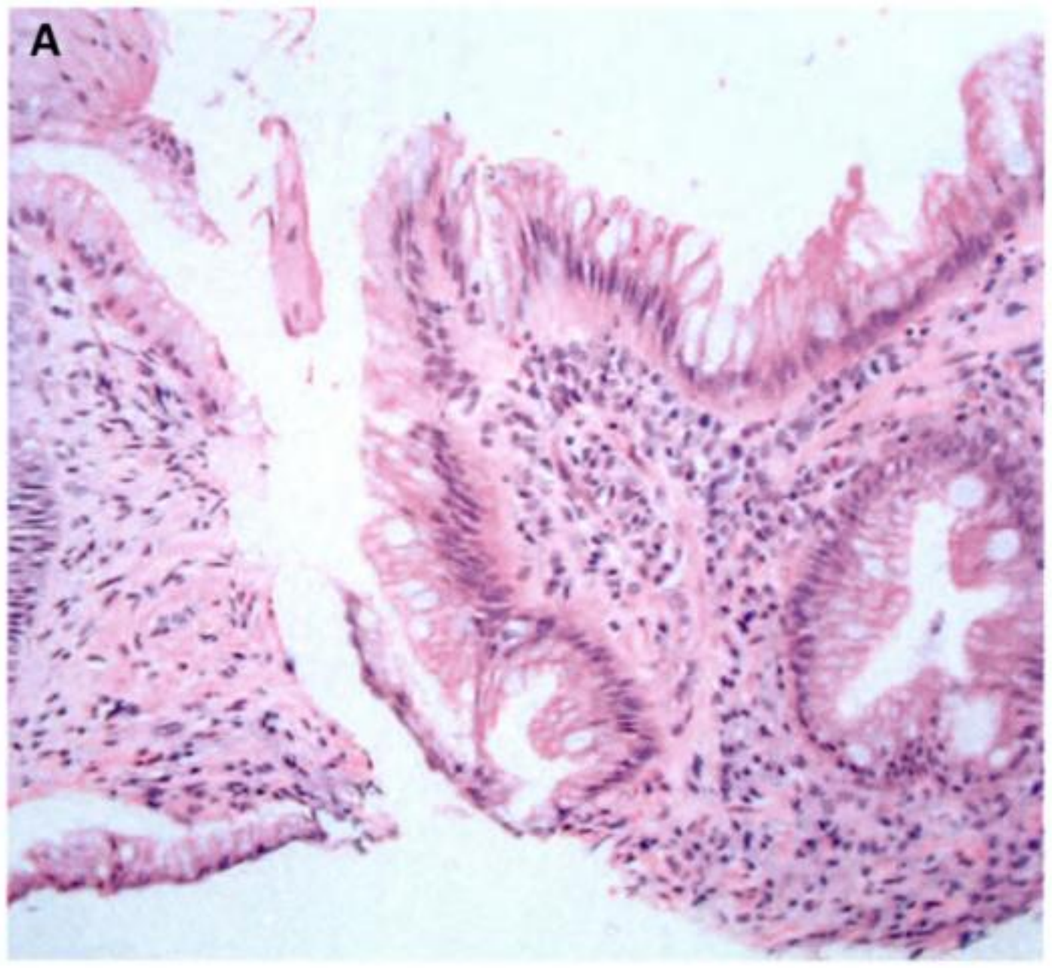
71. Normal. (Image courtesy of Rachel Brown, FRCPath.)

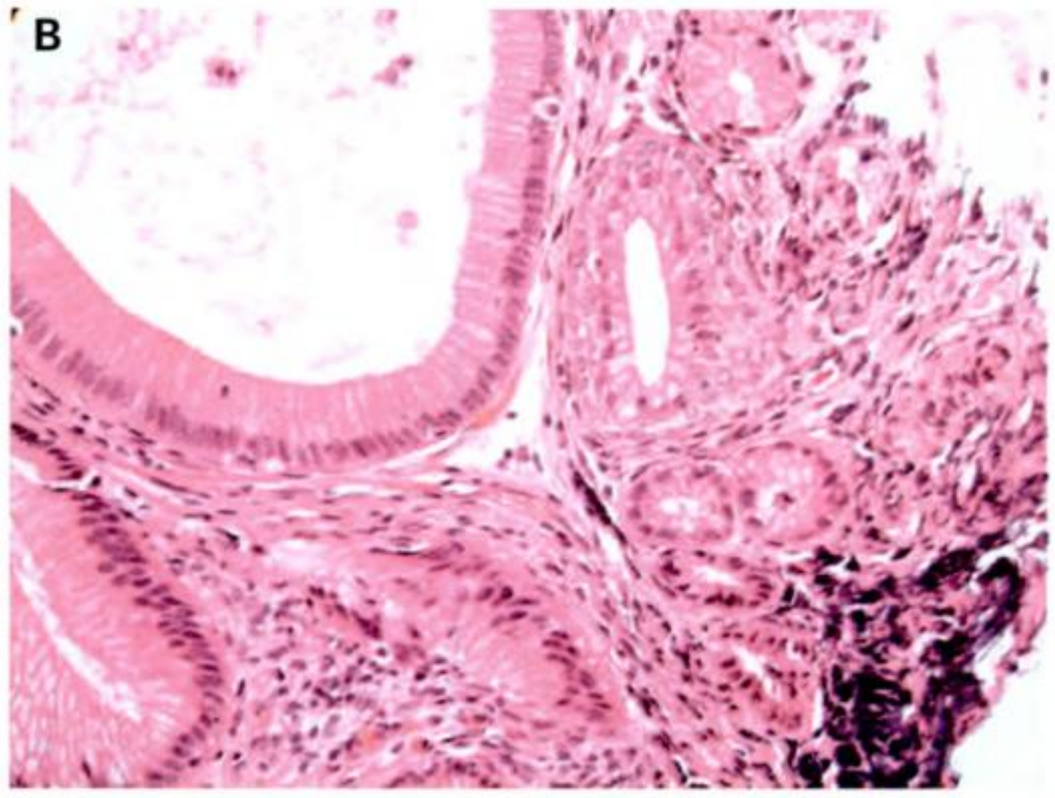


72. Peptic esophagitis with intraepithelial eosinophils. (Image courtesy of Rachel Brown, FRCPath.)

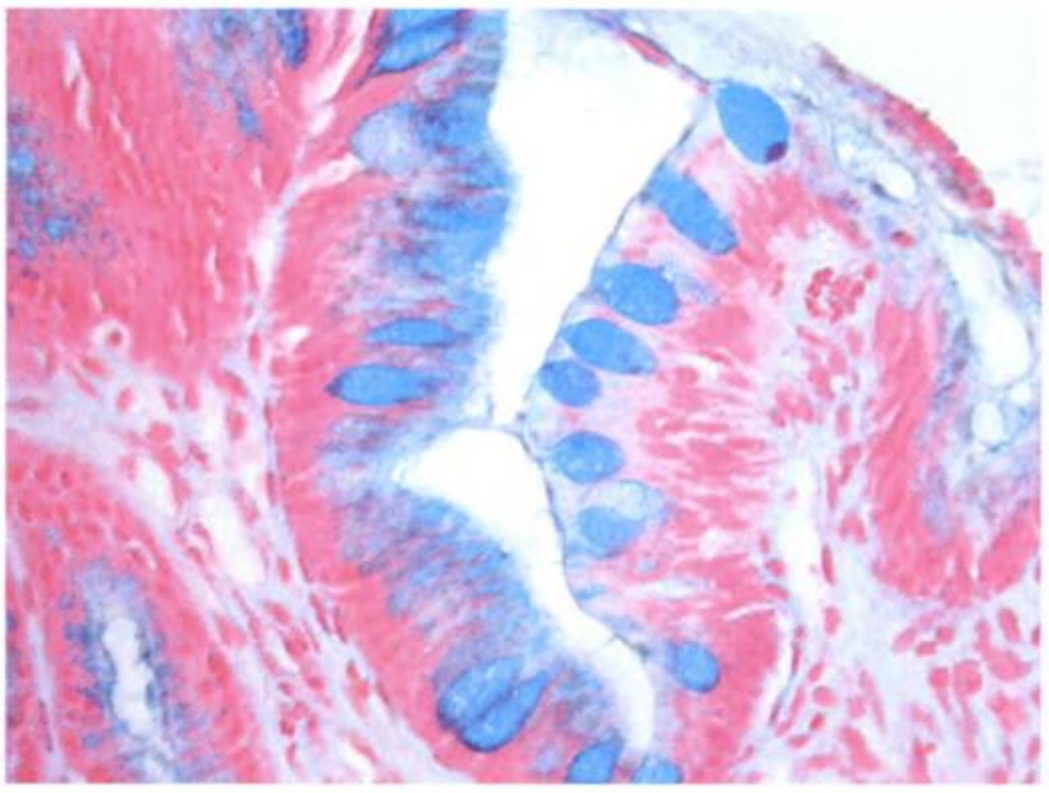


73. Peptic esophagitis with elongated papillae and infiltration of the epithelium by eosinophils. (Images courtesy of Rachel Brown, FRCPath.)

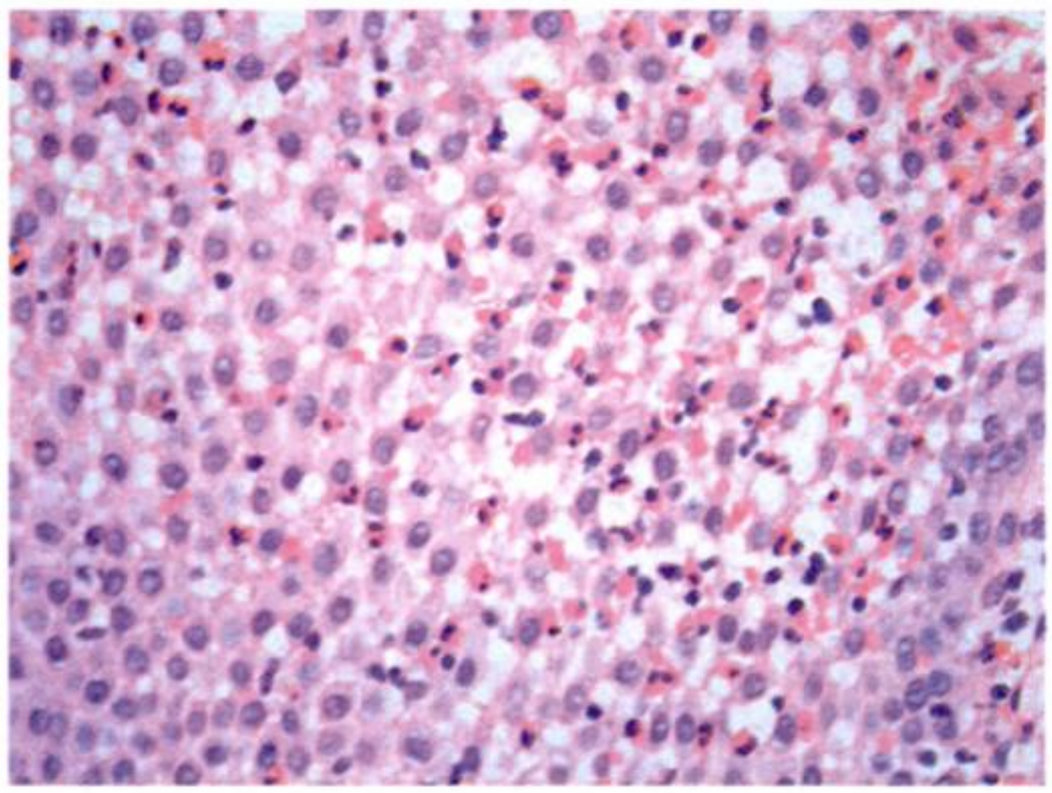




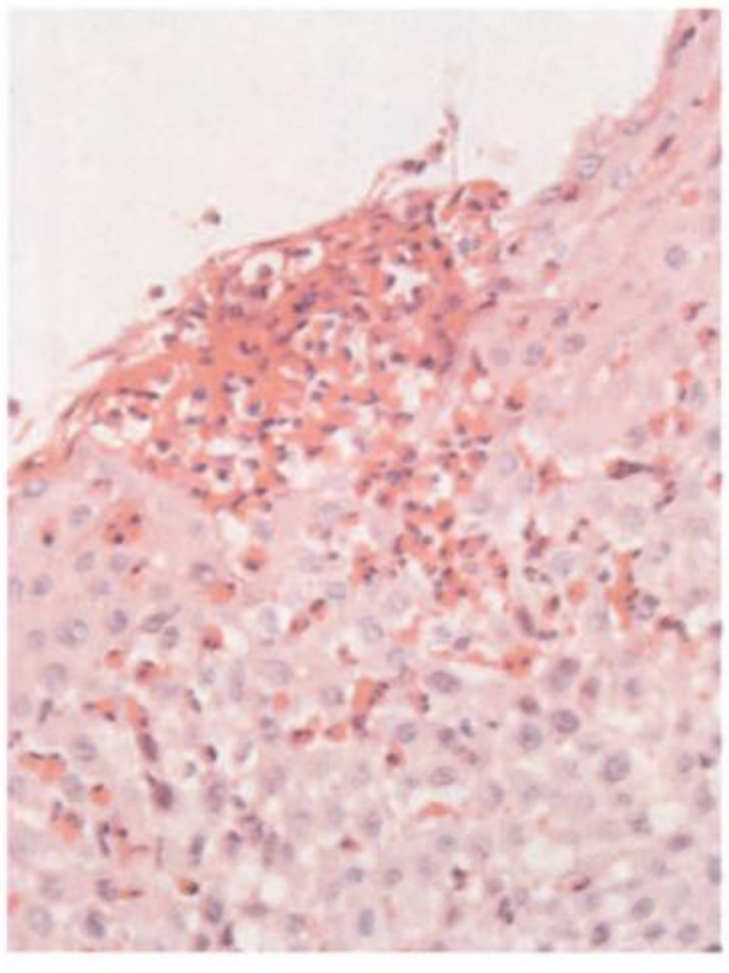
74. Barrett's esophagus. (Images courtesy of Rachel Brown, FRCPath.)



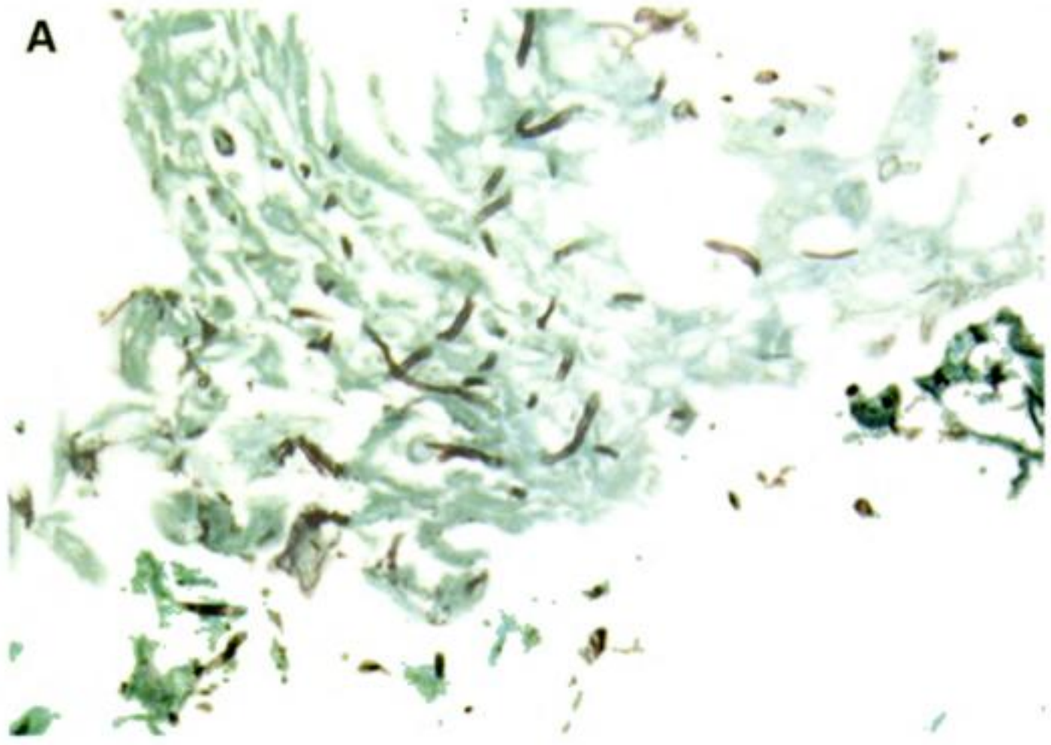
75. Barrett's esophagus with intestinal metaplasia highlighted by Alcian blue staining which identifies goblet cells. (Image courtesy of Rachel Brown, FRCPath.)

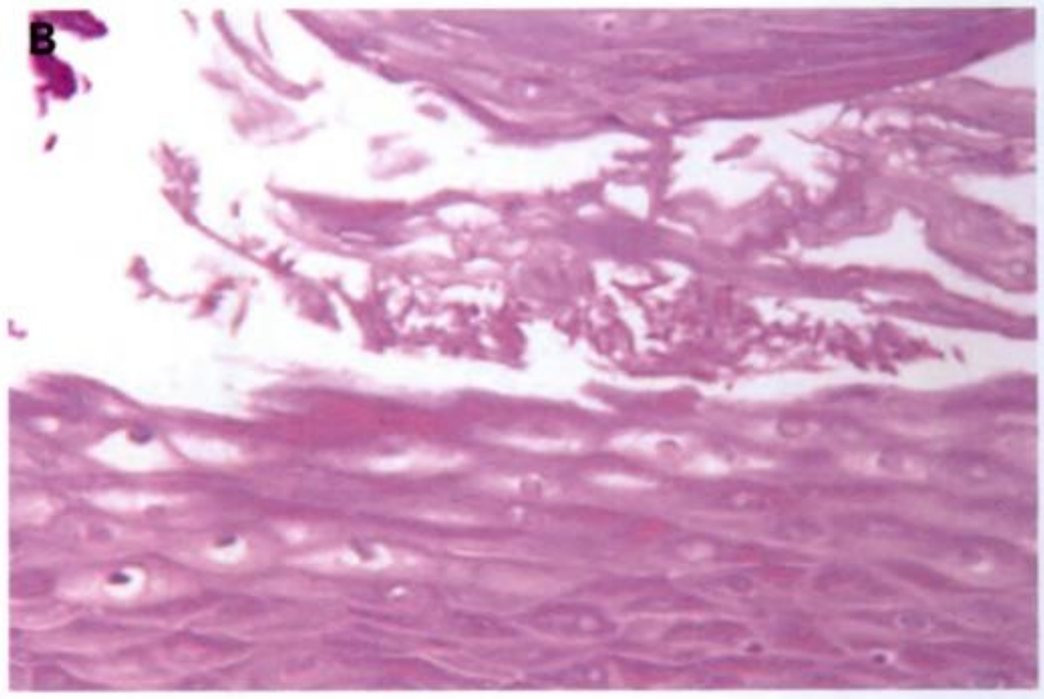


76. Eosinophilic esophagitis with numerous eosinophils associated with intercellular oedema. (Image courtesy of Rachel Brown, FRCPath.)

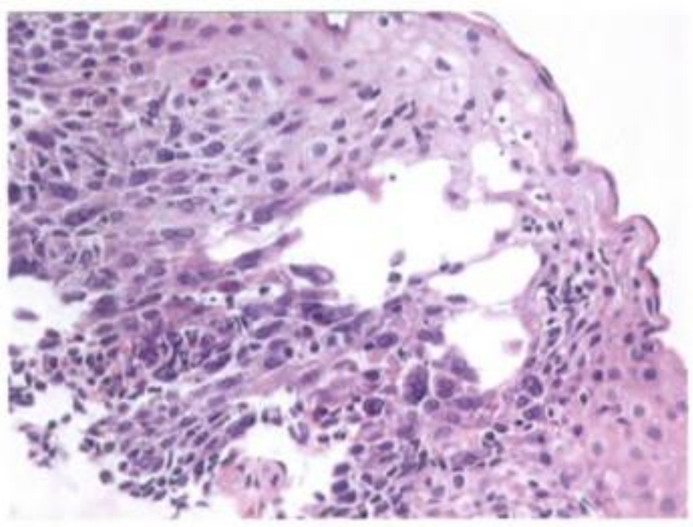


77. Eosinophilic esophagitis with superficial eosinophilic abscess. (Image courtesy of Rachel Brown, FRCPath.)

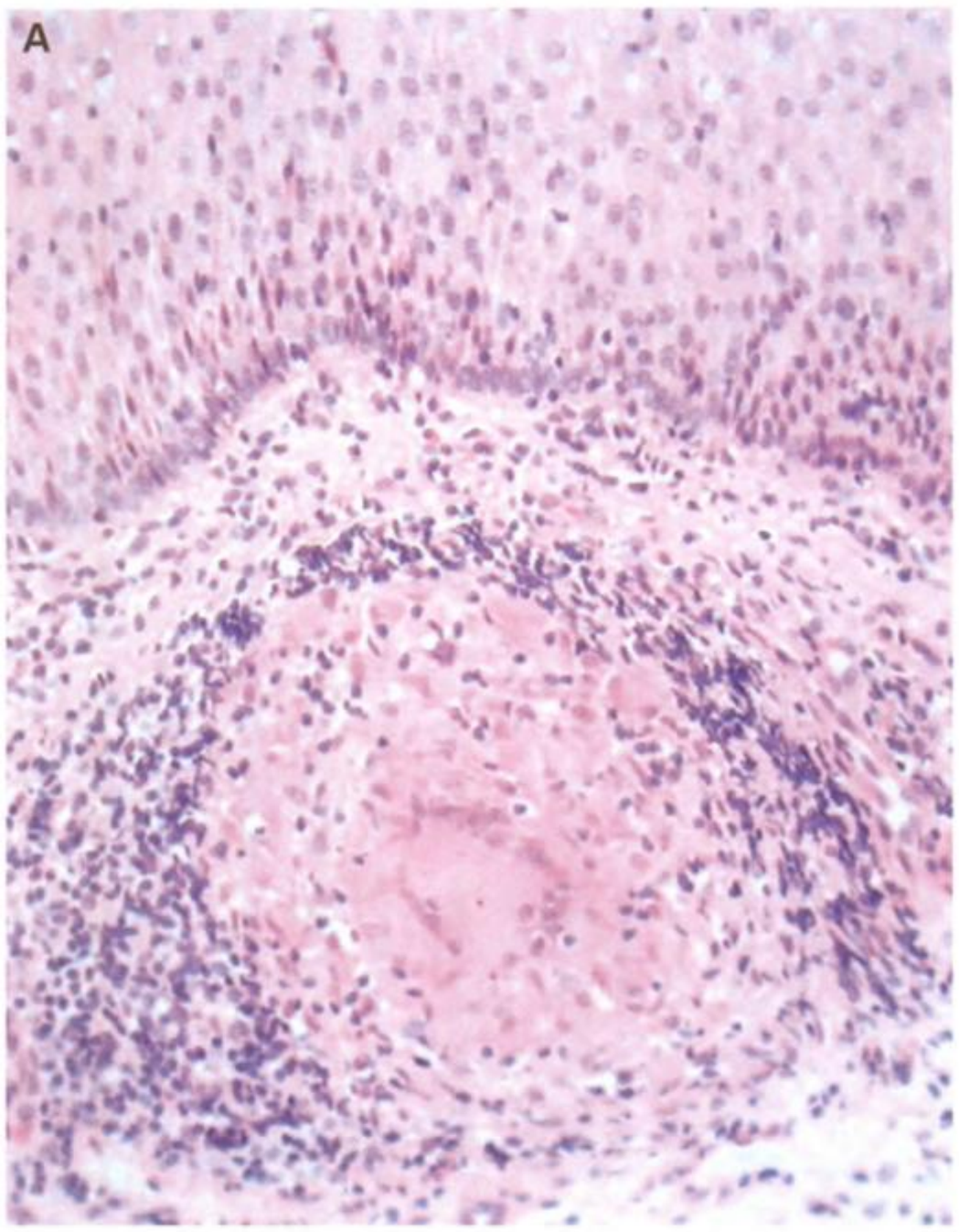


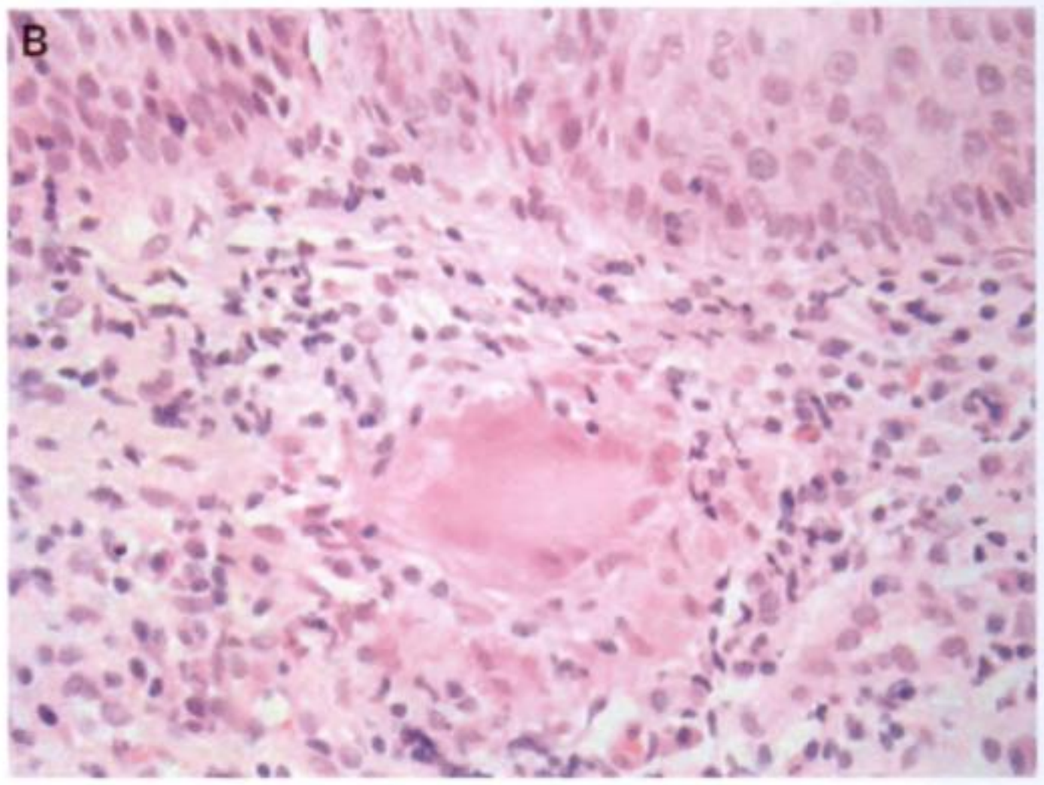


78. Candida esophagitis. *A*, Grocott stain. (Image courtesy of Rachel Brown, FRCPath.) *B*, PAS stain. (Image courtesy of Nicole Brousse, MD.)



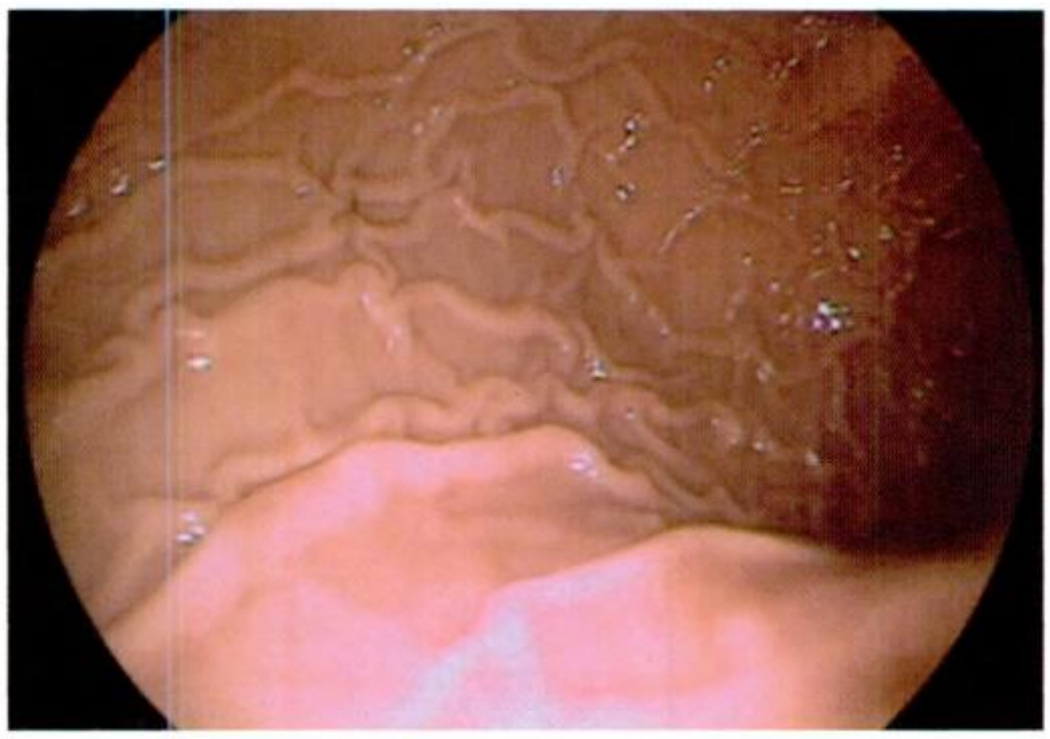
79. Herpetic esophagitis.



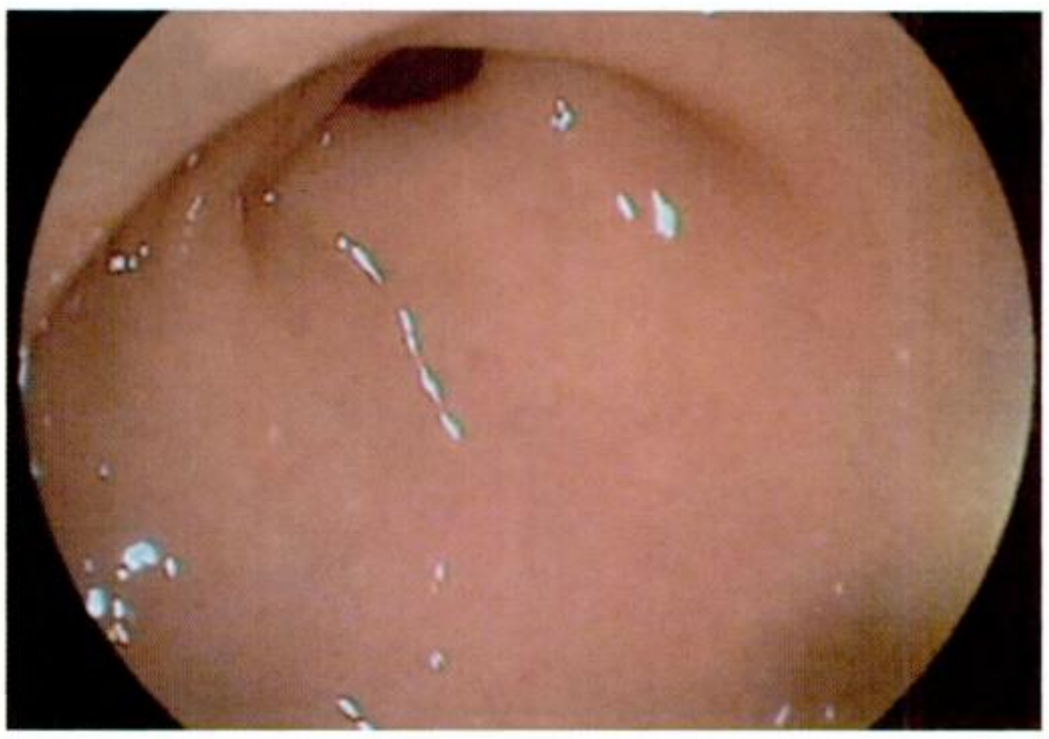


80. *A*, Submucosal Crohn's granuloma. *B*, Submucosal subepithelial giant cell in esophageal Crohn's disease. (Images courtesy of Rachel Brown, FRCPath.)

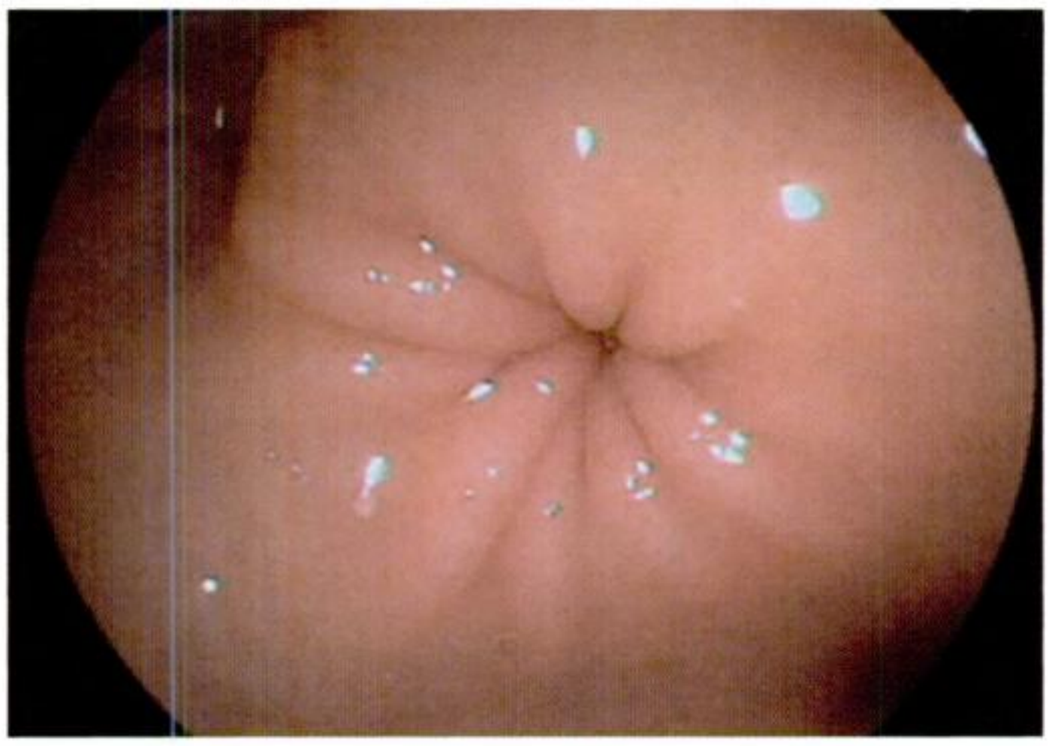
Normal Stomach



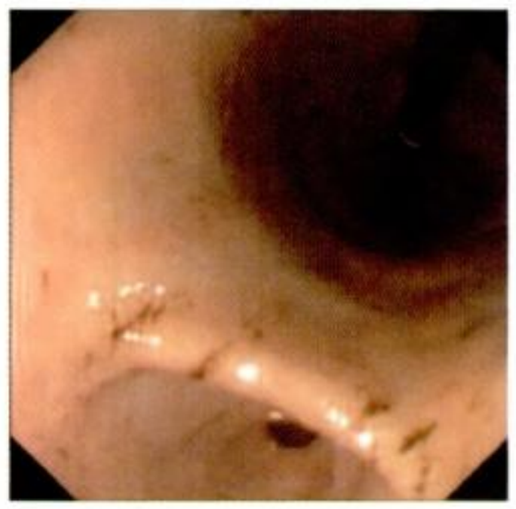
81. Gastric corpus.



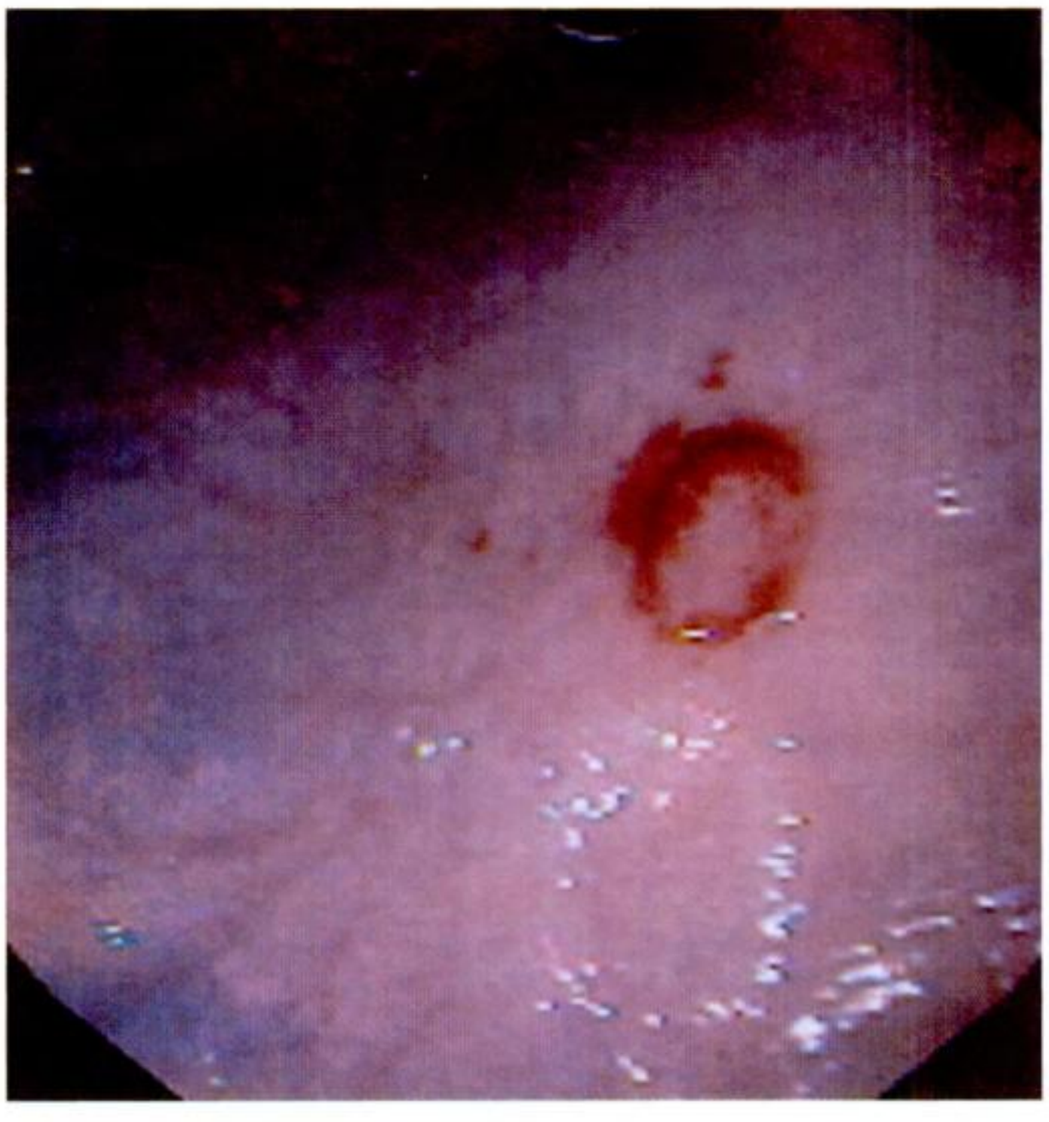
82. Antrum, angulus and pylorus.



83. Closed pylorus.

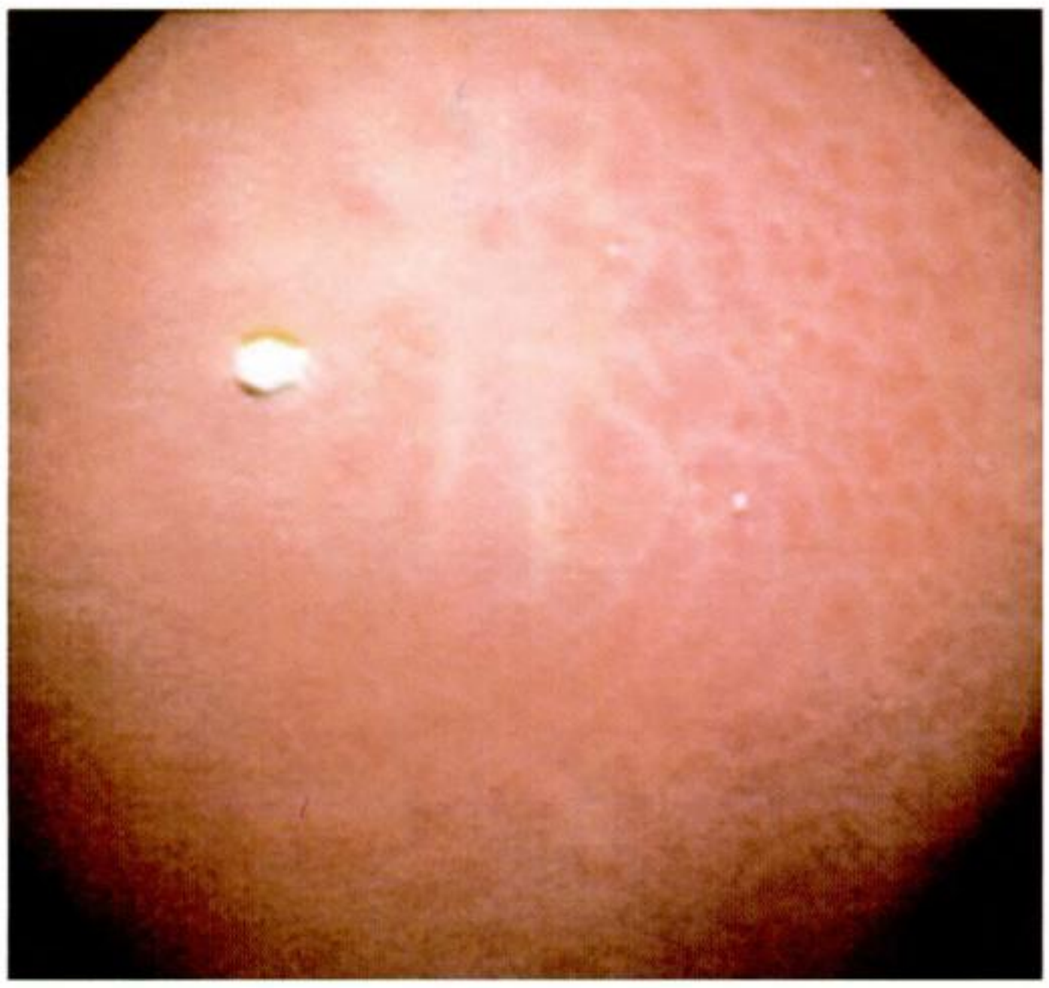


84. Antrum with retroflexed view of the cardia.

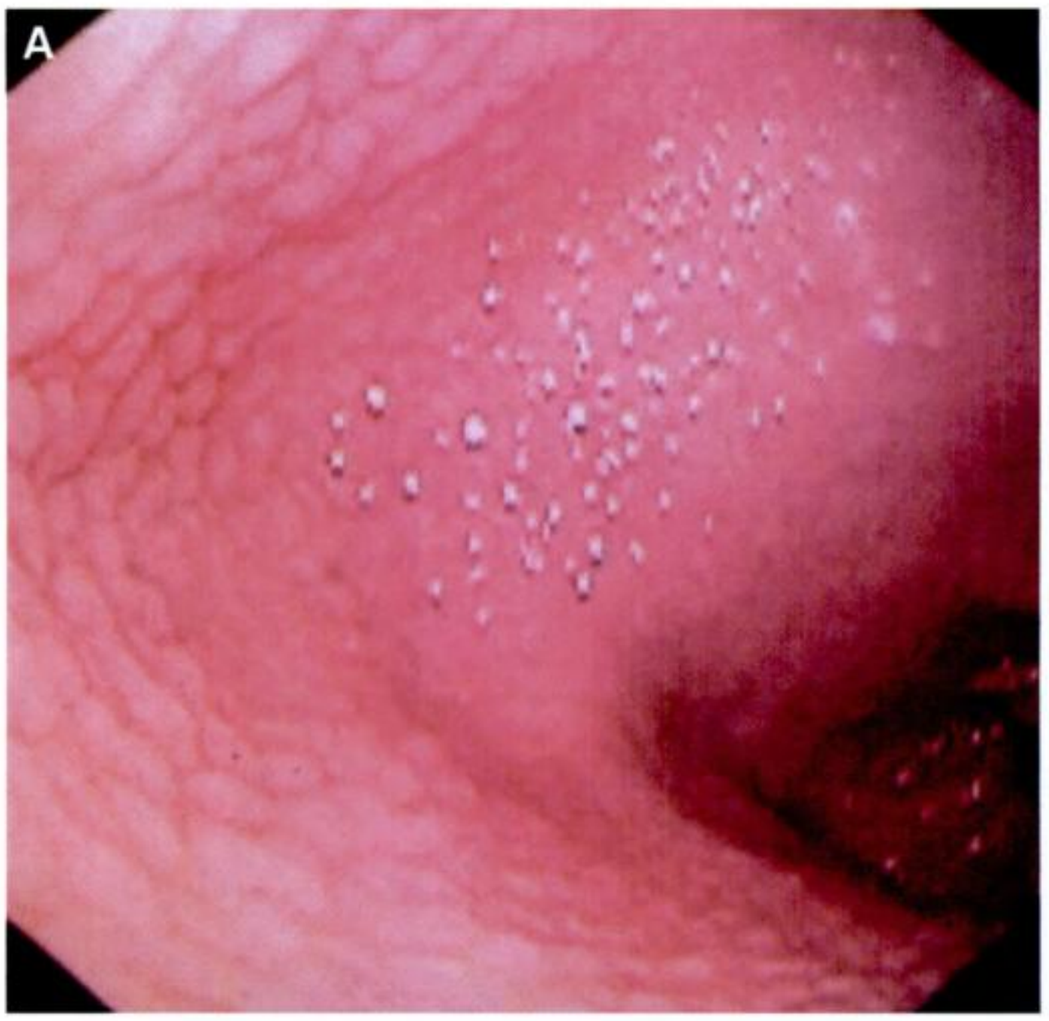


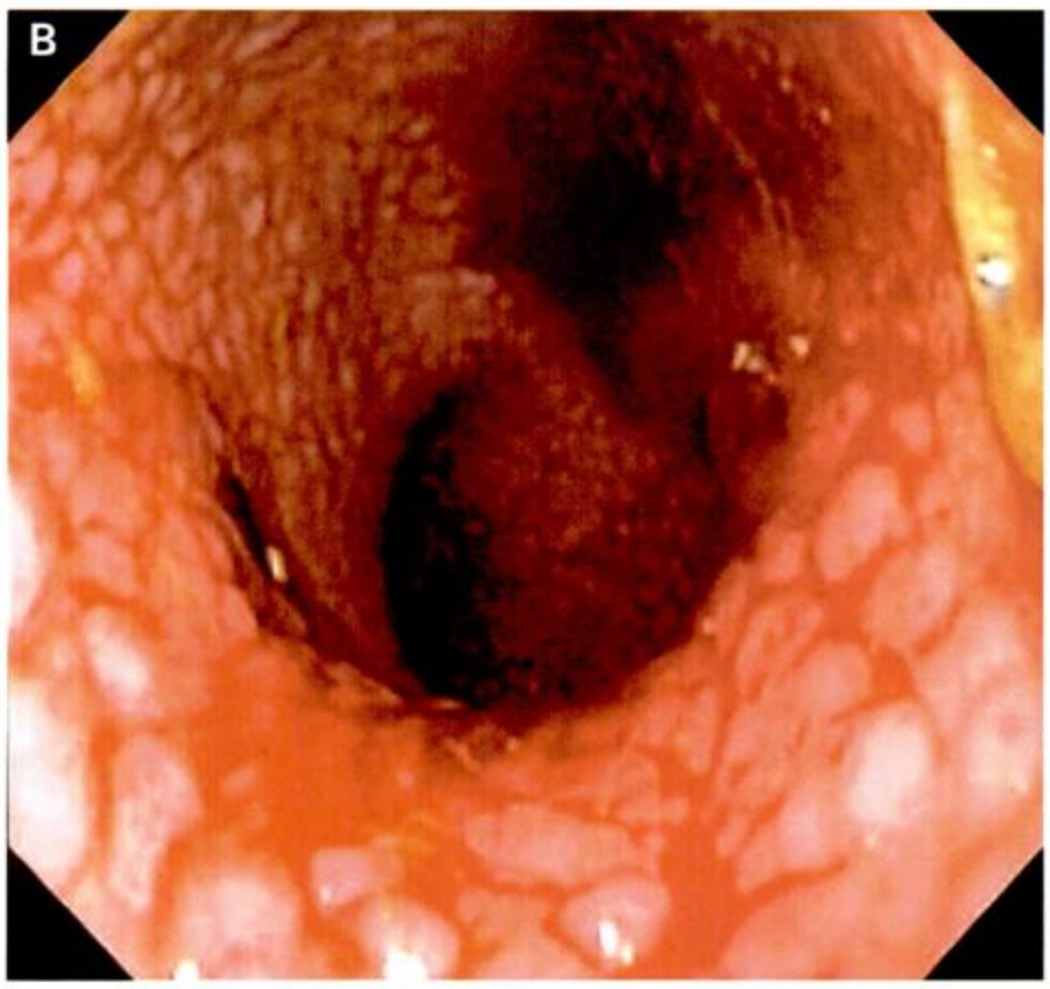
85. Suction lesion caused by suction channel of endoscope.

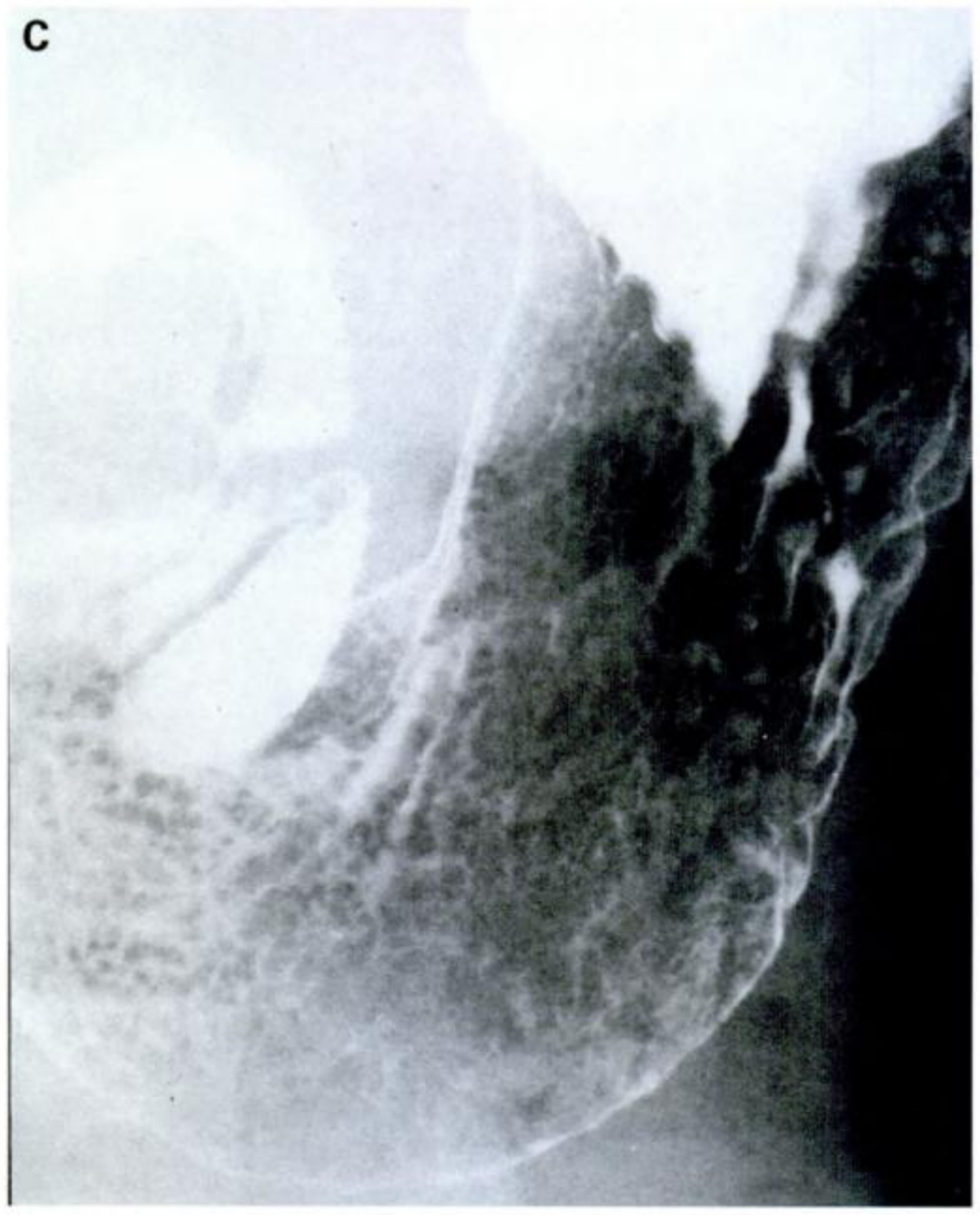
Helicobacter pylori gastritis



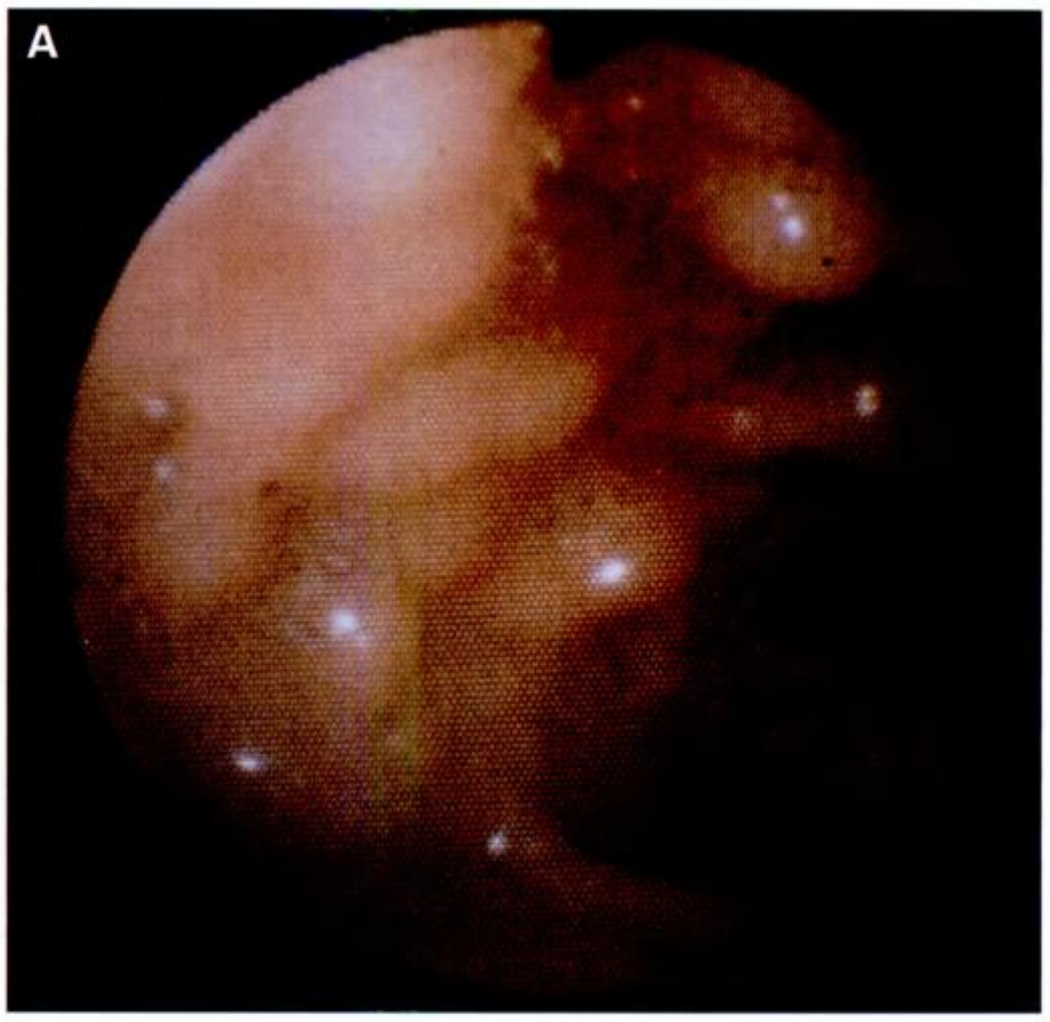
86. Gastric antral erythema in one year old child with *H. pylori* associated gastritis.

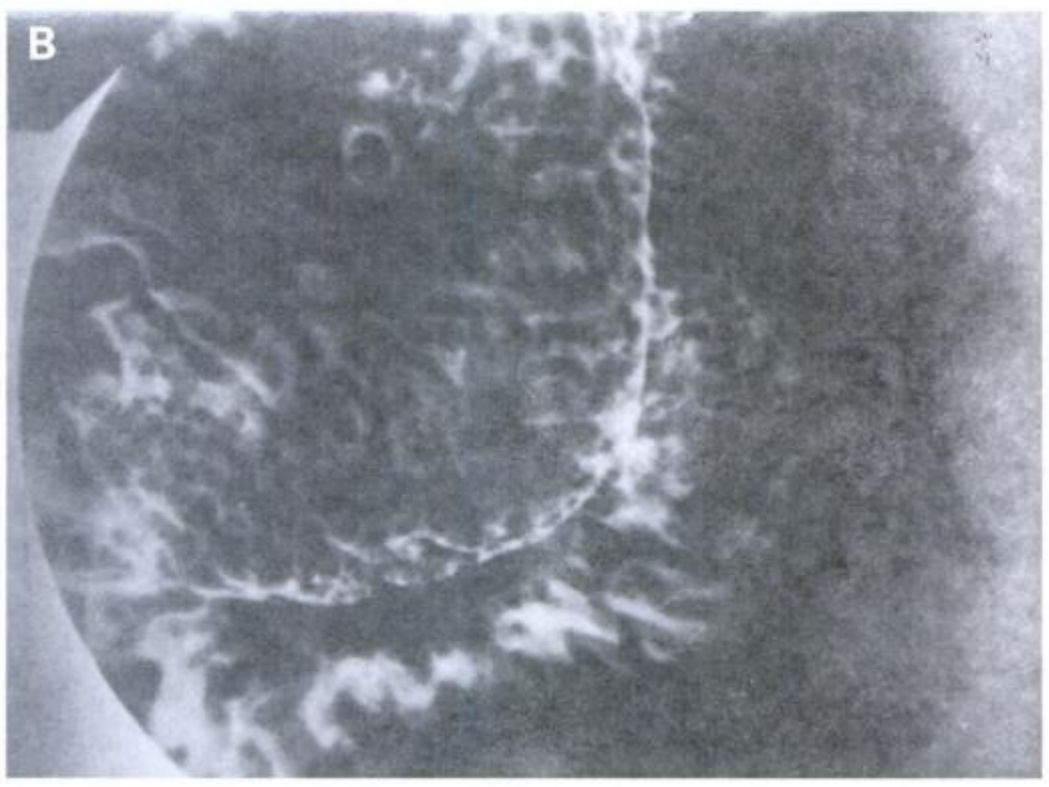






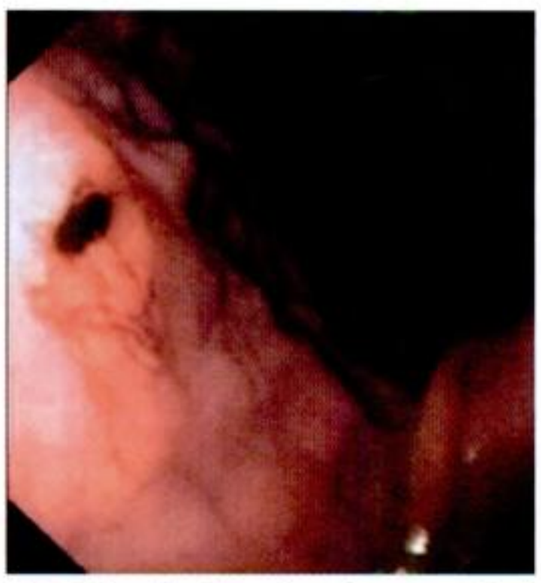
87. *A*, Antral nodularity may be present in varying degrees. *B*, Bleeding from biopsy site highlights *H. pylori* associated nodularity. (Image courtesy of Yves Vannerom, MD.) *C*, Double contrast barium radiograph showing extensive gastric antral nodularity associated with *H. pylori*.



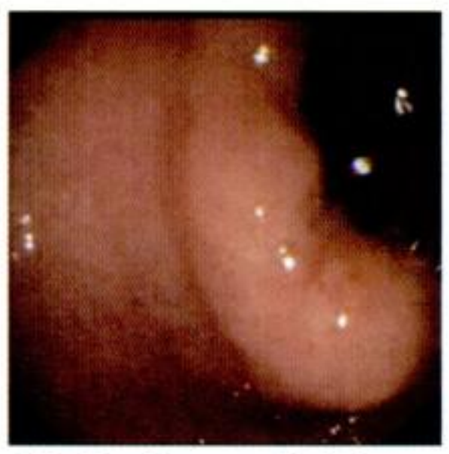


88. *A,B,* Marked gastric nodularity associated with G-cell hyperplasia.

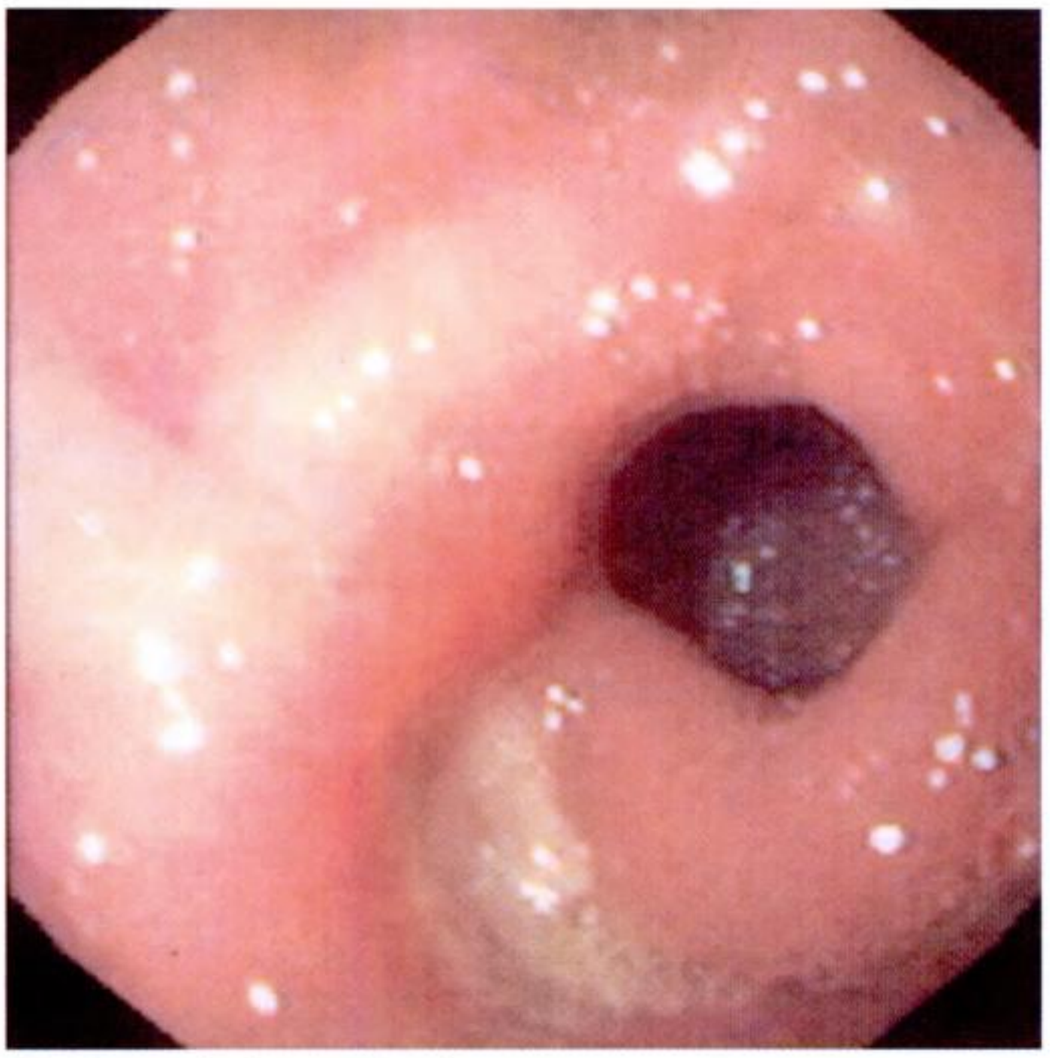
Gastric Ulcer



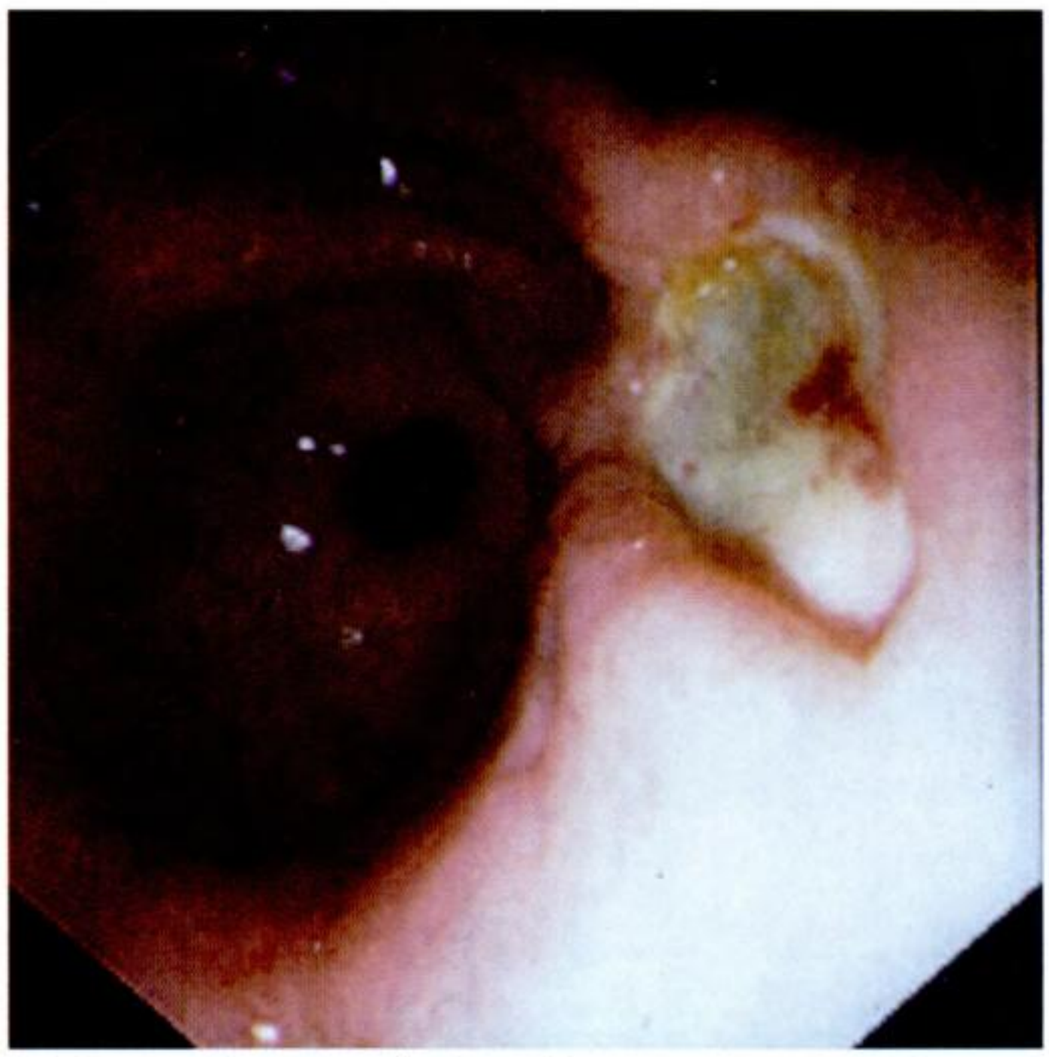
89. Focal ulcer in the gastric body with adherent clot.



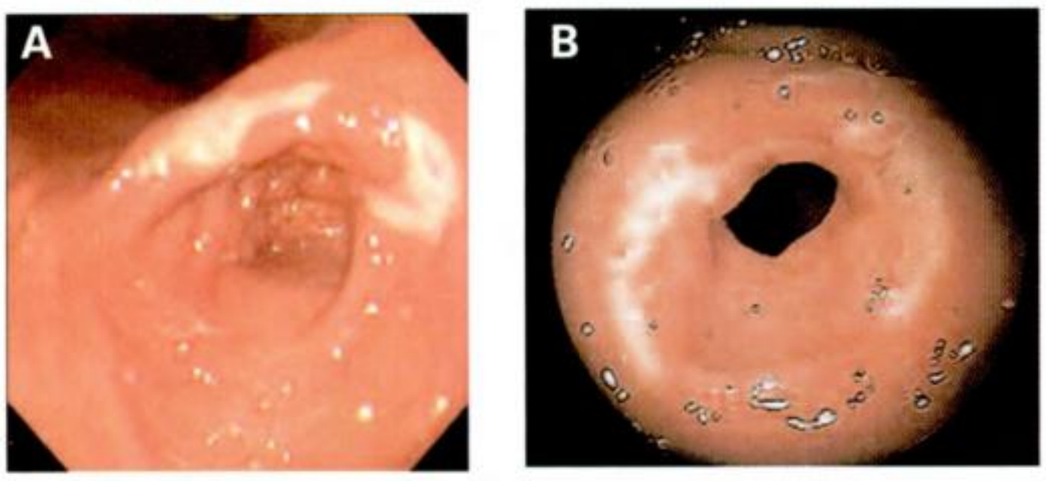
90. Small superficial gastric ulcer just distal the GE junction seen only by reflexed view.



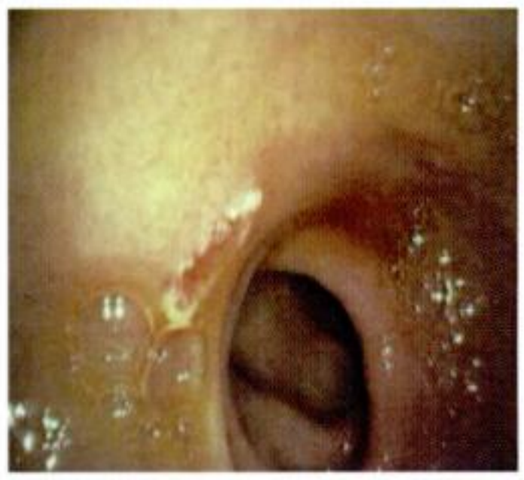
91. Pre-pyloric gastric ulcer.



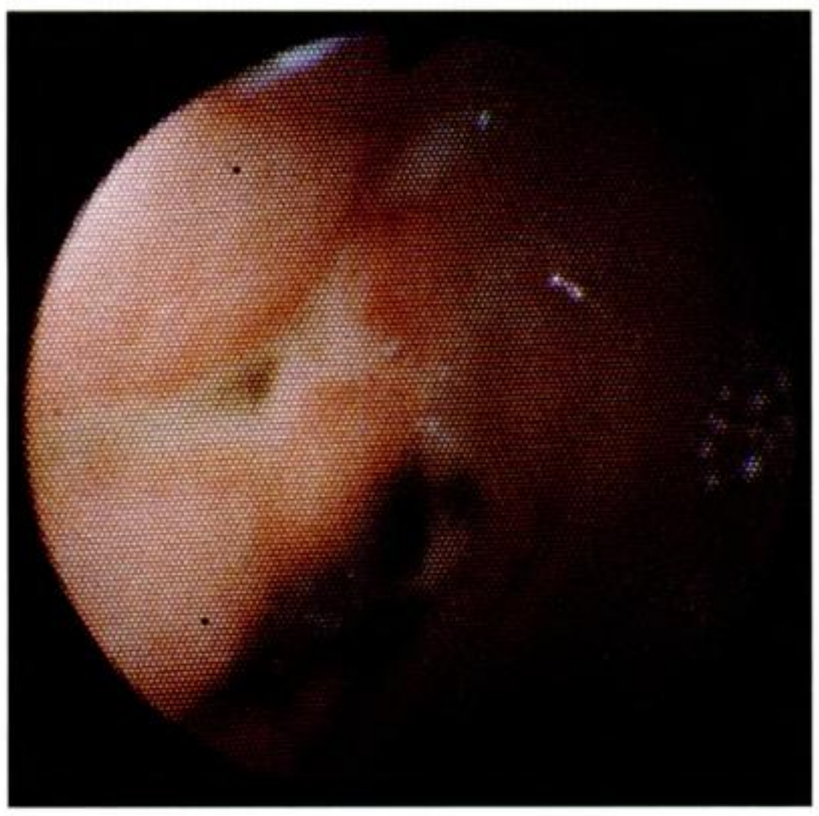
92. Large deep antral ulcer. (Image courtesy of Gary J. Russell, MD.)



93. *A,B,* Aspirin induced "kissing" antral ulcer. (Images courtesy of Jeong Kee Seo, MD and Jorge Oscar Donatone, MD.)

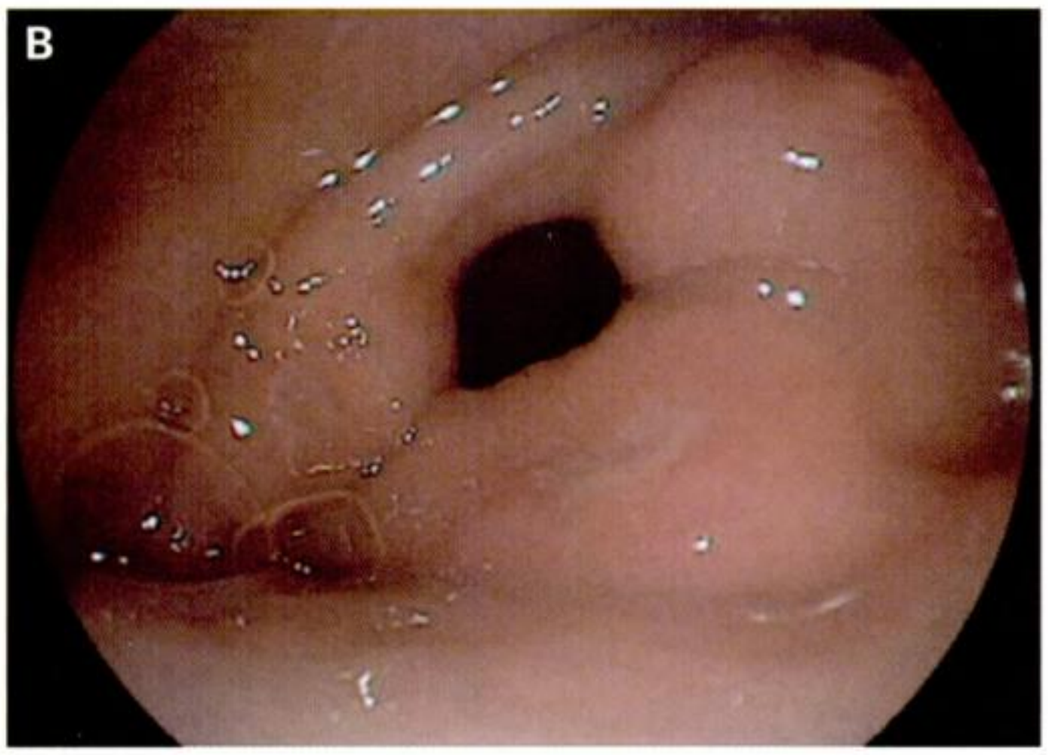


94. Idiopathic solitary antral ulcer.

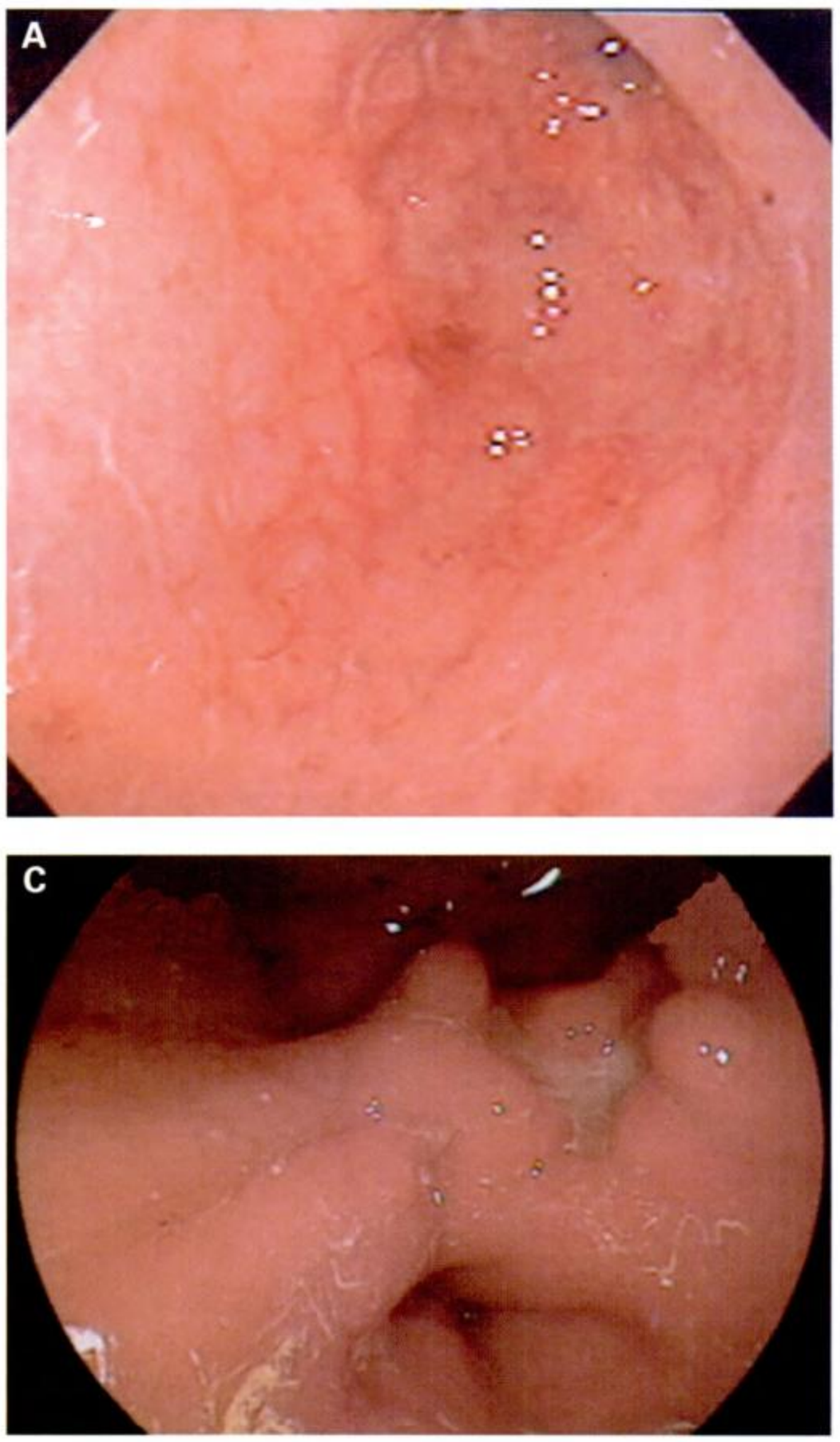


95. Gastric antral ulcer due to aspirin.

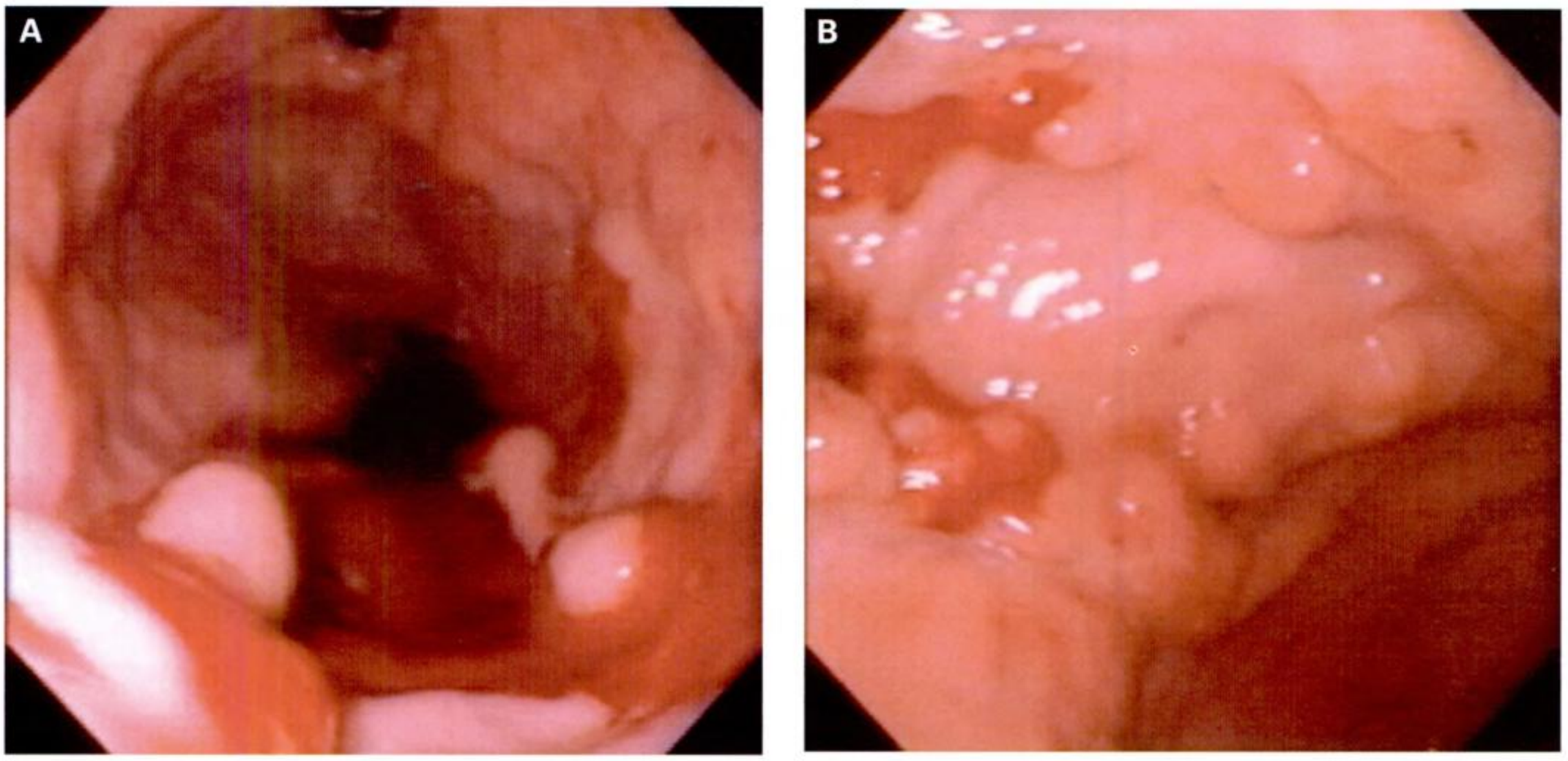
Crohn's Disease



96. *A,* Antral erythema, loss of vascular pattern and slight nodularity. *B,* Multiple aphthoid ulcers. *C,* Antral ulcer with pyloric obstruction.

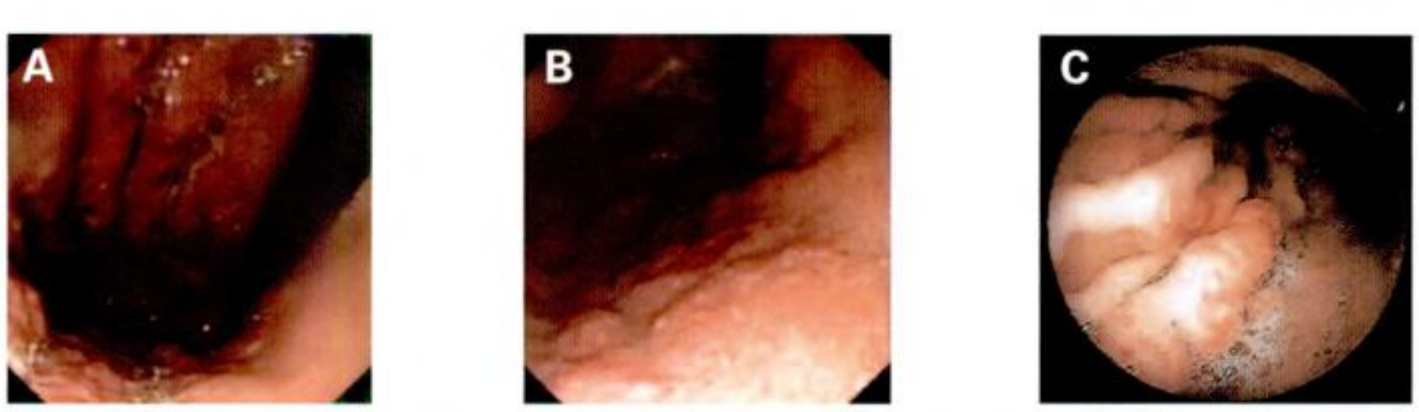


Menetrier's Disease



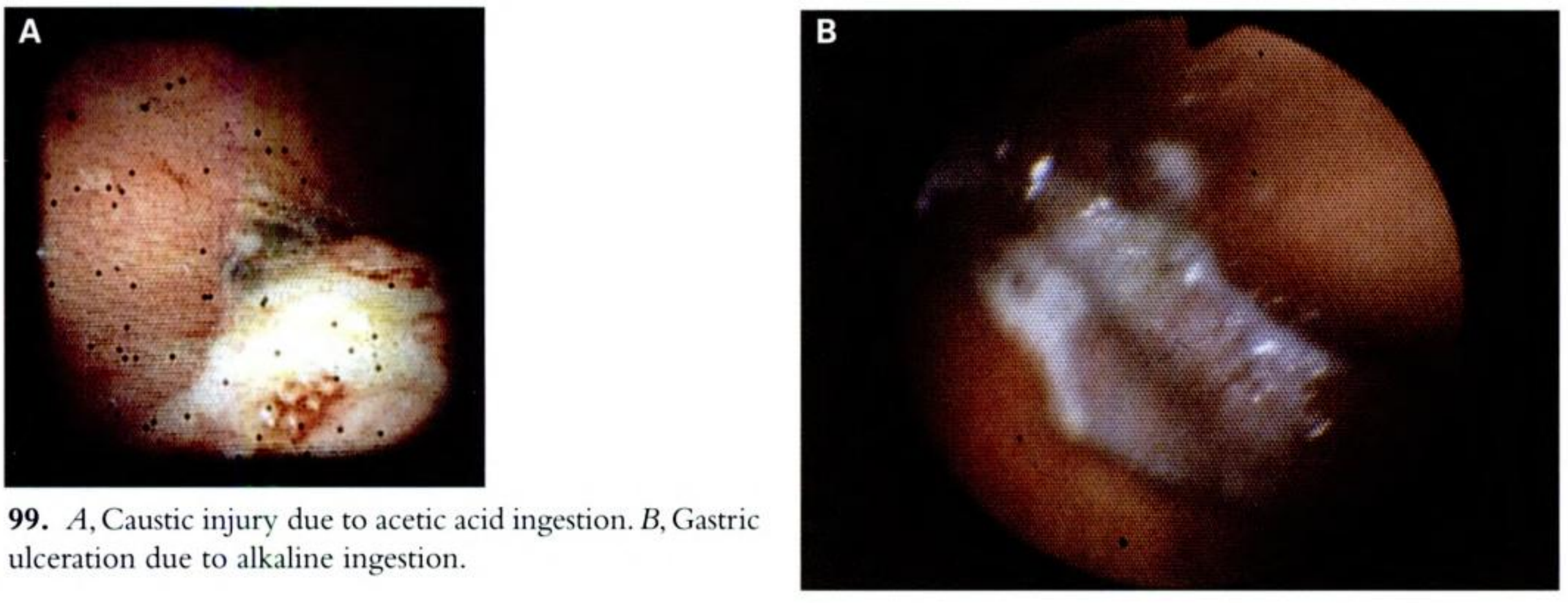
97. Enlarged corpus folds that do not flatten with air insufflation.

Cytomegalovirus Gastritis



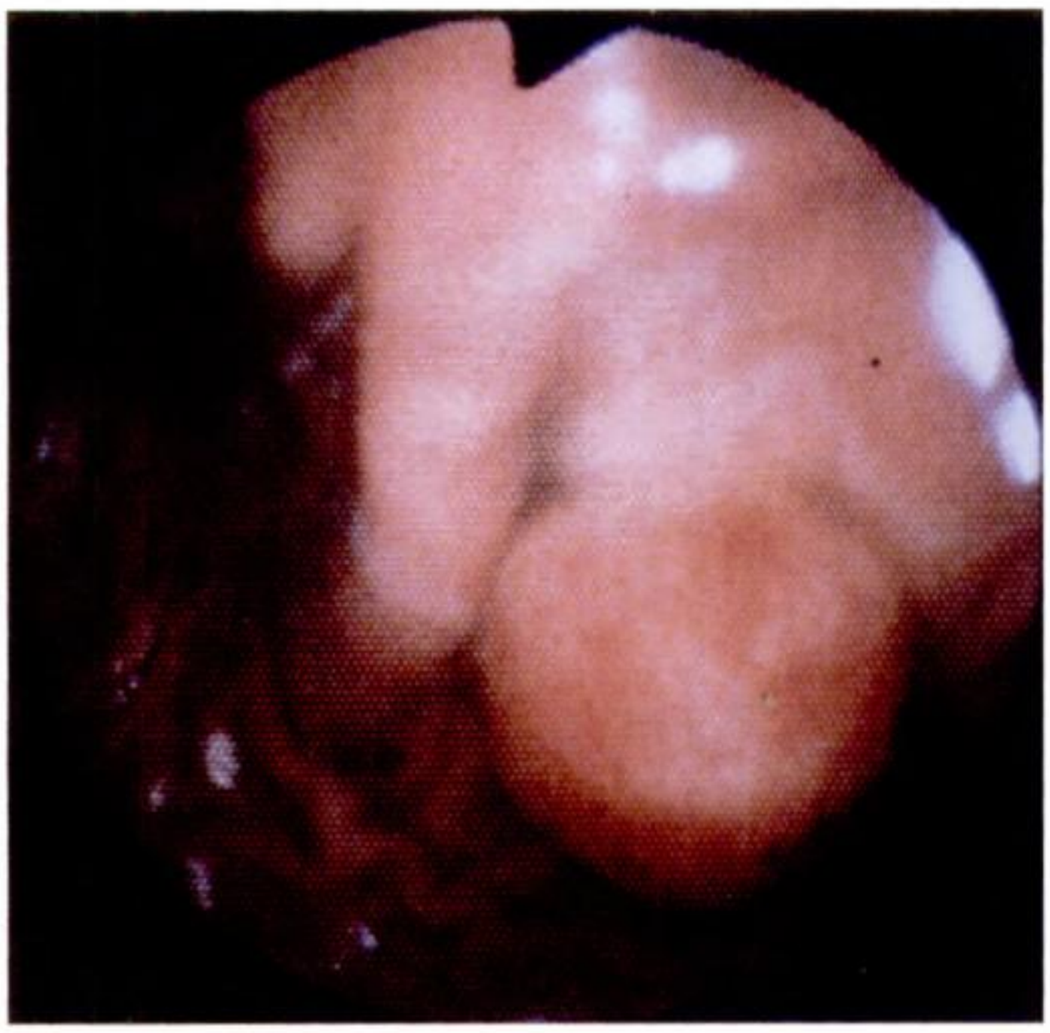
98. *A*, Swollen erythematous gastric folds and linear ulcerations between folds. *B*,C, After two weeks of ganciclovir therapy, mucosal swelling has resolved, but the mucosa remains ulcerated and irregular.

Caustic Gastritis

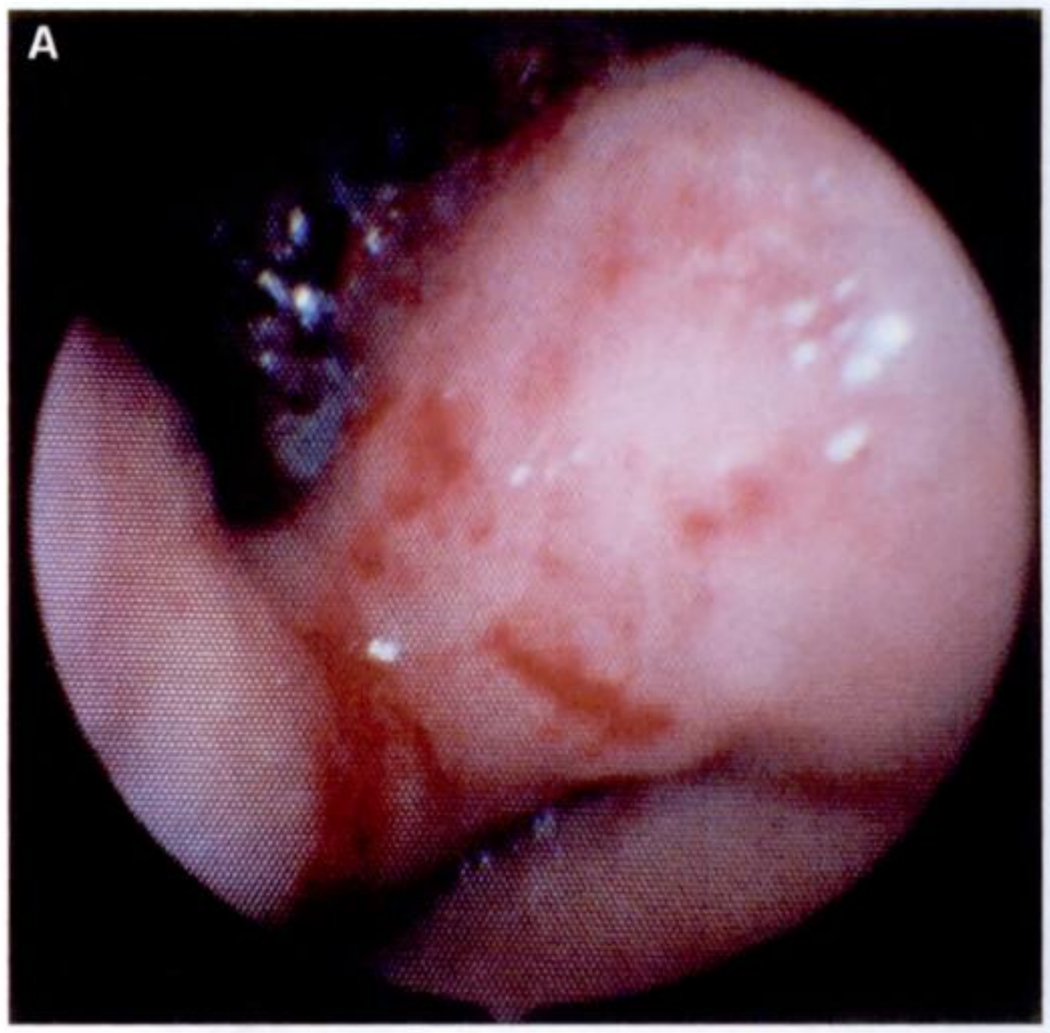


99. *A*, Caustic injury due to acetic acid ingestion. *B*, Gastric ulceration due to alkaline ingestion.

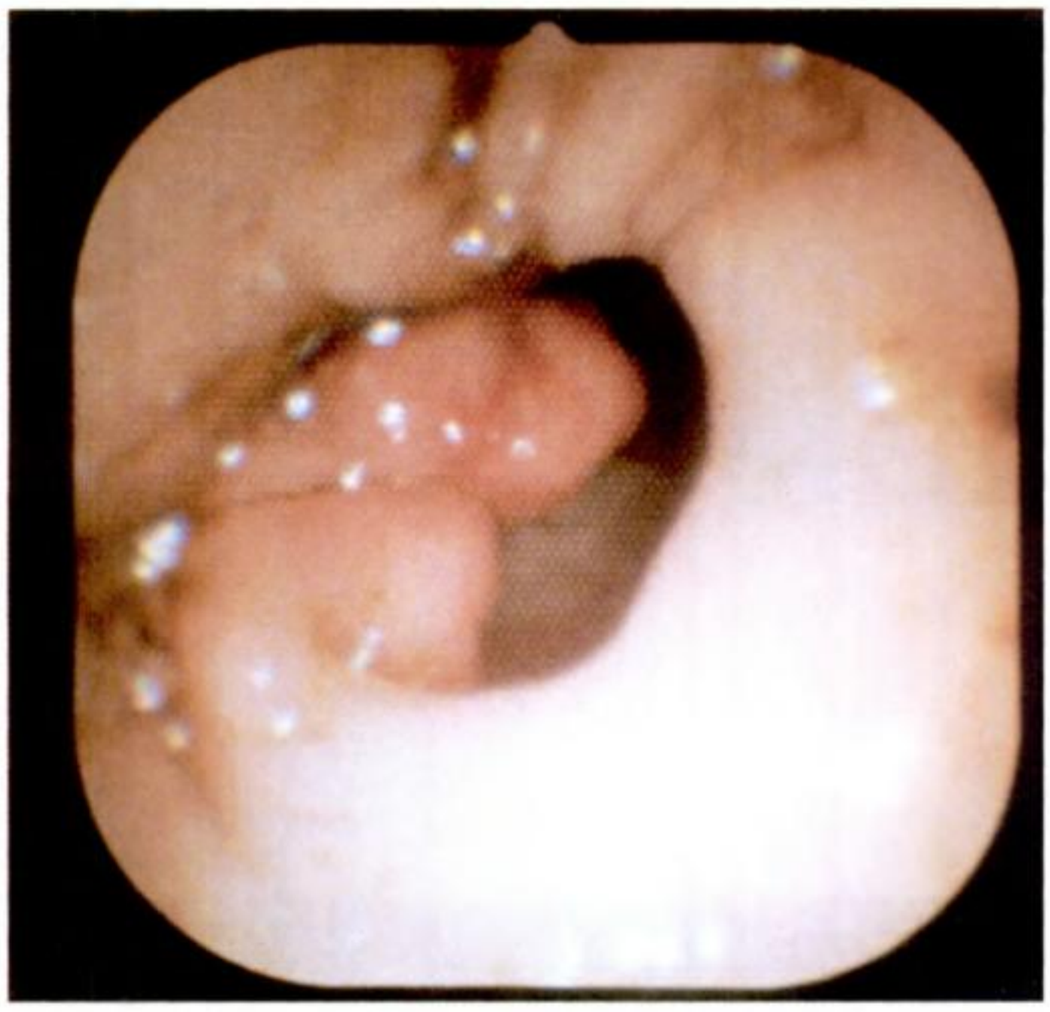
Gastric Malignancy



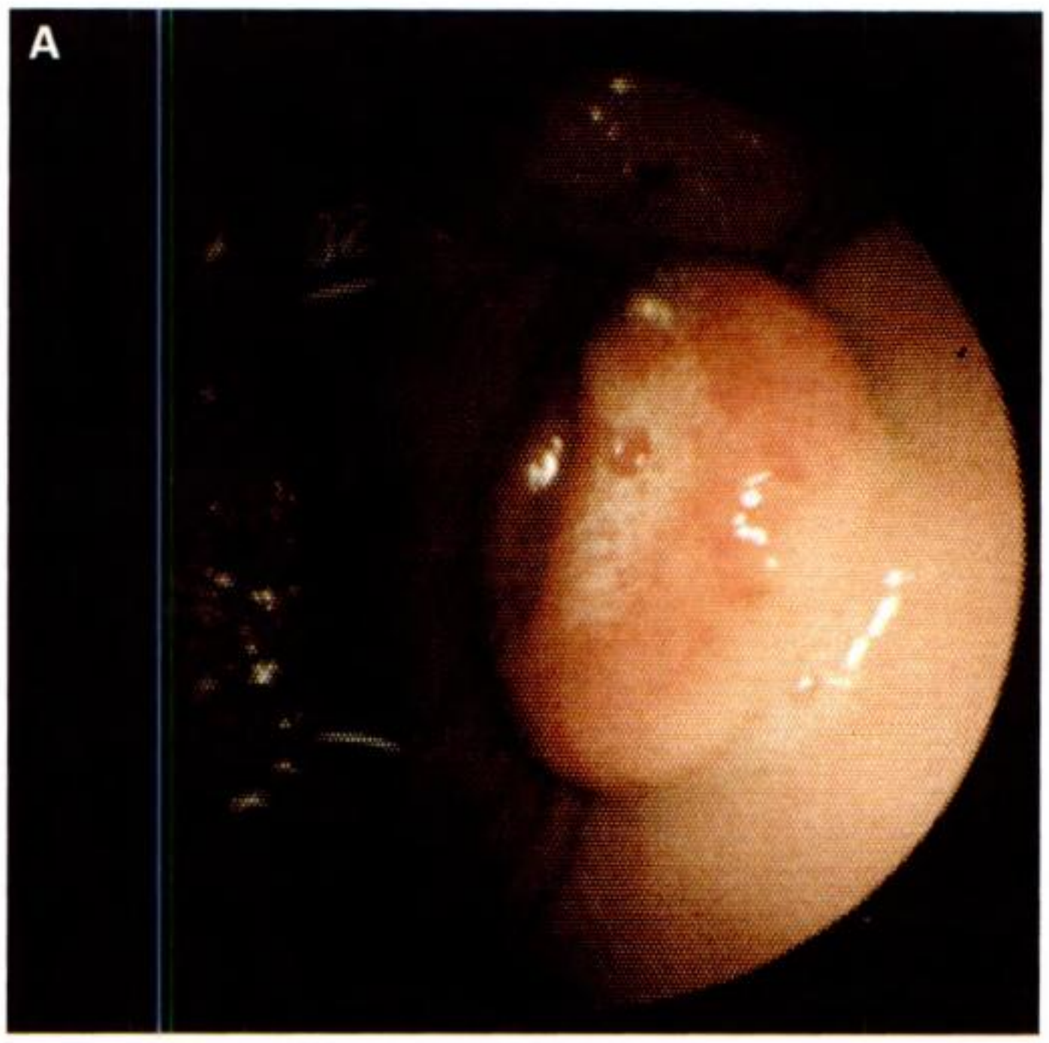
100. Polypoid lesion in gastric non-Hodgkin lymphoma.

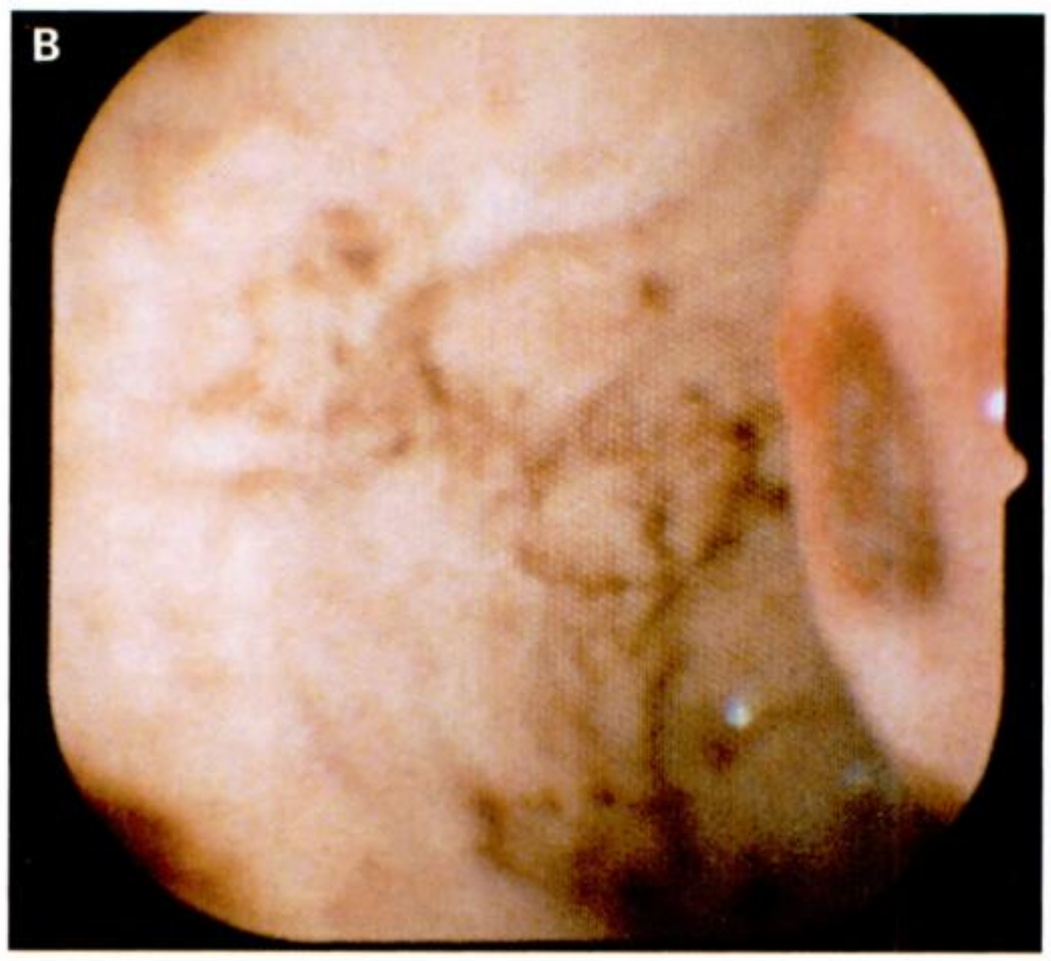


101. *A, B,* Hemorrhagic lesion due to non-Hodgkin lymphoma.

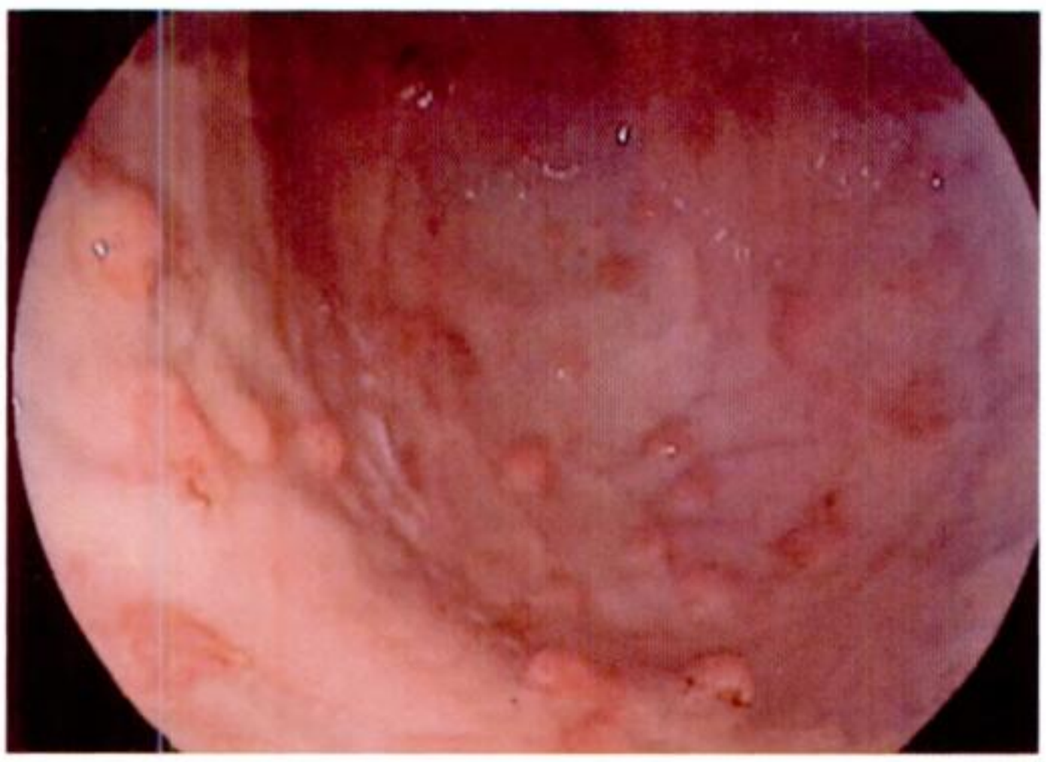


102. Gastric mesenchymal tumor associated with Carney's triad.



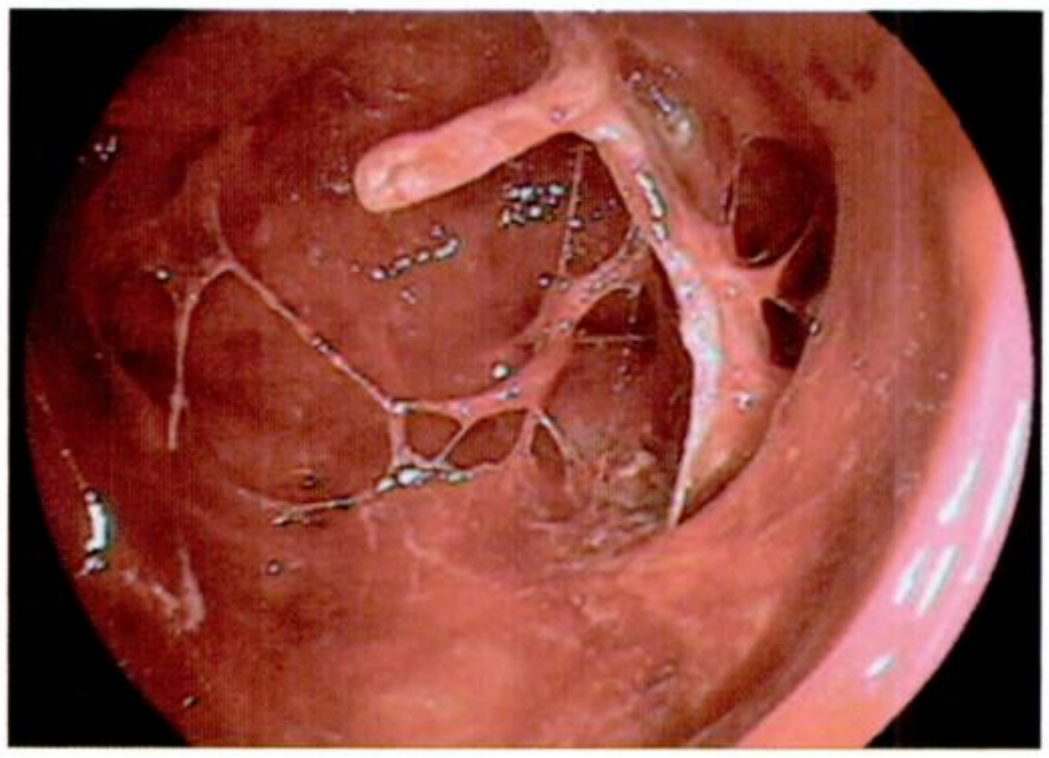


103. Gastric lymphoma in corpus seen as umbilicated mass with central ulceration.

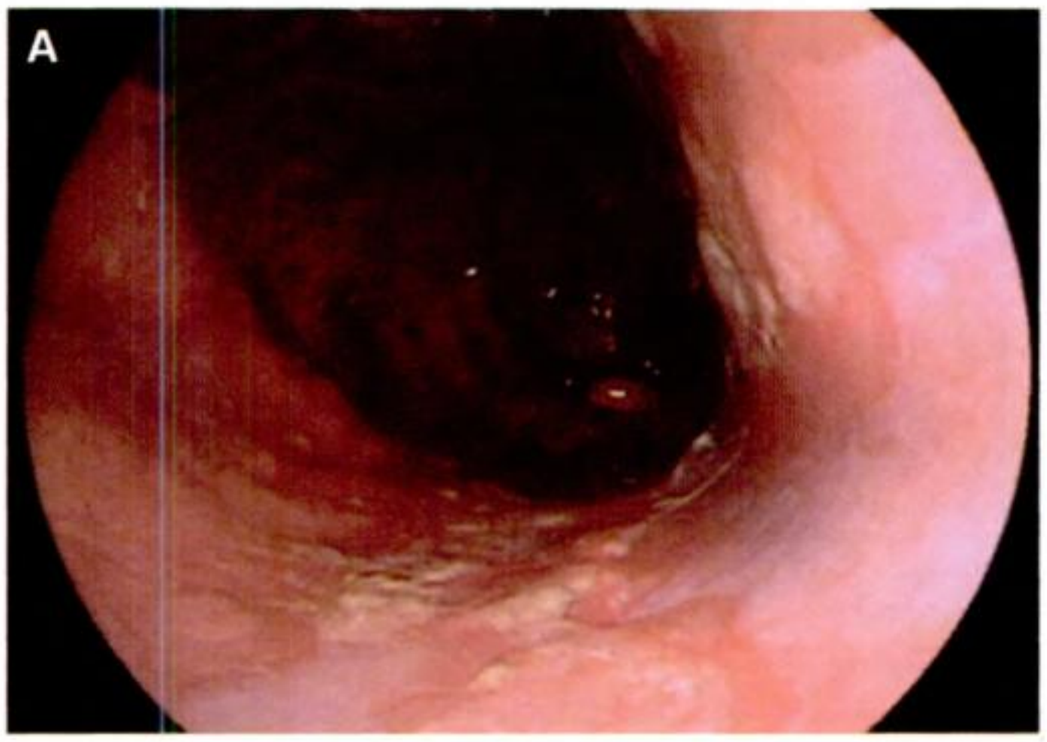


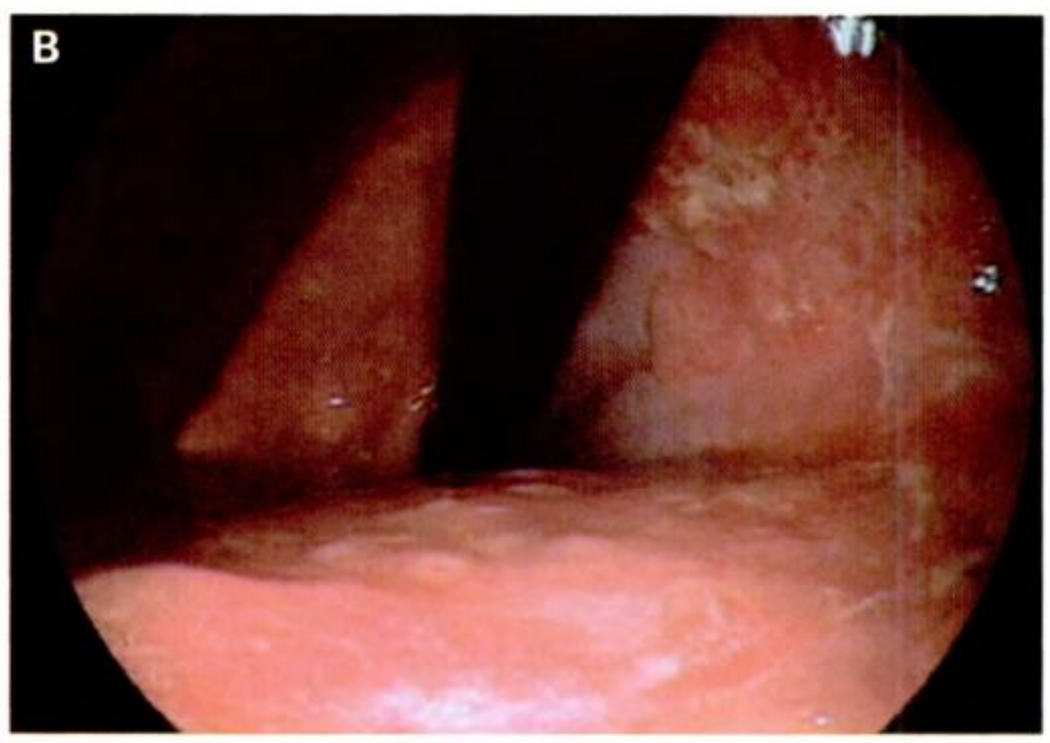
104. Kaposi's sarcoma.

Gastric Graft-versus-host Disease



105. Extensive mucosal sloughing with diffuse exudate.

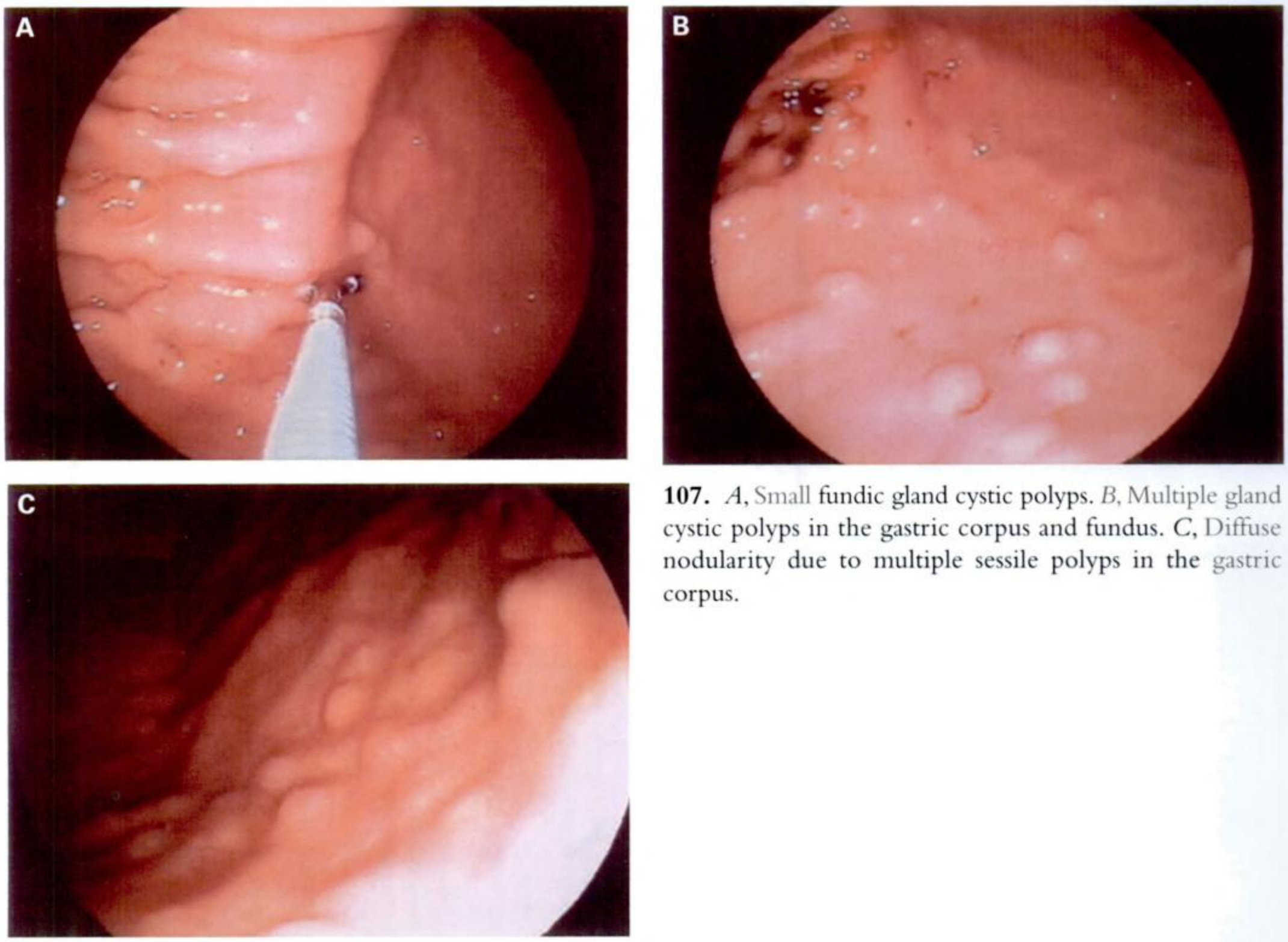




106. Extensive sloughing of gastric mucosa with focal areas of mucosal sparing.

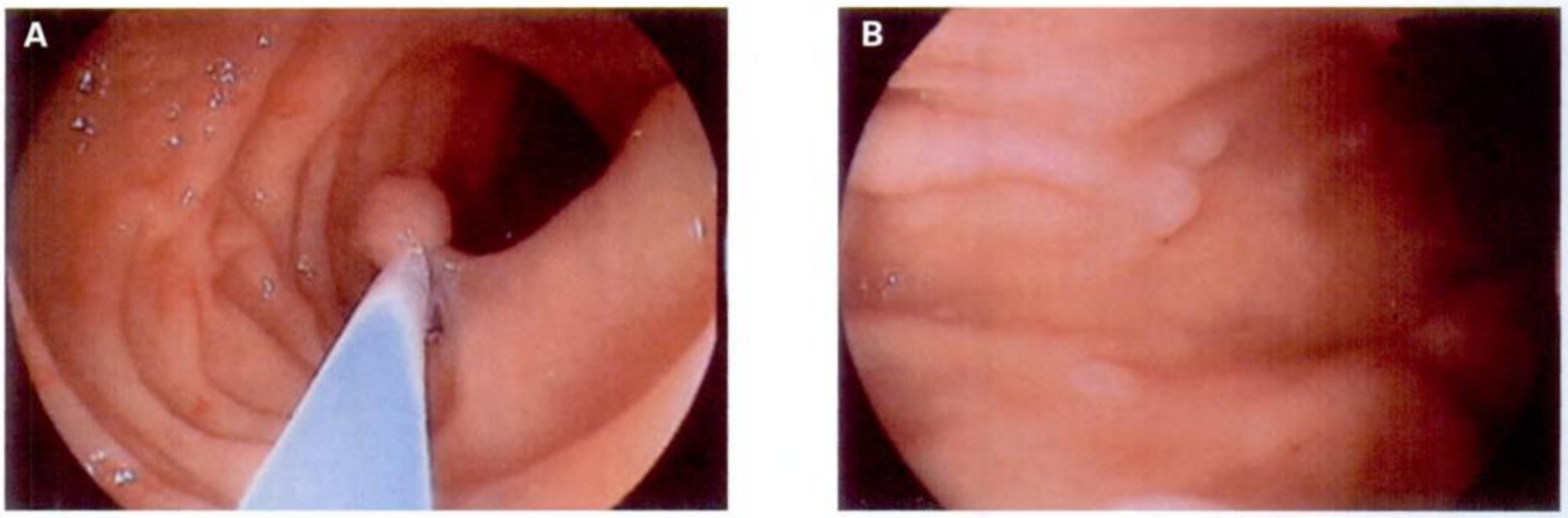
Gastric Polyps

Familial adenomatous polyposis

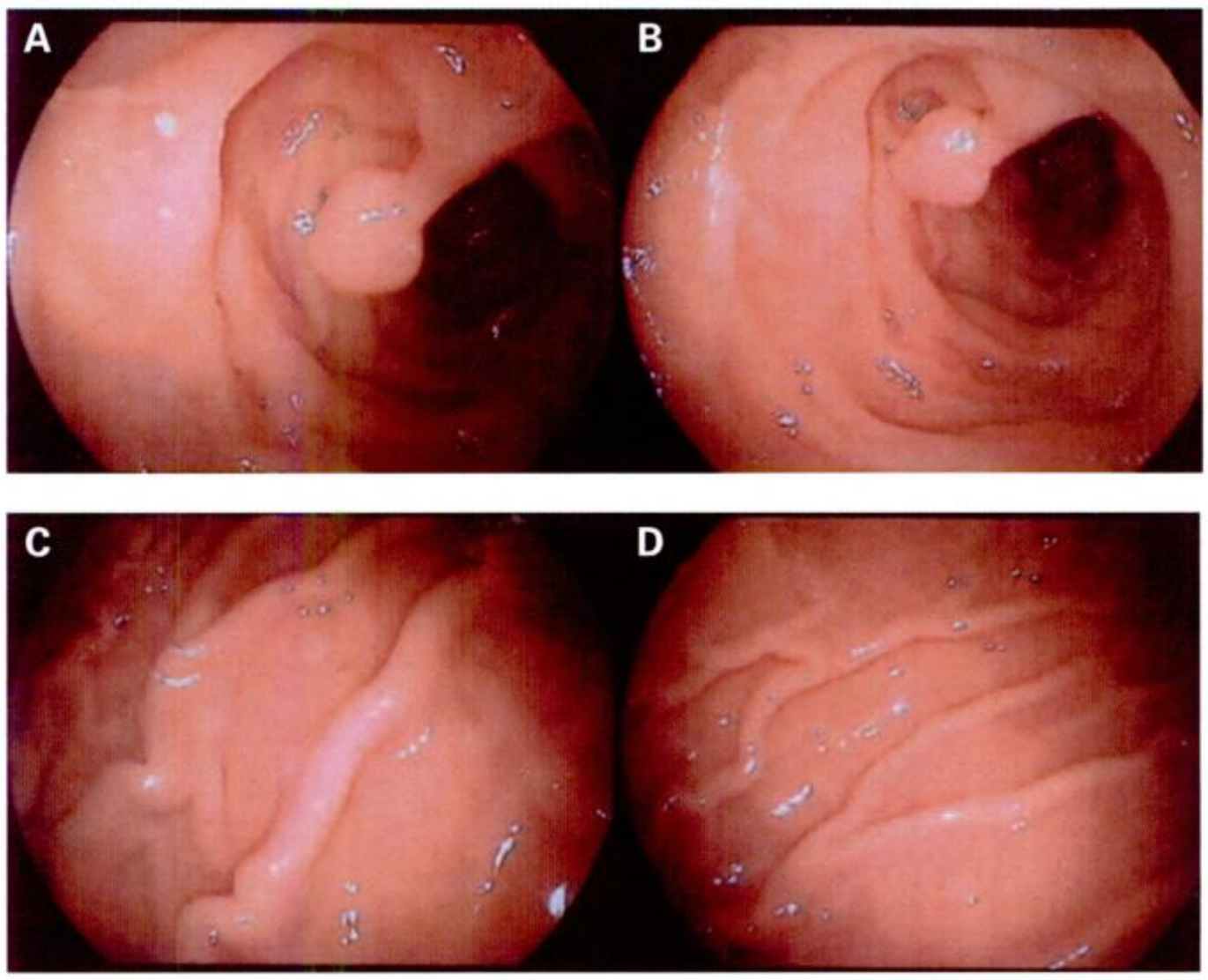


107. *A*, Small fundic gland cystic polyps. *B*, Multiple gland cystic polyps in the gastric corpus and fundus. *C*, Diffuse nodularity due to multiple sessile polyps in the gastric corpus.

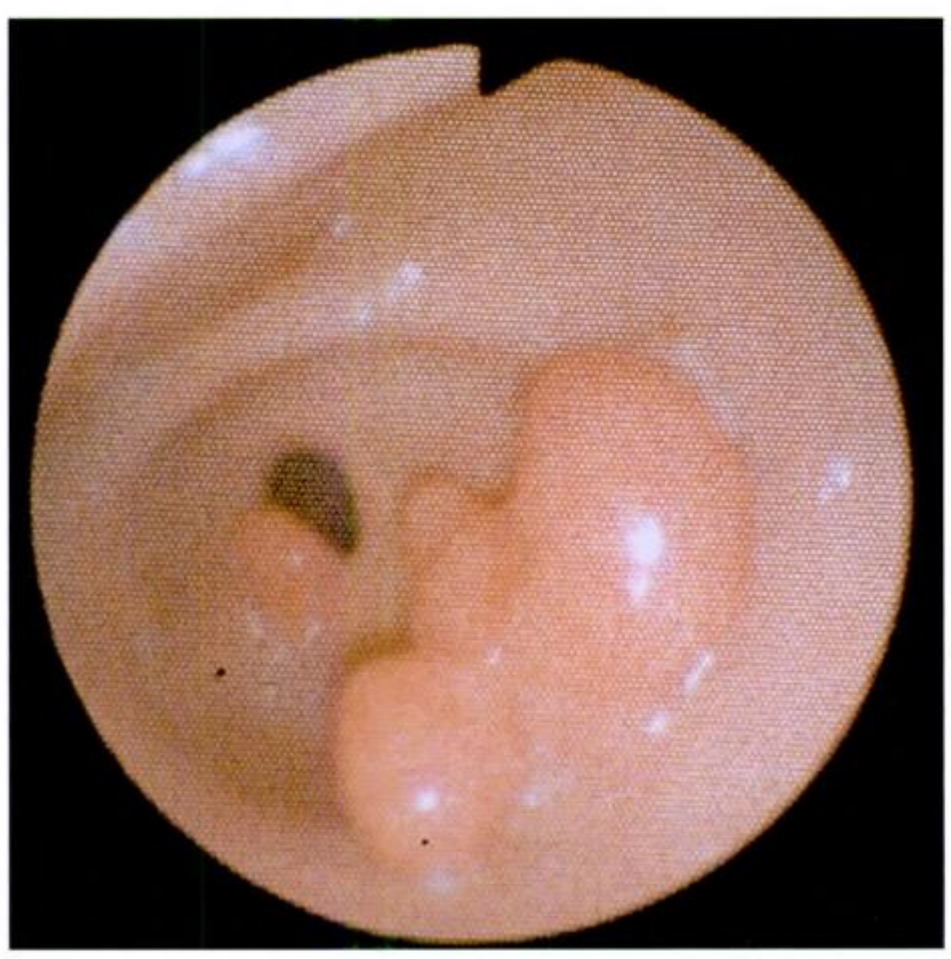
Peutz-Jeghers Syndrome



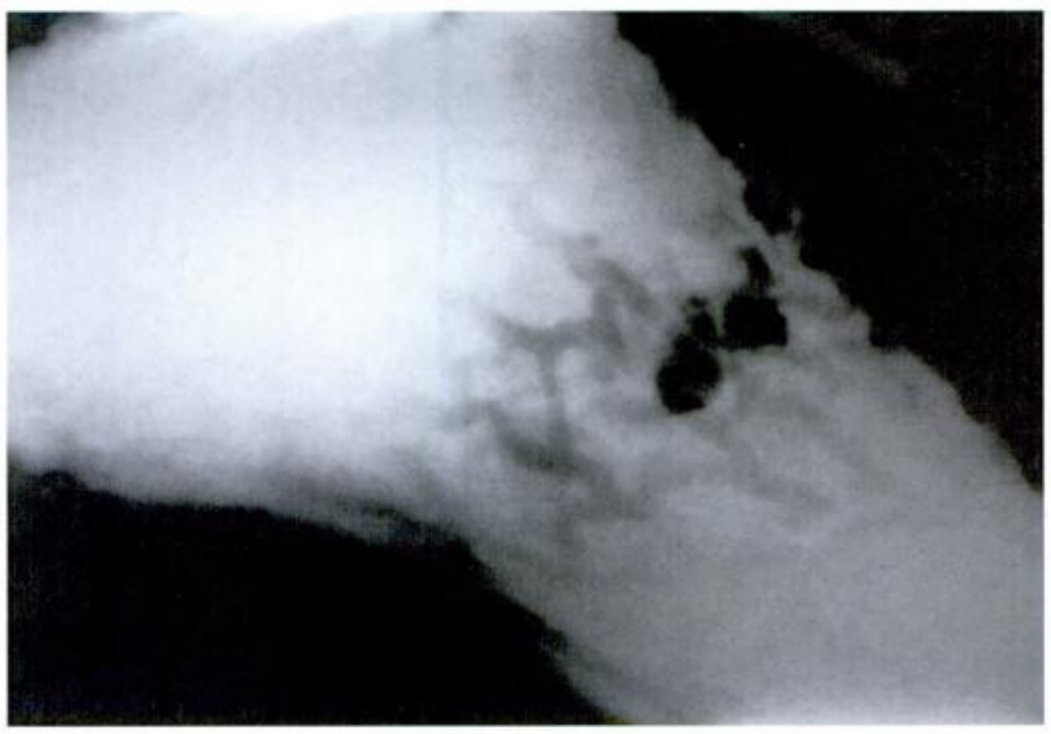
108. *A*, Small pedunculated polyp. *B*, Small sessile polyps in the gastric corpus.



109. *A,B,* Large pedunculated antral polyp. *C,D,* Tiny sessile polyps in the gastric corpus.

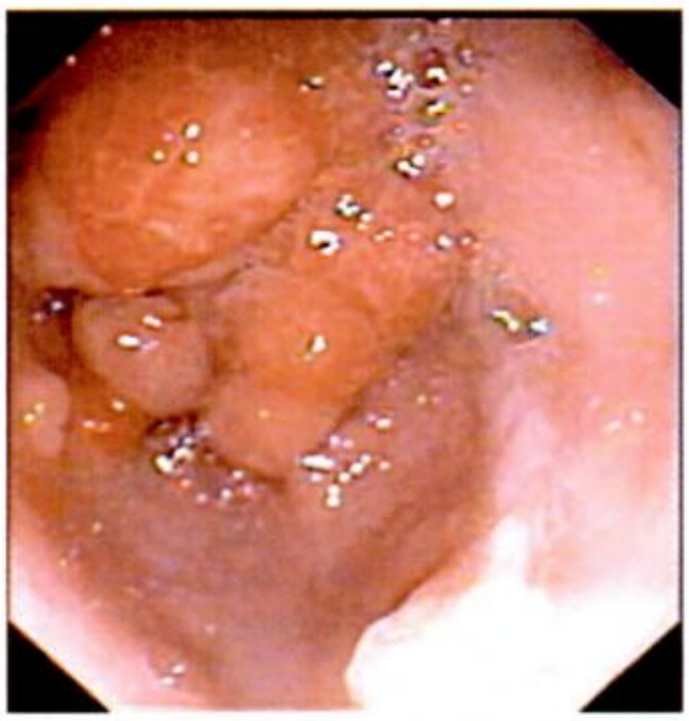


110. Multiple large sessile gastric polyps.



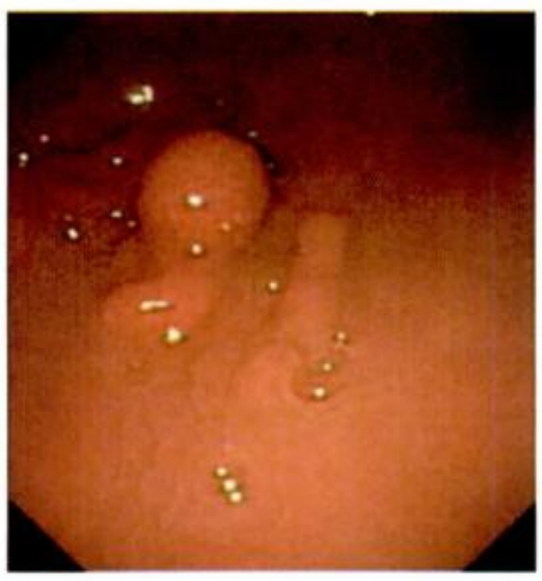
111. Barium contrast study showing a gastric polyp.

Cowden's Syndrome



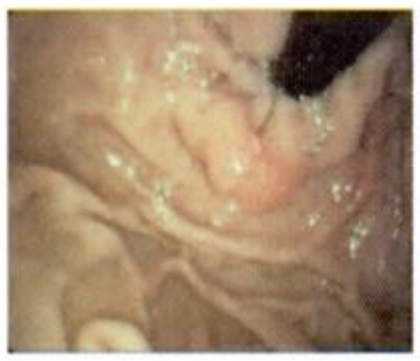
112. Multiple large sessile antral polyps blocking the pylorus.

Gastric polypoid lesions

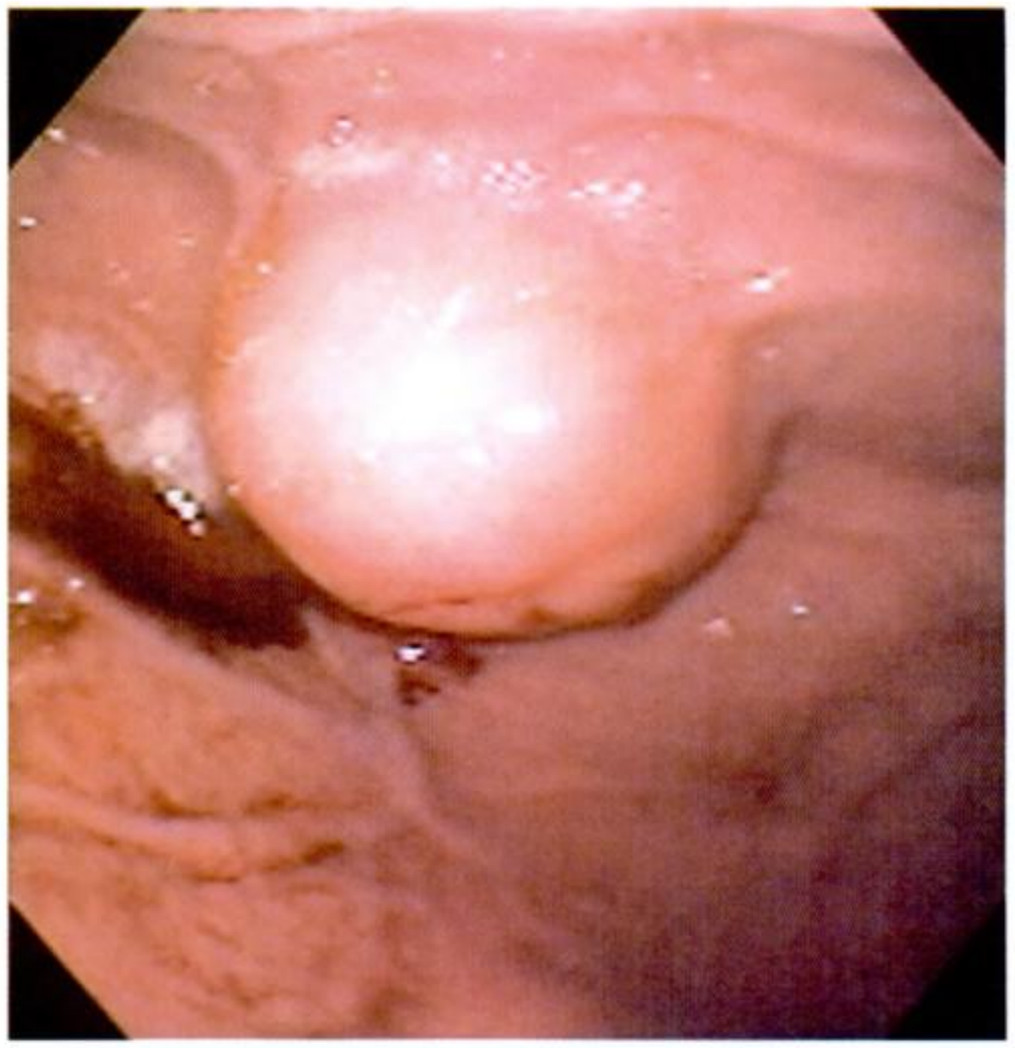


114. Antral polyp associated with portal hypertension.

Generalized Juvenile Polyposis

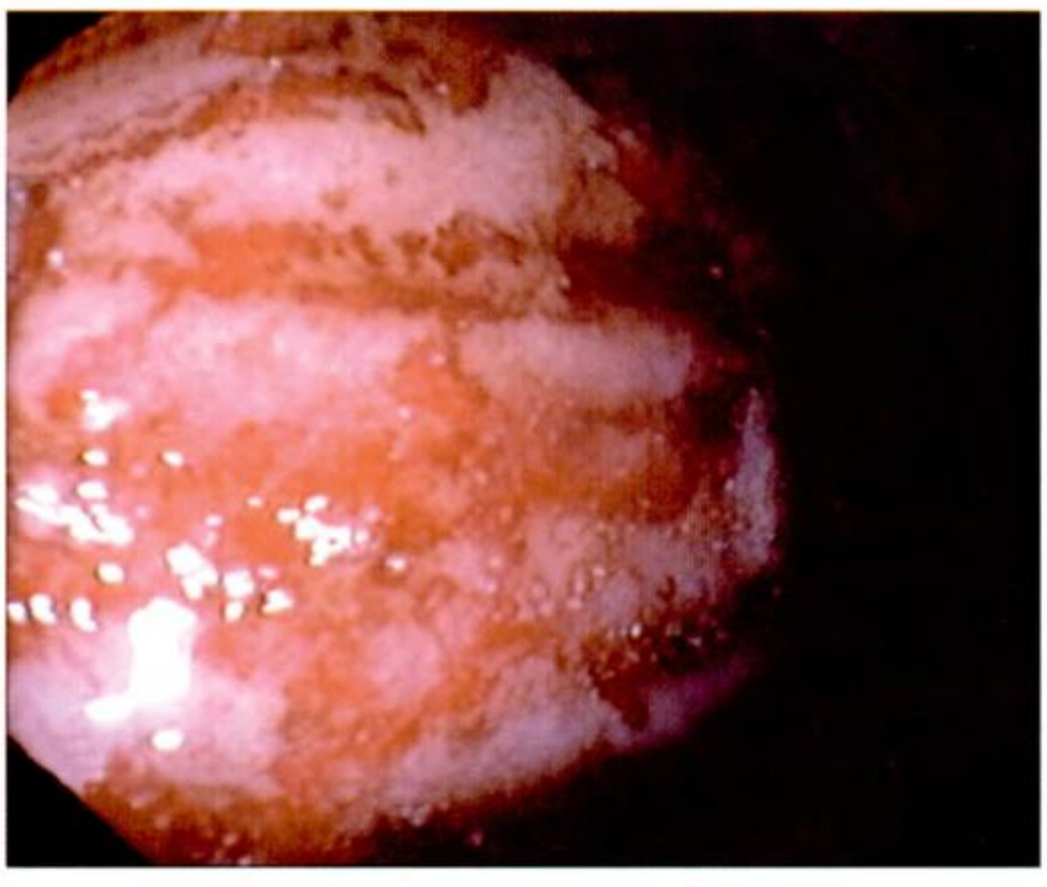


113. Gastric juvenile polyp in the cardia.

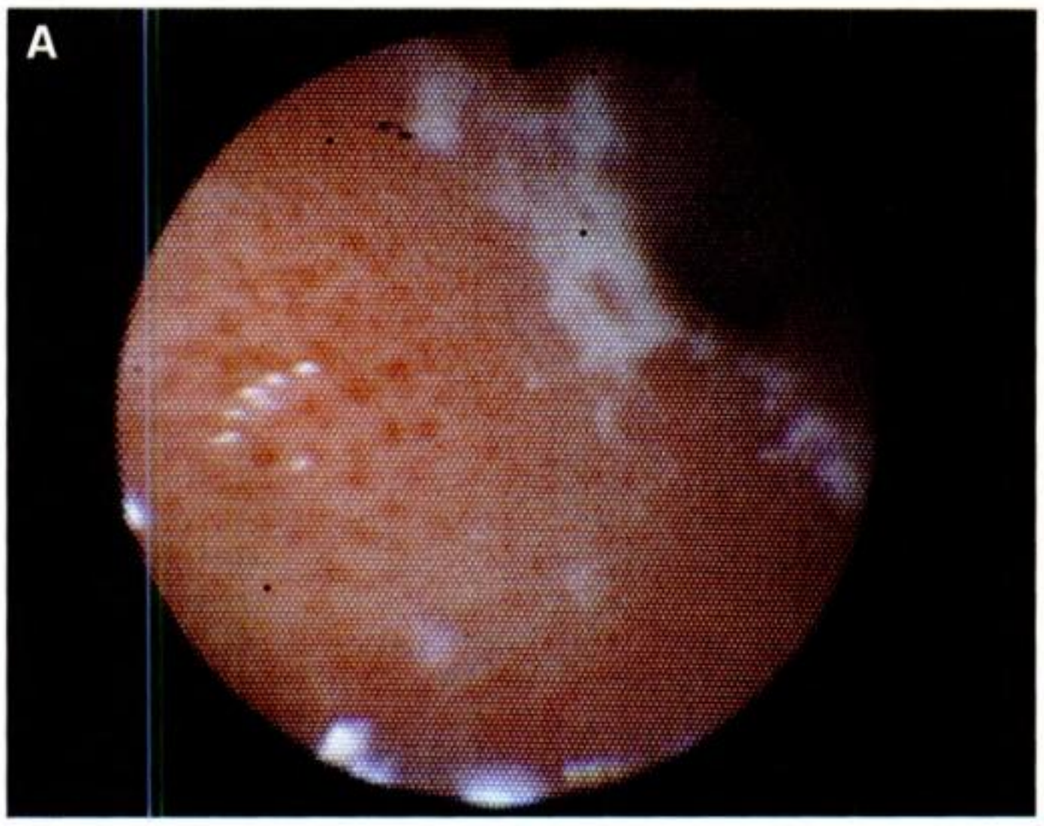


115. Gastric hamartoma.

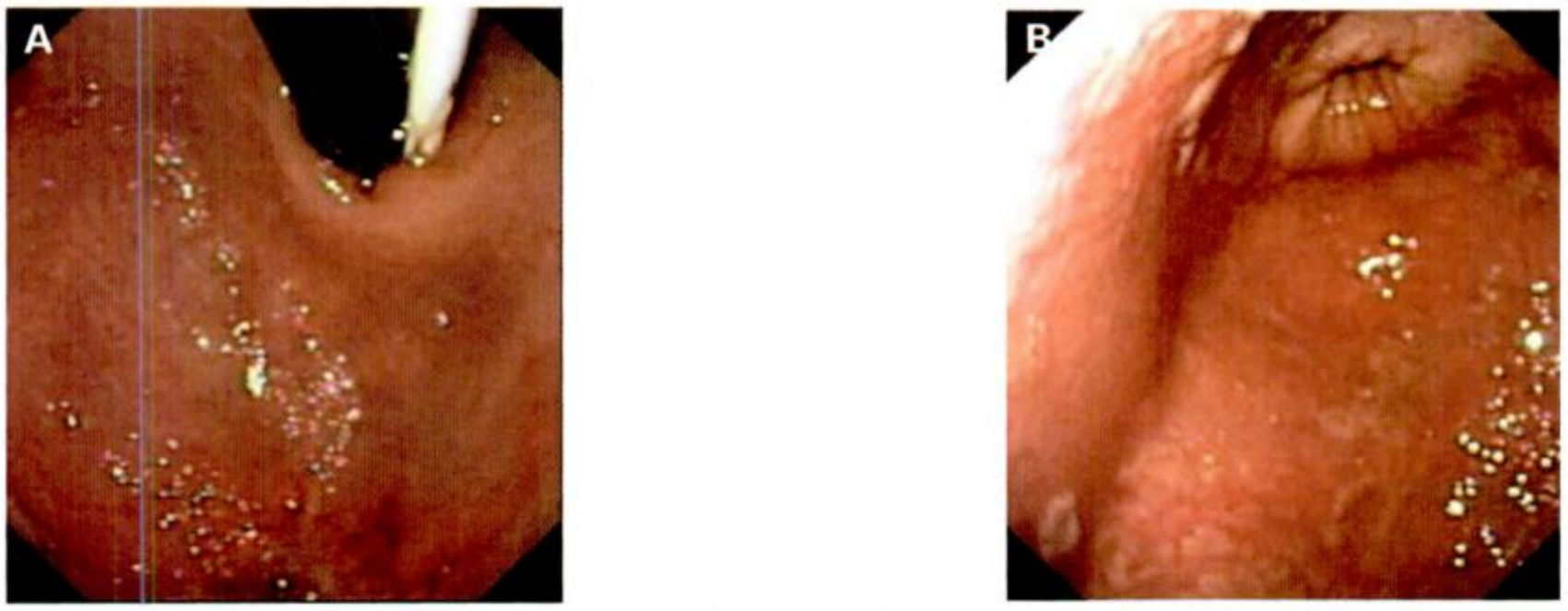
Gastropathies



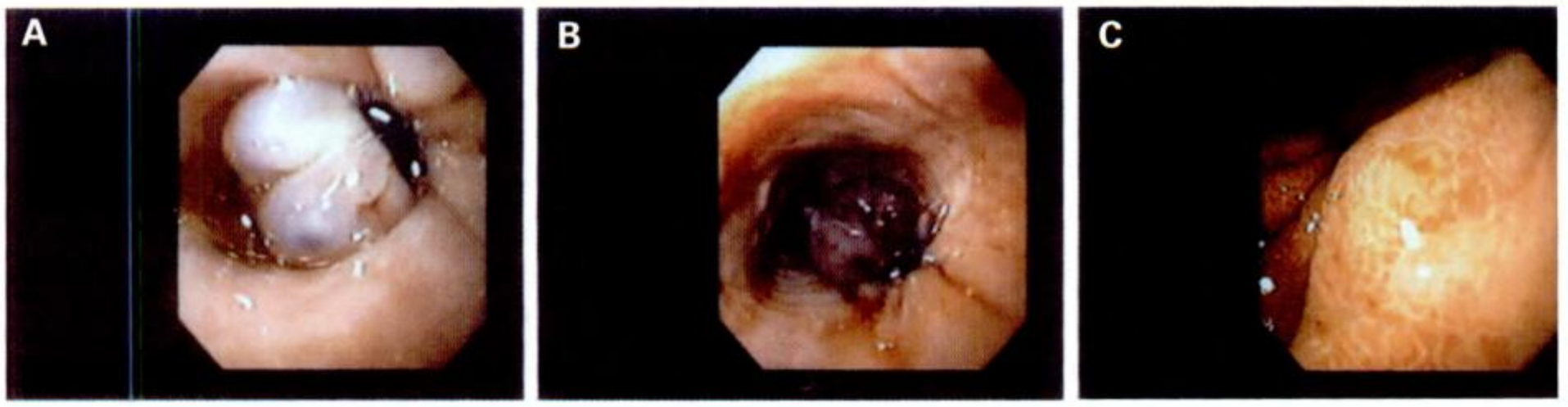
116. Traumatic gastropathy associated with persistent vomiting.



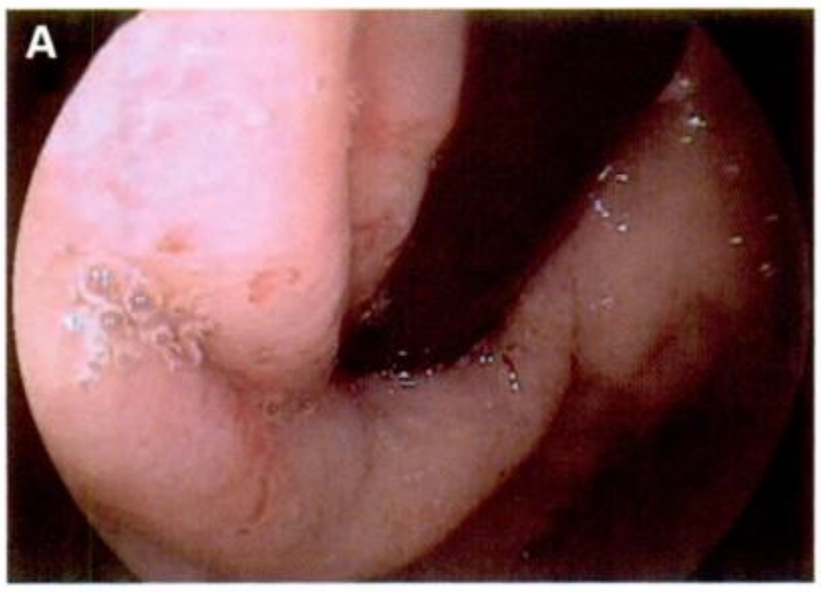
117. *Idiopathic Gastropathy. A*, In neonate with hematemesis. *B*, In an older child.

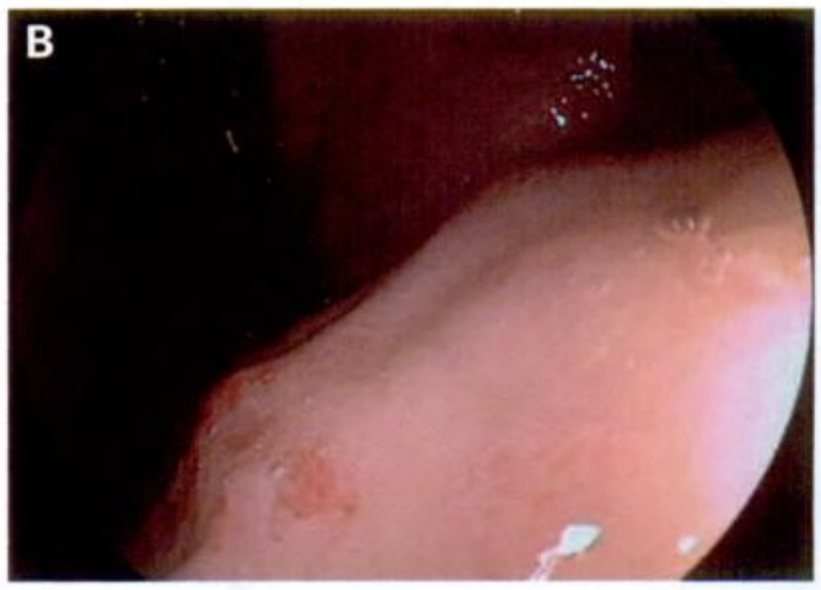


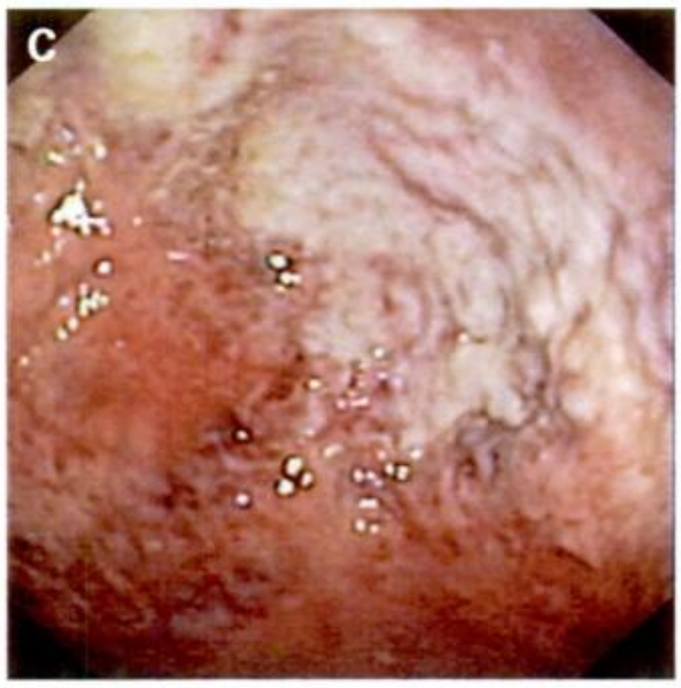
118. *Autoimmune gastropathy. A*, With metaplastic esophageal squamous mucosa in the cardia. *B*, With intestinal metaplasia of the gastric antrum.



119. *A, B*, Ligation of esophageal varices. *C*, Mild portal hypertensive gastropathy with "snakeskin" appearance. (Images courtesy of Manoel Ernesto Gonçalves, MD.)

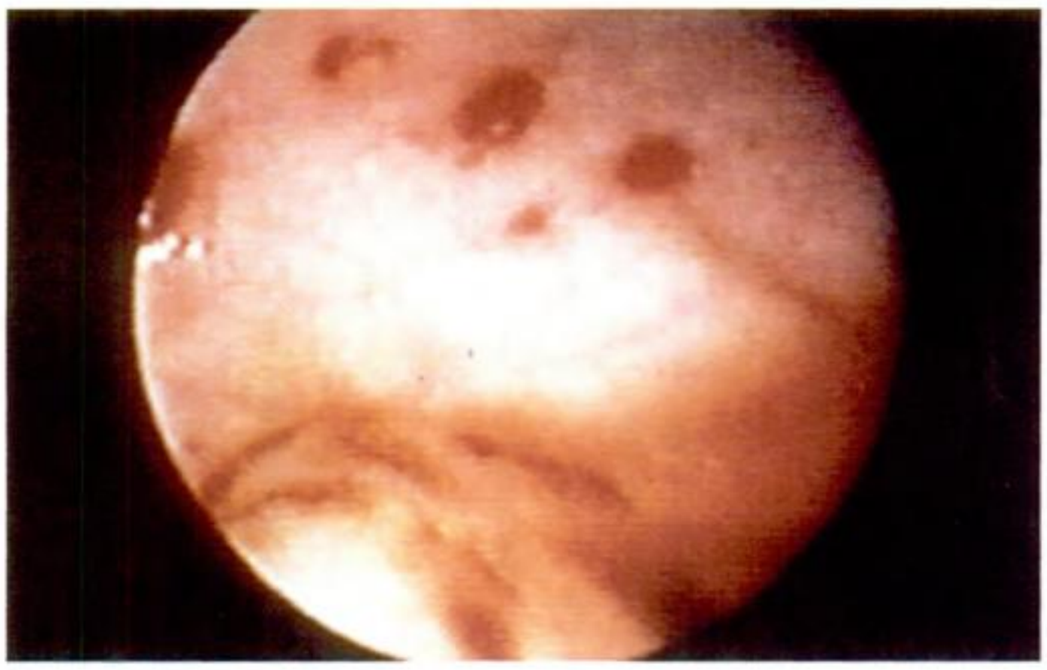




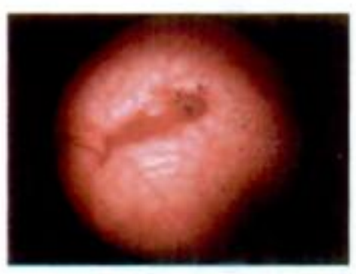


120. *A*, *B*, Idiopathic gastritis. *C*, Severe hemorrhagic and necrotizing gastritis of unknown origin. Toxic ingestion suspected.

Gastric Vascular Lesions

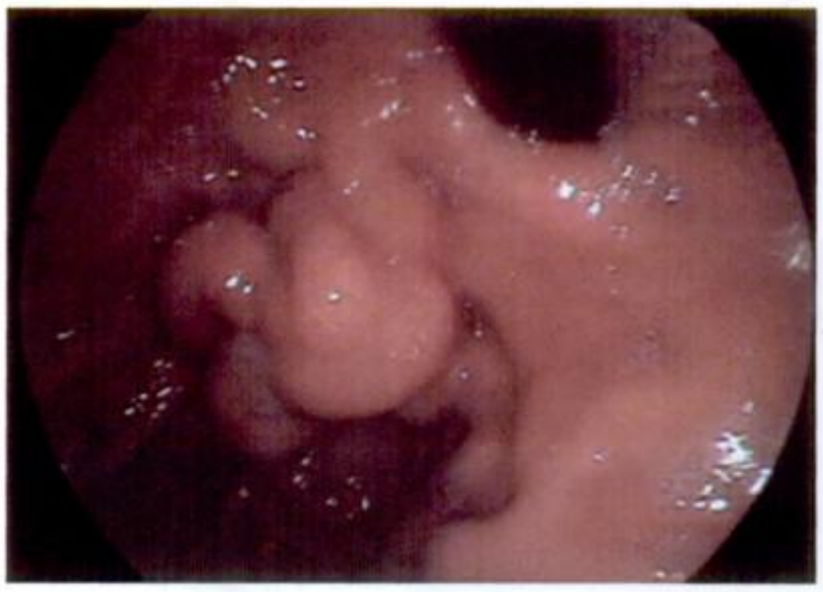


121. Hereditary hemangiomatosis and associated thrombocytopenia (Kasabach-Merritt syndrome). (Image courtesy of Julie Bines, MD.)

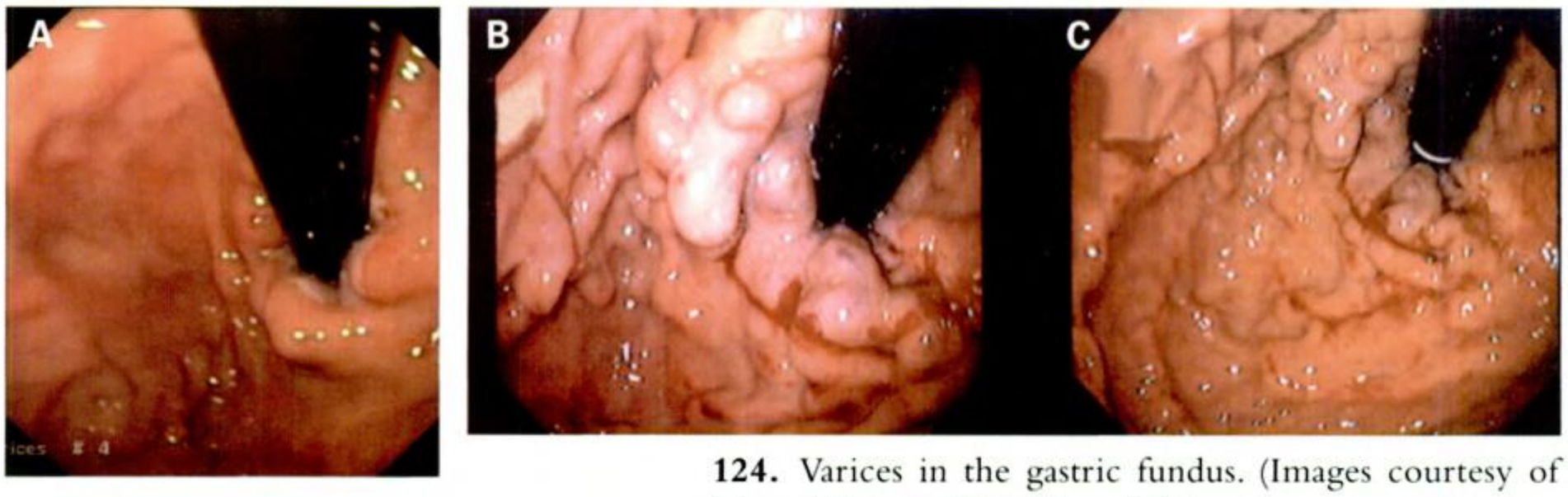


122. Hemangioma. (Image courtesy of Jorge Oscar Donatone, MD.)

Gastric Varices

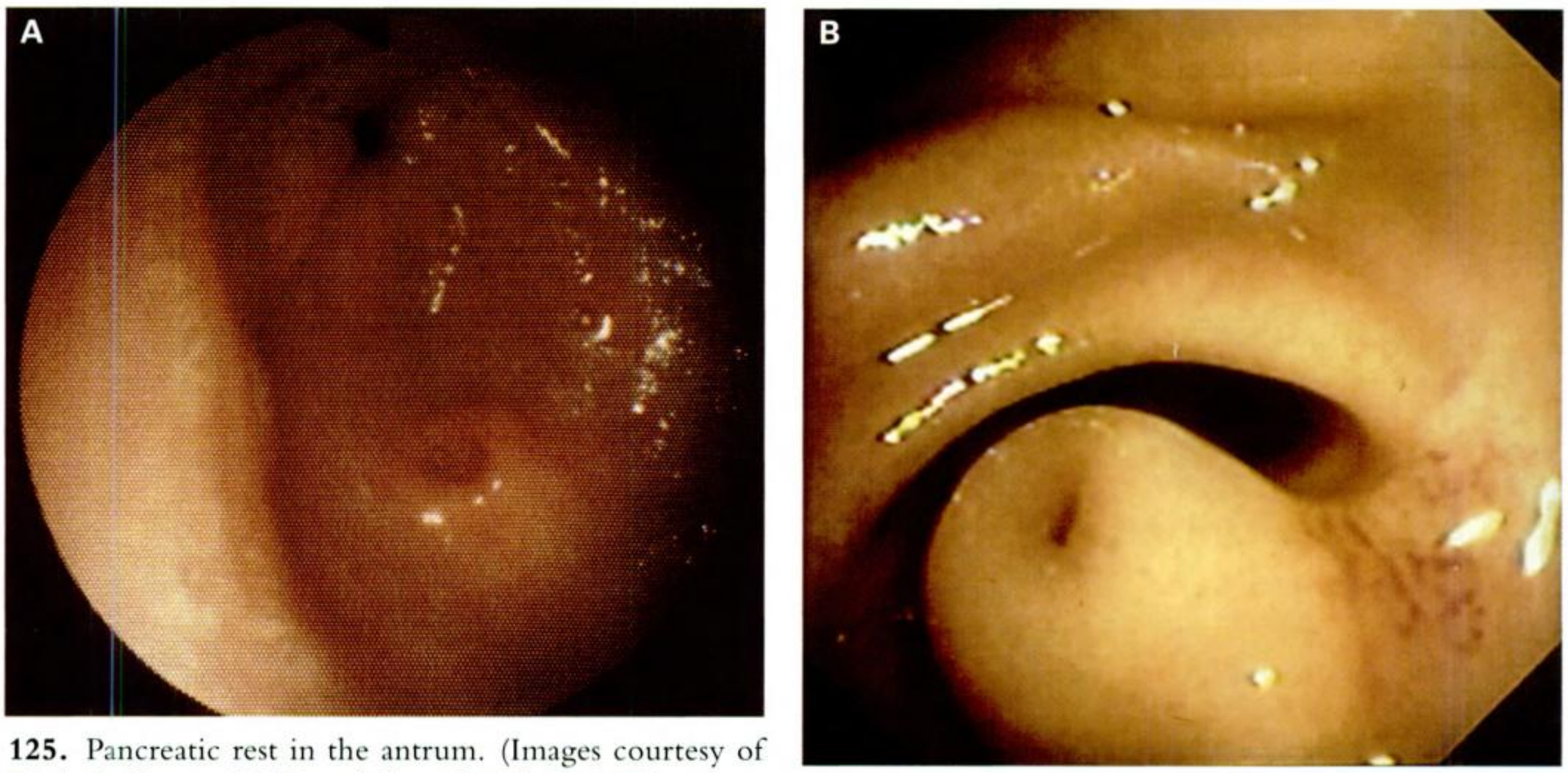


123. Large gastric varices.

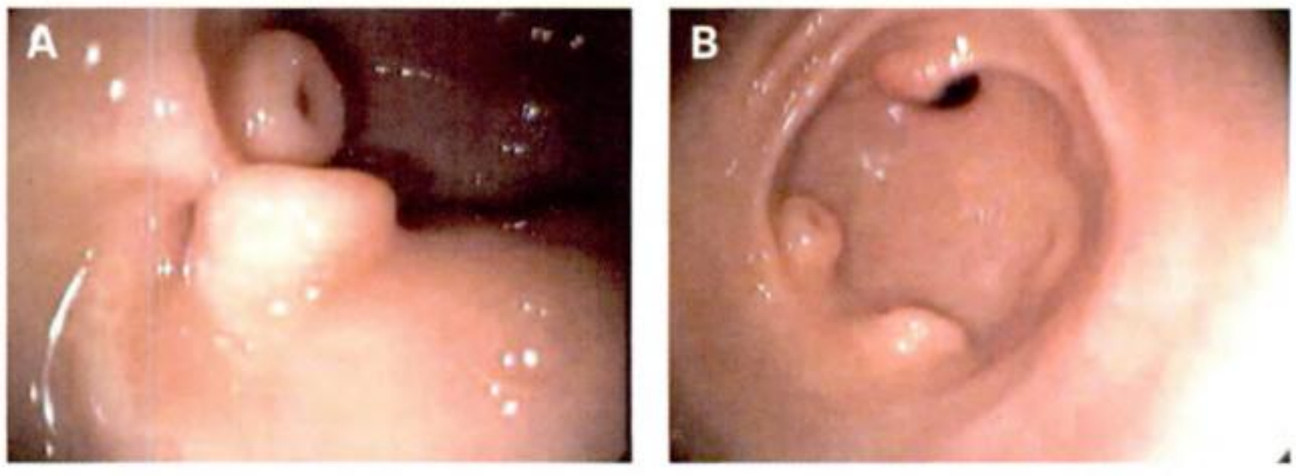


124. Varices in the gastric fundus. (Images courtesy of Manoel Ernesto Gonçalves, MD.)

Pancreatic Rest

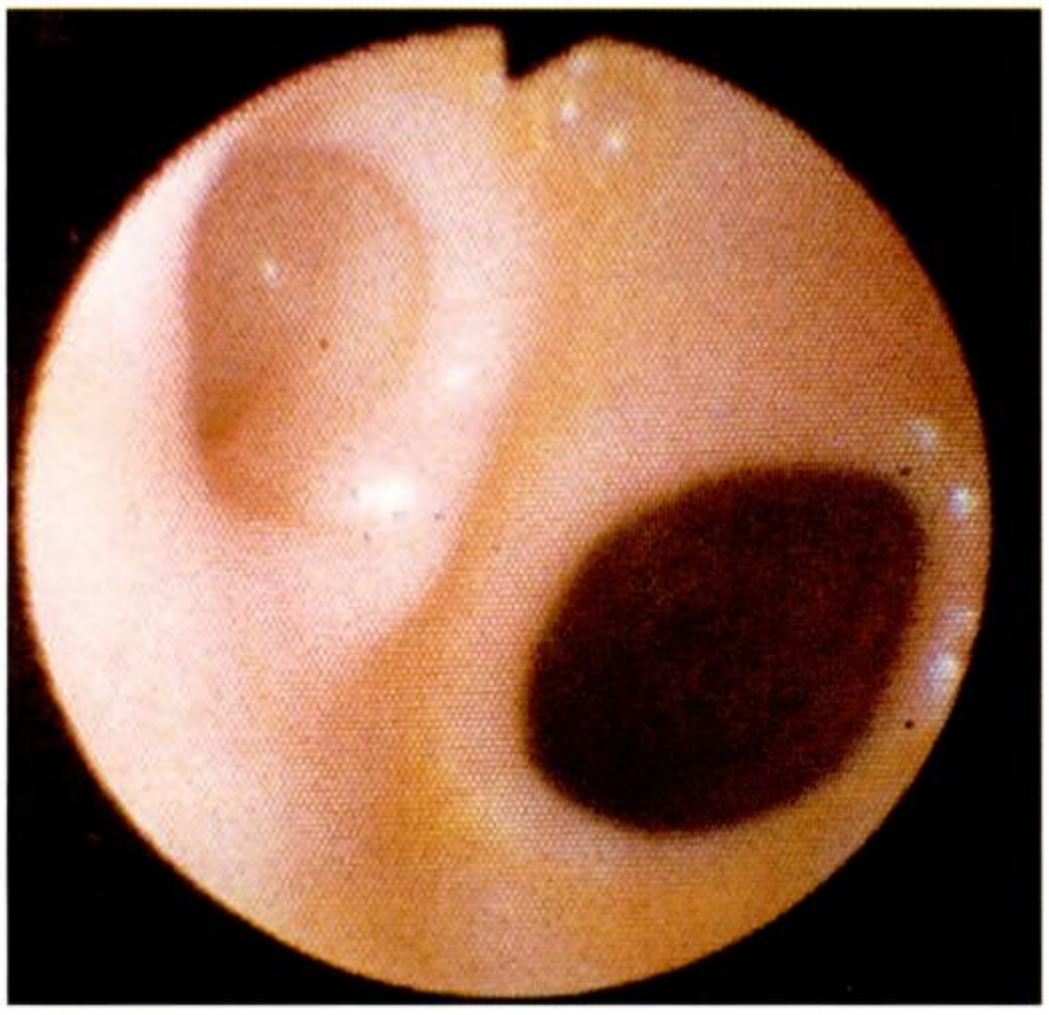


125. Pancreatic rest in the antrum. (Images courtesy of Frederic Gottrand, MD and Ahmed Maherzi, MD.)

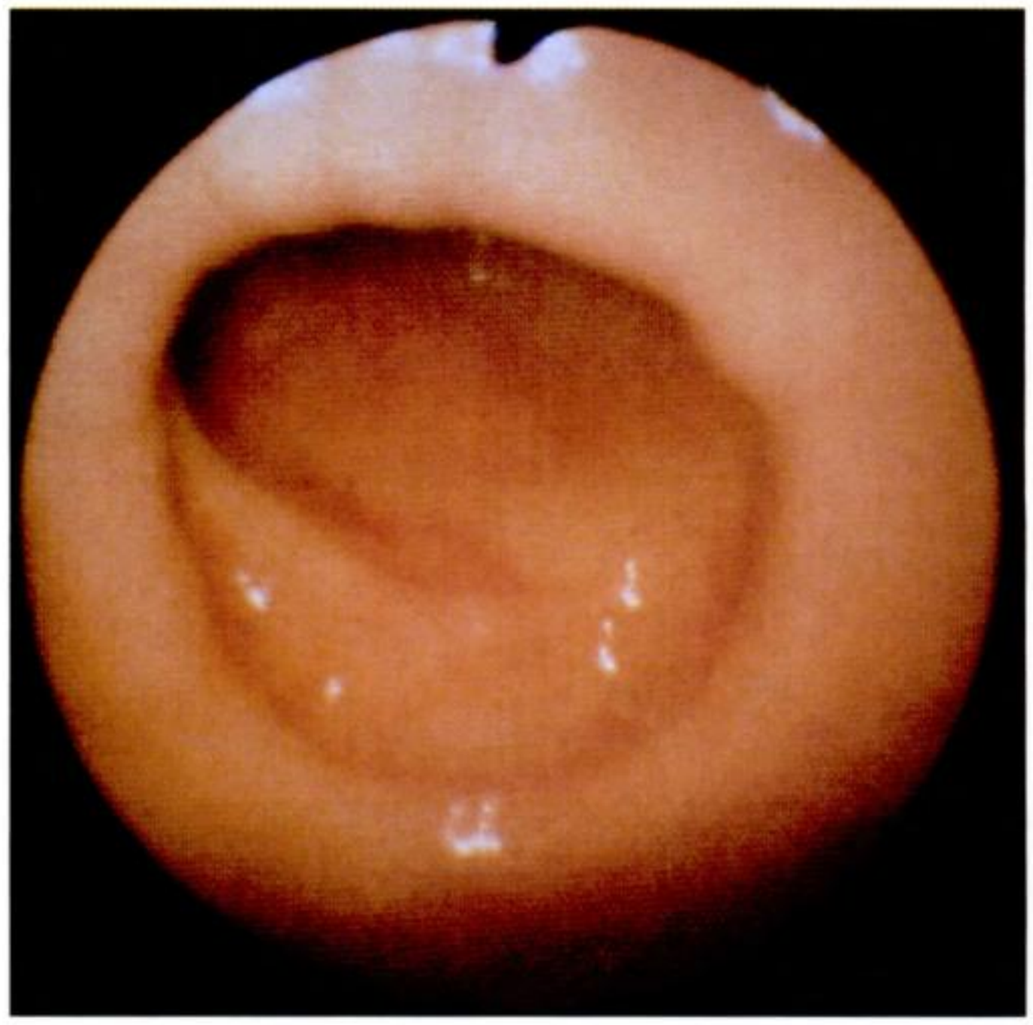


126. Multiple pancreatic rests in the antrum. (Images courtesy of Timothy M. Buie, MD.)

Congenital Gastric Anomalies



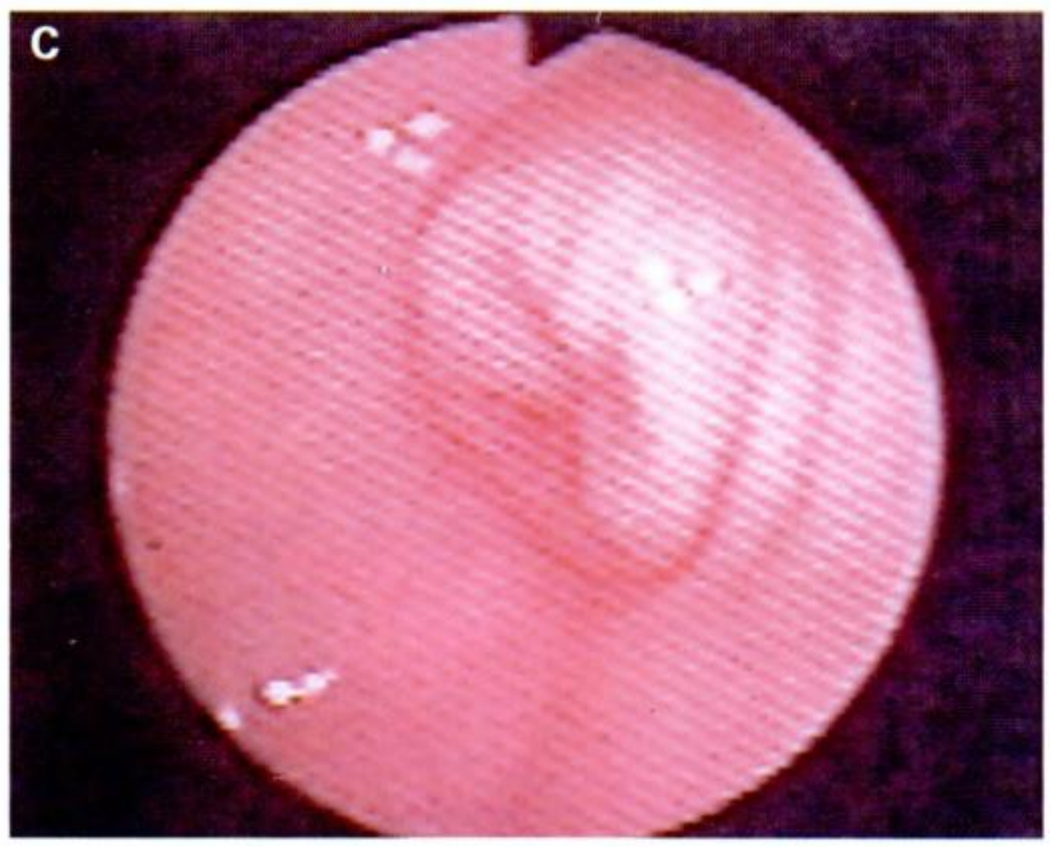
127. Gastric duplication.

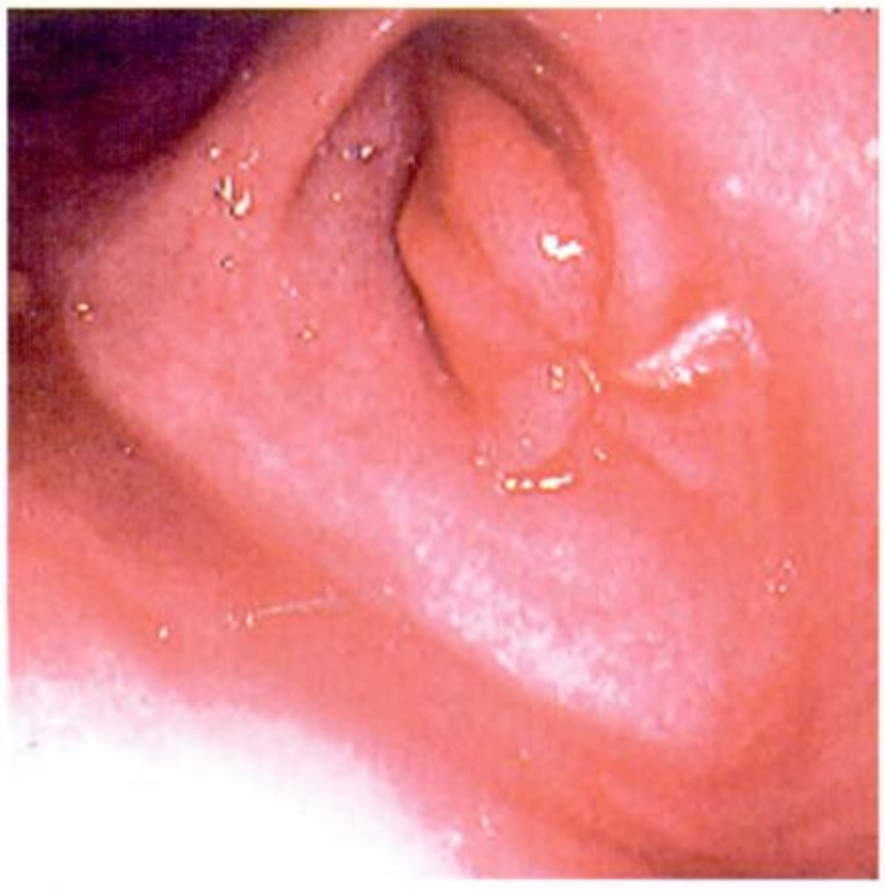


128. Congenital antral web.

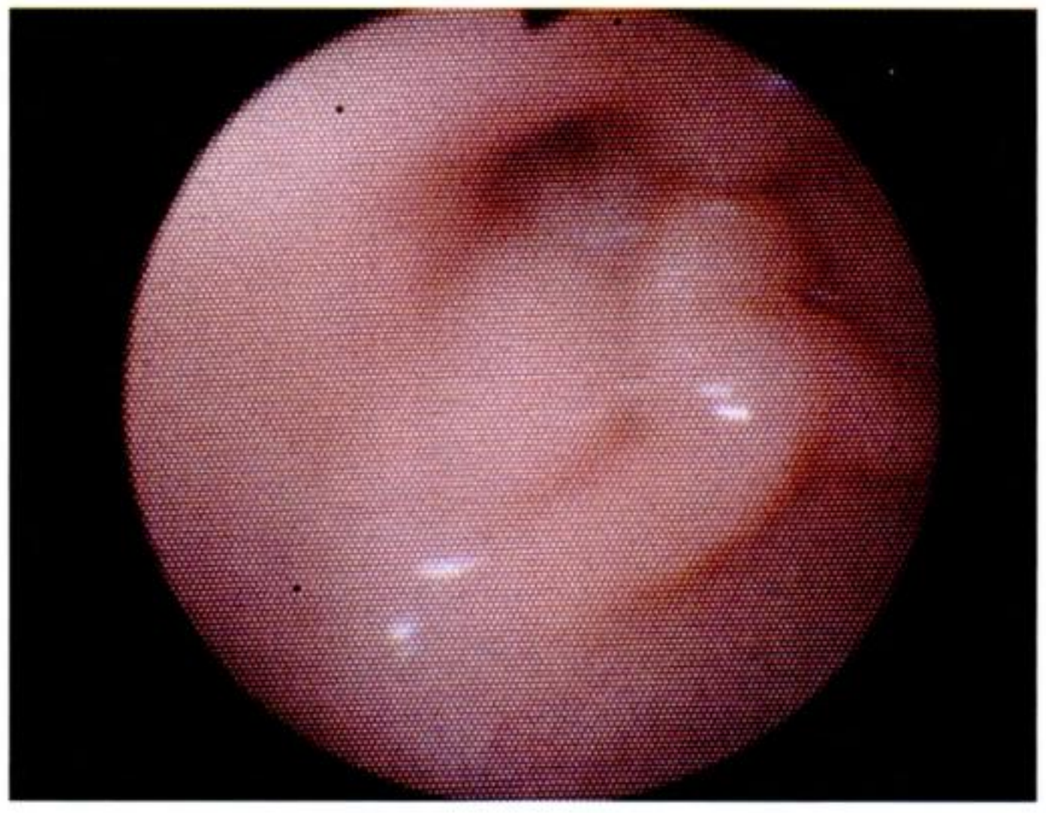
Pyloric Stenosis

129. *A*, Antral contraction. *B, C,* Idiopathic hypertrophic pyloric stenosis in infant. (Images courtesy of Tarek Saleh, MD.)



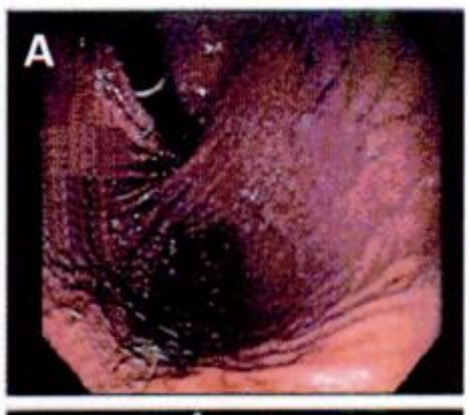


130. Secondary pyloric stenosis following severe ulceration.

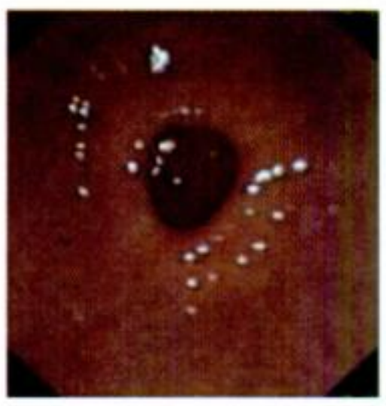


131. Pyloric stenosis following unsuccessful surgical repair.

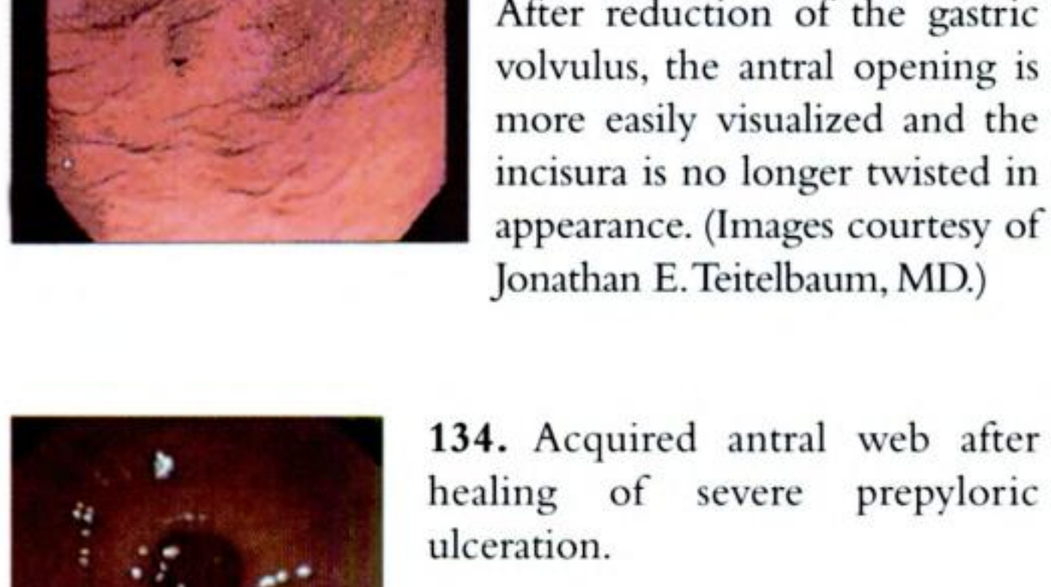
Other Gastric Anomalies



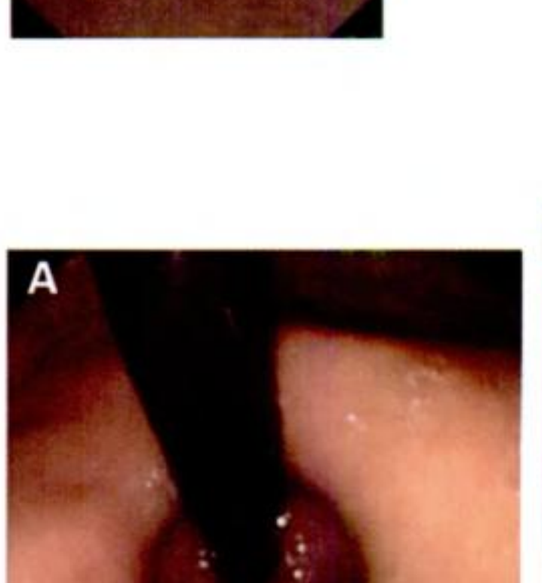
132. *A*, Endoscopic view of organoaxial and mesenteroaxial gastric volvulus in a boy with absent gastric ligaments and an unattached spleen. The antral opening is obscured and is very close in proximity to the LES, and could only be seen upon retroflexion of the endoscope. The incisura appears twisted. *B*, After reduction of the gastric volvulus, the antral opening is more easily visualized and the incisura is no longer twisted in appearance. (Images courtesy of Jonathan E. Teitelbaum, MD.)



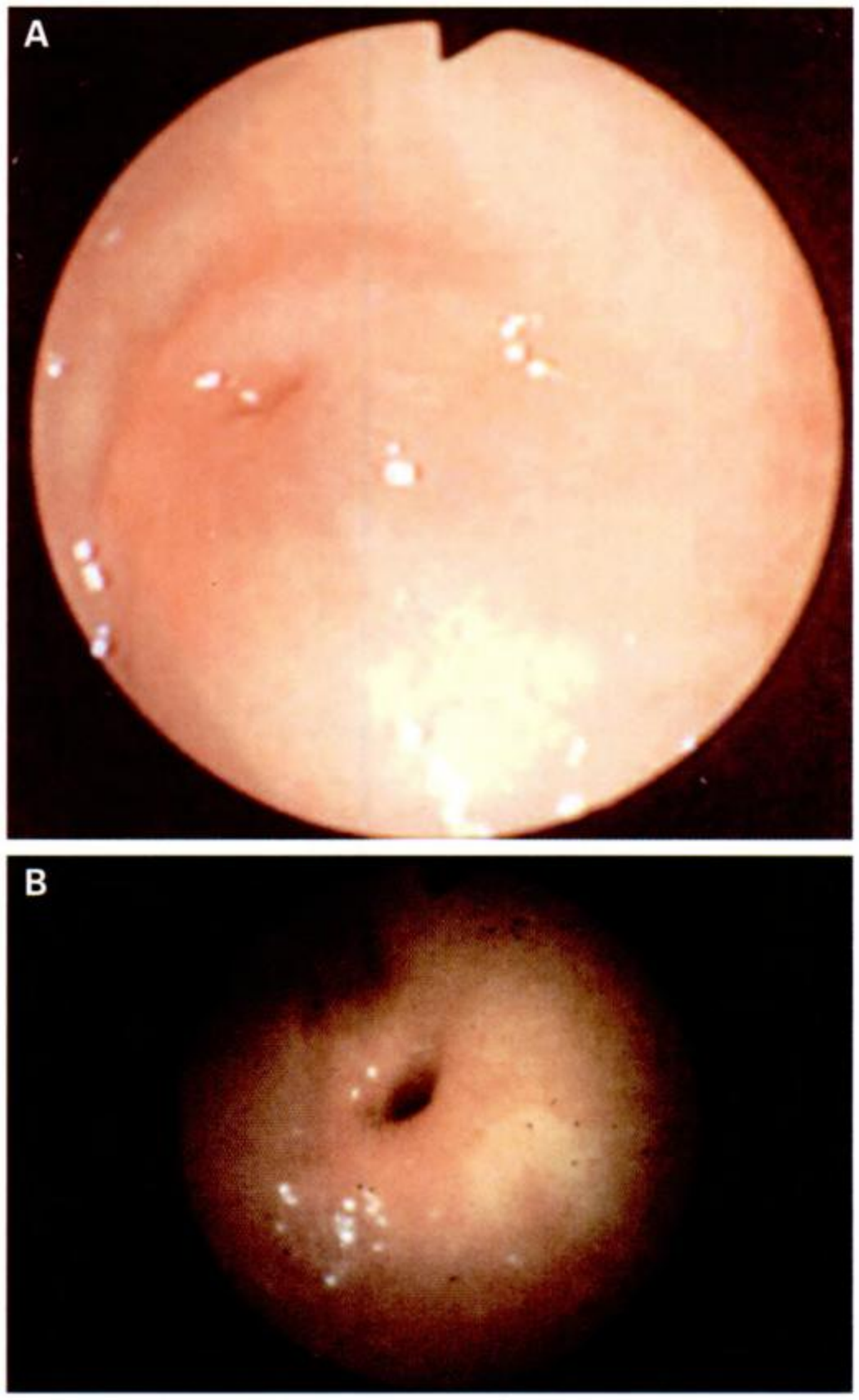
134. Acquired antral web after healing of severe prepyloric ulceration.



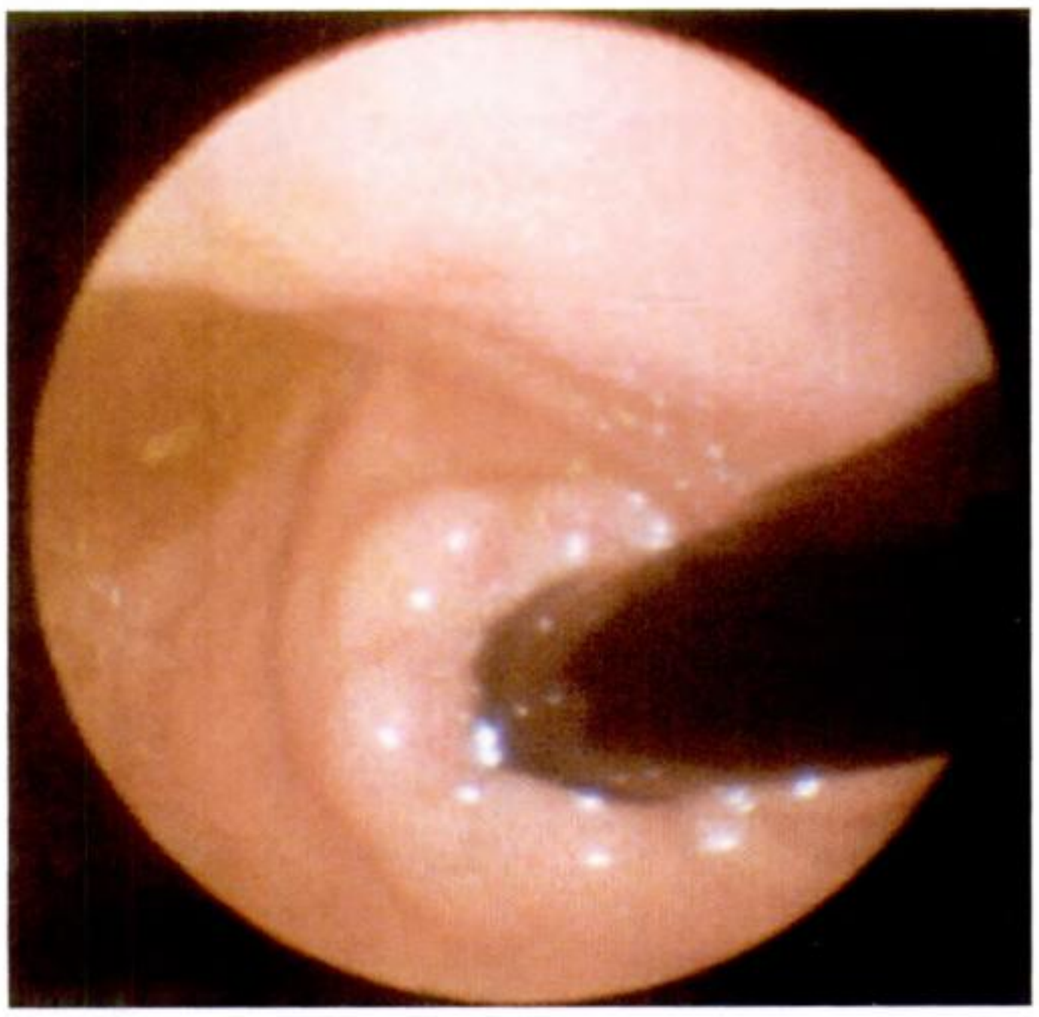
135. Retroflexed view of hiatal hernia.



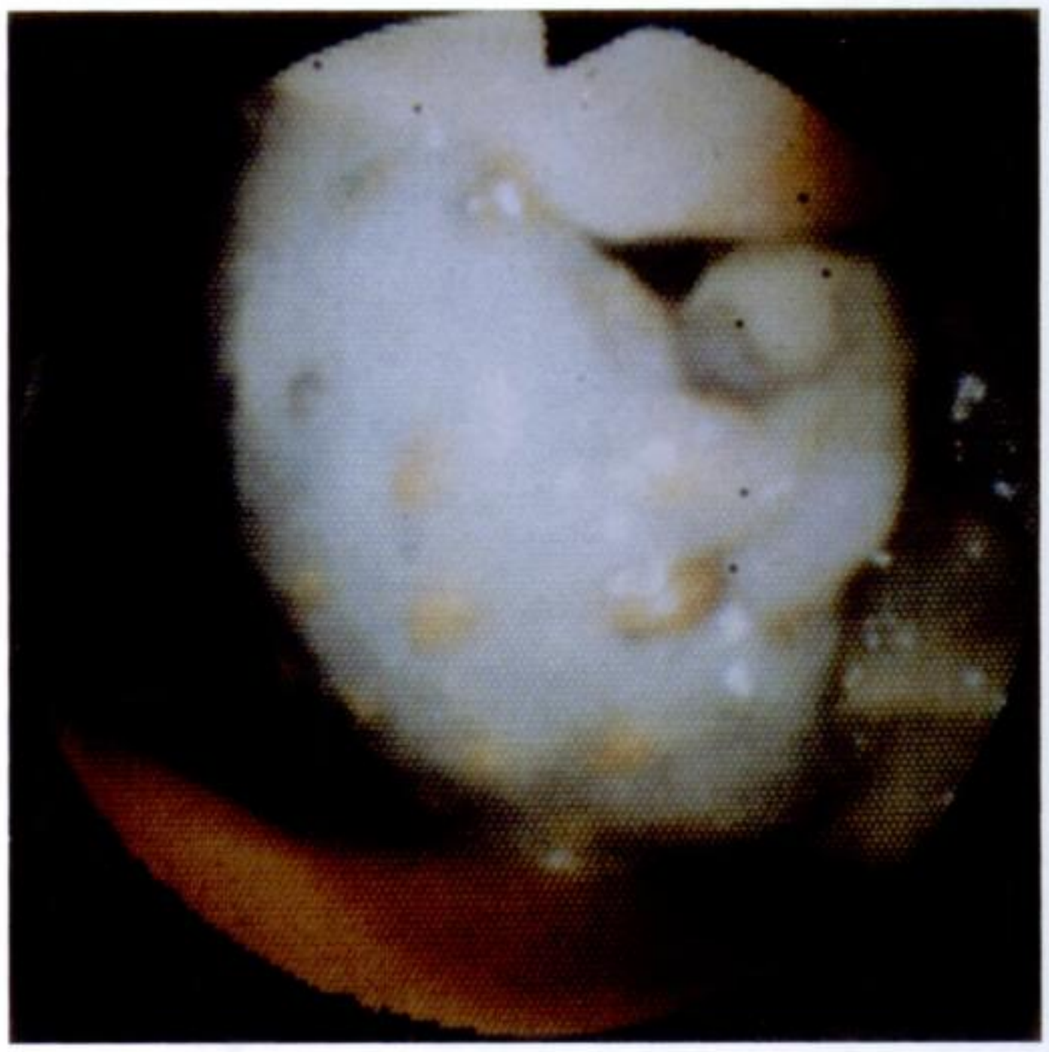
136. Competent fundal wrap after Nissen fundoplication.



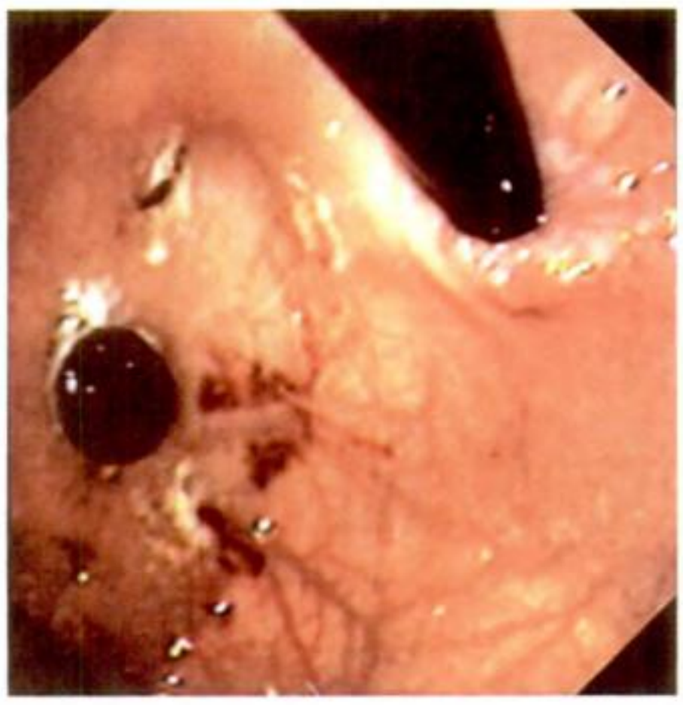
133. *A*, Severe antral stricture complicating a circumferential antral aspirin-induced ulcer. *B*, Prepyloric stricture (pseudodiaphragm) due to salicylate injury.



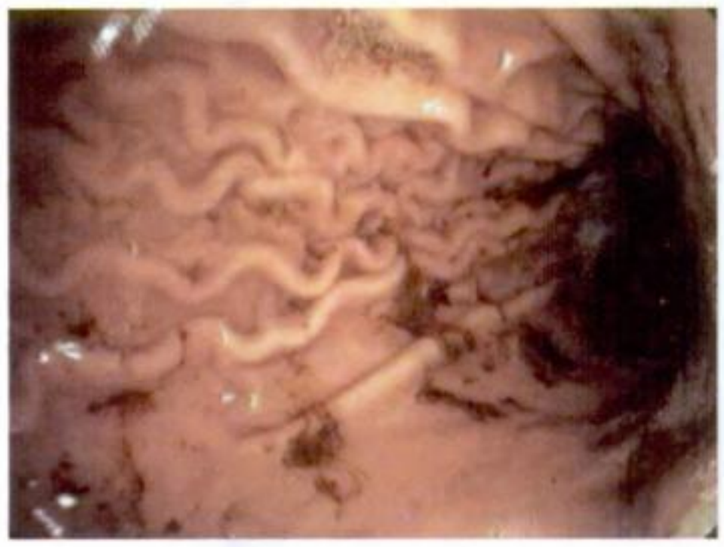
137. Retroflexion view of snug gastroesophageal junction with protruding mucosal fold seen in achalasia.



138. Gastric bezoar.

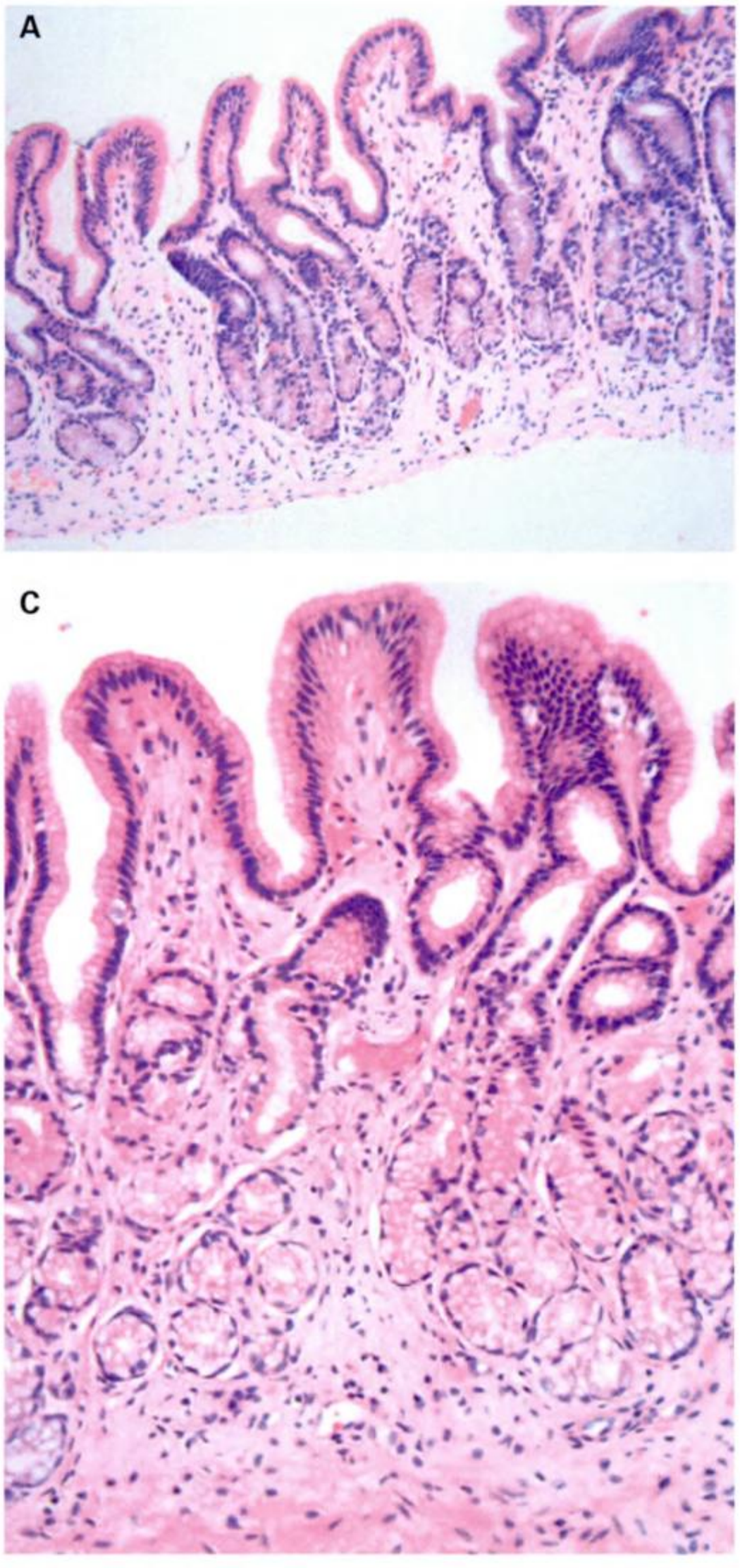


139. Focal gastric necrosis caused by ingested battery. (Image courtesy of Frederic Gottrand, MD and Ahmed Maherzi, MD.)

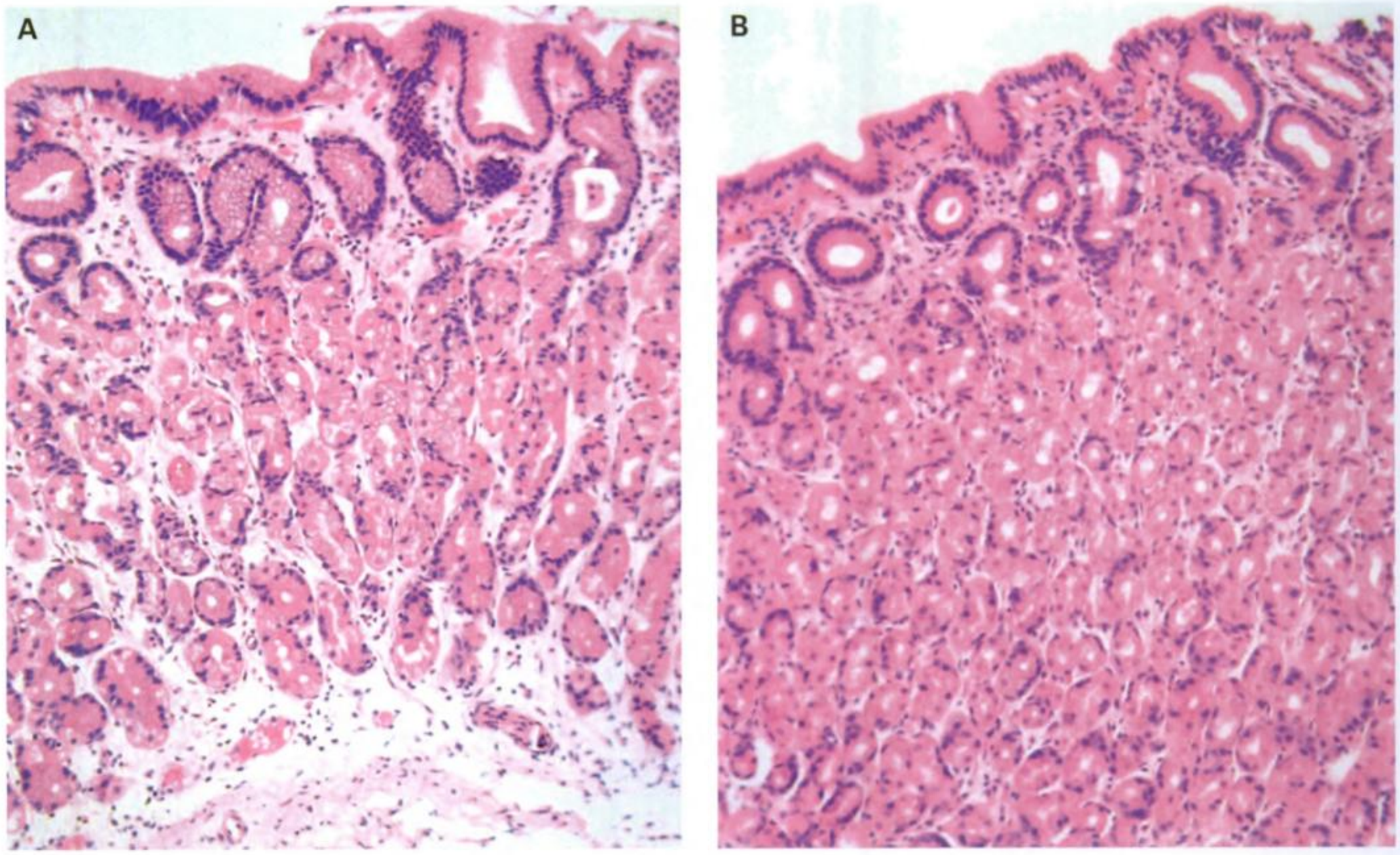


140. Cola in the stomach may look like blood.

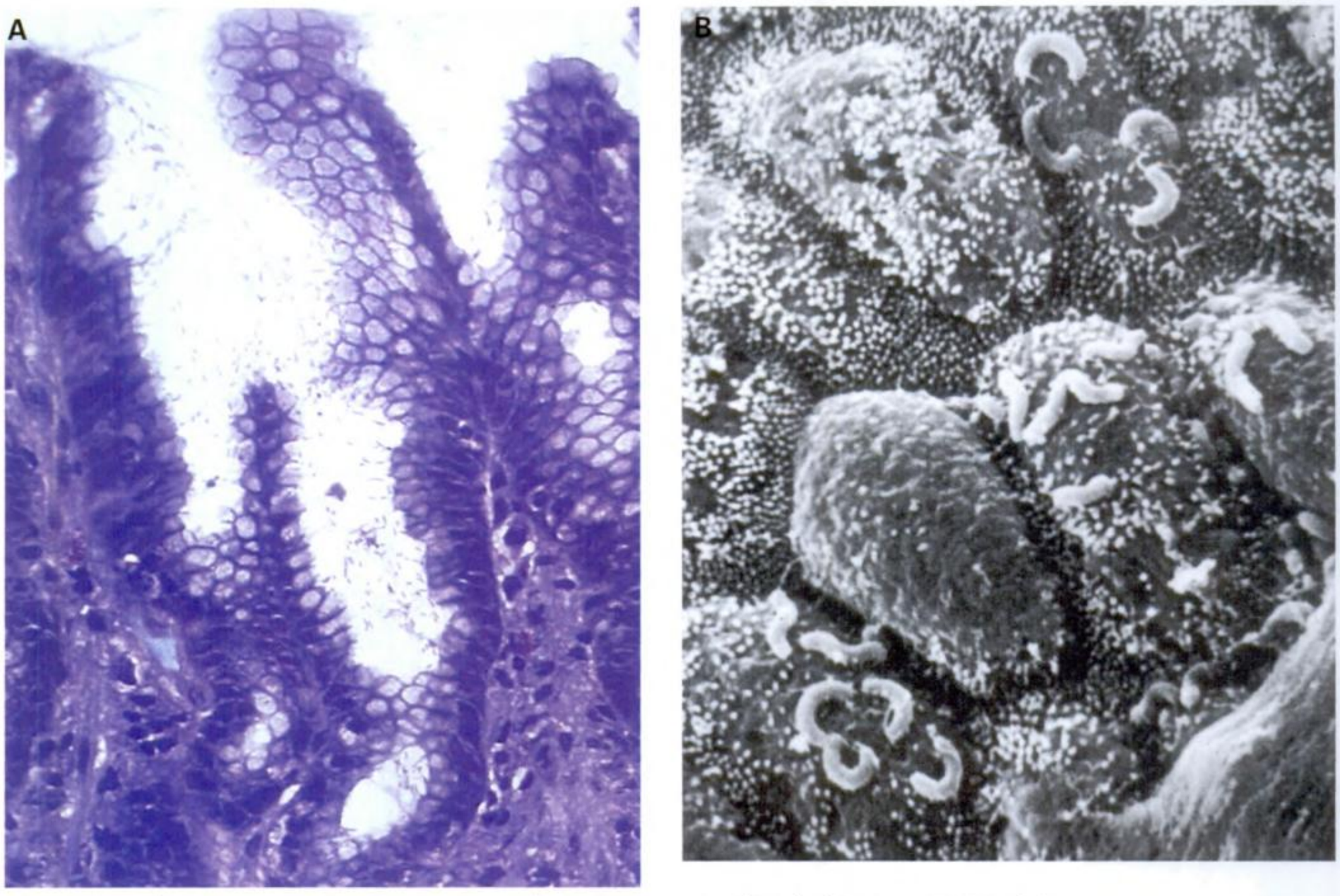
Gastric Histology



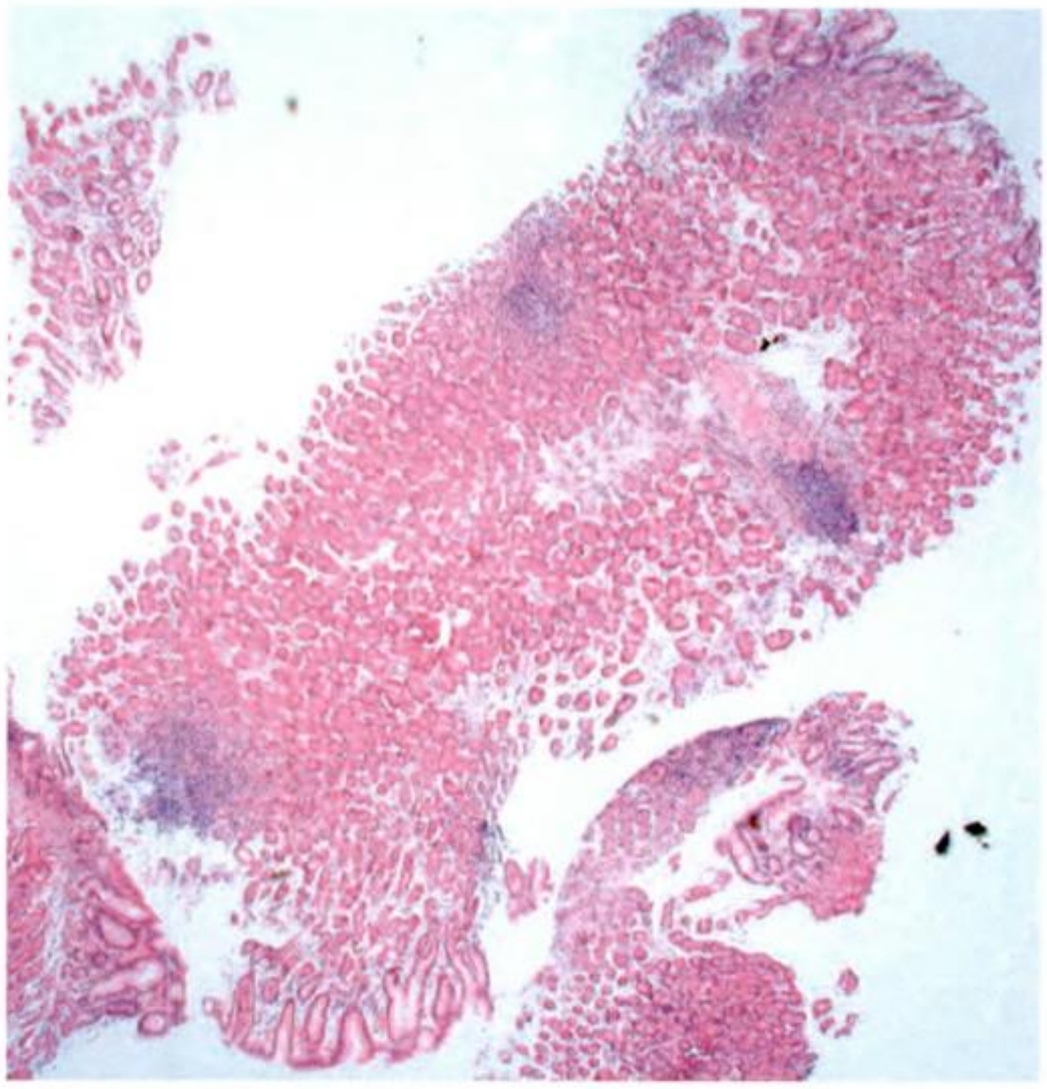
141. Normal antral mucosa. Nonspecialised glands. (Images courtesy of Rachel Brown, FRCPath.)



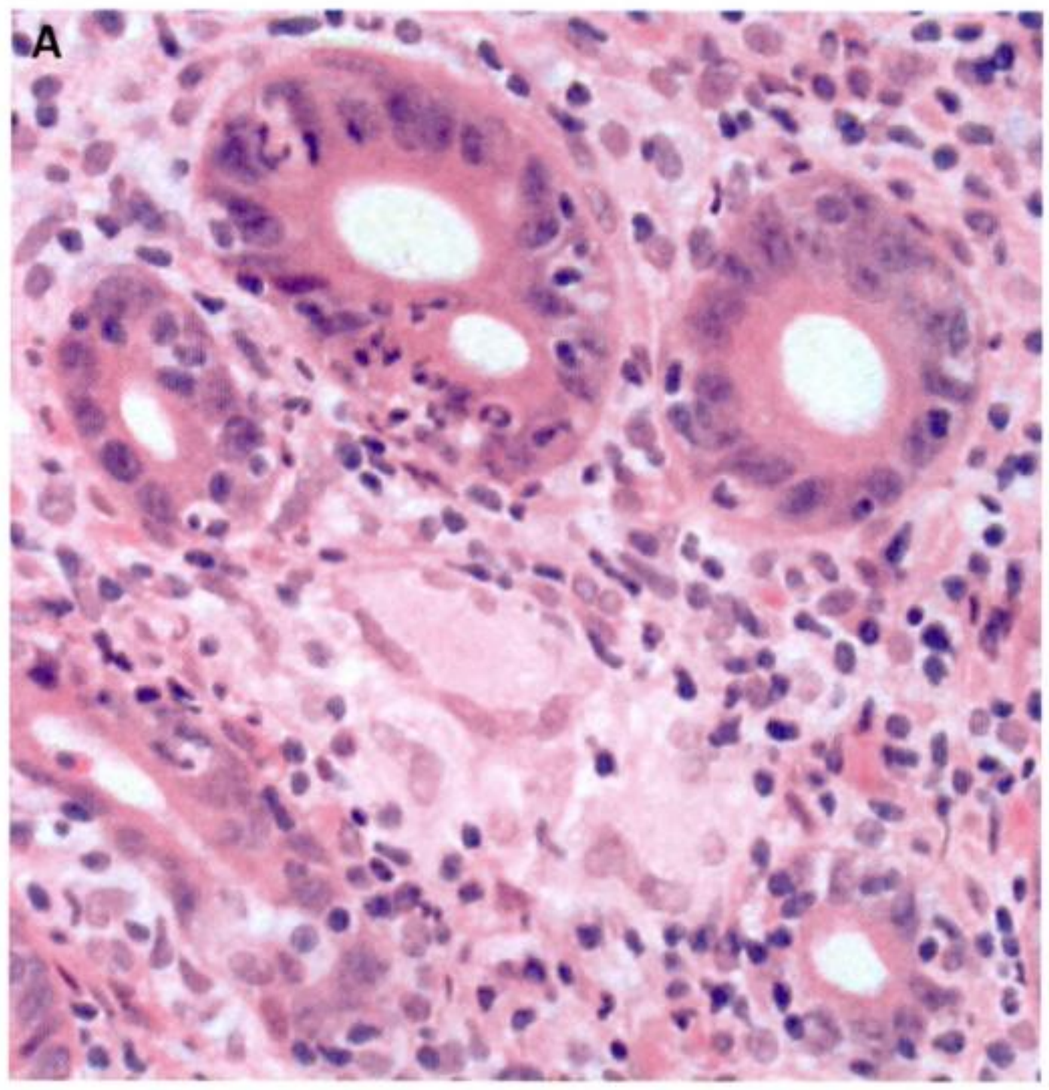
142. Normal gastric body mucosa. (Images courtesy of Rachel Brown, FRCPath.)



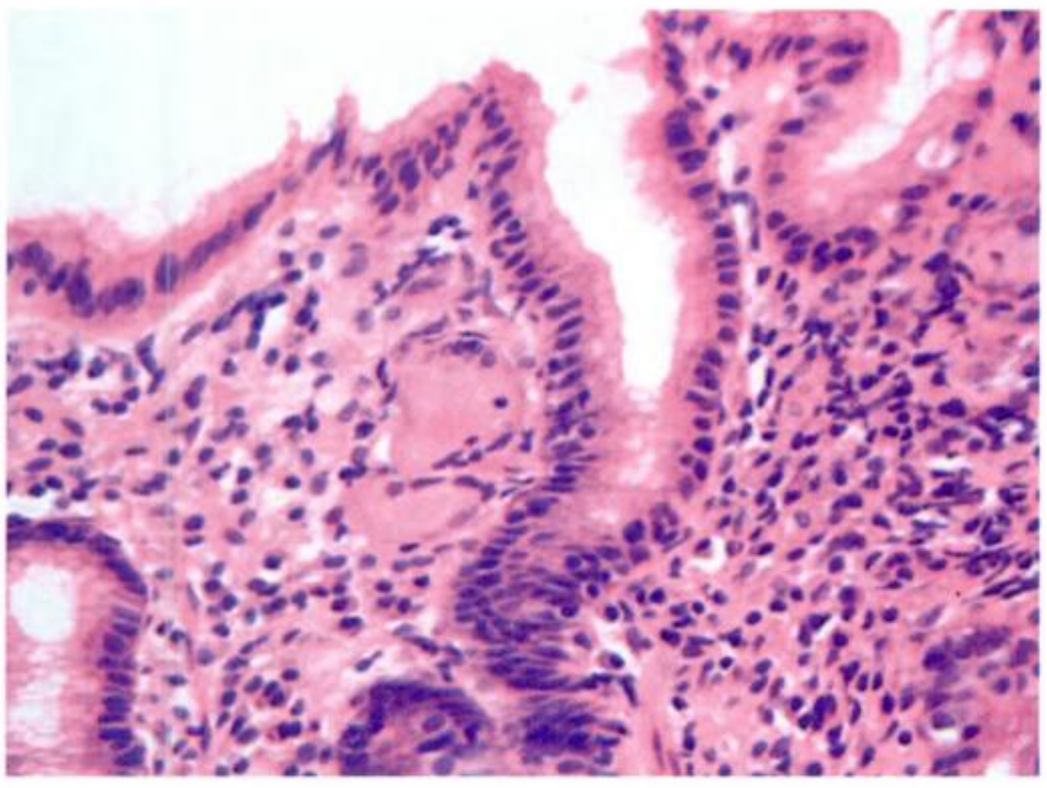
143. *A, H. pylori. B,* Scanning EM appearance. (Images courtesy of Rachel Brown, FRCPath.)



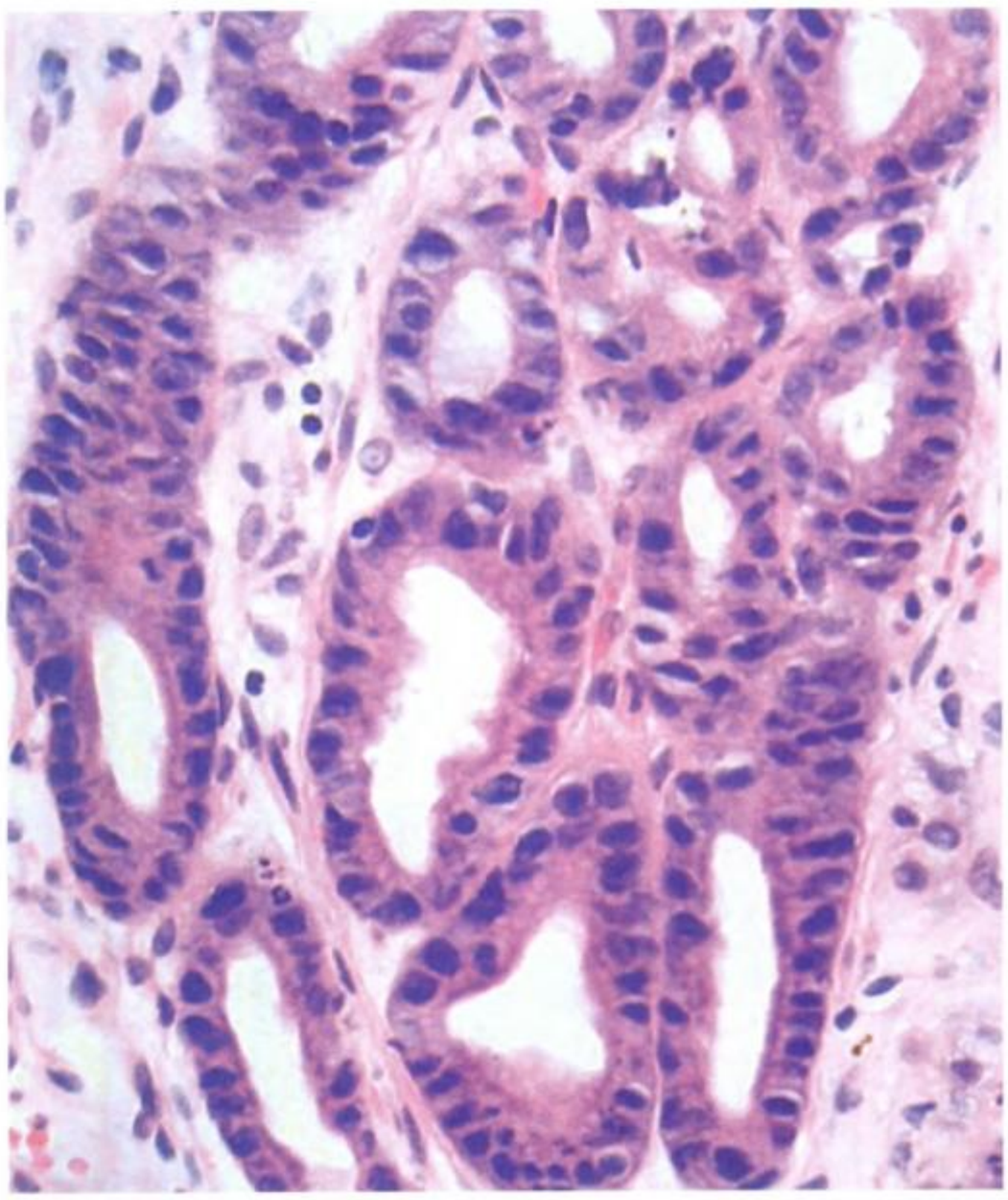
144. Focal inflammation in Crohn's disease. (Image courtesy of Rachel Brown, FRCPath.)



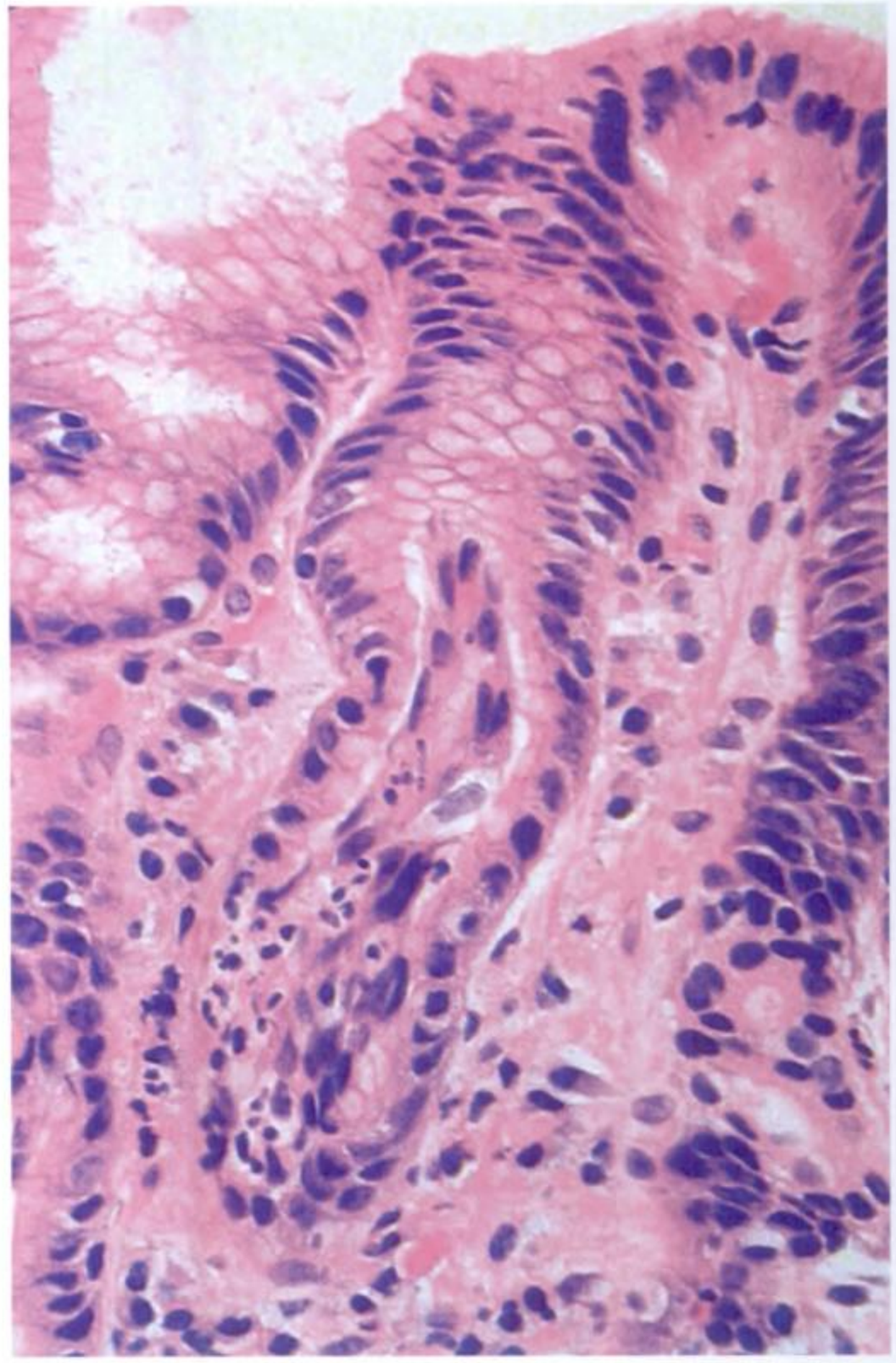
145. Crohn's granuloma. (Images courtesy of Rachel Brown, FRCPath.)



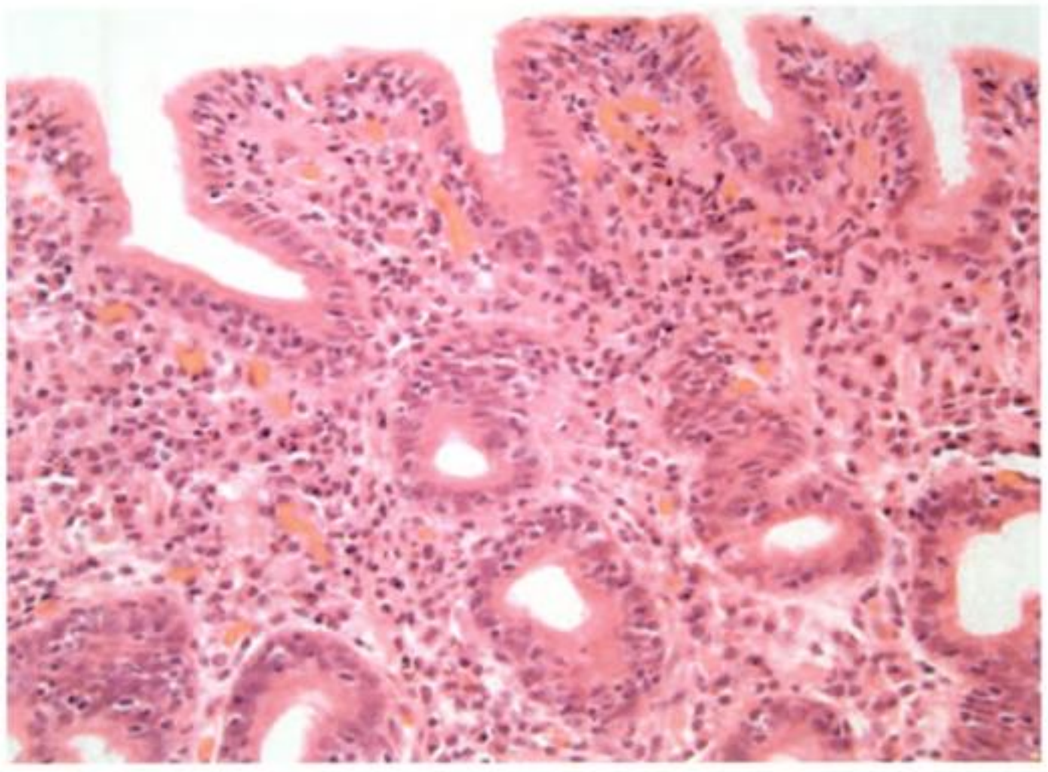
146. Giant cells are present in the lamina propria. (Image courtesy of Rachel Brown, FRCPath.)



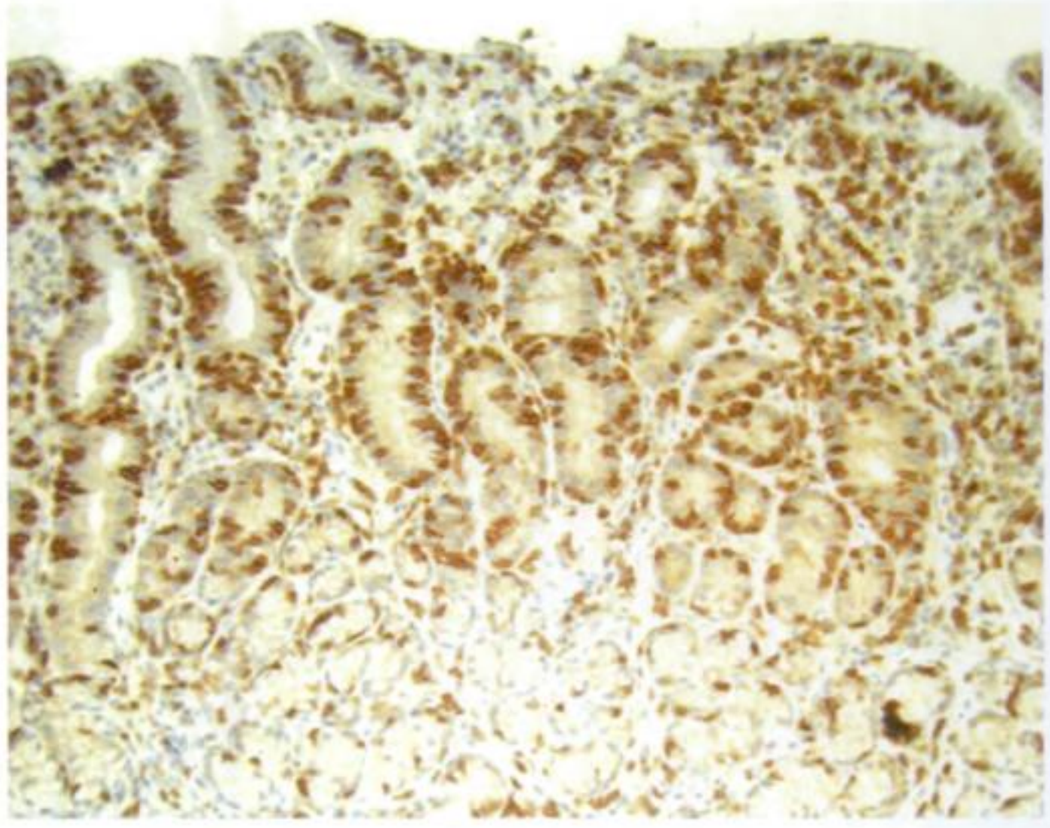
147. Graft-versus-host disease. (Image courtesy of Rachel Brown, FRCPath.)



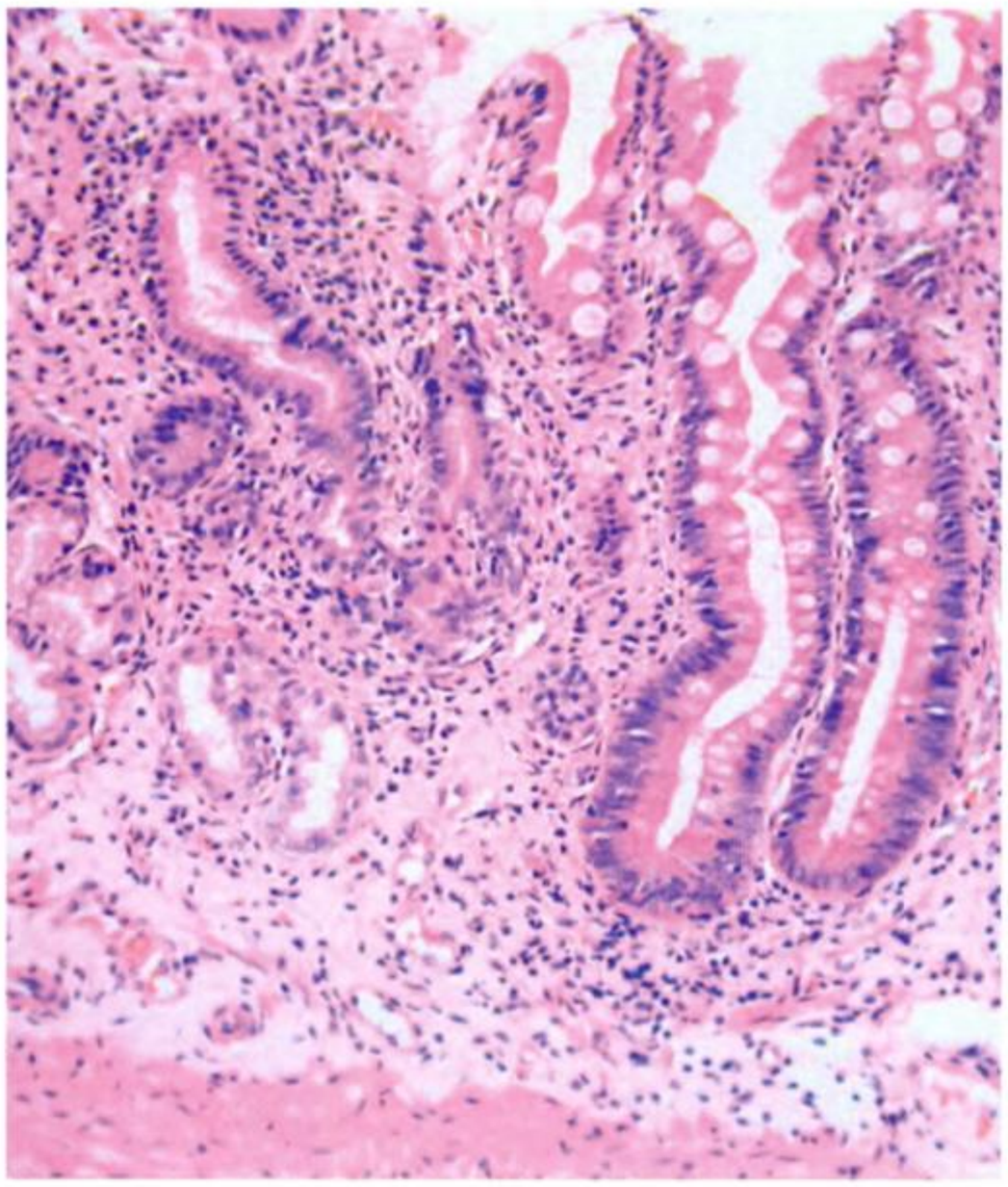
148. Active gastritis. (Image courtesy of Rachel Brown, FRCPath.)



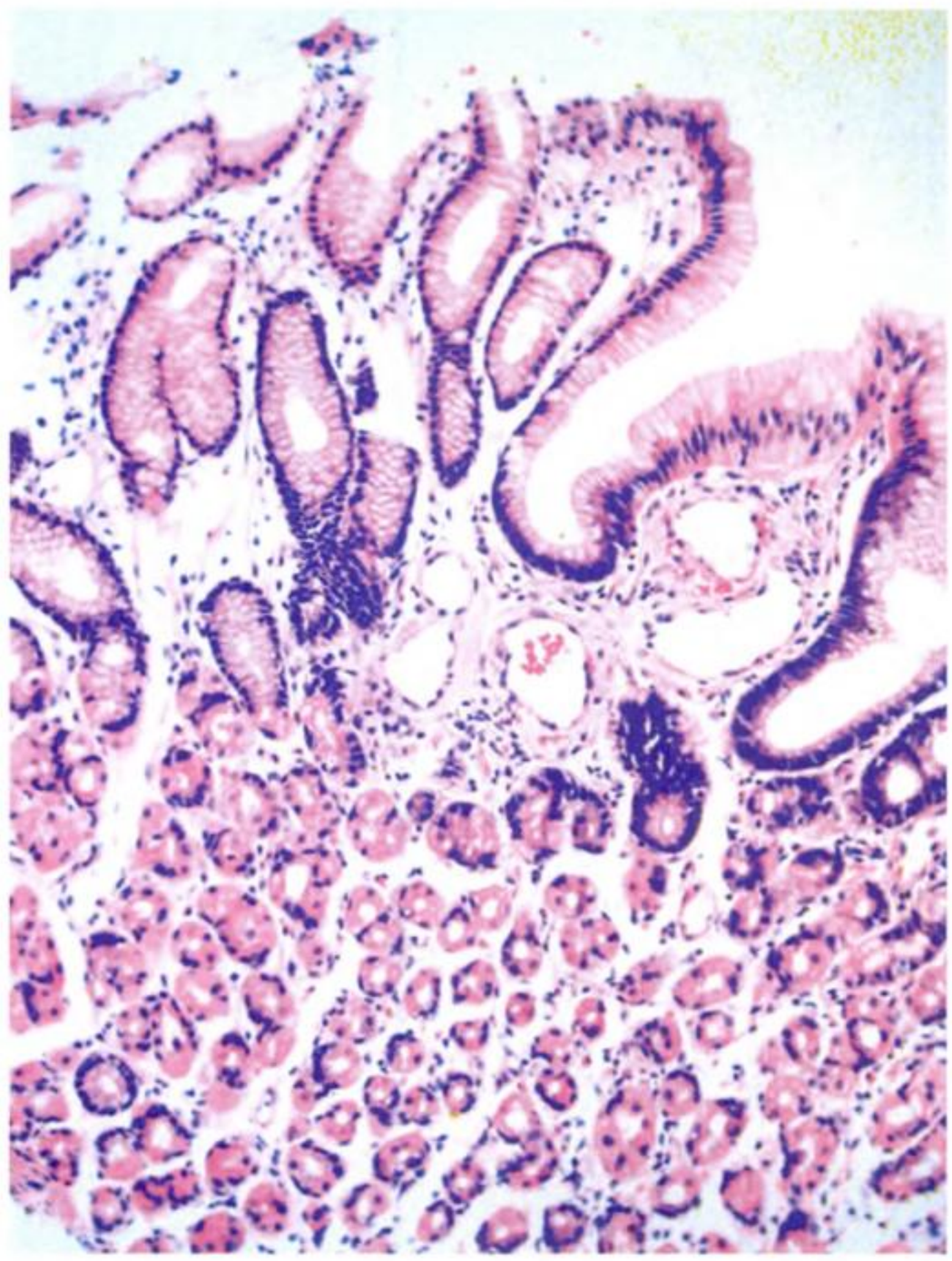
149. Lymphocytic gastritis. (Image courtesy of Rachel Brown, FRCPath.)



150. Lymphocytic gastritis with CD3+ cells stain. (Image courtesy of Rachel Brown, FRCPath.)

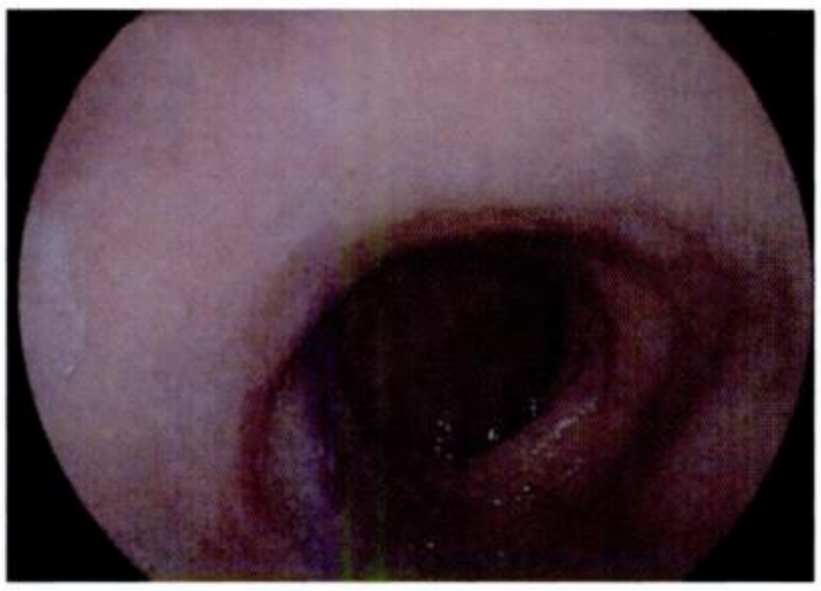


151. Autoimmune gastritis. (Image courtesy of Rachel Brown, FRCPath.)

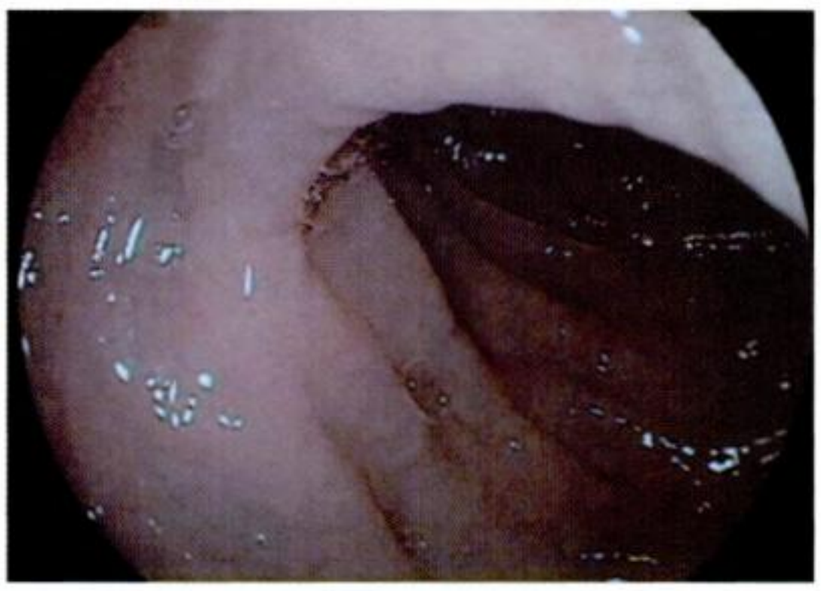


152. Telangiectasia. (Image courtesy of Rachel Brown, FRCPath.)

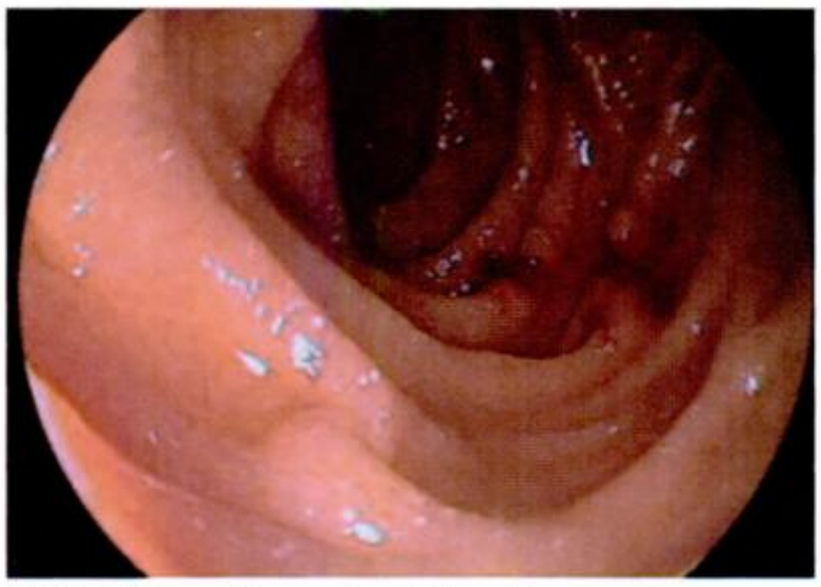
Normal Duodenum



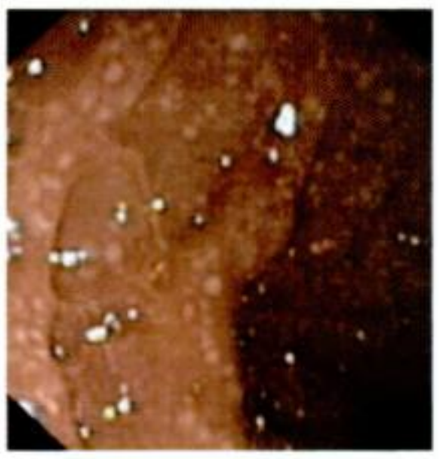
153. First portion of duodenum.



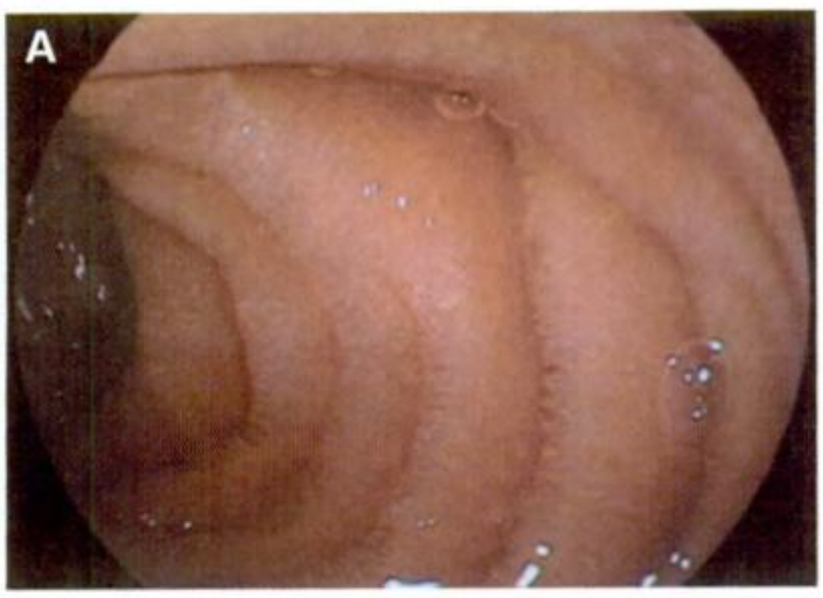
154. Second portion of duodenum.

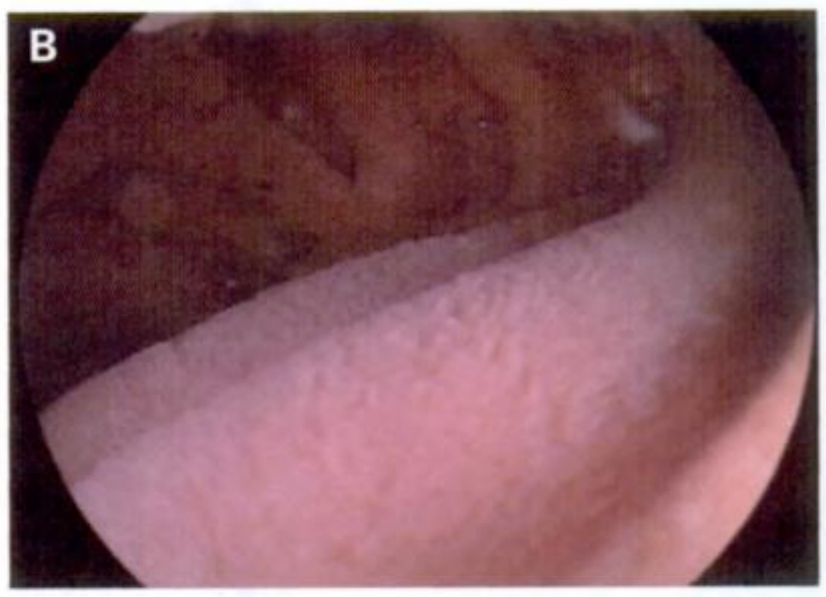


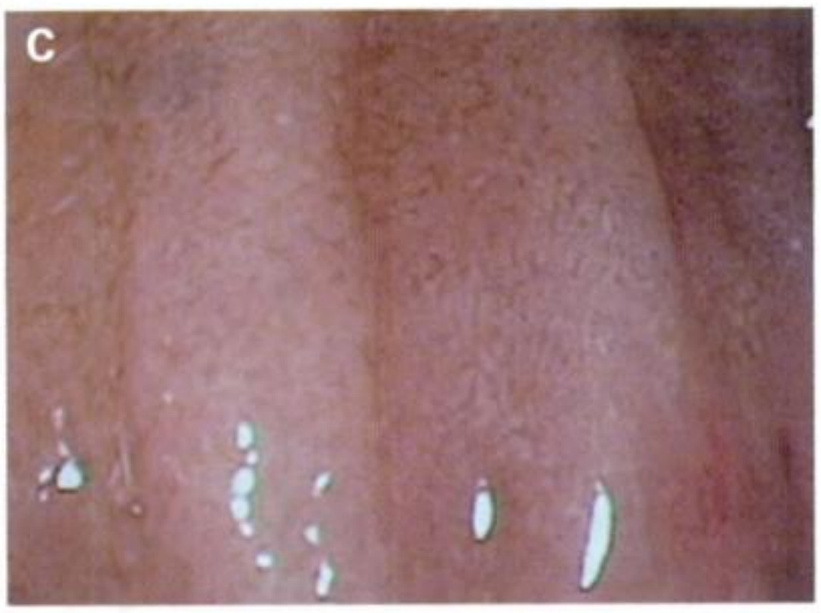
155. Dilated lacteals with adjacent biopsy.

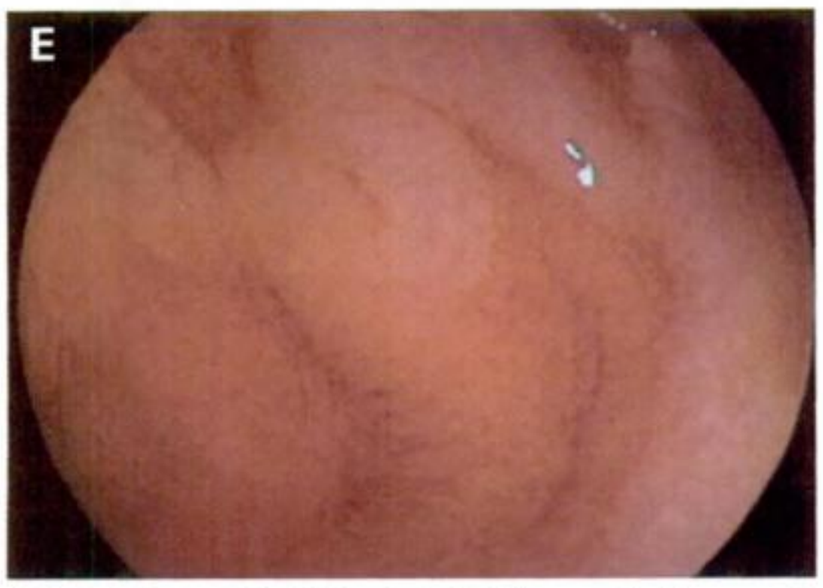


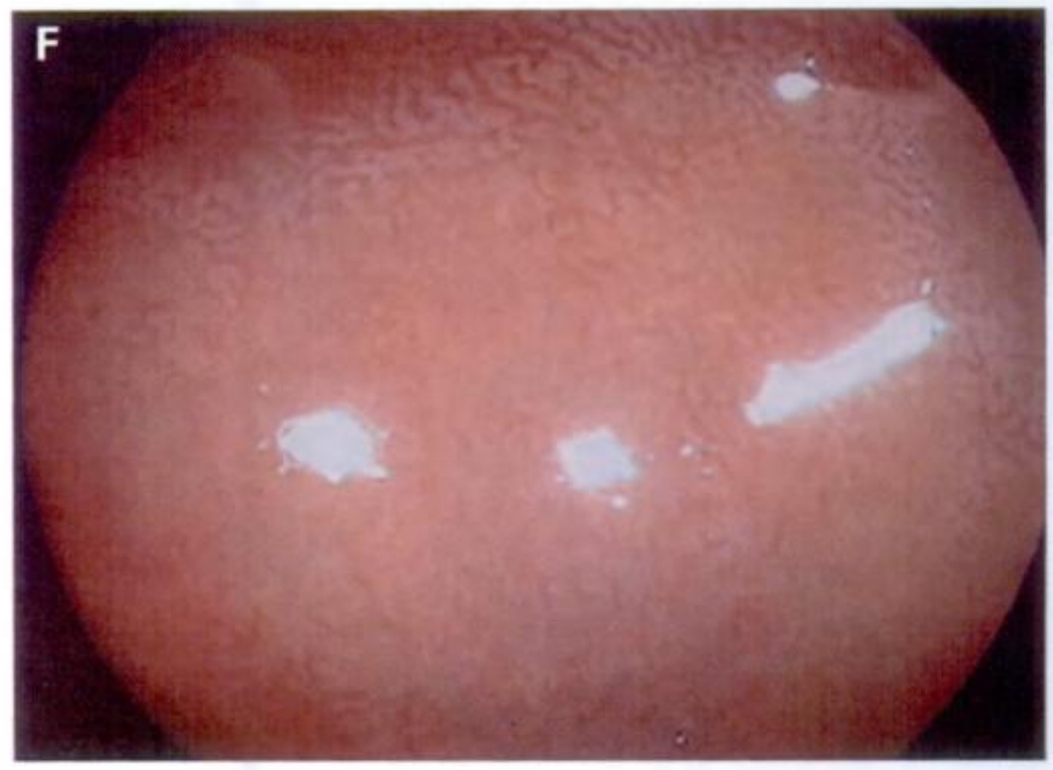
156. Normal duodenum with unusually prominent lacteals in a child receiving enteral tube feedings.





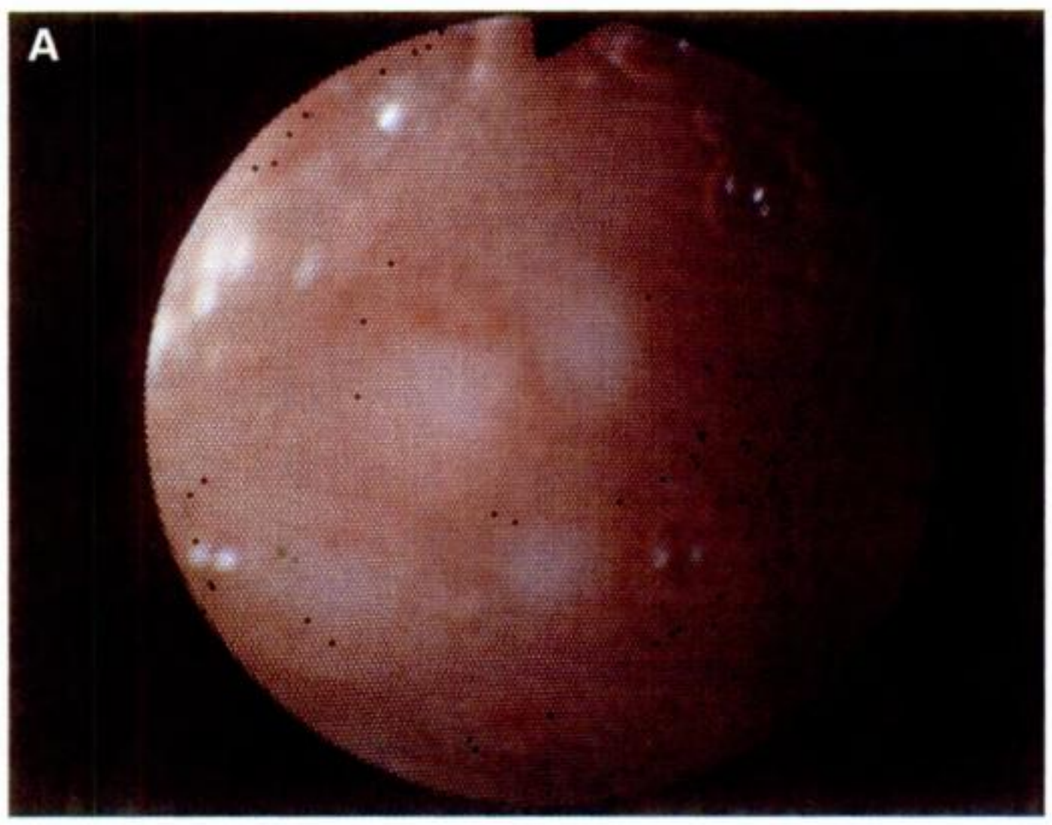


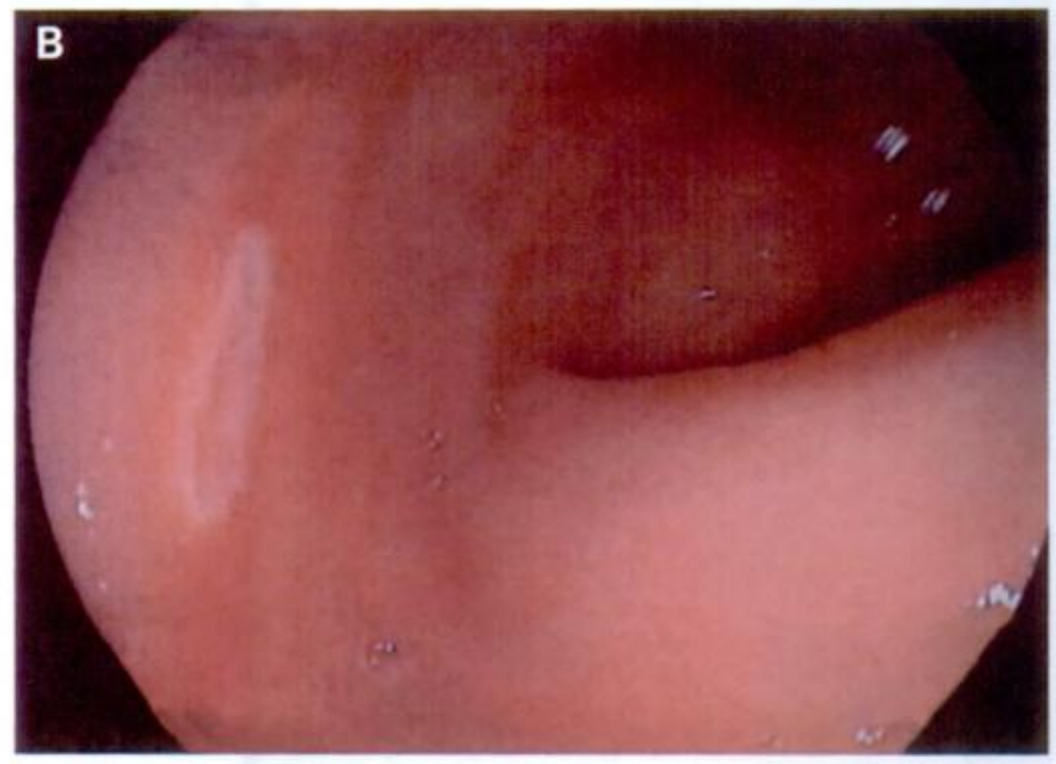




157. Normal villi with high resolution endoscope. Note additional digital magnification in *C* and *D*.

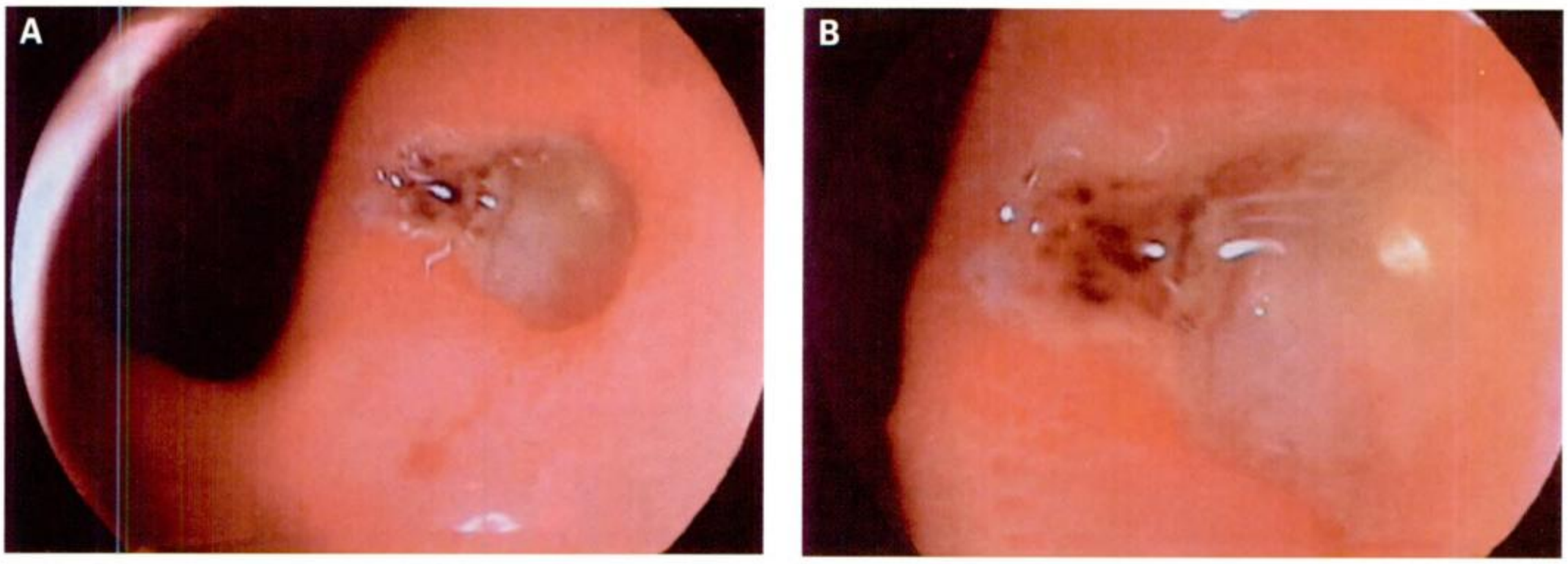
HELICOBACTER PYLORI



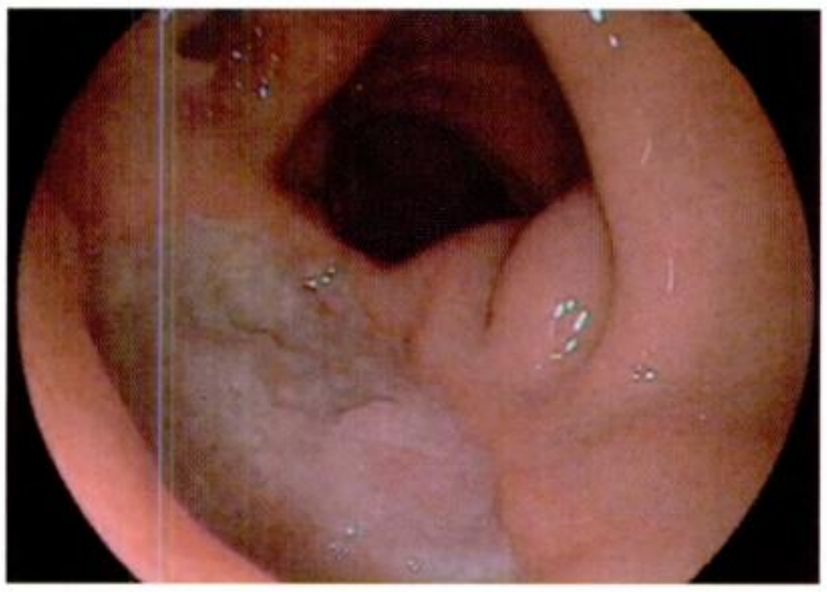


158. *A*, Nodularity in the duodenal bulb in *H. pylori* infection. *B*, Bulbar ulceration due to *H. pylori*.

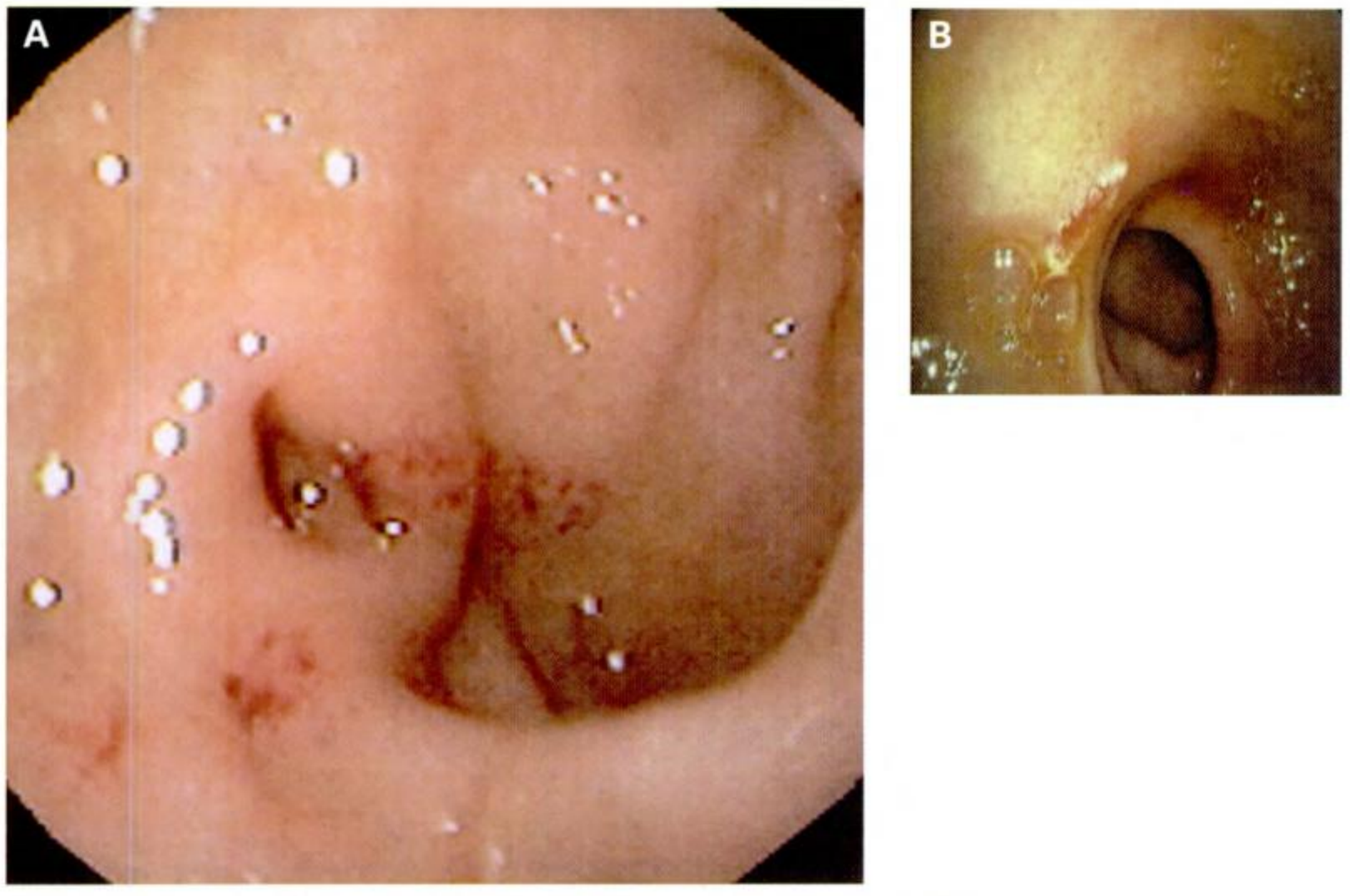
Duodenal Ulcers



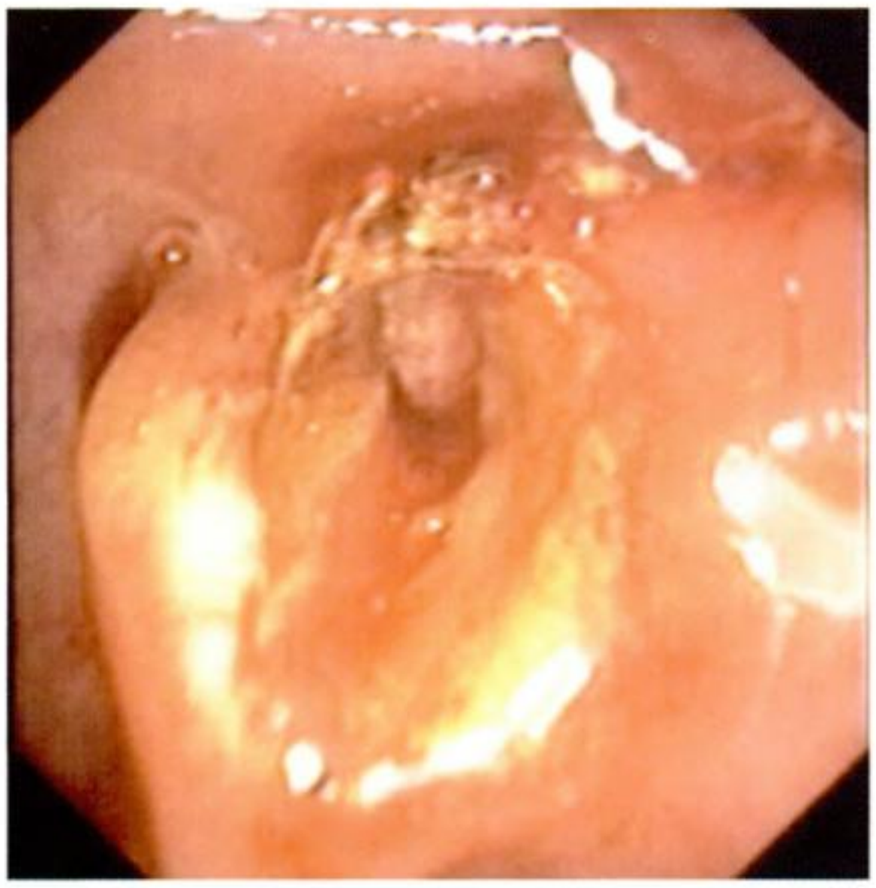
159. Bulbar ulceration with visible vessel due to stress.



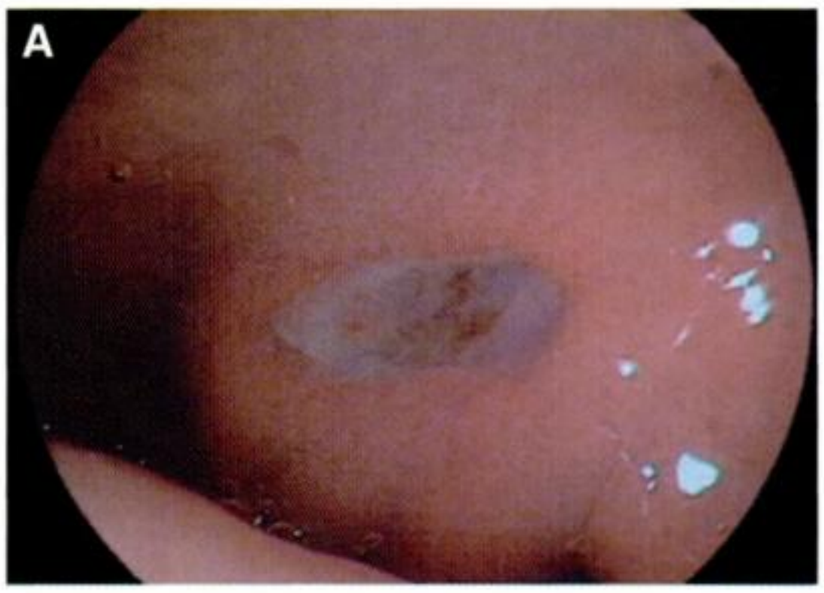
160. Giant duodenal ulcer, *H. pylori* negative.

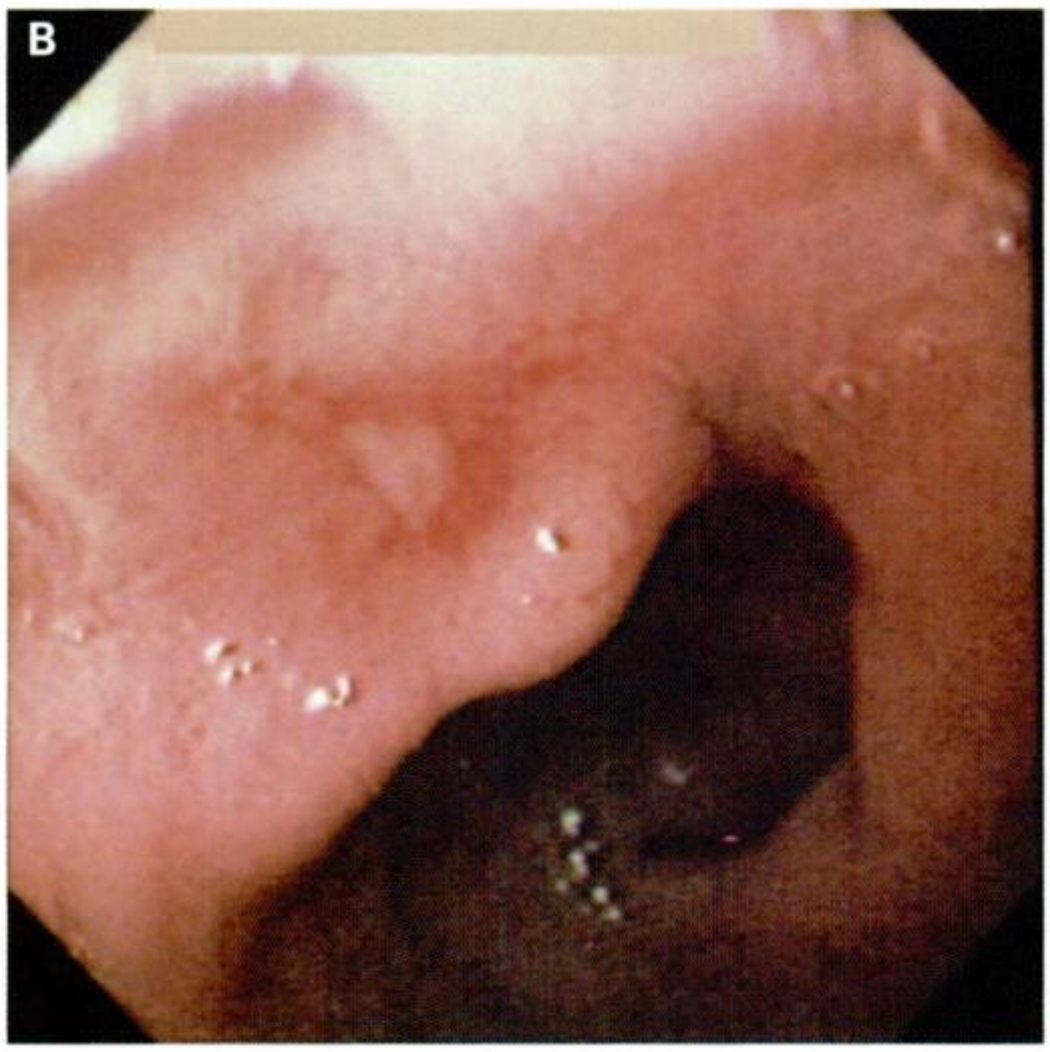


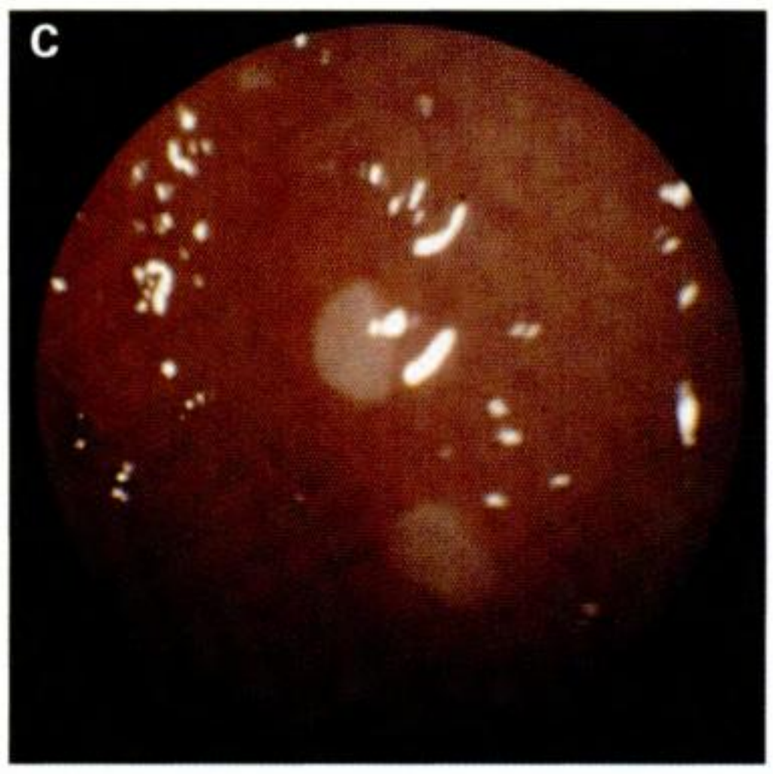
161. *A*, Ulcer in the duodenal bulb. *B*, Circumscribed bulbar ulcer.



162. Bulbar ulceration with bile stain and visible vessel.

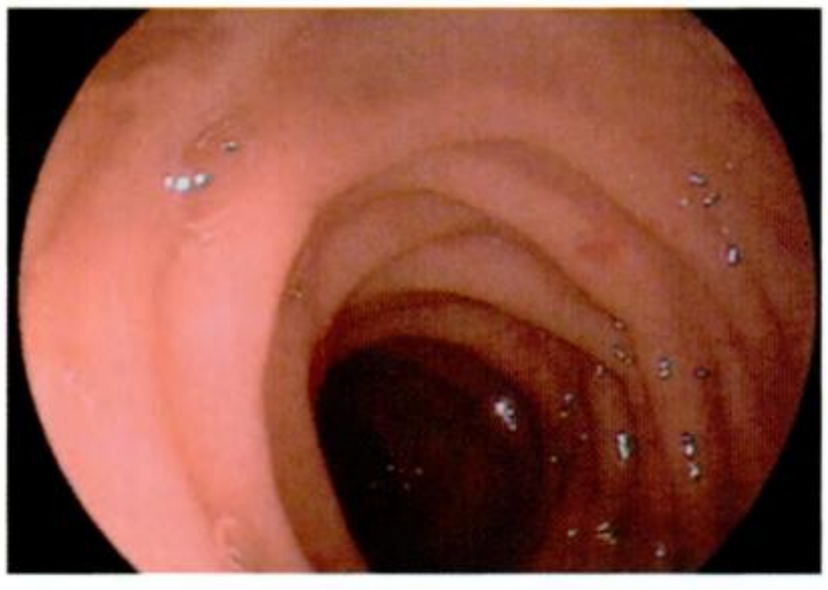




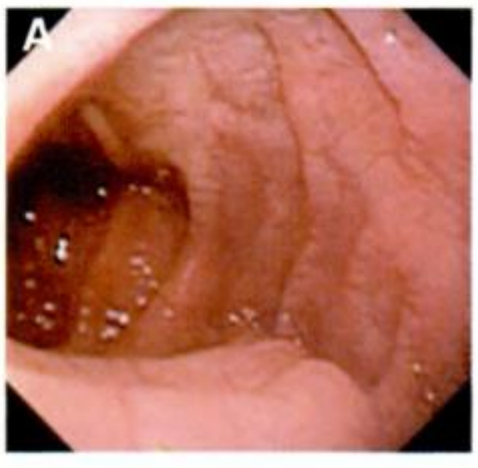


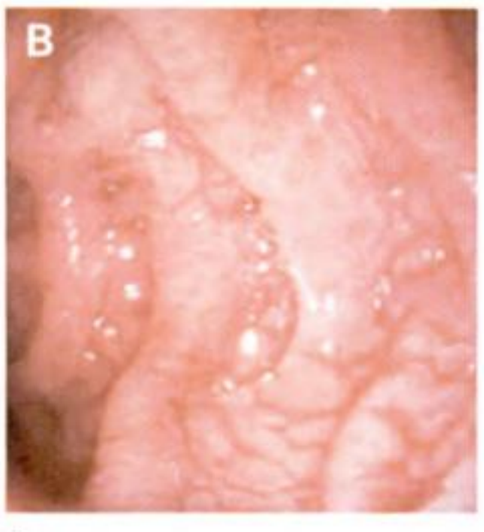
163. Duodenal ulcer, *H. pylori* negative.

Celiac Disease and Enteropathy



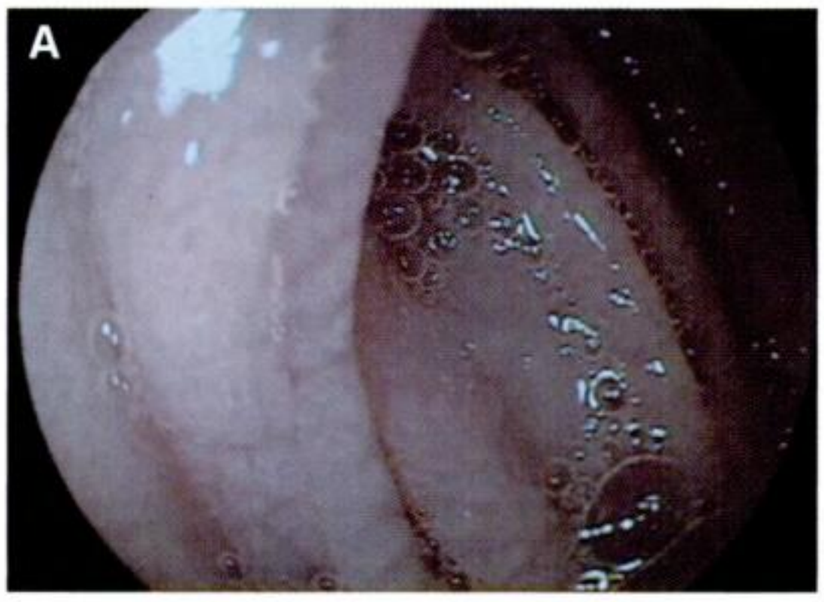
164. Standard view of mucosa with flat villous lesion.

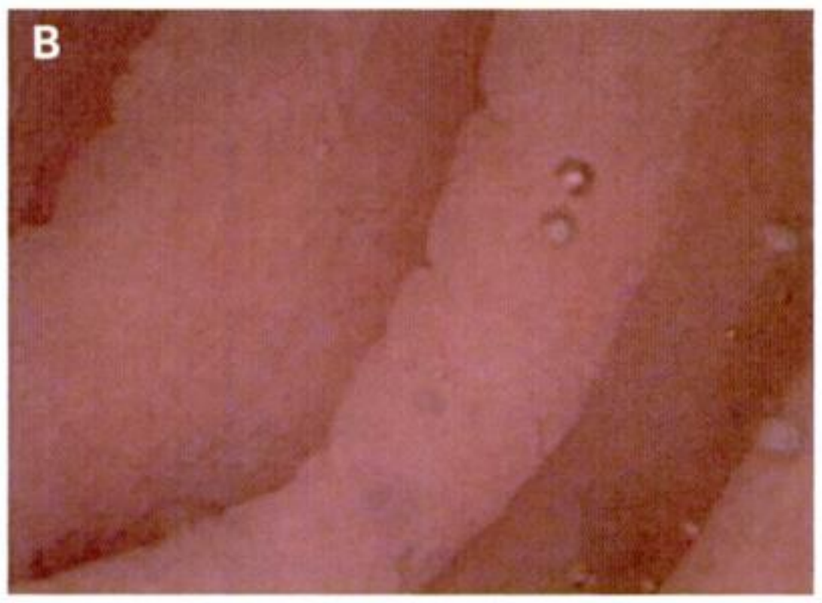




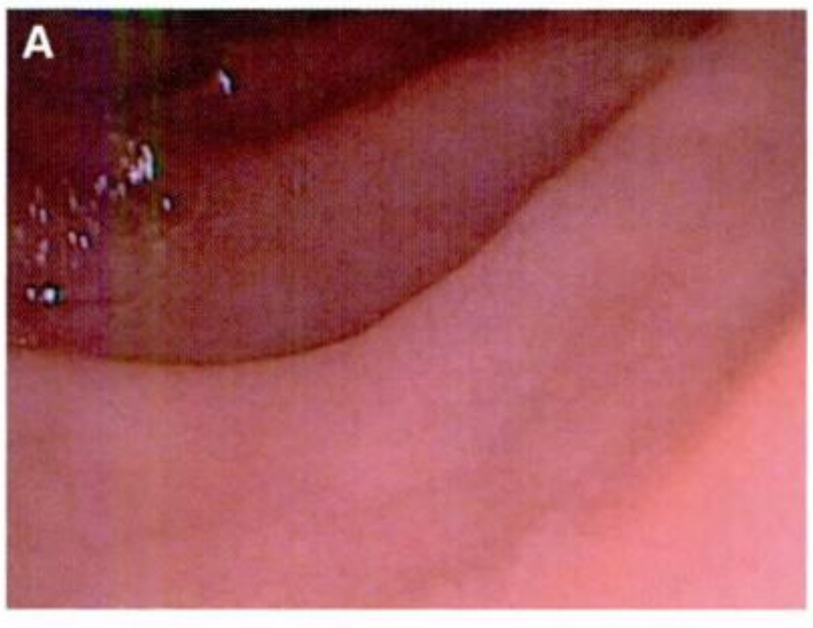
165. Celiac disease with scalloping.

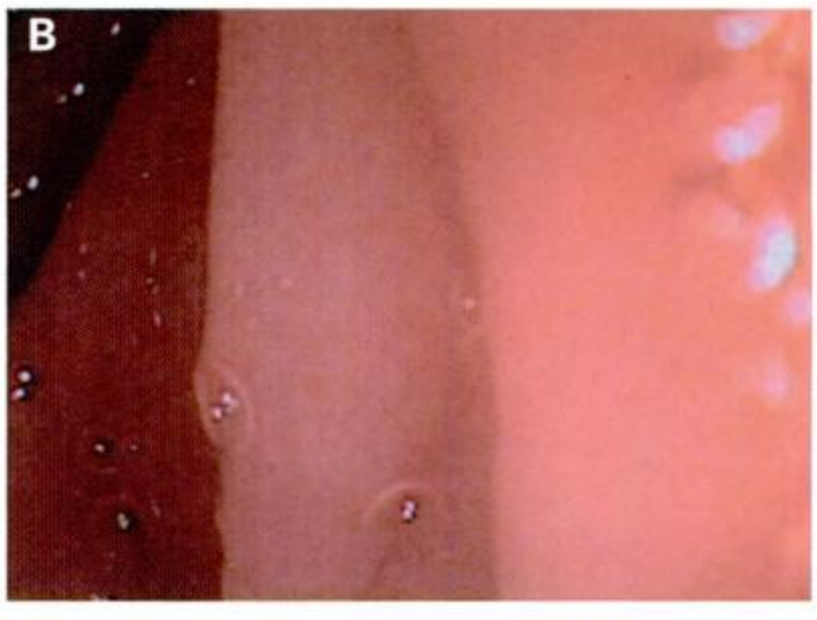
166. Villous atrophy with methylene blue staining.





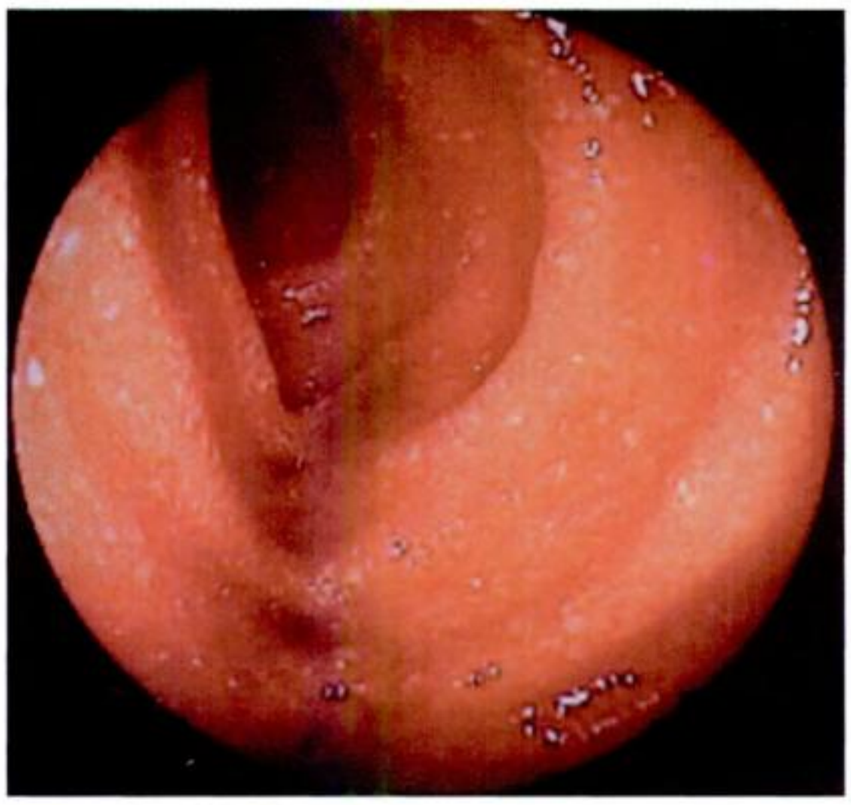
167. *A,* High resolution view with scalloping of valvulae. *B,* Digital magnified view with scalloping of valvulae.





168. Digital magnified view showing absence of villi.

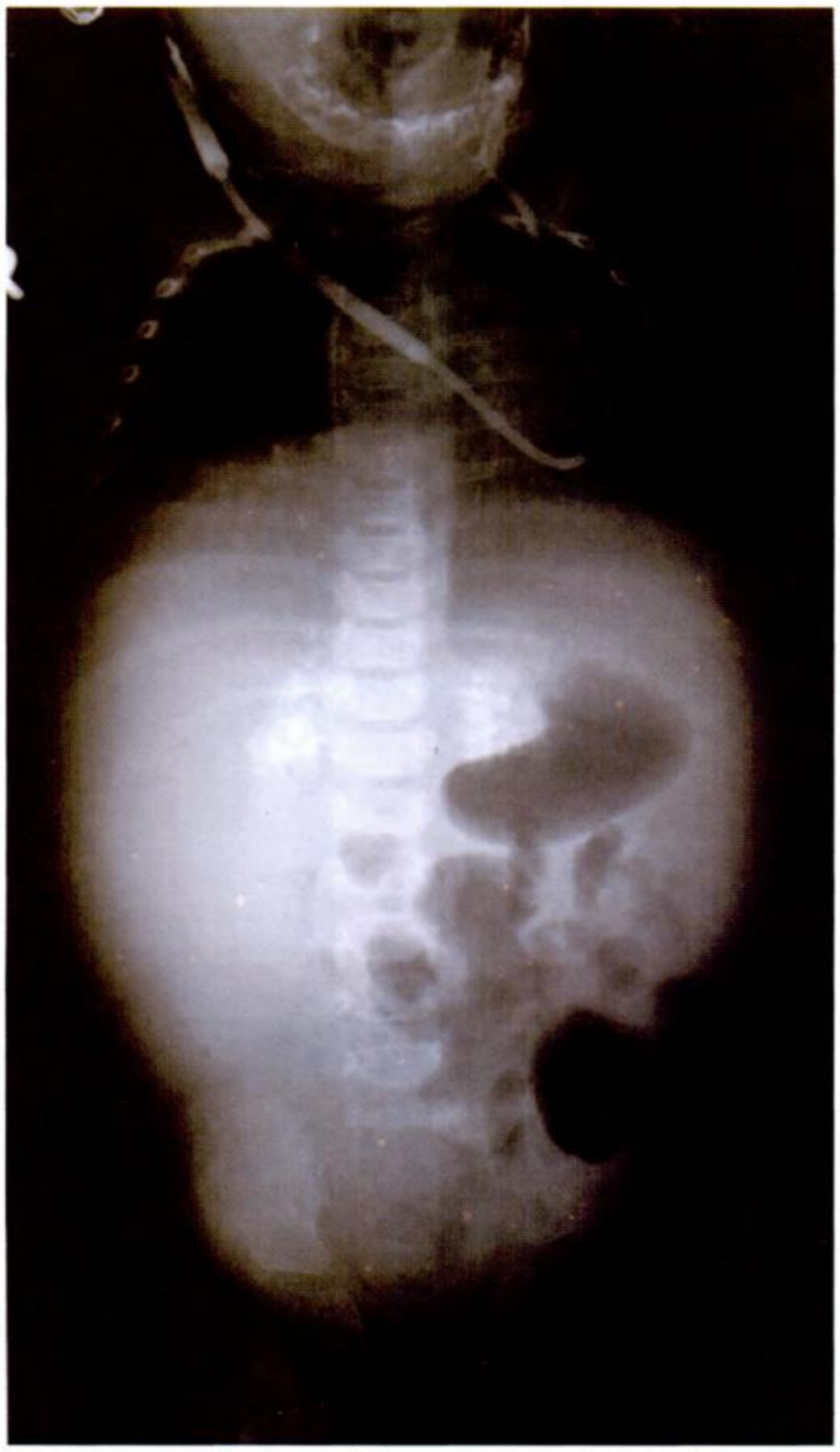
LYMPHANGIECTASIA



169. Intestinal lymphangiectasia with white speckled pattern caused by dilated lymphatics. (Image courtesy of Adolfo Bautista Casasnovas, MD.)

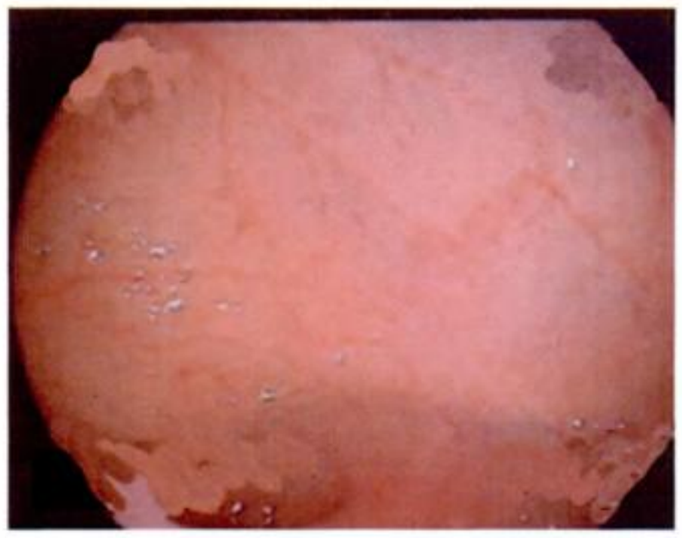
Wolman's disease

170. White lesions in the duodenum in infants with Wolman's disease.



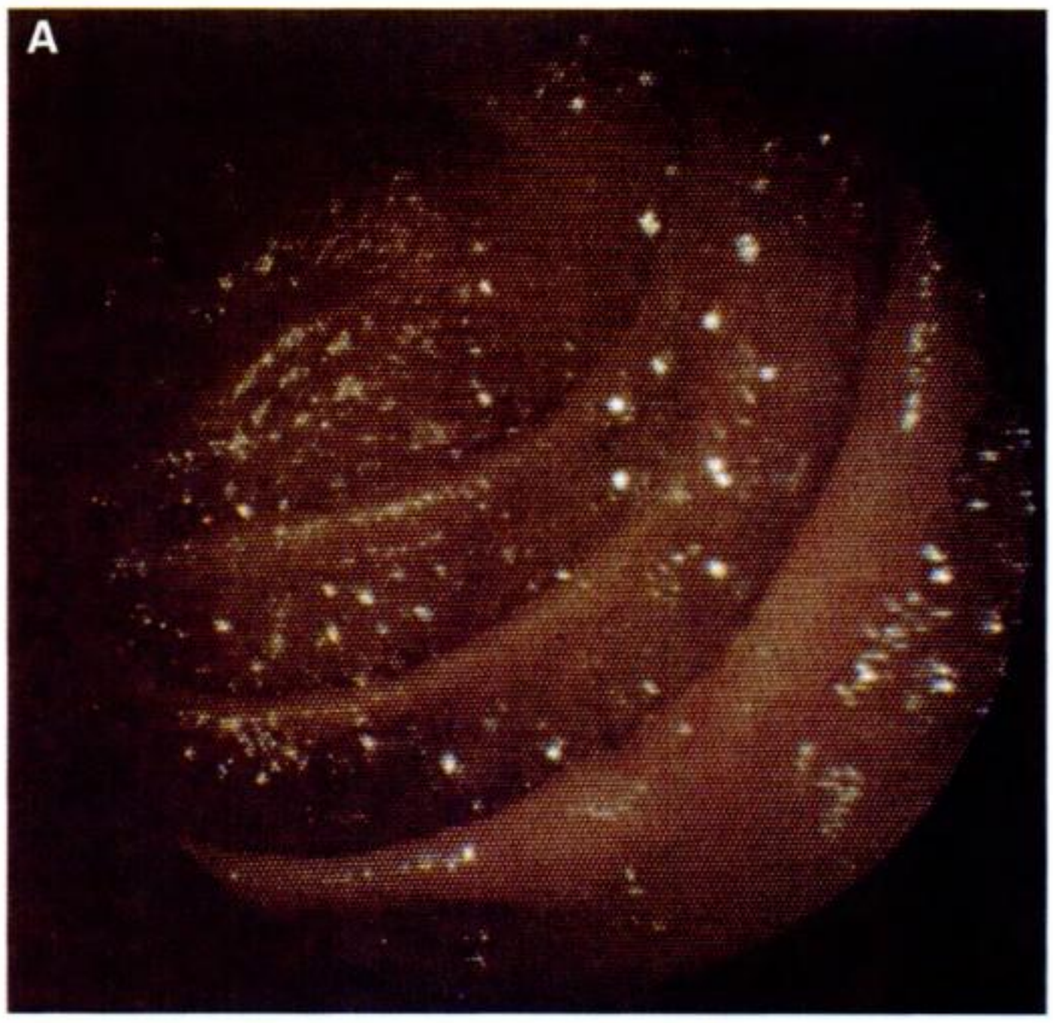
171. X-ray showing bilateral adrenal calcification in Wolman's disease.

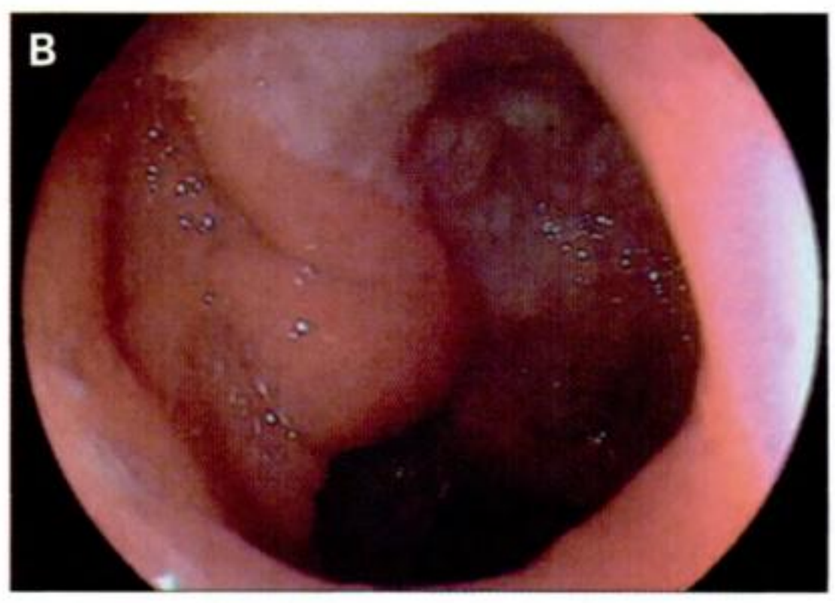
Microvillous inclusion disease



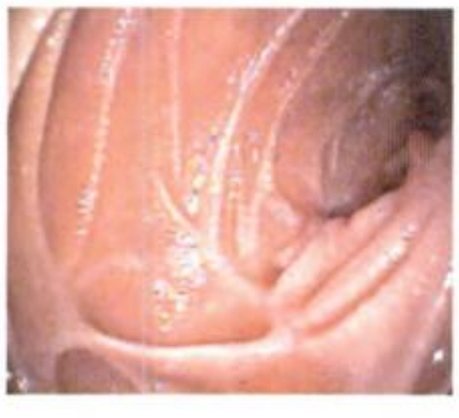
172. Enhanced vascular pattern due to thin mucosa and flat villous lesion in microvillous inclusion.

Duodenal Crohn's Disease

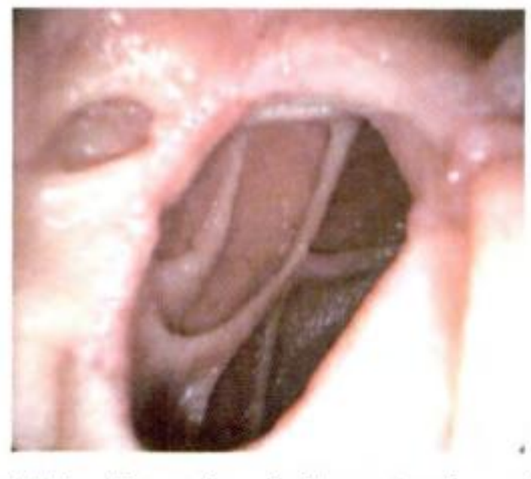




173. Duodenal ulceration and edema.

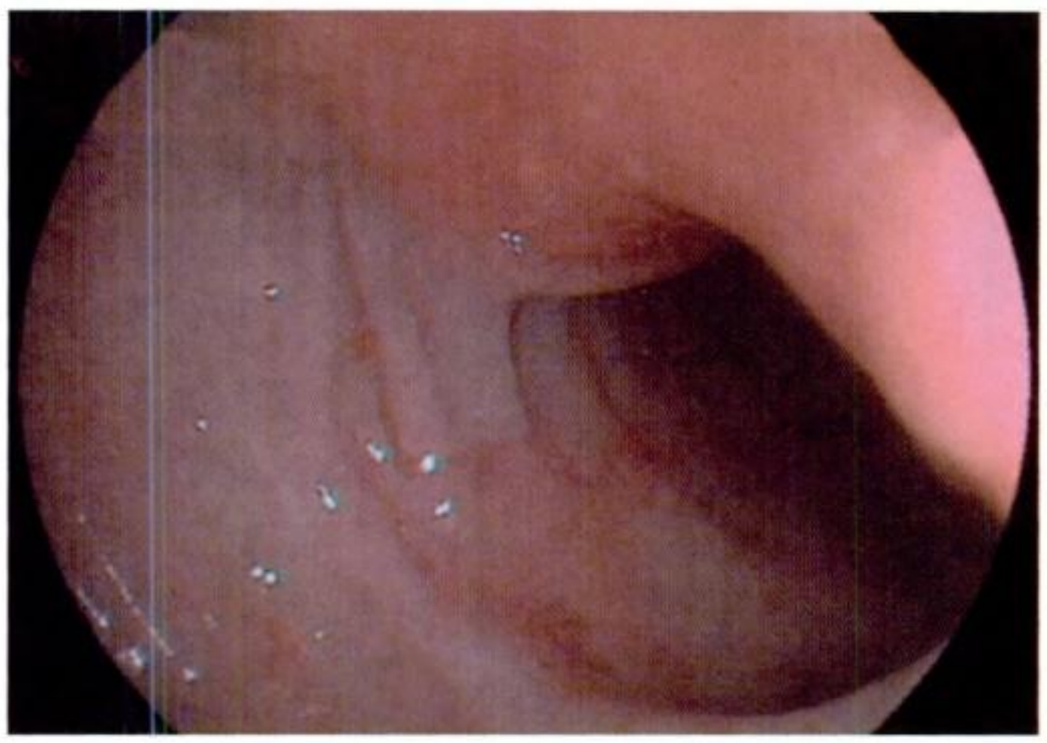


174. Chronic scarring without active disease. Note the irregularity of the mucosal folds.

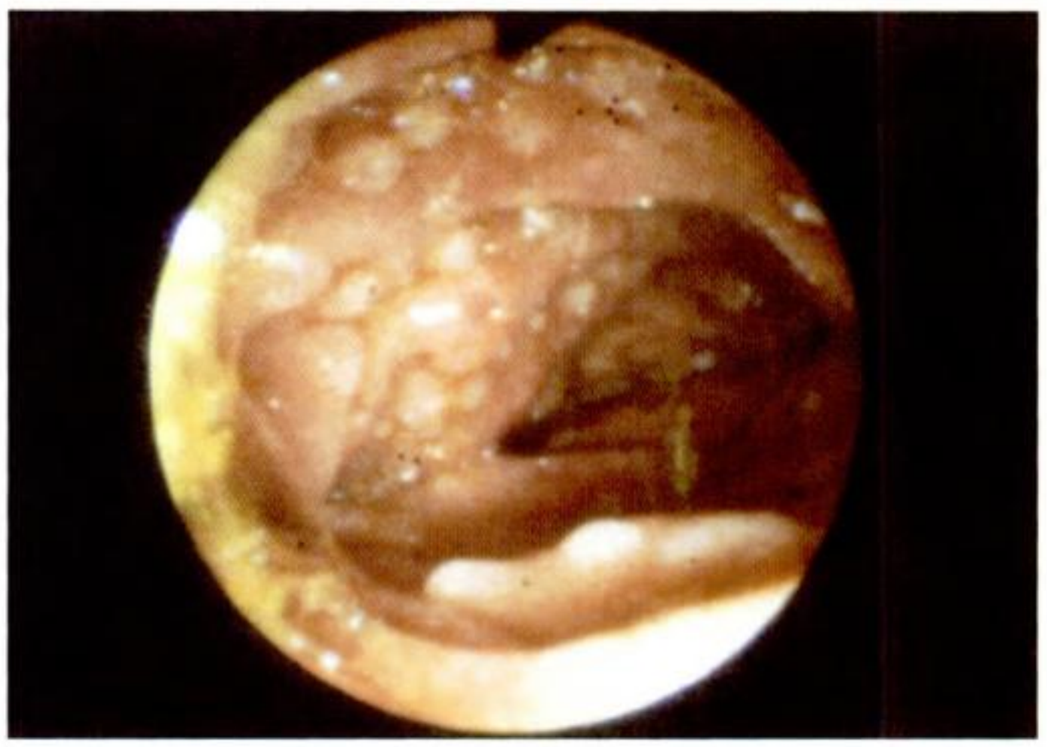


175. Duodenal diverticulum in scarred duodenum without active inflammation.

Cancer in the Duodenum

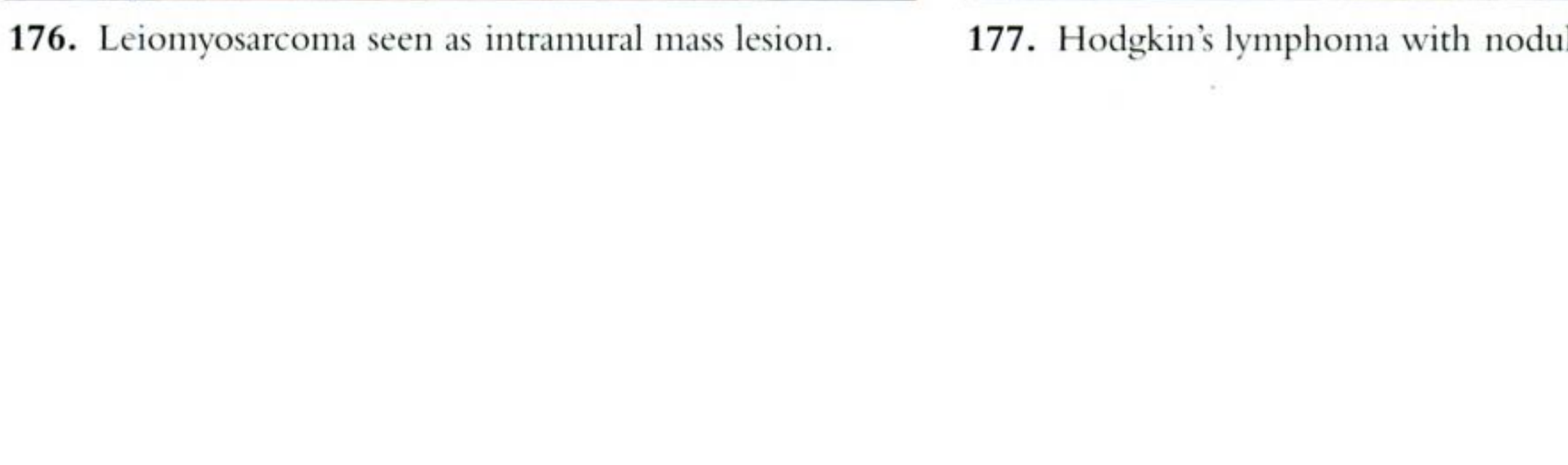


176. Leiomyosarcoma seen as intramural mass lesion.

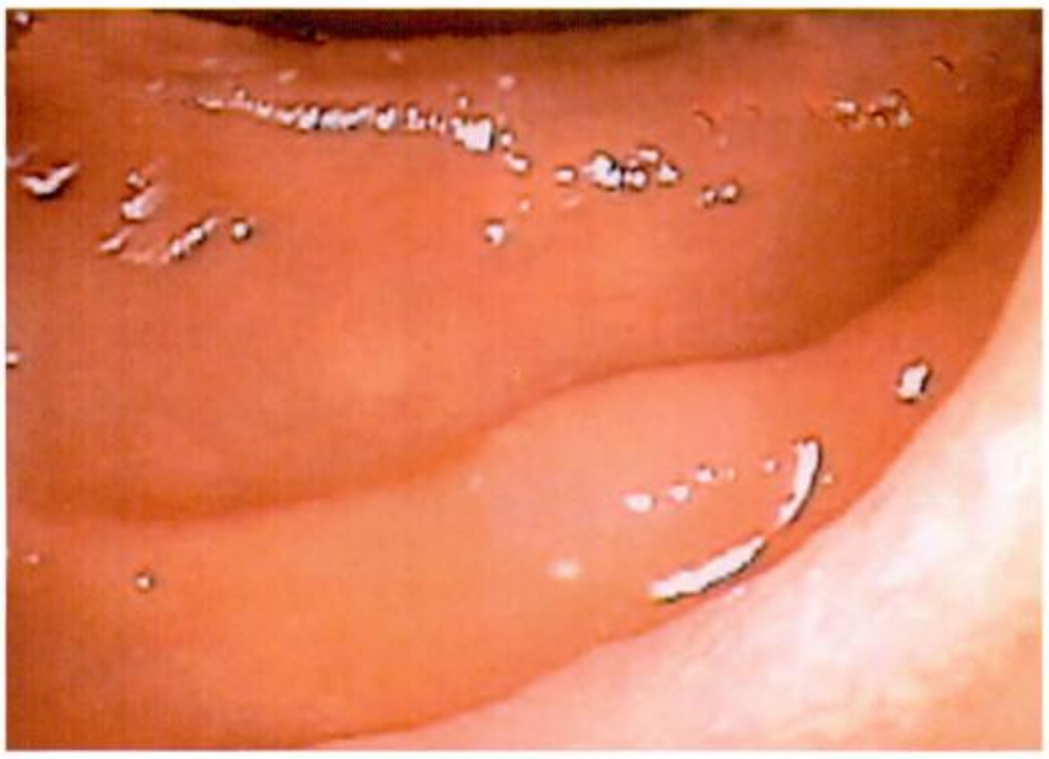


177. Hodgkin's lymphoma with nodularity.

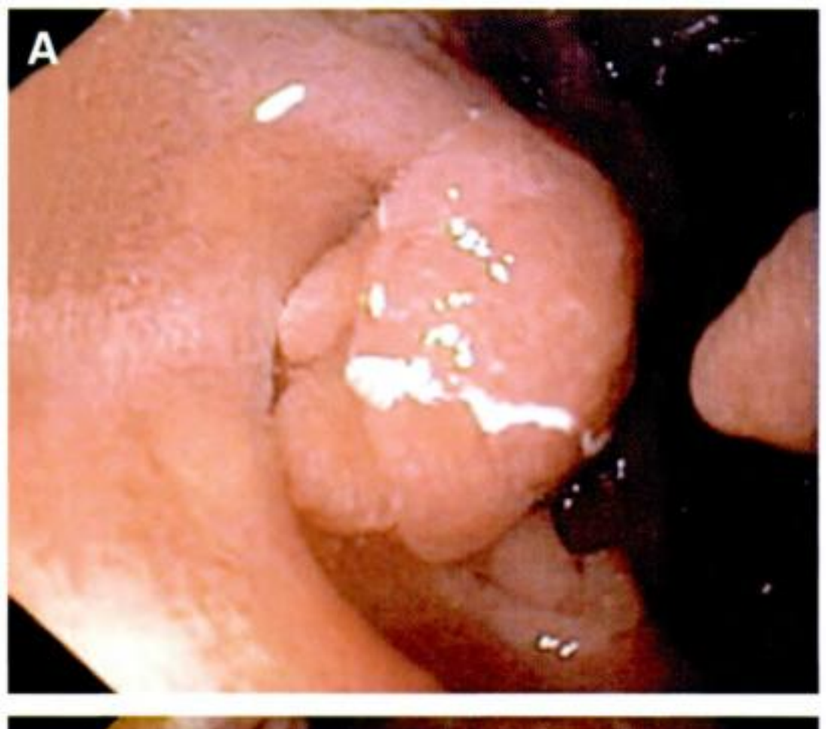
Duodenal Polyps

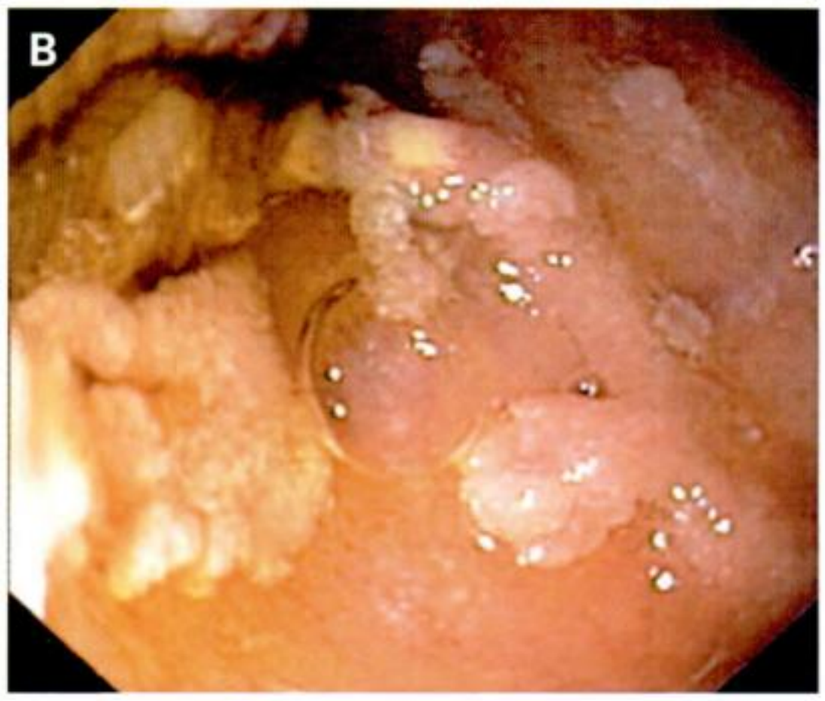


178. *A*, *B*, Sessile adenomatous polyp in child with familial adenomatous polyposis. *C*, Duodenal adenoma with vital stain. (Images courtesy of Jorge Oscar Donatone, MD.)

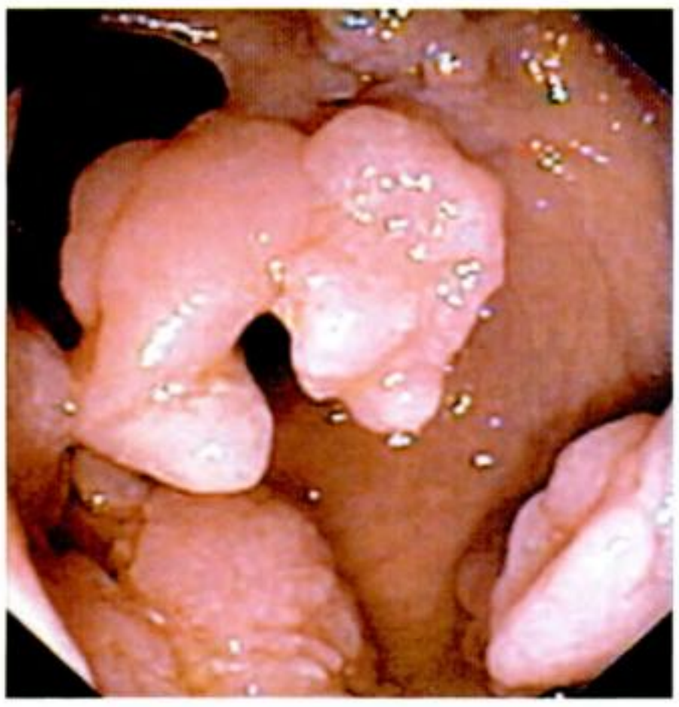


179. Adenoma in familial adenomatous polyposis seen with digital zoom.

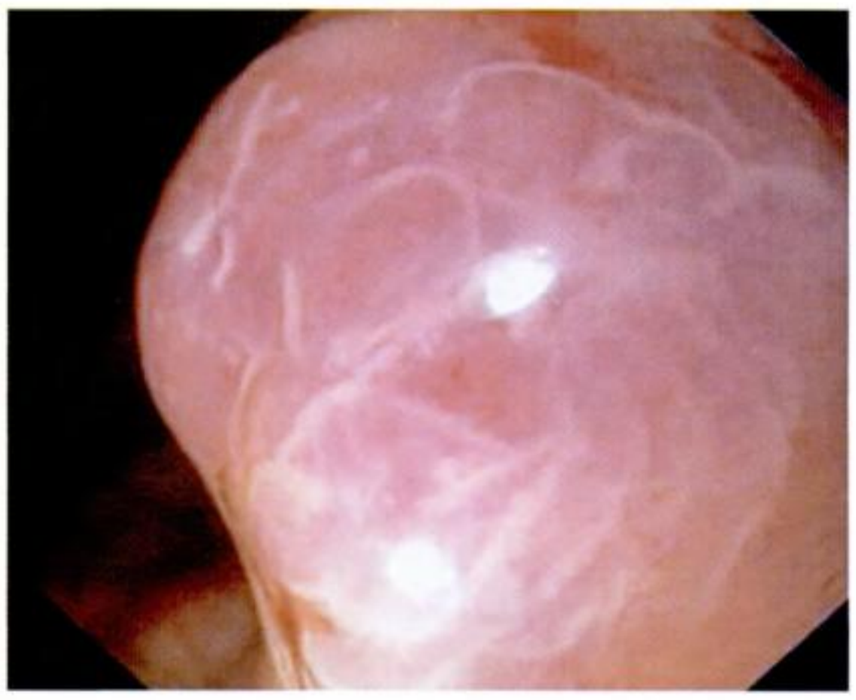




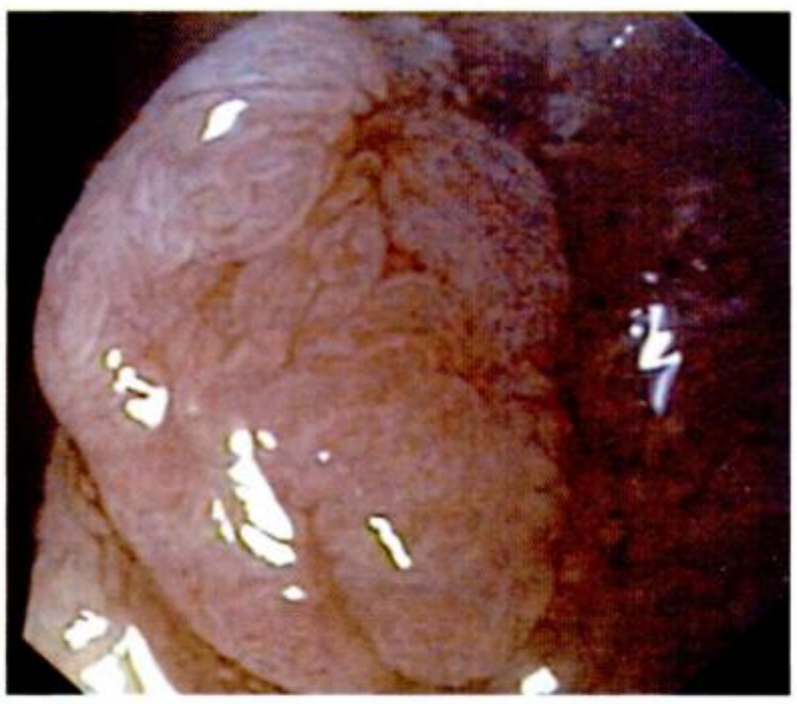
180. Multiple polyps in Cowden's syndrome.



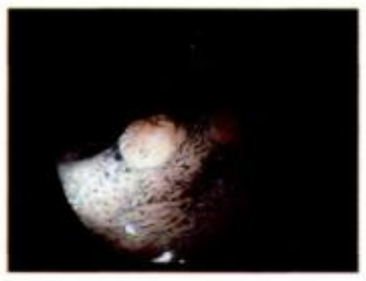
181. Pedunculated multilobulated polyps at the junction of the duodenum and jejunum in Cowden's syndrome.



182. View with endoscopic zoom of duodenal adenoma in Cowden's syndrome.

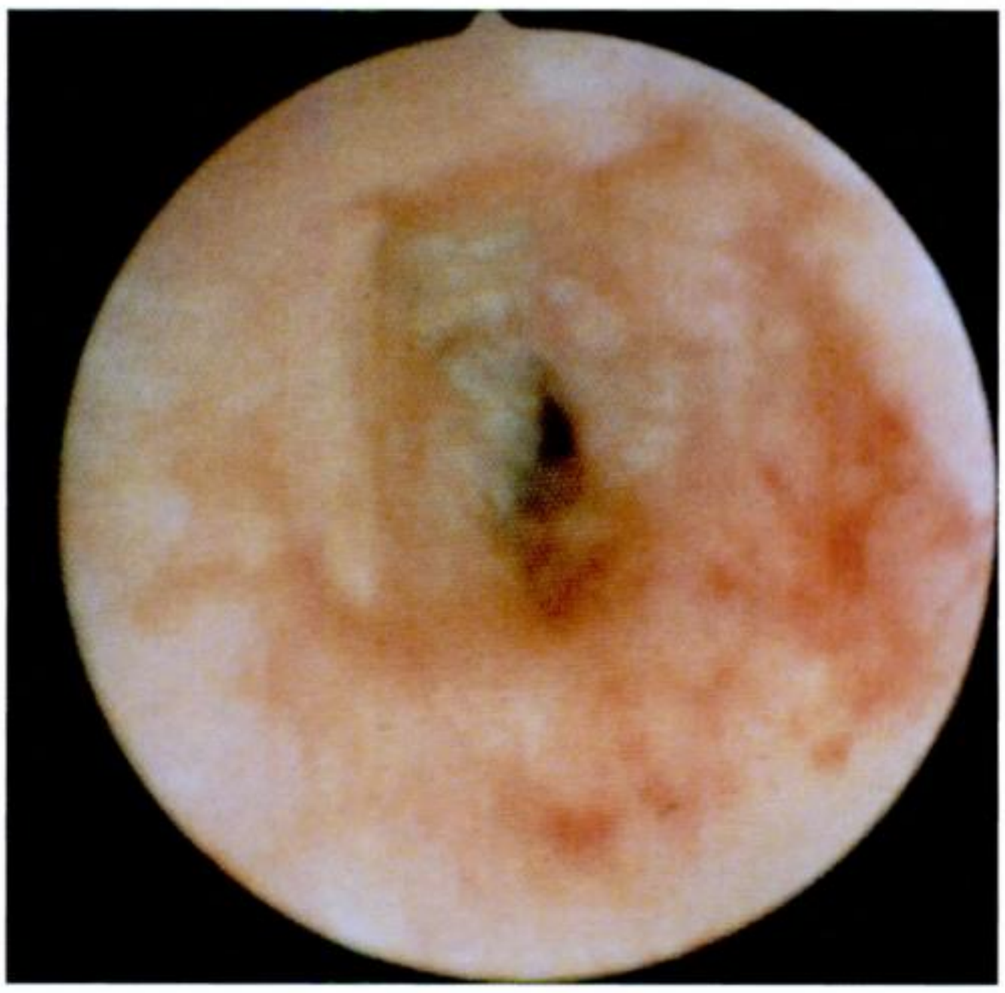


183. Adenomatous transformation in duodenal polyp in Cowden's syndrome characterized by the pit pattern seen with optical zoom.



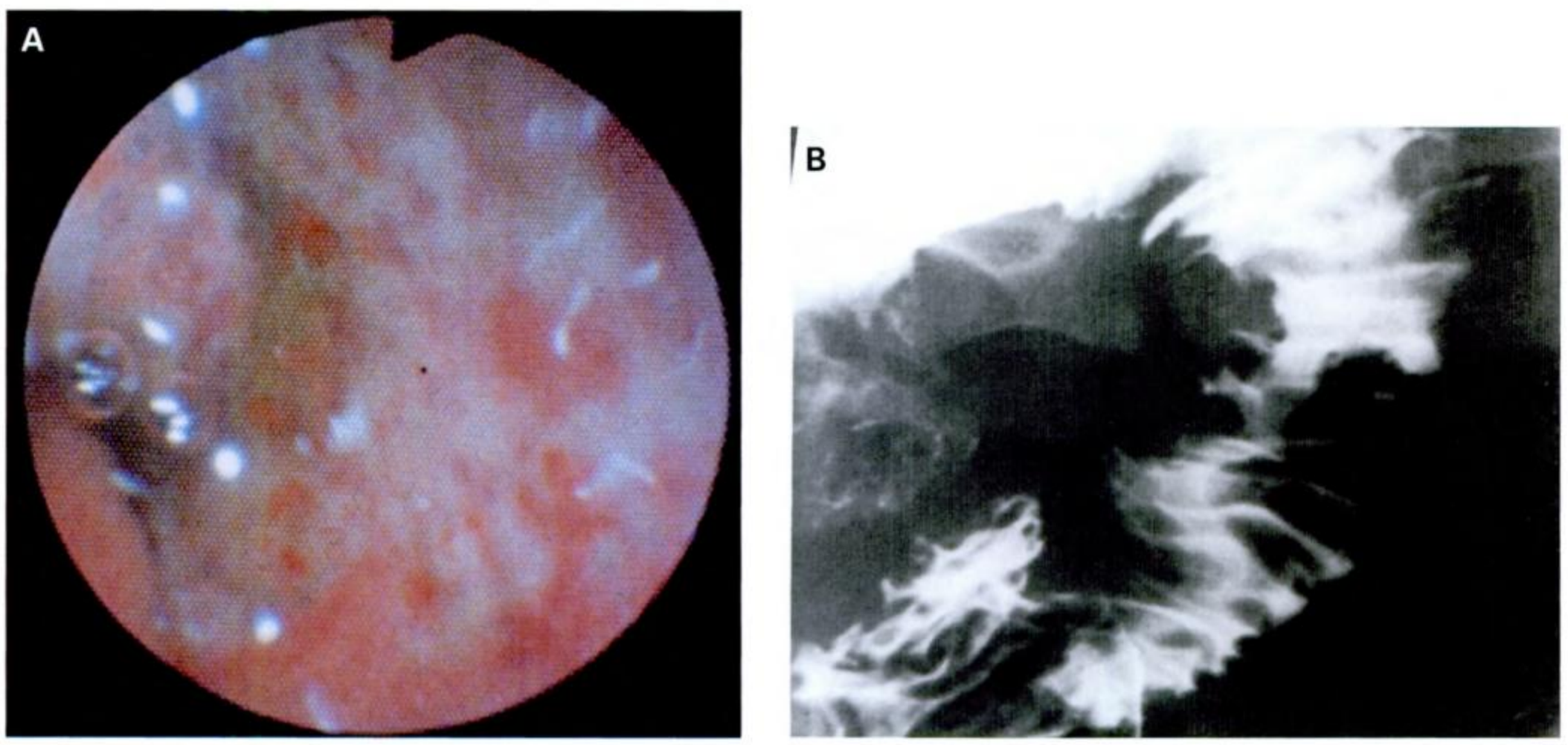
184. Sessile appearing duodenal juvenile polyp. (Image courtesy of Jorge Oscar Donatone, MD.)

Radiation Enteritis



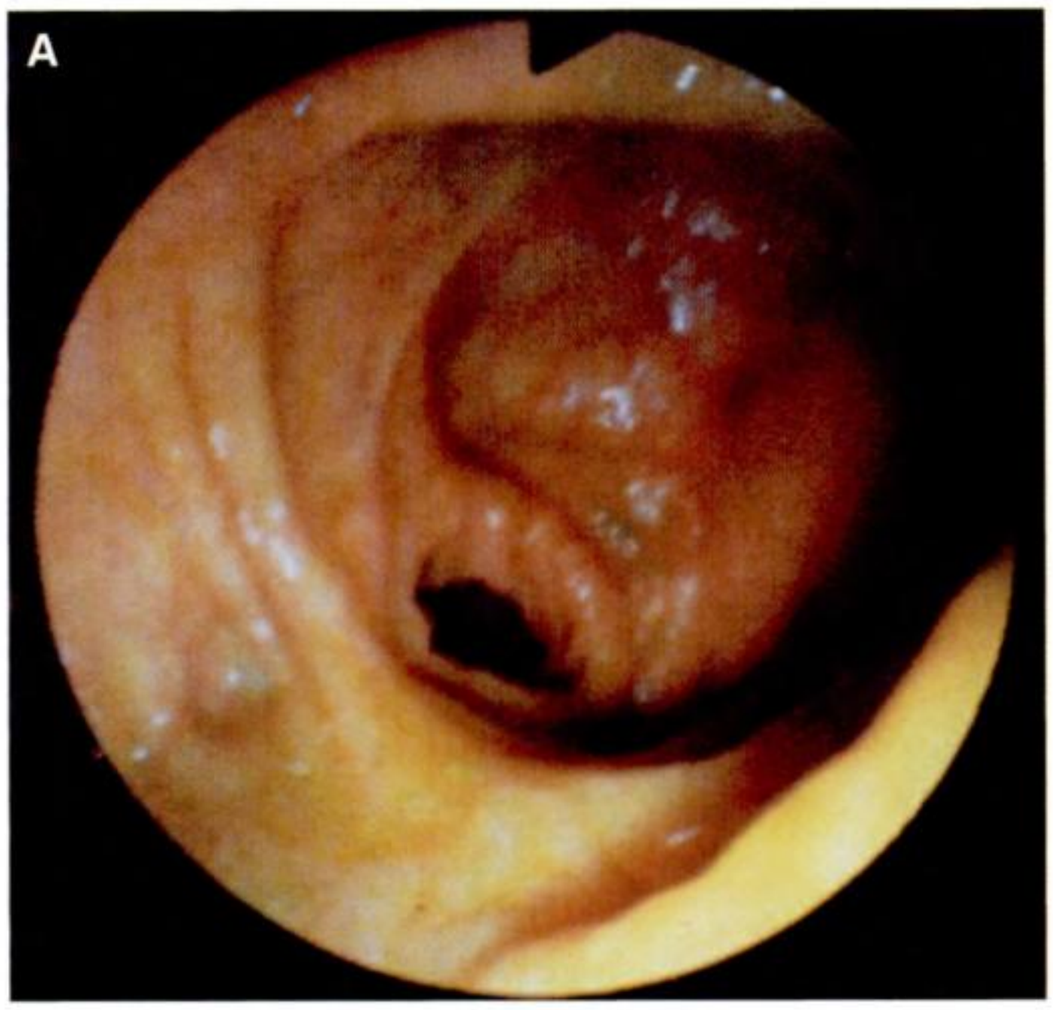
185. Radiation enteritis characterized by a pale nodular mucosa and hemorrhage.

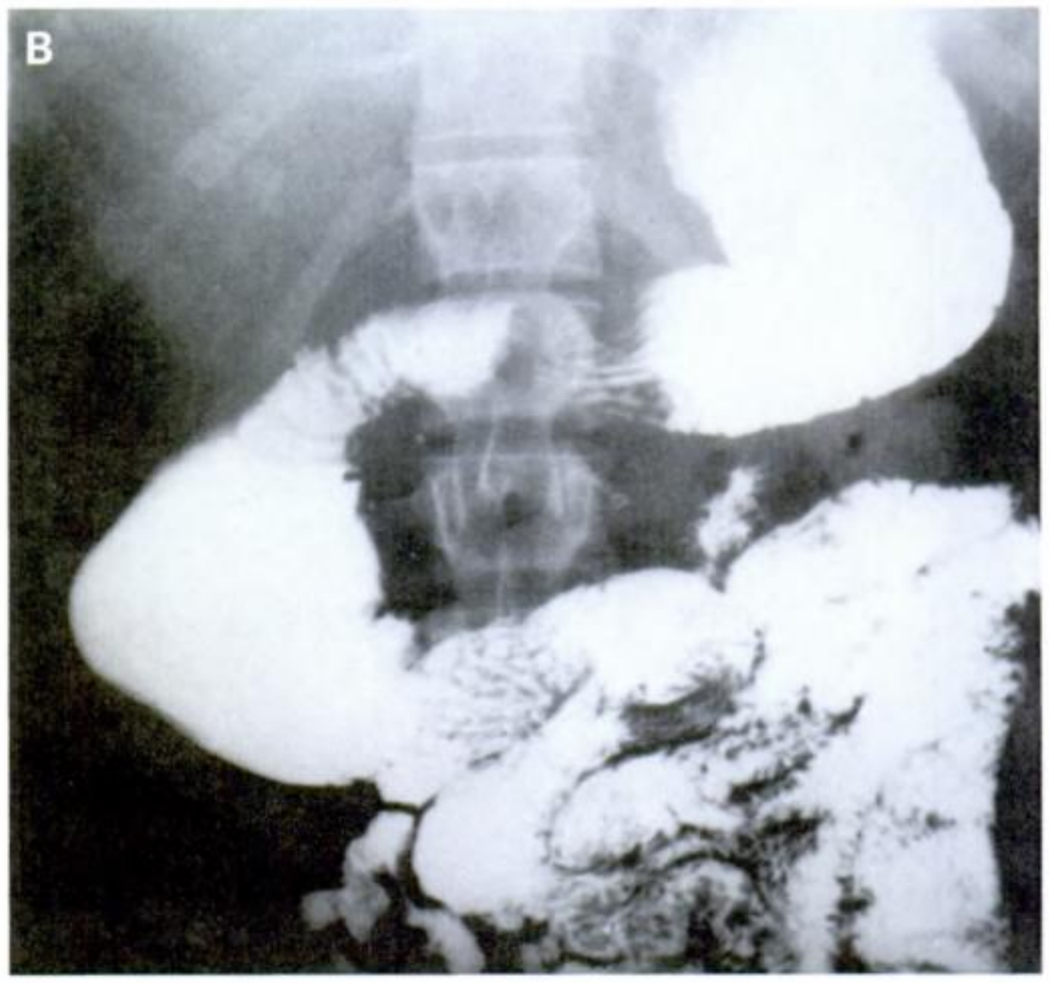
Henoch Schonlein purpura



186. *A*, Hemorrhagic ulcerated duodenal mucosa in Henoch Schonlein purpura. *B*, Duodenal mucosal fold thickening.

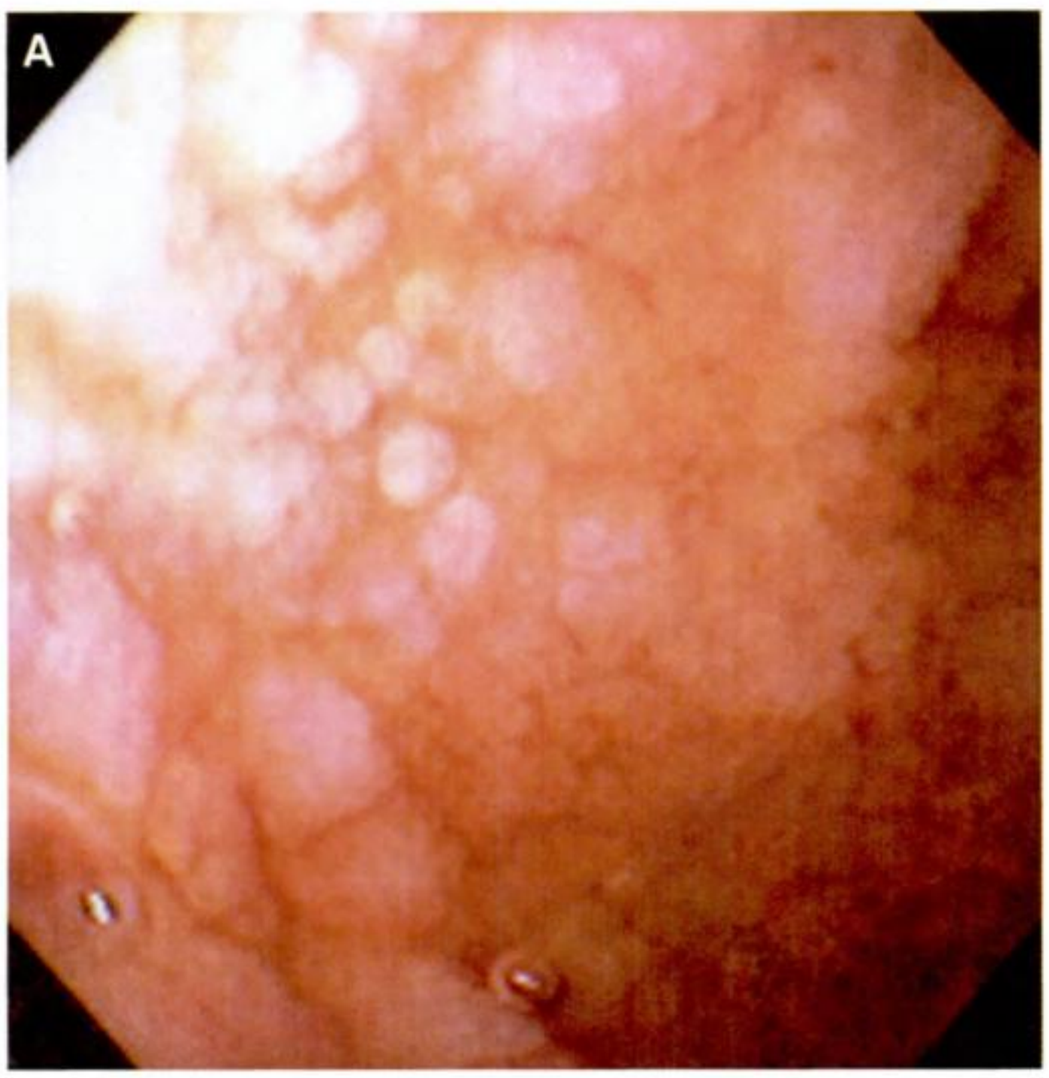
Intestinal Pseudo-obstruction

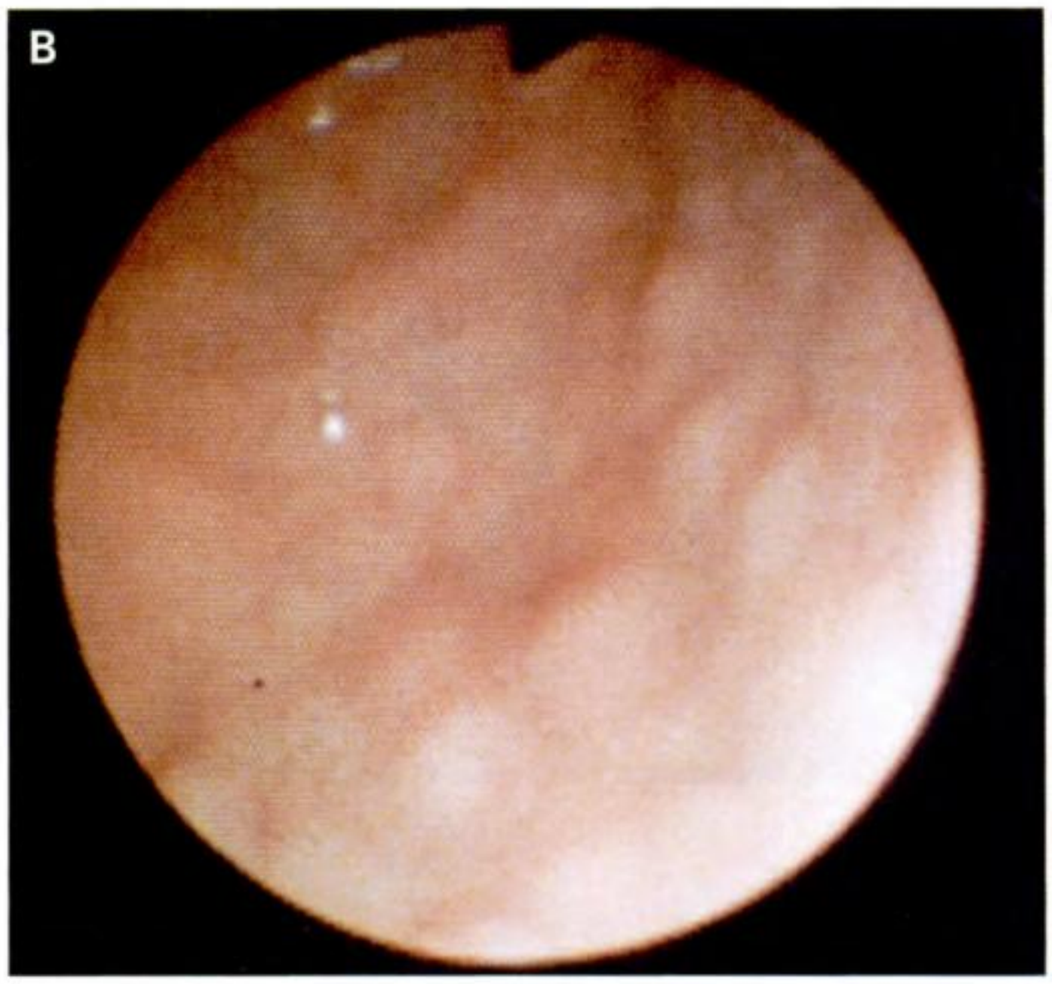




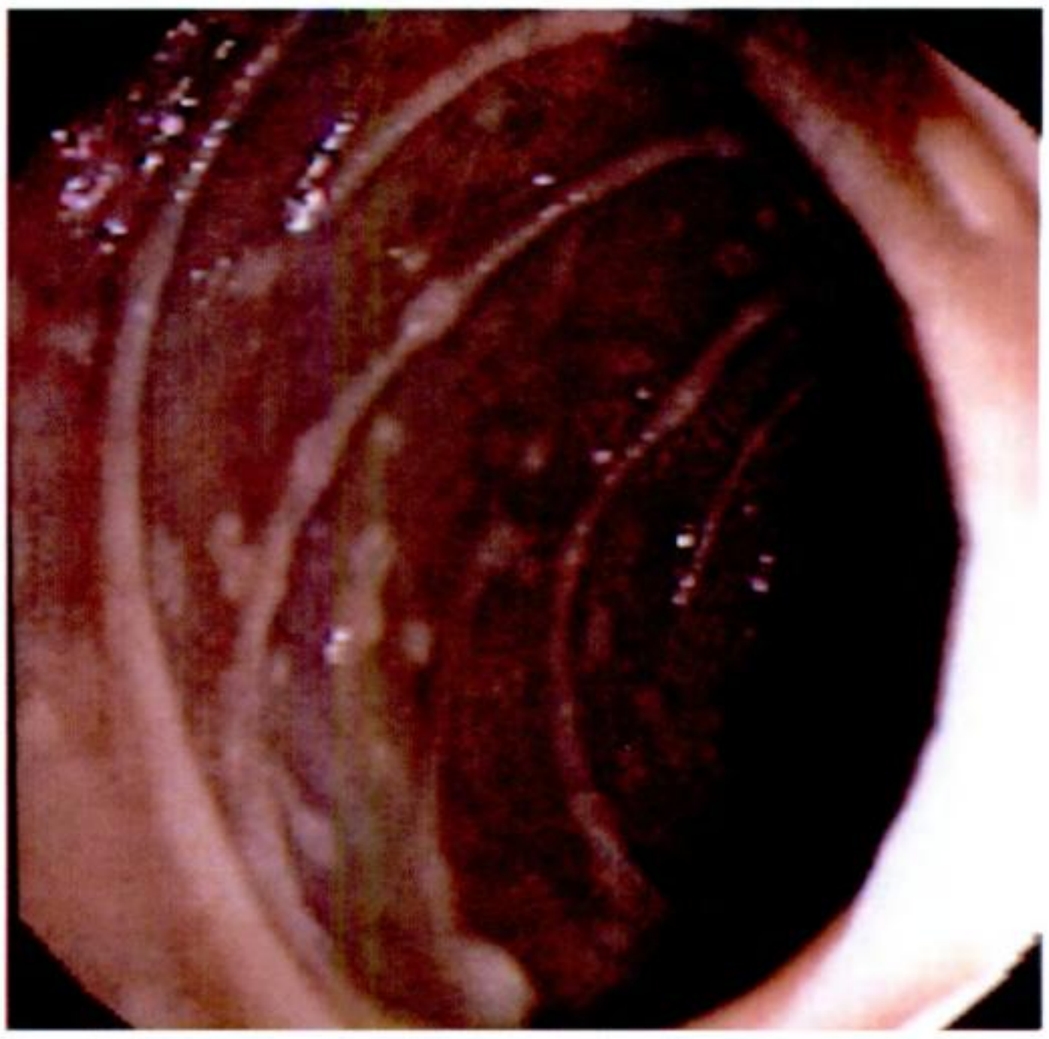
187. Megaduodenum in a patient with pseudo-obstruction.

Human Immunodeficiency Virus (HIV) Disease



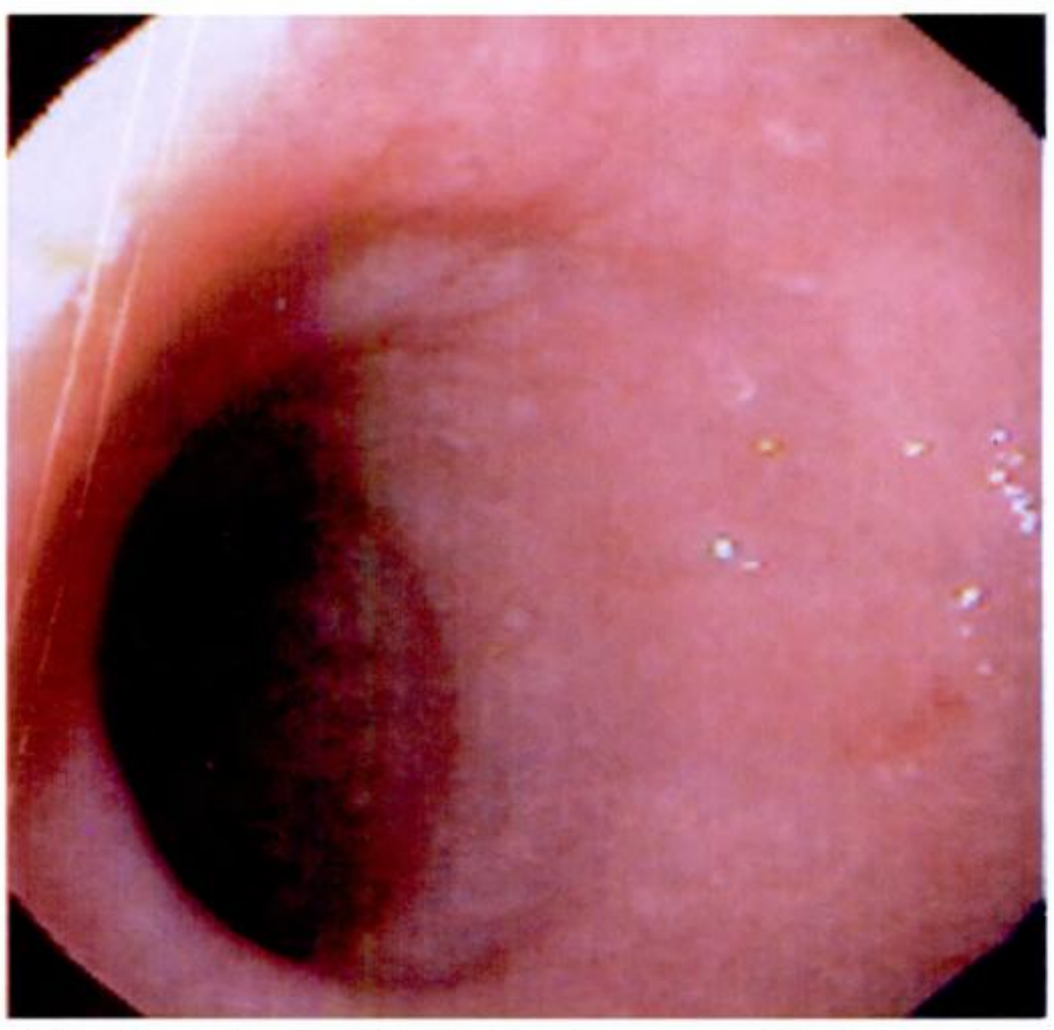


188. Nodularity and lymphoid hyperplasia in the duodenum characteristic of HIV. No enteric pathogen identified.

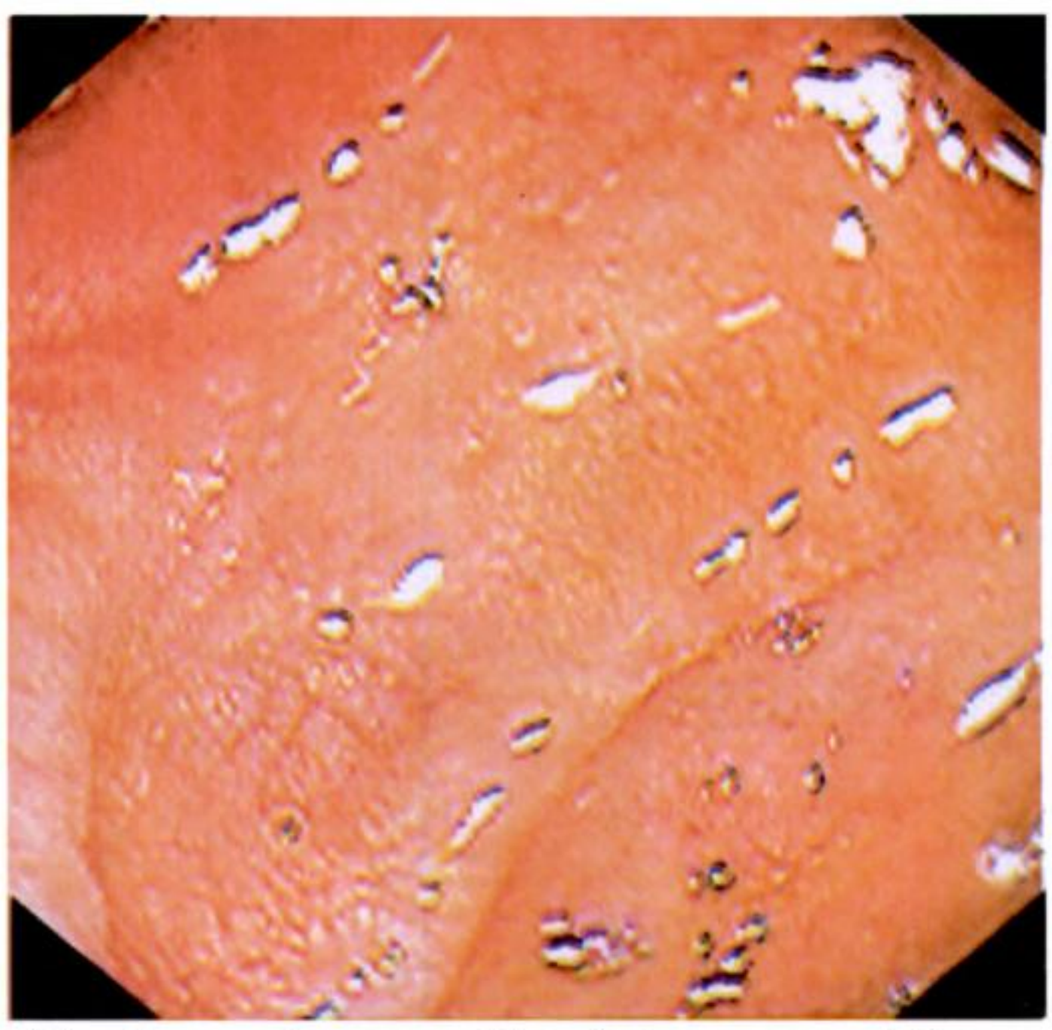


189. Duodenal nodularity in HIV caused by *Mycobacterium avium intracellulare.*

Primary Immunodeficiency

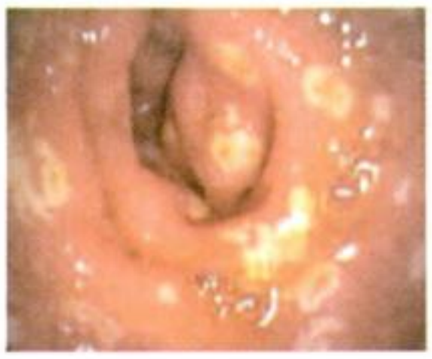


190. Smooth atrophic duodenal mucosa with tiny erosions associated with primary T cell deficiency.

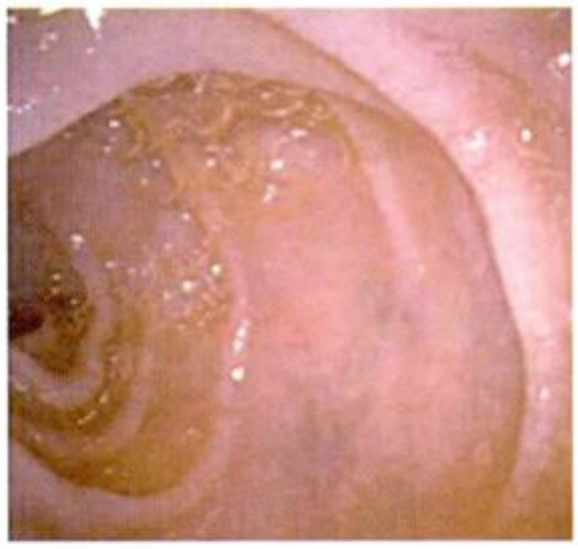


191. Abnormal mucosa with reticular pattern and absence of villi associated with primary T cell deficiency.

Autoimmune Enteropathy

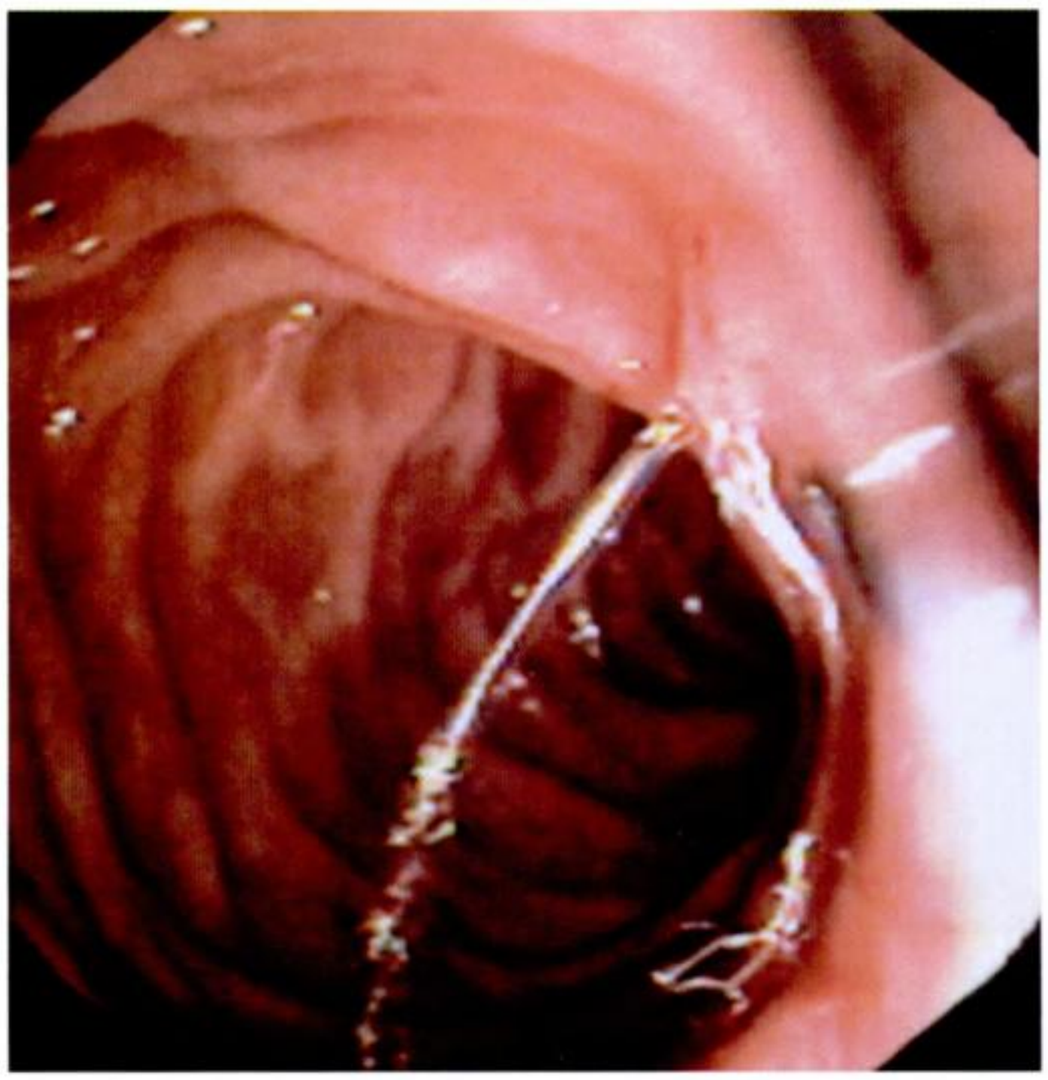


192. Severe active enteritis with white plaques in a child with autoimmune enteropathy. Bacterial, fungal and viral cultures were negative.



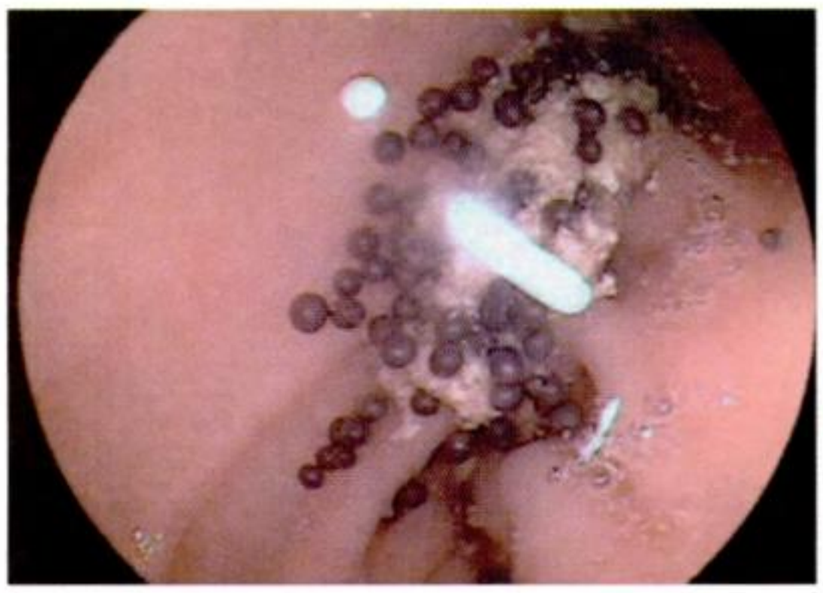
193. Smooth and pale appearance of the duodenal mucosa in an infant with a flat villus lesion associated with autoimmune enteropathy after treatment with cyclosporine.

Pancreas Divisum



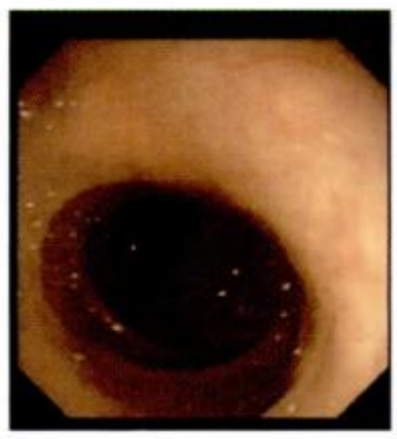
194. Forceful ejection of pancreatic fluid from a narrow duct of Santorini in pancreas divisum.

Intraluminal Medication



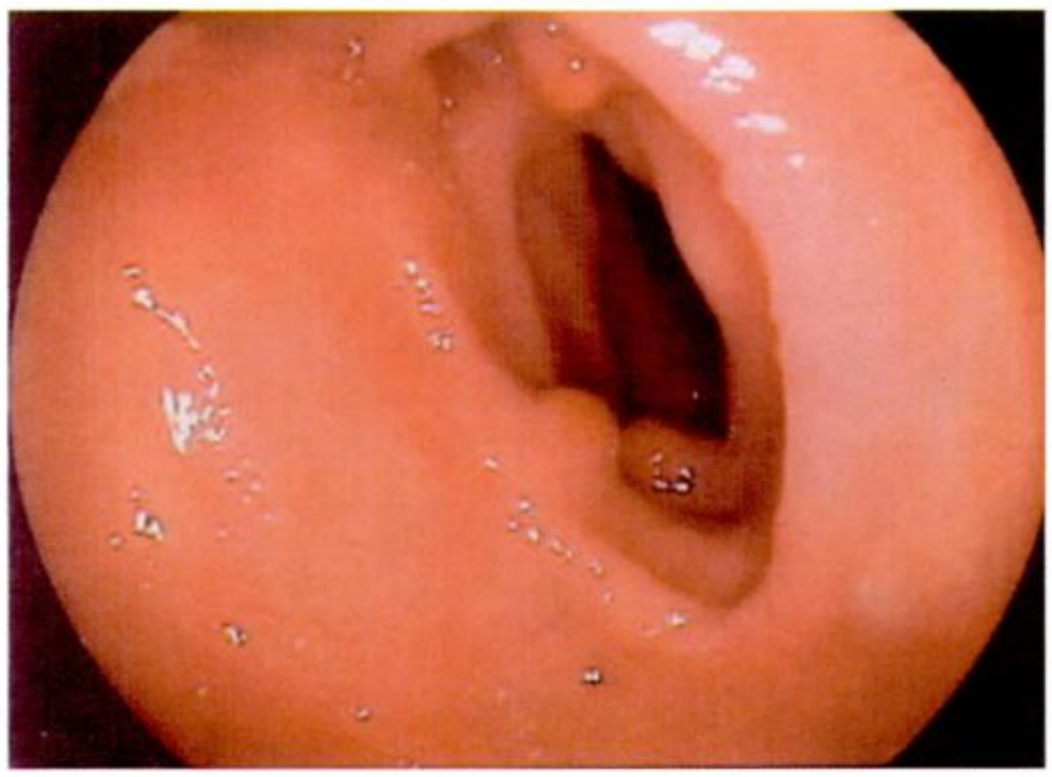
195. Tablet containing microspheres dissolving in the duodenum.

Malrotation



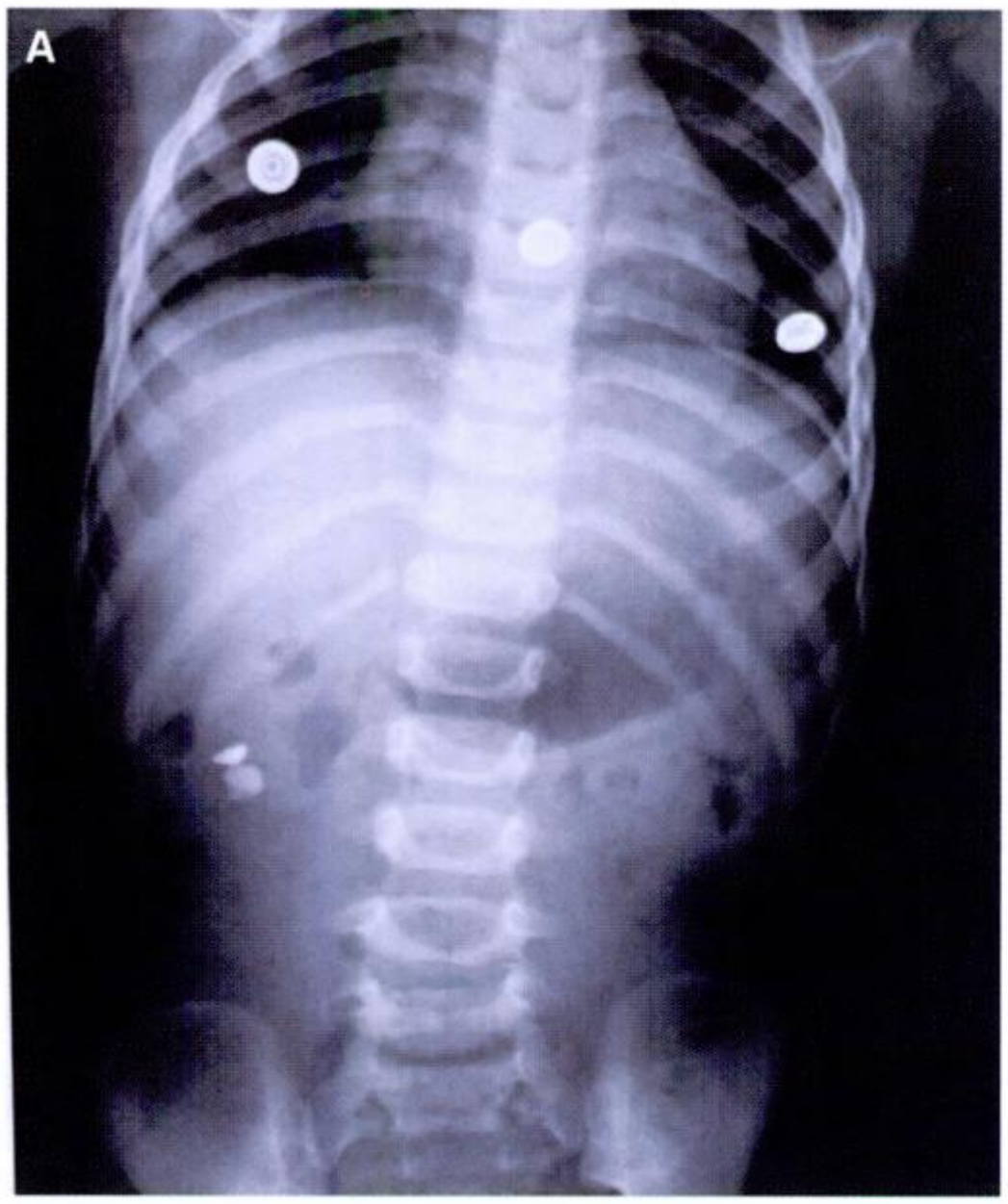
196. Unusually long, straight segment of duodenum in an neonate with malrotation.

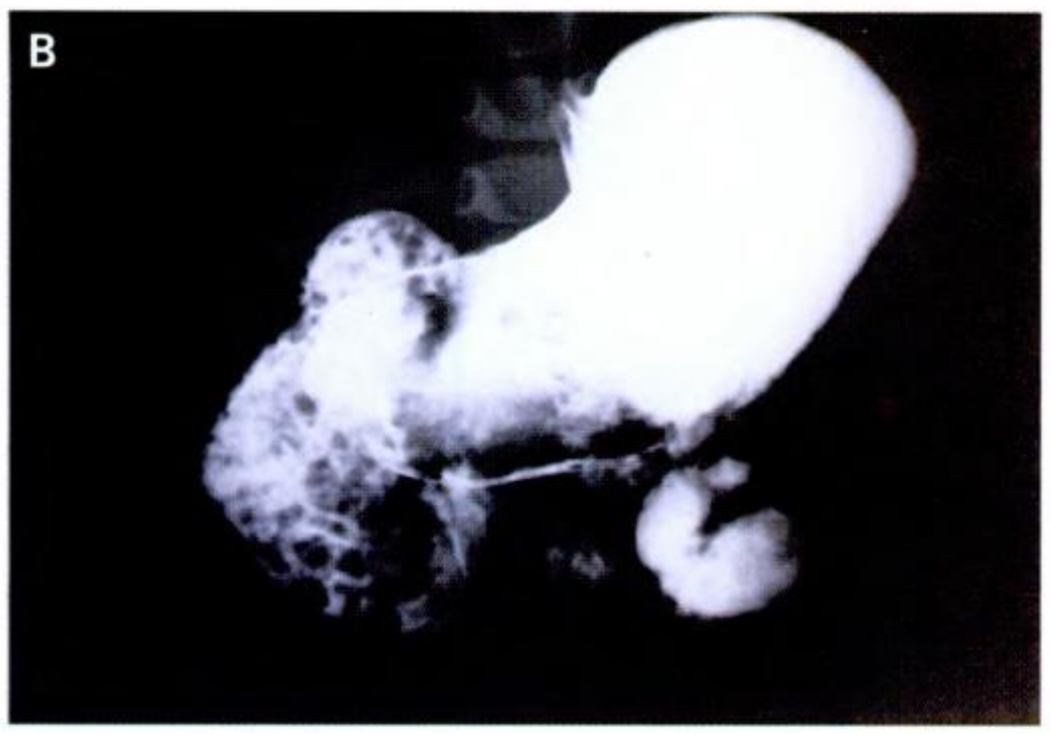
Duodenal Varices

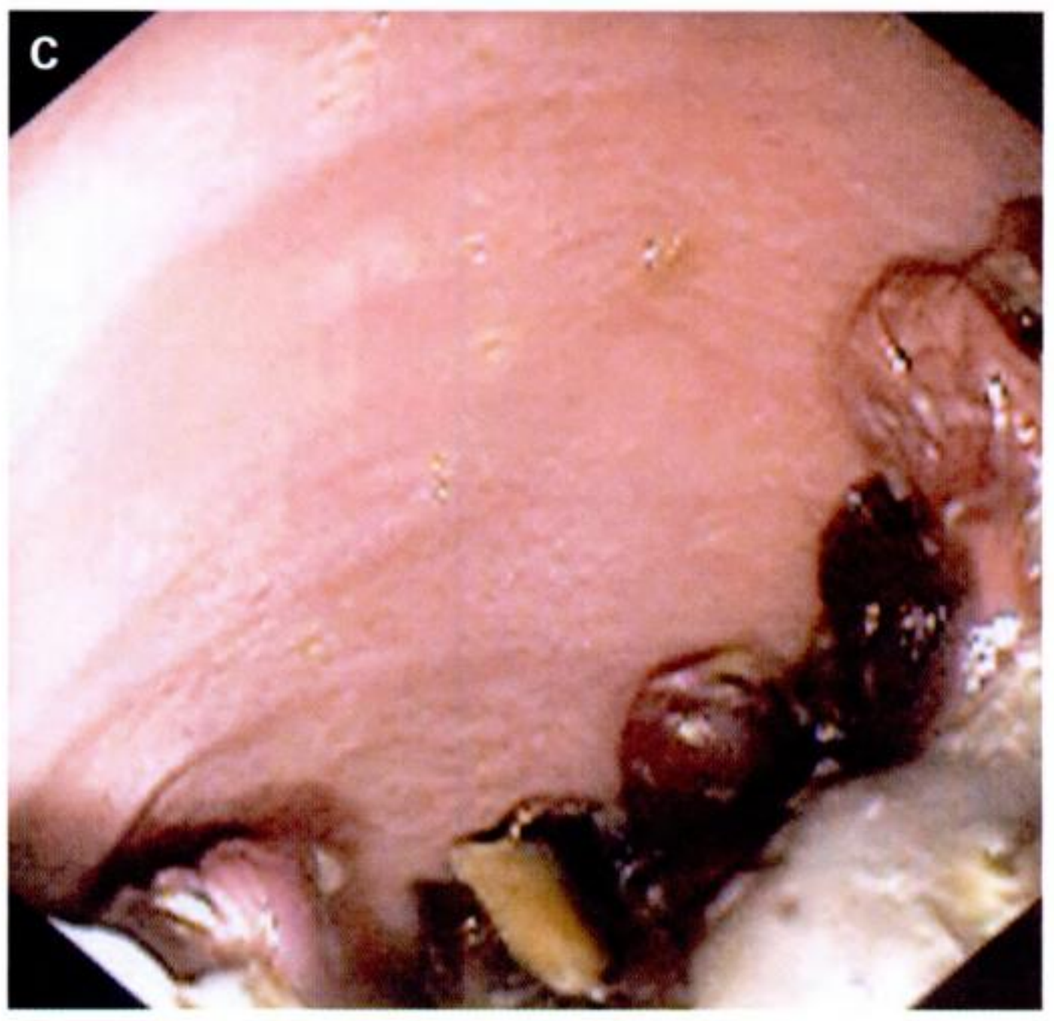


197. Duodenal varices on opposite walls.

Duodenal Web

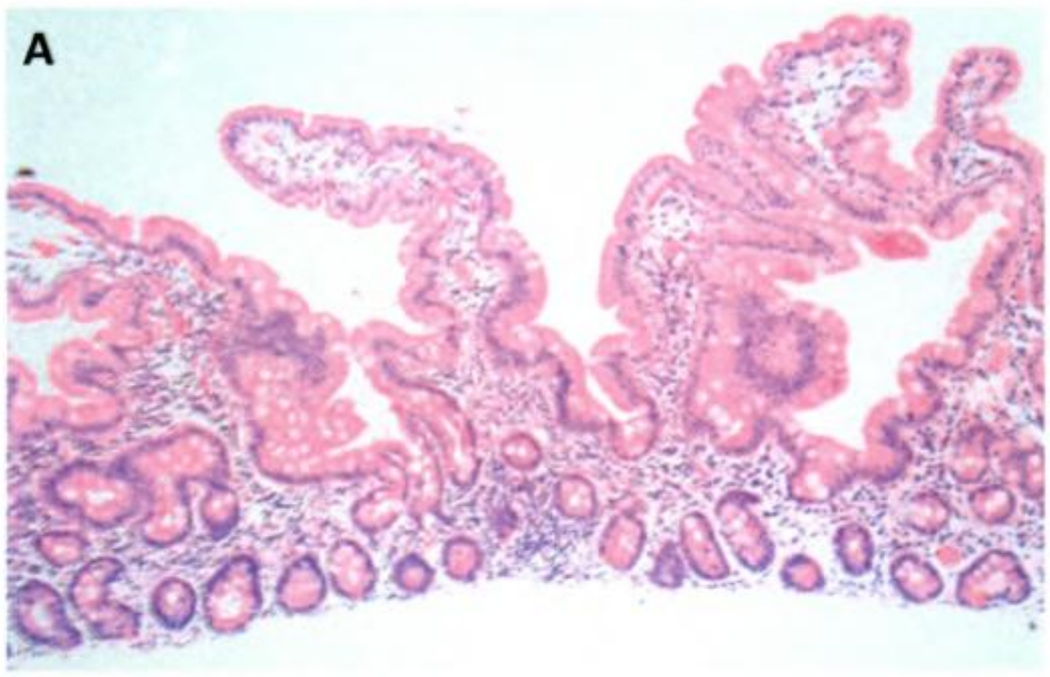


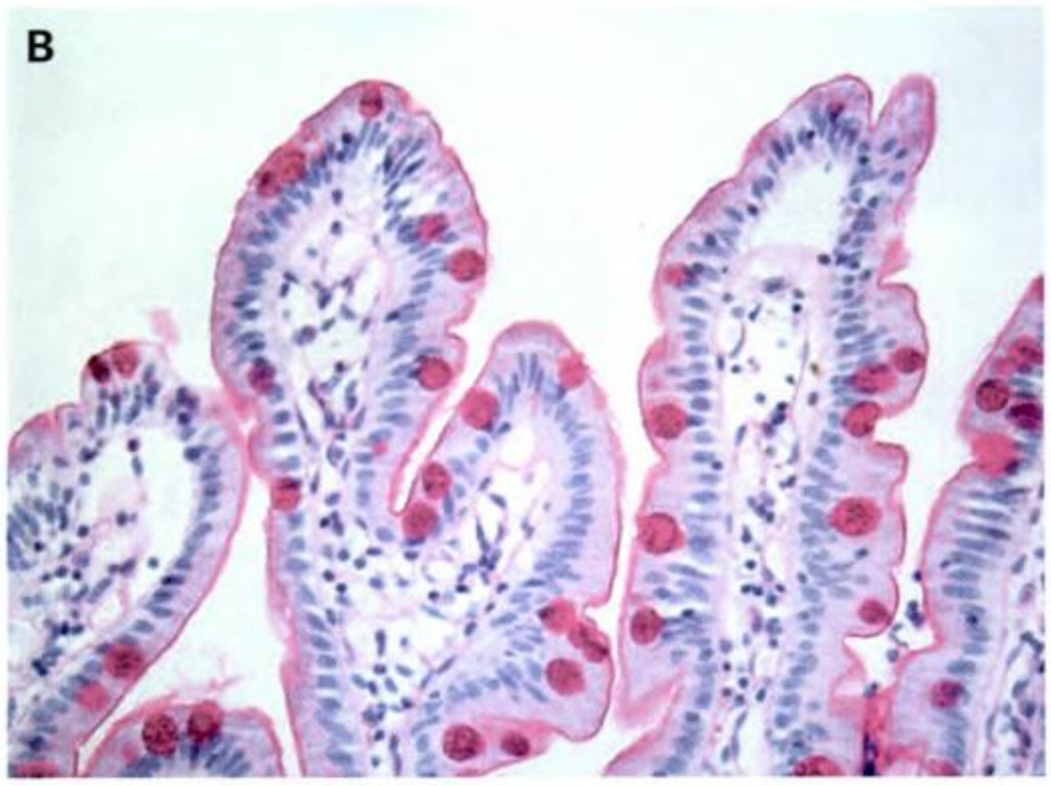




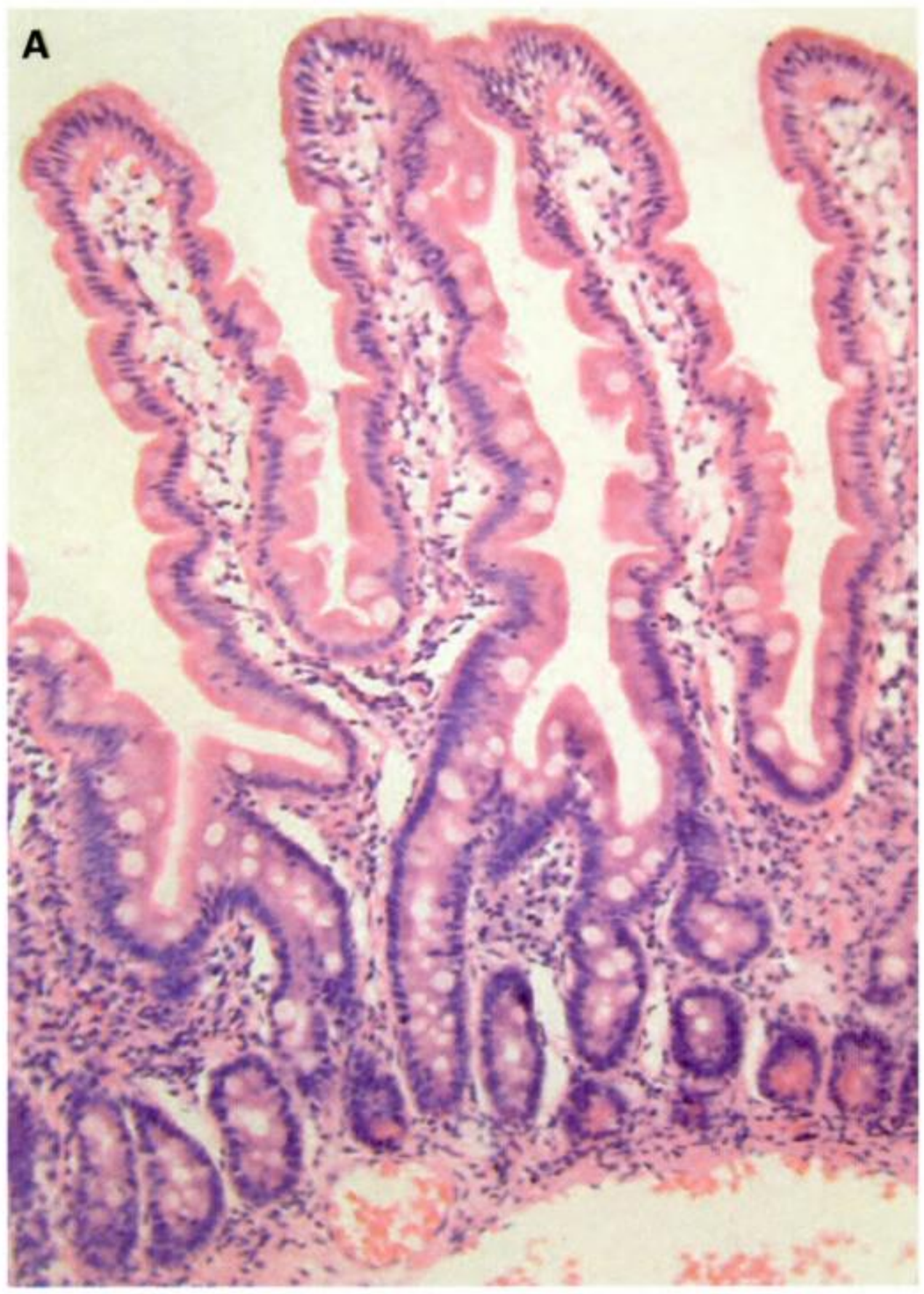
198. *A*, Double bubble on KUB characteristic of duodenal stenosis. B, Duodenal stenosis with wind socket web of the duodenum. C, Duodenal stenosis with wind socket web of the duodenum with retained food. (Images courtesy of Joel R. Rosh, MD.)

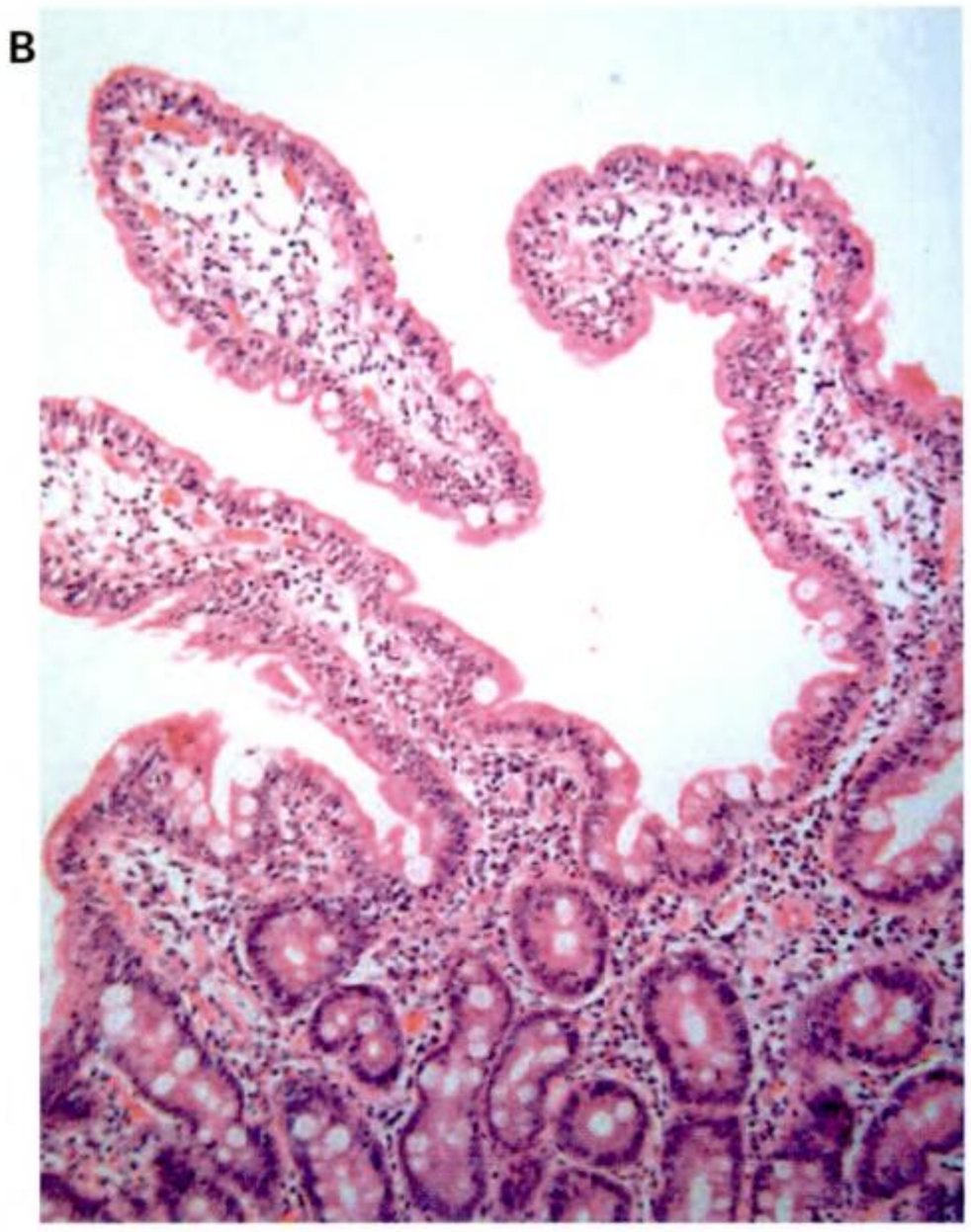
Duodenal Histology





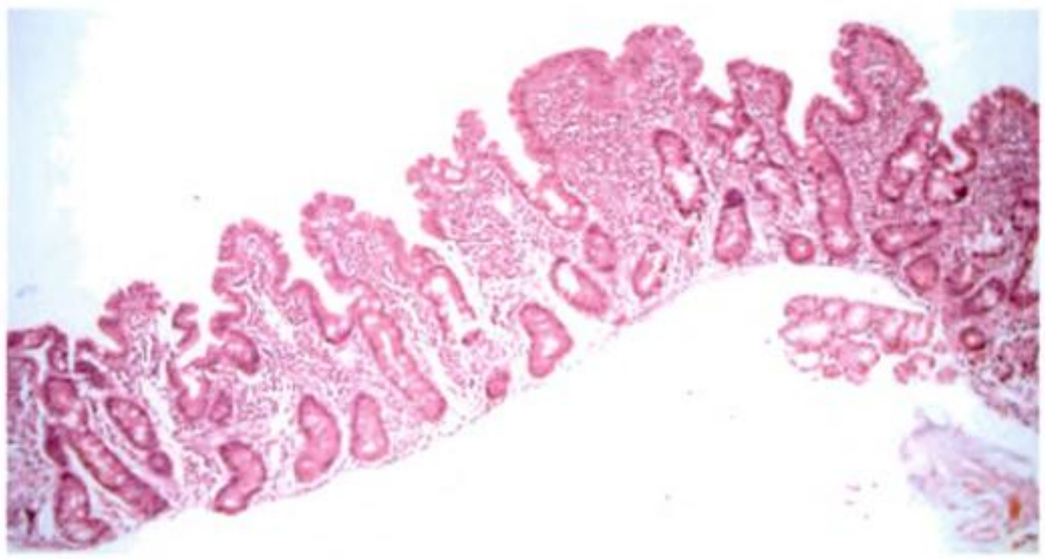
199. Normal duodenum. (Images courtesy of Rachel Brown, FRCPath.)





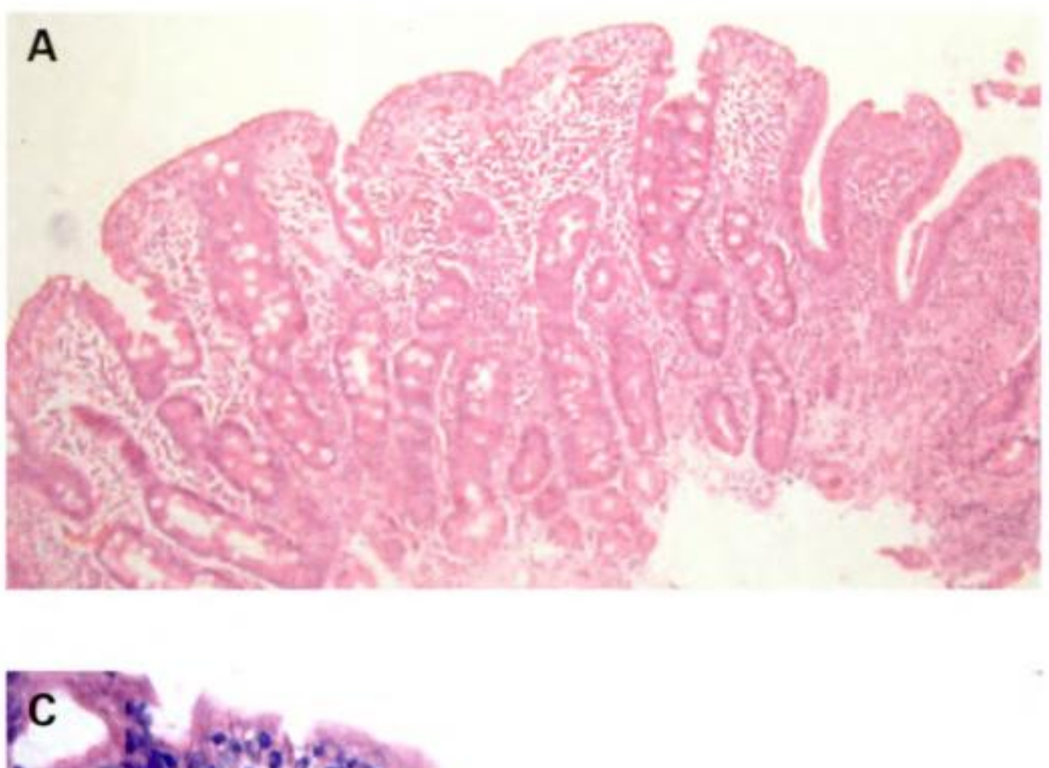
200. *A*, Normal villus-crypt ratio. *B*, Normal villi with increased intraepithelial lymphocytes. (Images courtesy of Rachel Brown, FRCPath.)

Partial Villous Atrophy



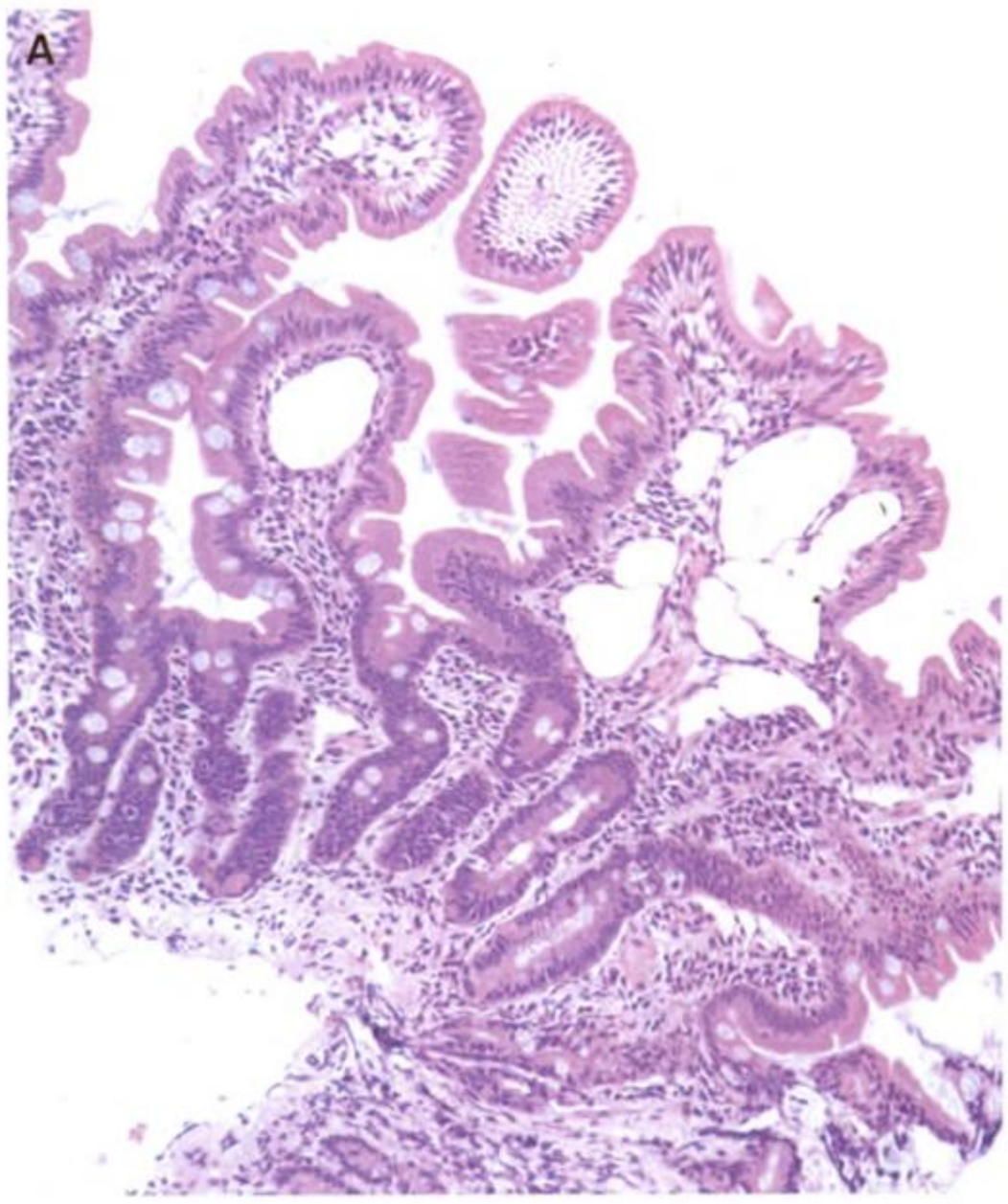
201. Decreased villus to crypt ration of 1:1. (Image courtesy of Rachel Brown, FRCPath.)

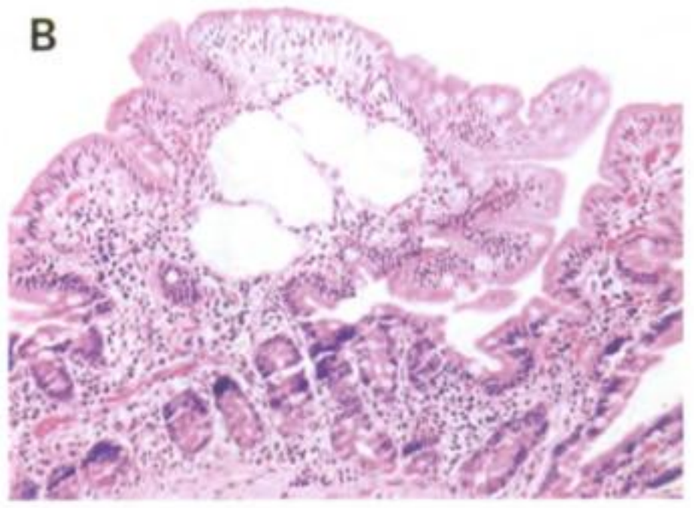
Celiac Disease

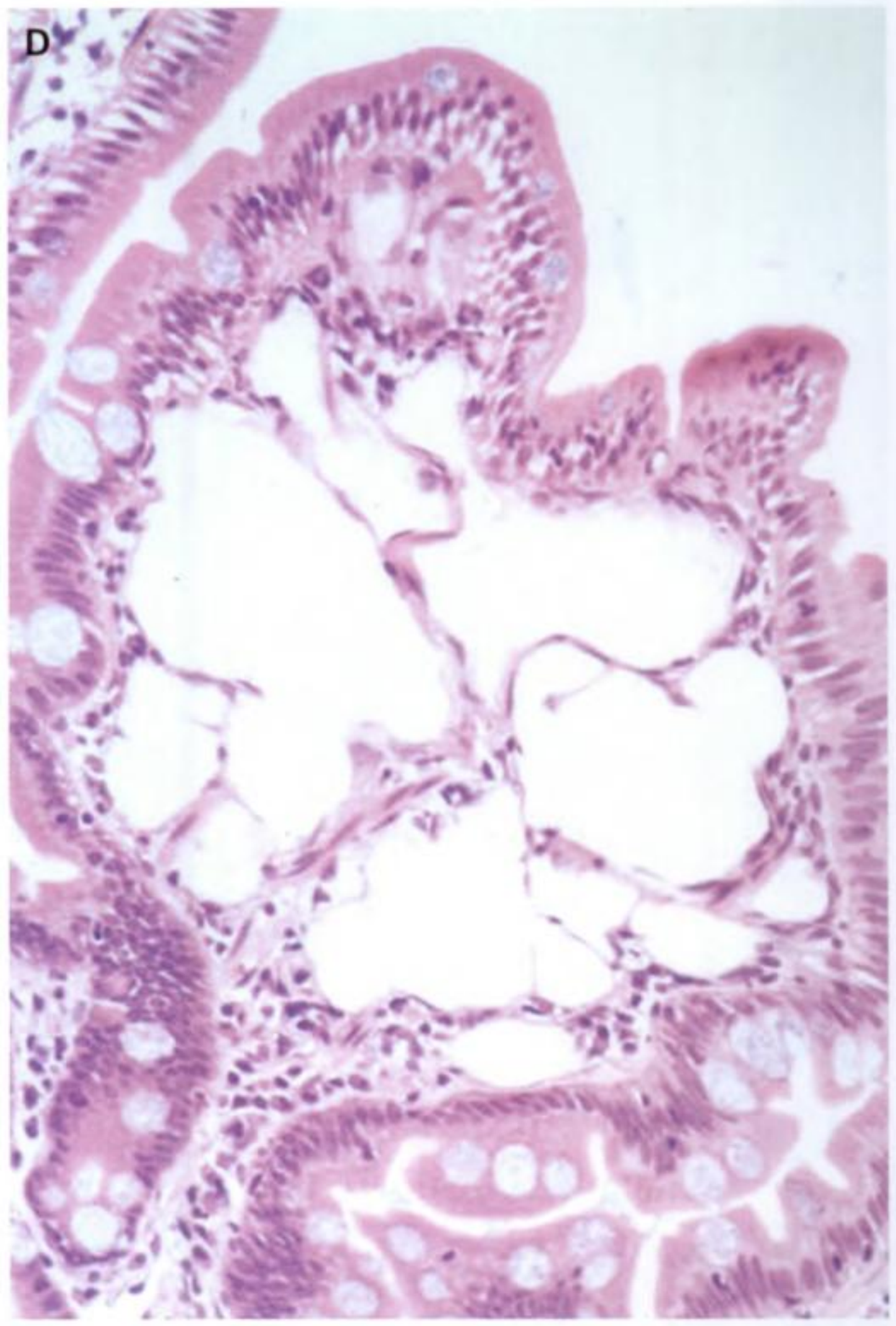


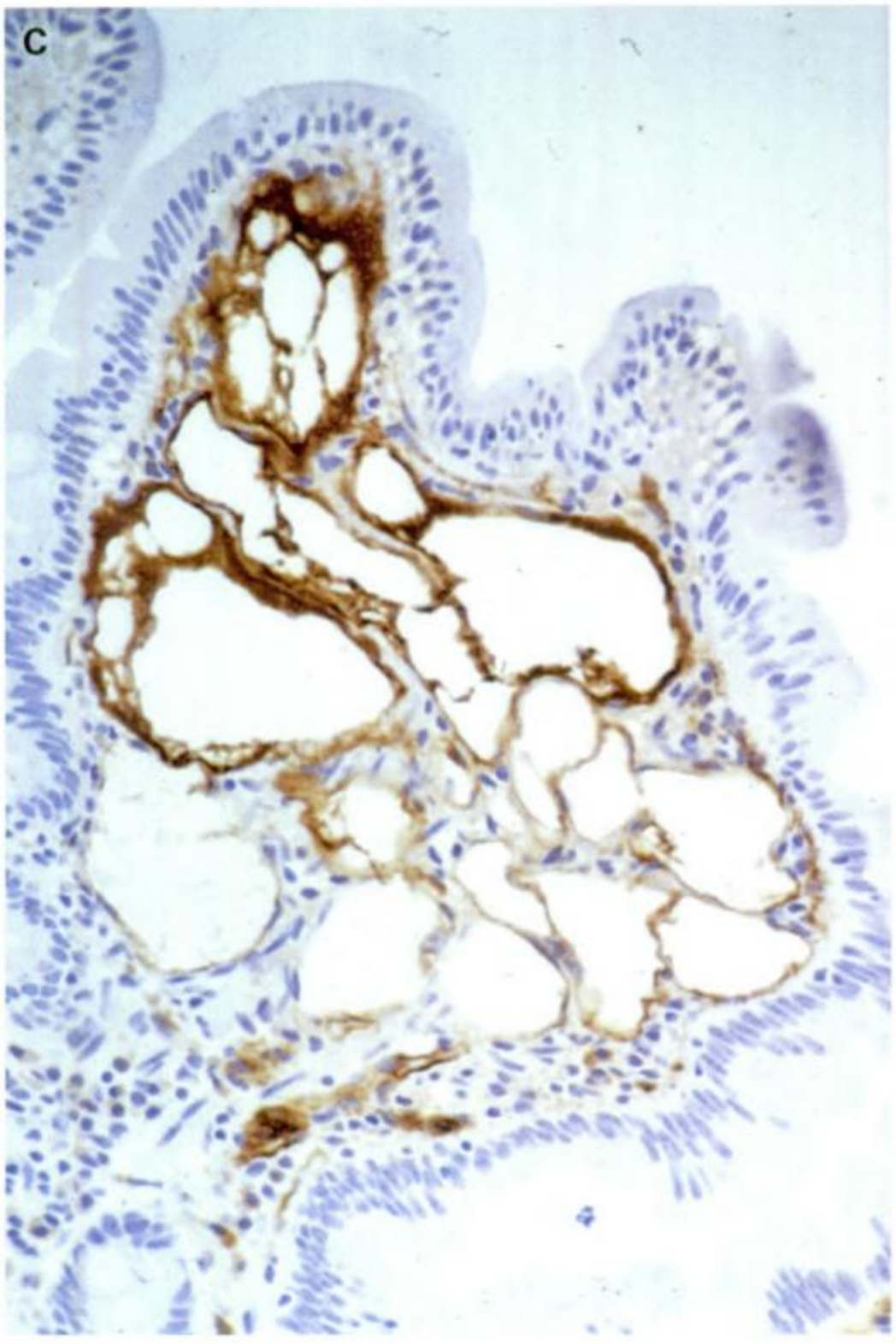
202. *A*, Villous atrophy in celiac disease. *B*, *C*, Increased intraepithelial lymphocytes. (Images courtesy of Rachel Brown, FRCPath.)

Intestinal Lymphangiectasia



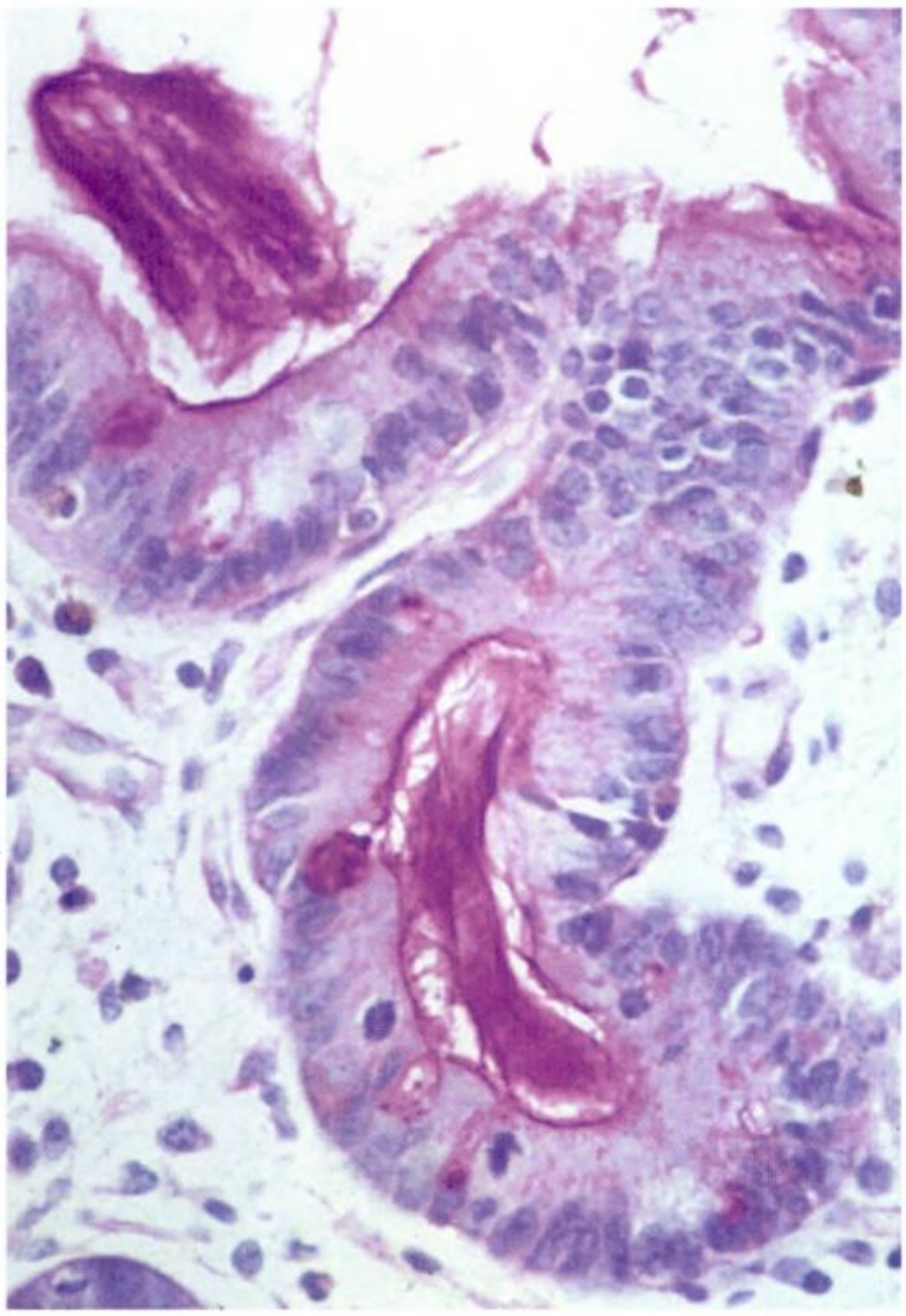






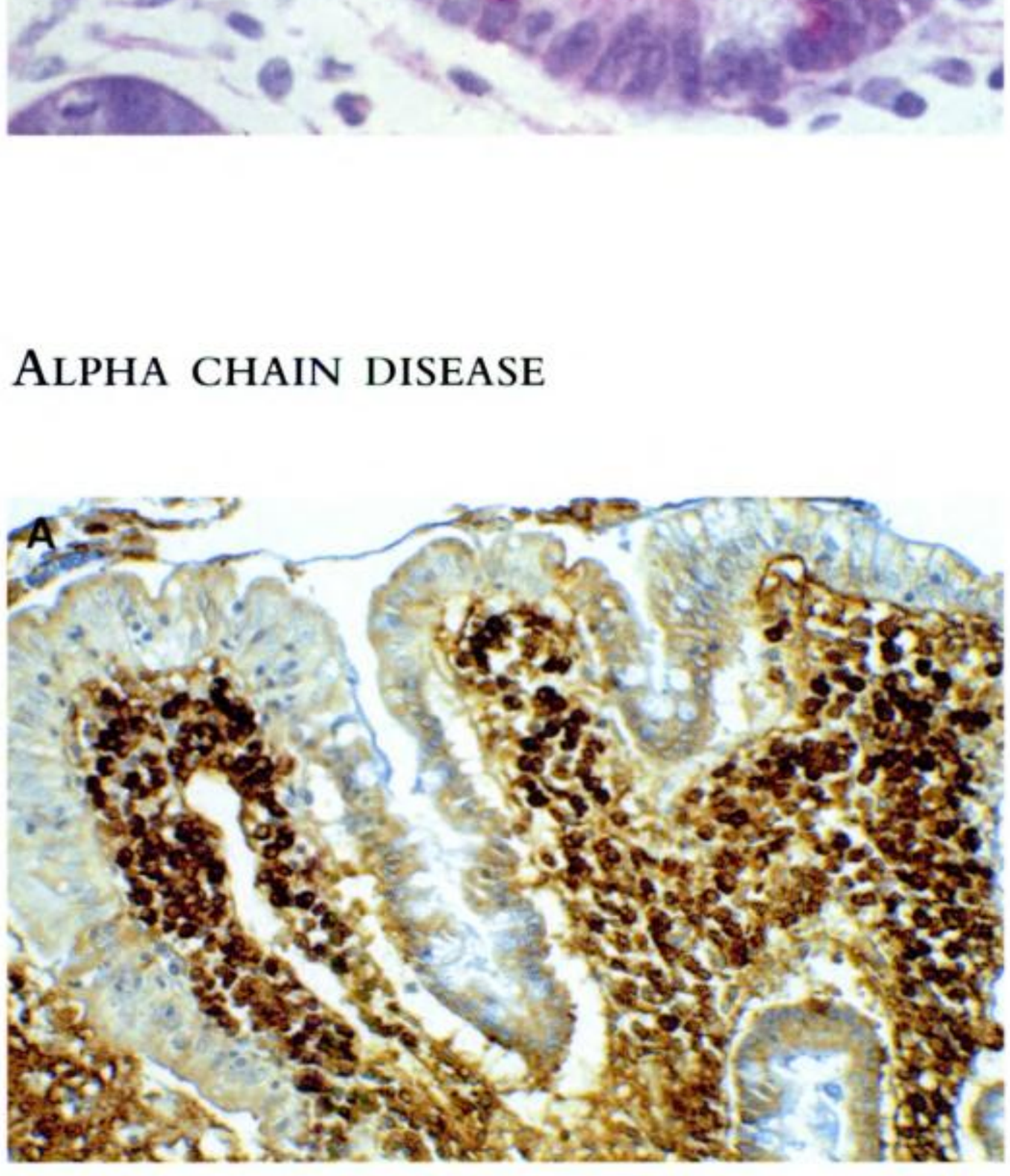
203. *A–C*, Deformed villi with dilated lymphatics. *D*, Dilated lymphatics in the villous highlighted by immunohistochemical stain. (Images courtesy of Rachel Brown, FRCPath.)

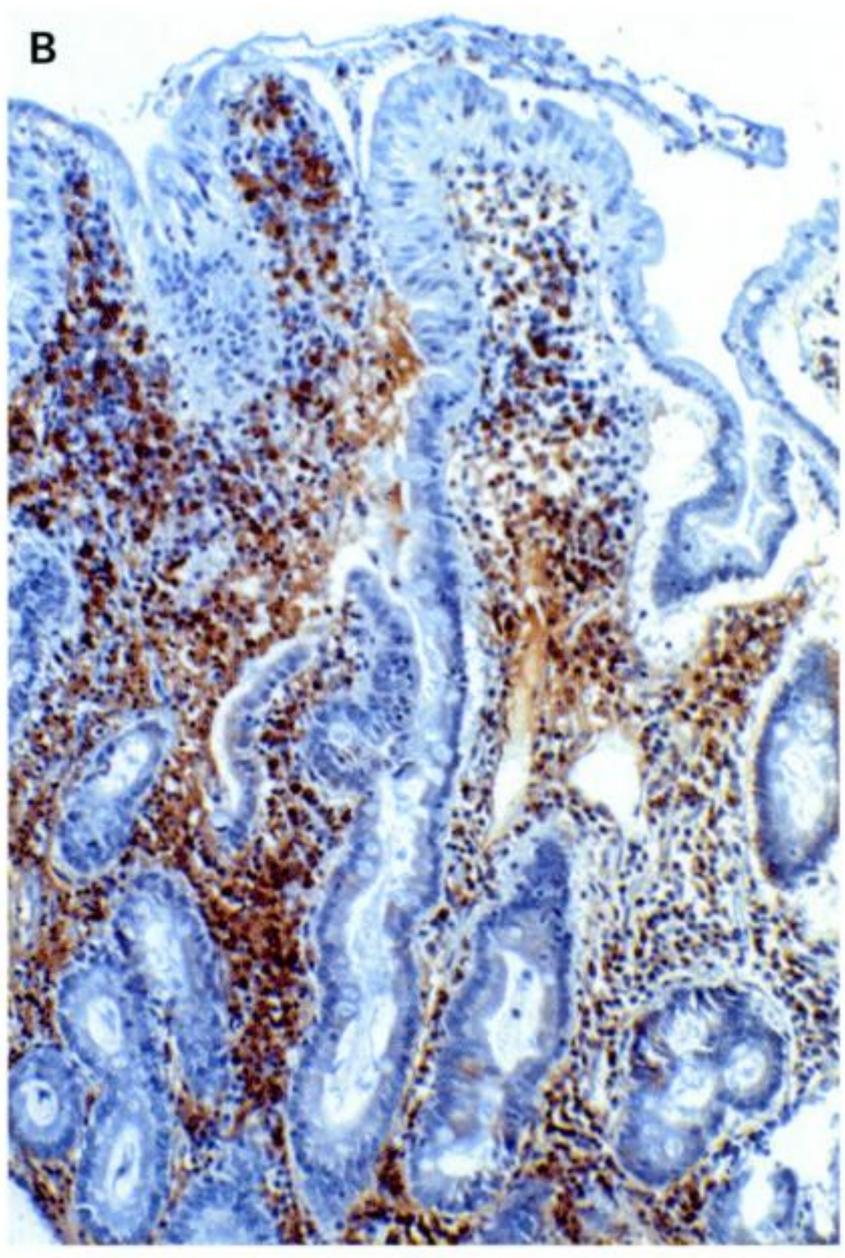
Cystic Fibrosis



204. Cystic Fibrosis. Presence of inspissated mucus in crypt lumen of child with chronic diarrhea and failure to thrive, subsequently confirmed to have cystic fibrosis. Periodic acid-Schiff stained histology. (Image courtesy of Alan Phillips, PhD.)

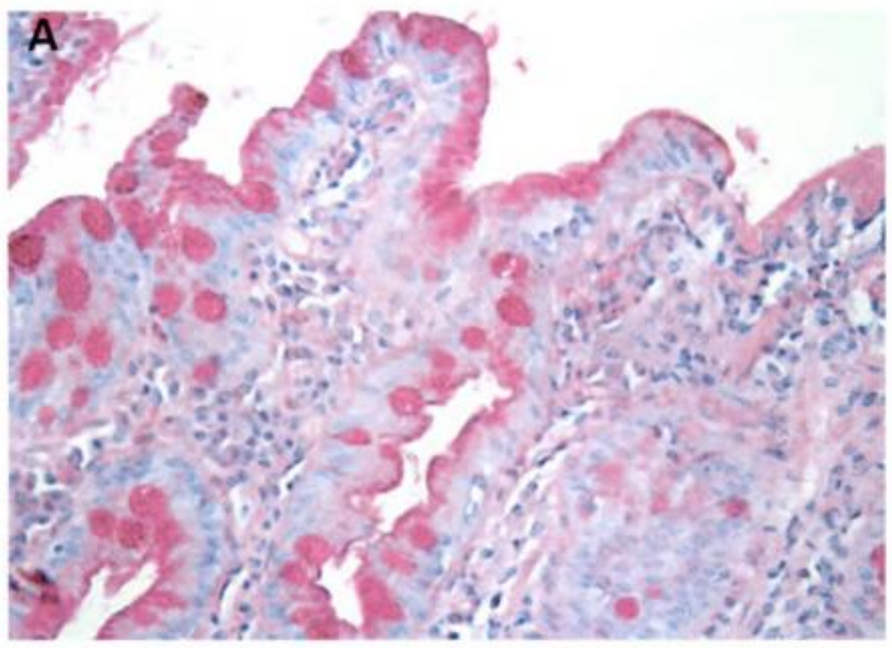
Alpha chain disease

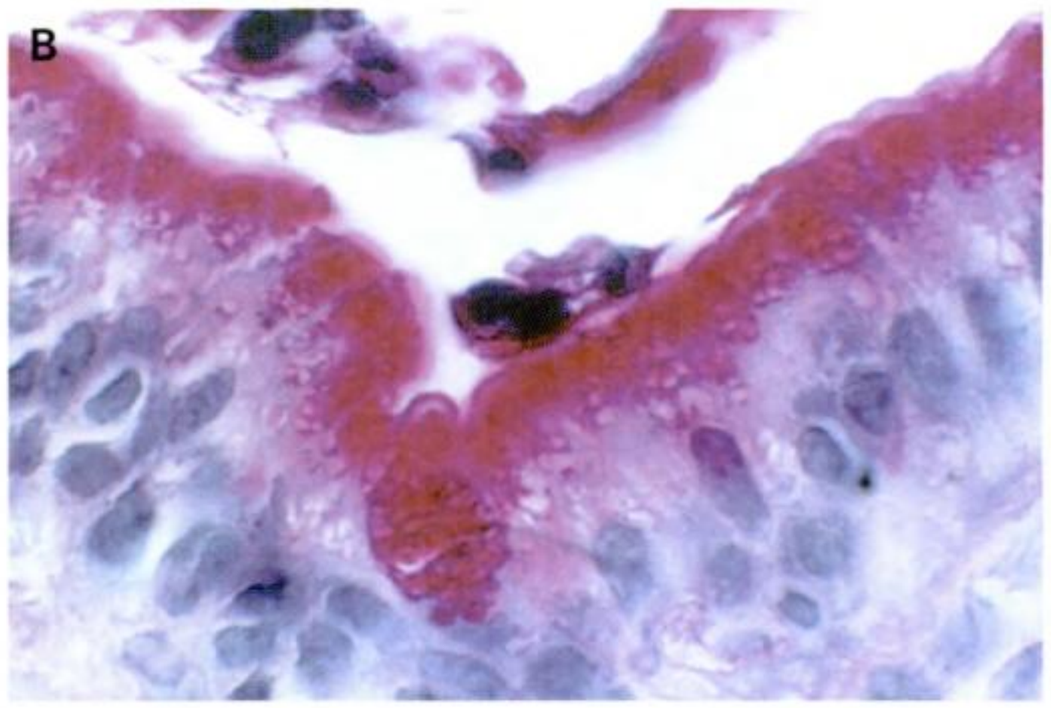


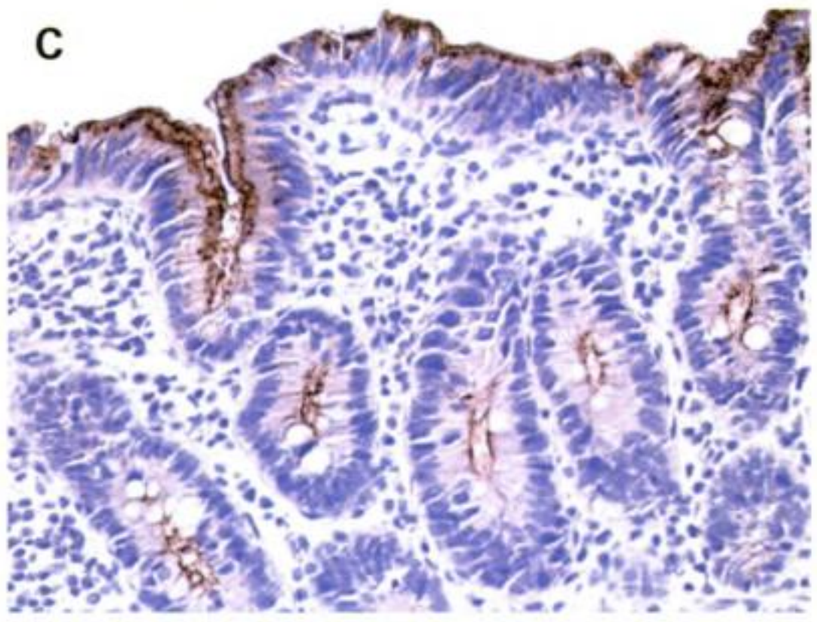


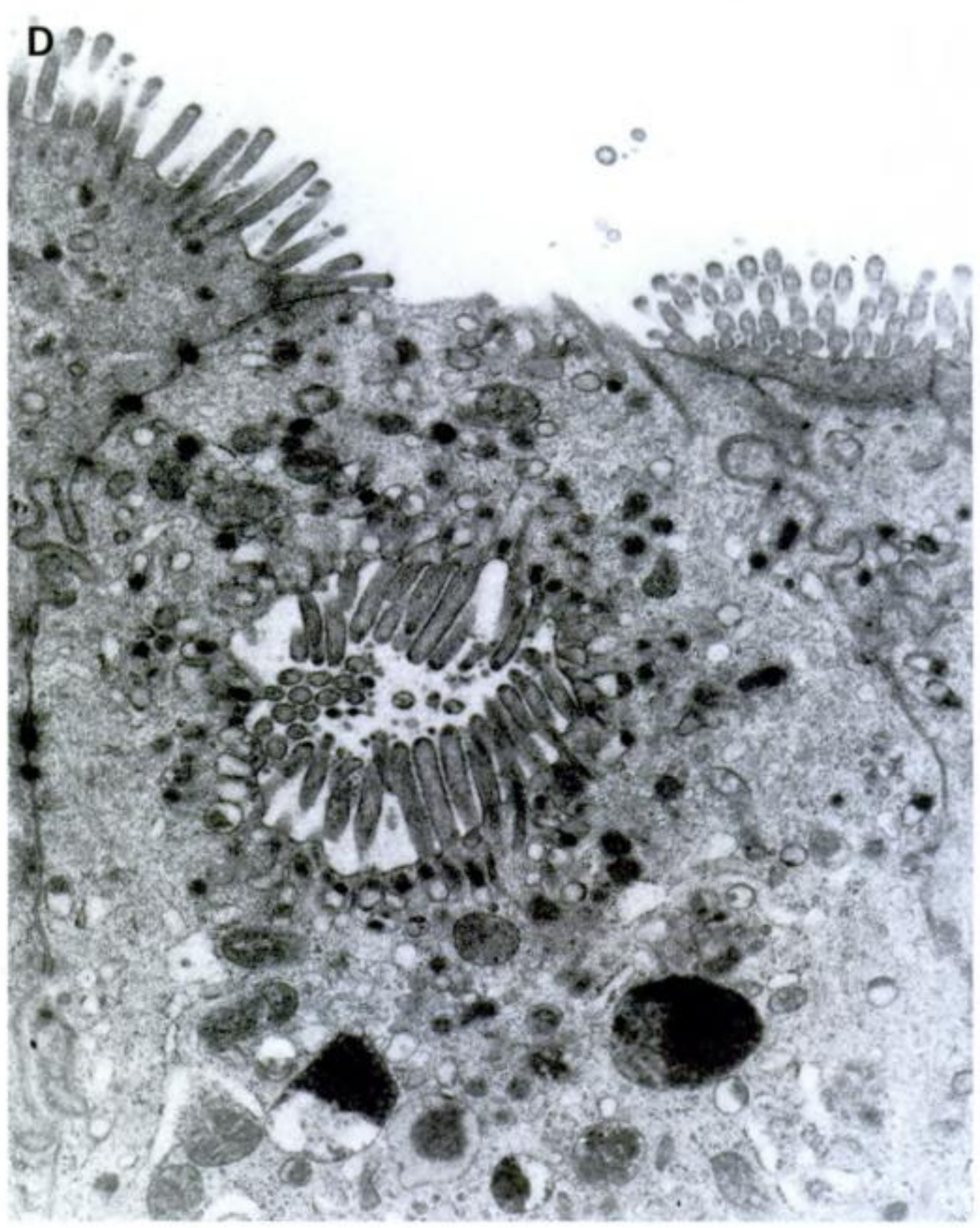
205. Alpha chain disease immunostained with anti-IgA (*A*) and anti-lambda chain (*B*) antibody. (Images courtesy of Nicole Brousse, MD.)

Microvillous Inclusion Disease



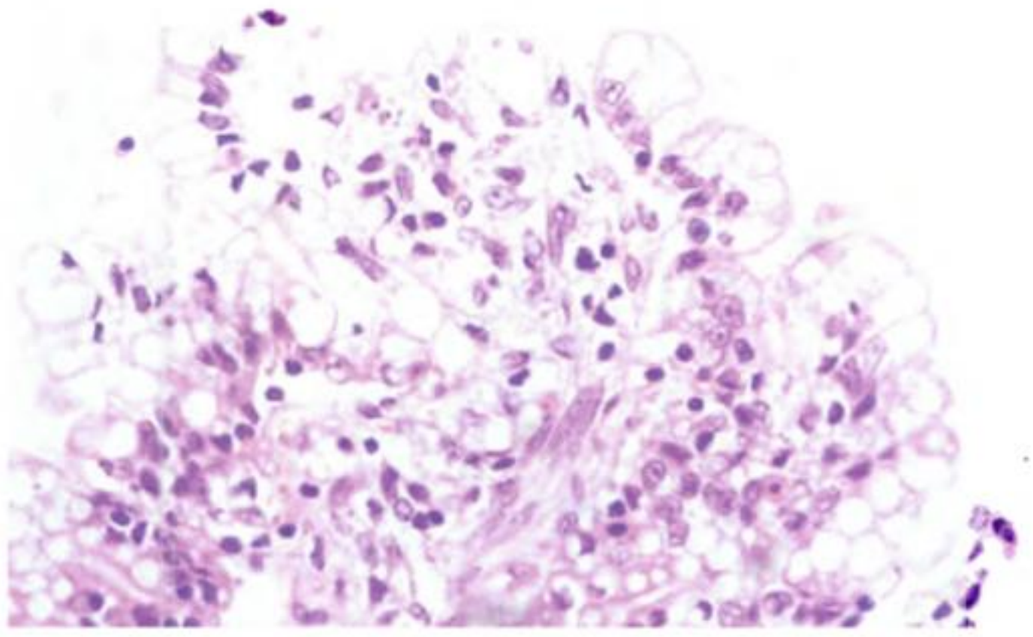


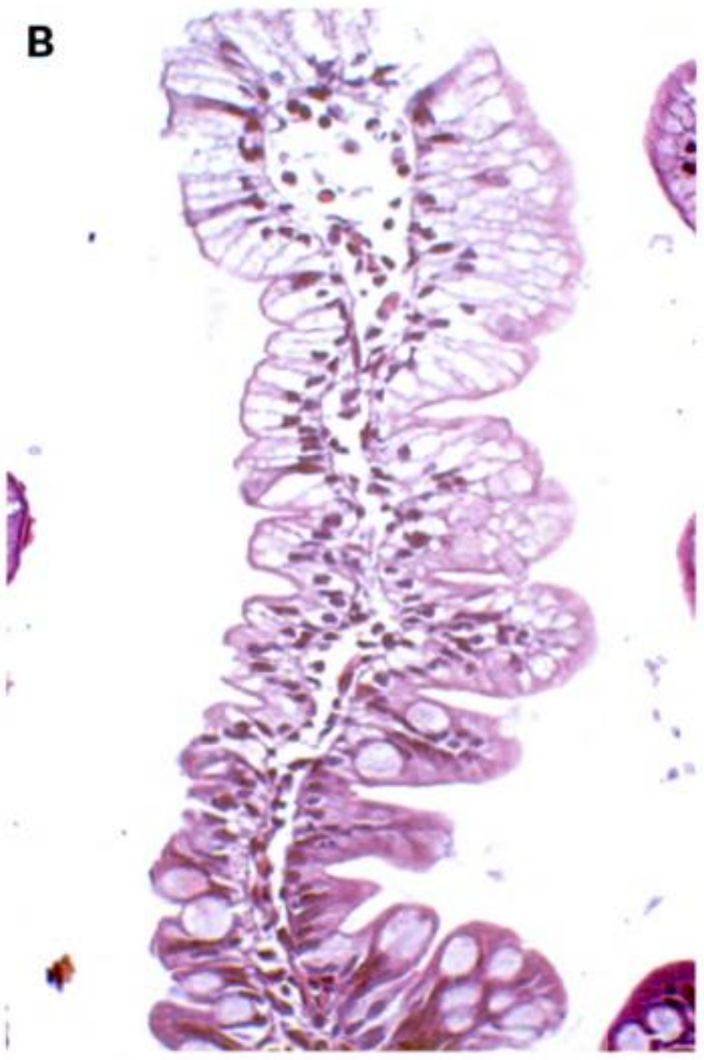


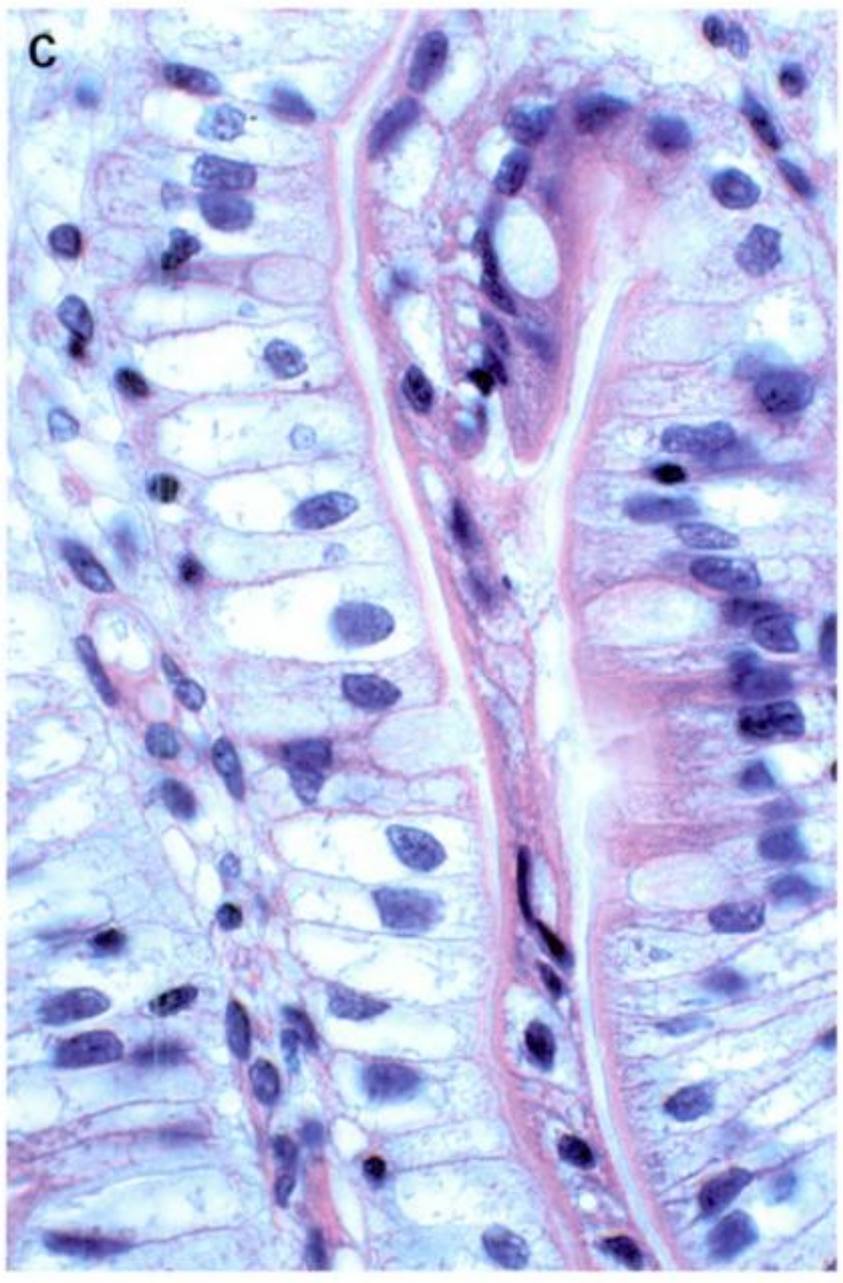


206. *A*, *B*, Periodic acid Schiff material in the apical cytoplasm of enterocytes. *C*, Carcino embryonic antigen immunostain. *D*, Electron micrograph showing loss of microvilli of the brush border and intracytoplasmic secretory granules and membrane-bound inclusions lined by microvilli. (*B*, *C*, Images courtesy of Nicole Brousse, MD; *A*, *D*, Images courtesy of Rachel Brown, FRCPath.)

ABETALIPOPROTEINEMIA

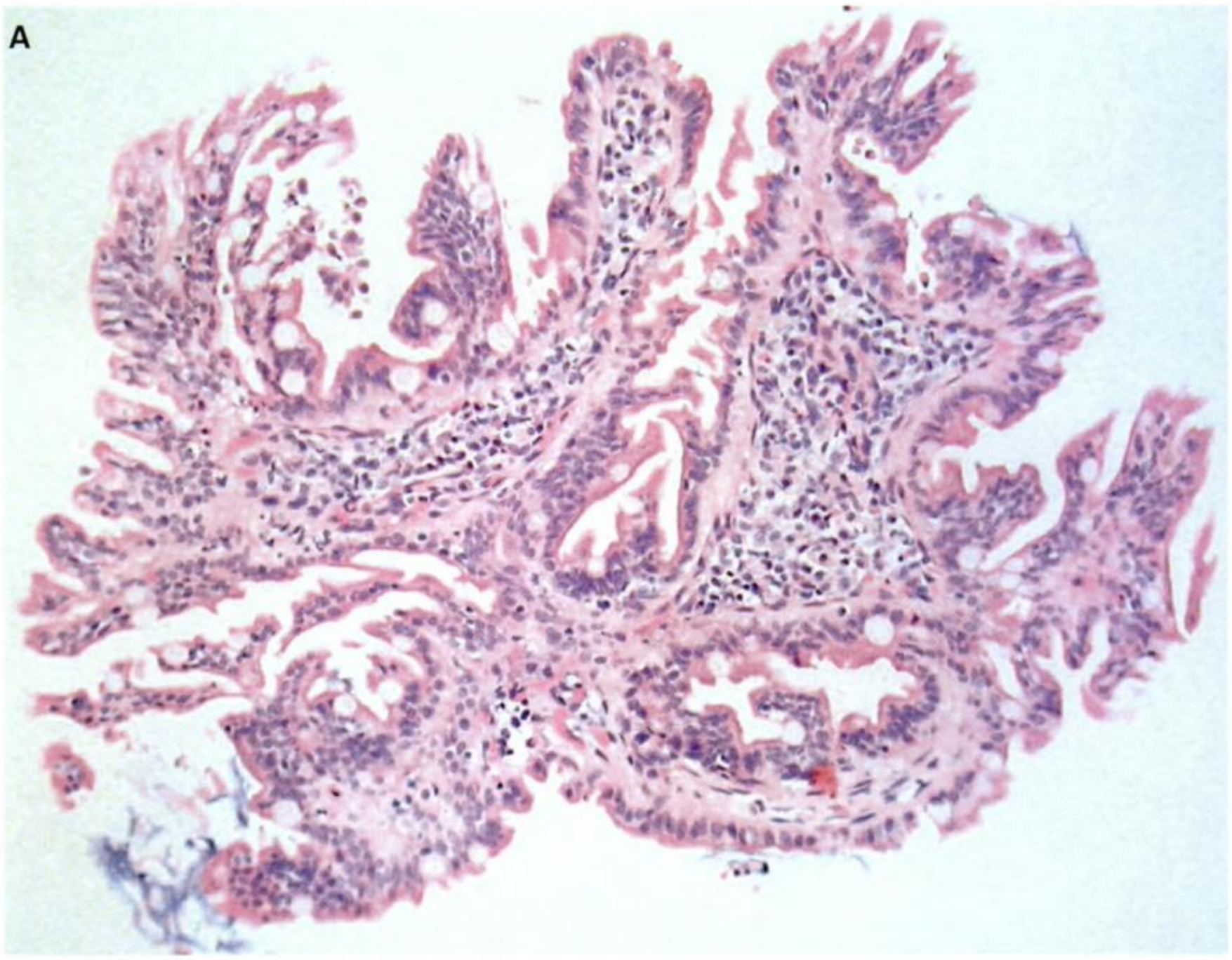


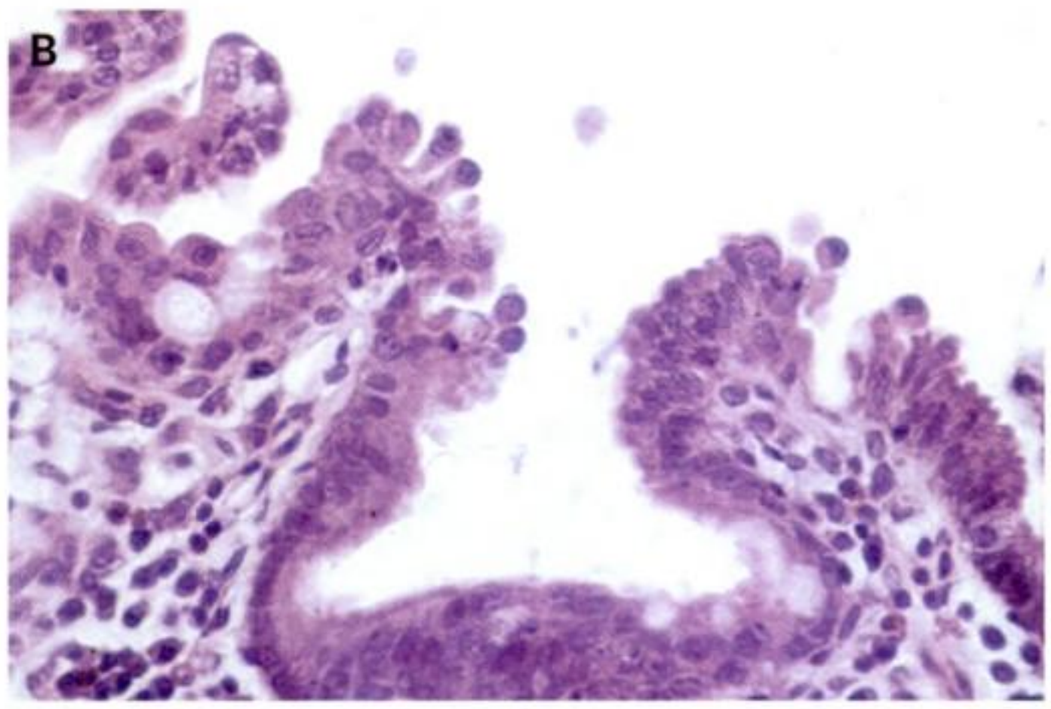


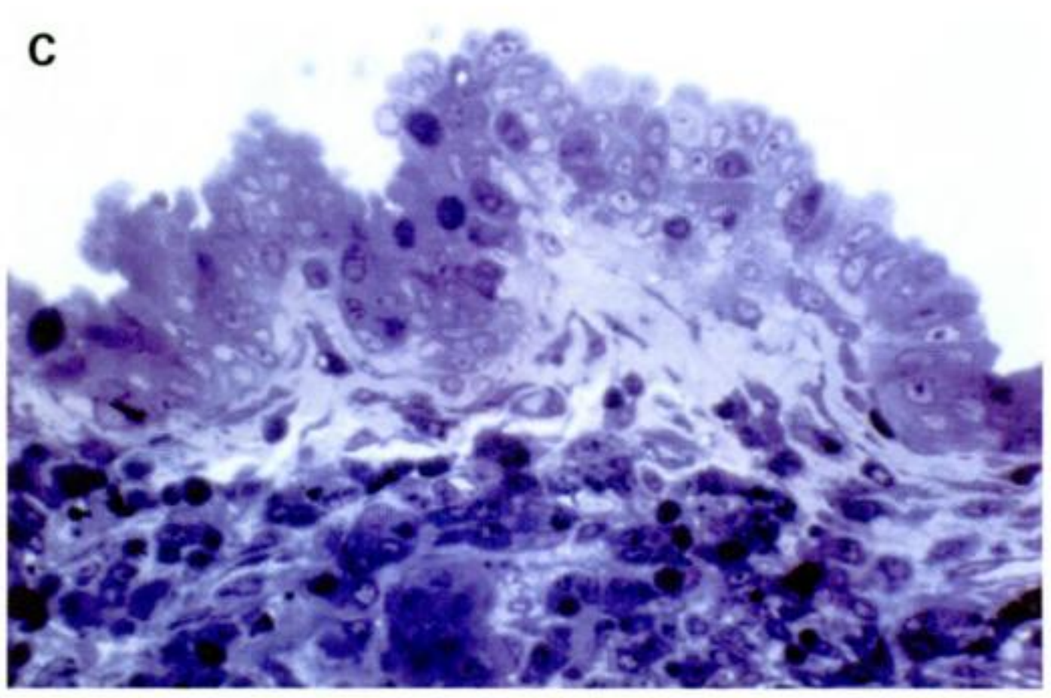


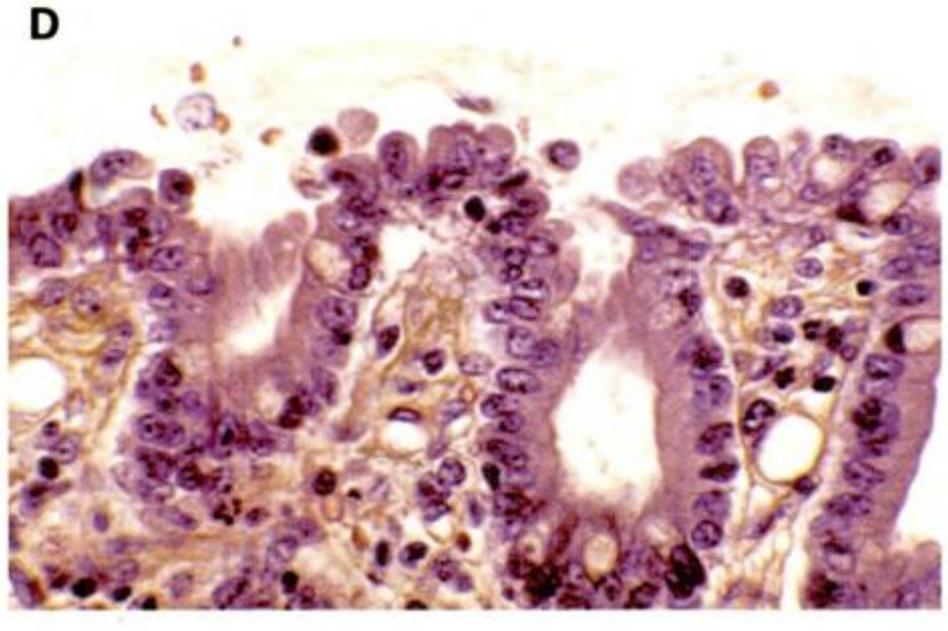
207. Enterocytes filled with lipid droplets distending the apical part of the cell. (Images courtesy of Rachel Brown, FRCPath.)

TUFTING ENTEROPATHY



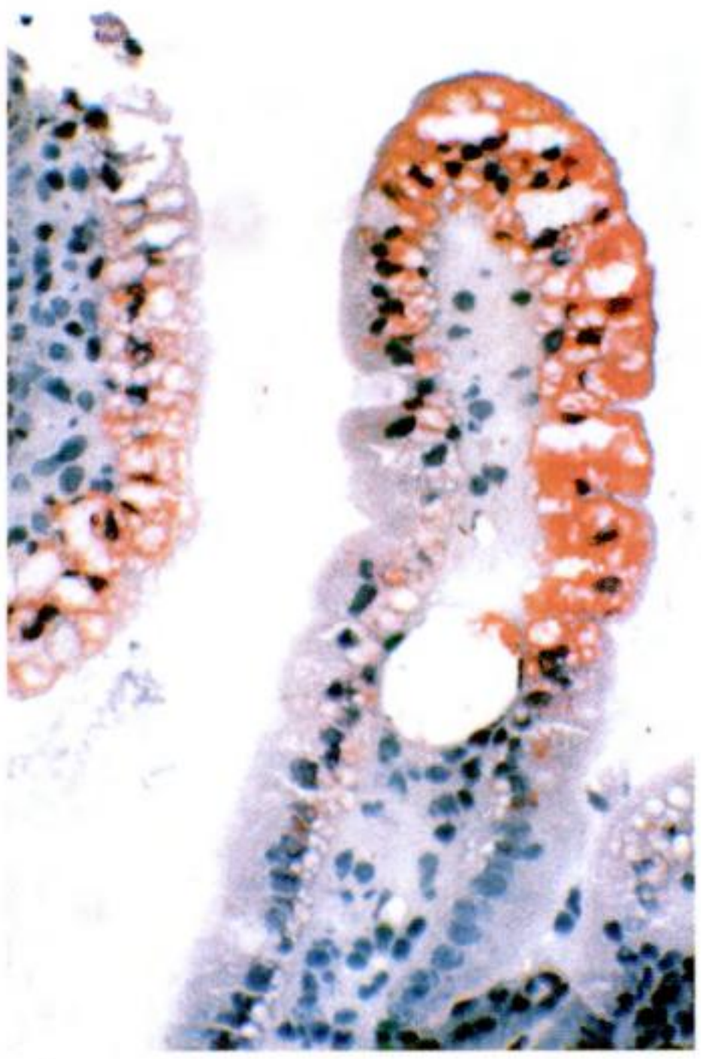






208. *A–D*, Partial villous atrophy with crypt hyperplasia and no inflammatory cells. There are typical focal epithelial tufts consisting of enterocytes with apical round protrusions of plasma membrane. (Images courtesy of Rachel Brown, FRCPath.)

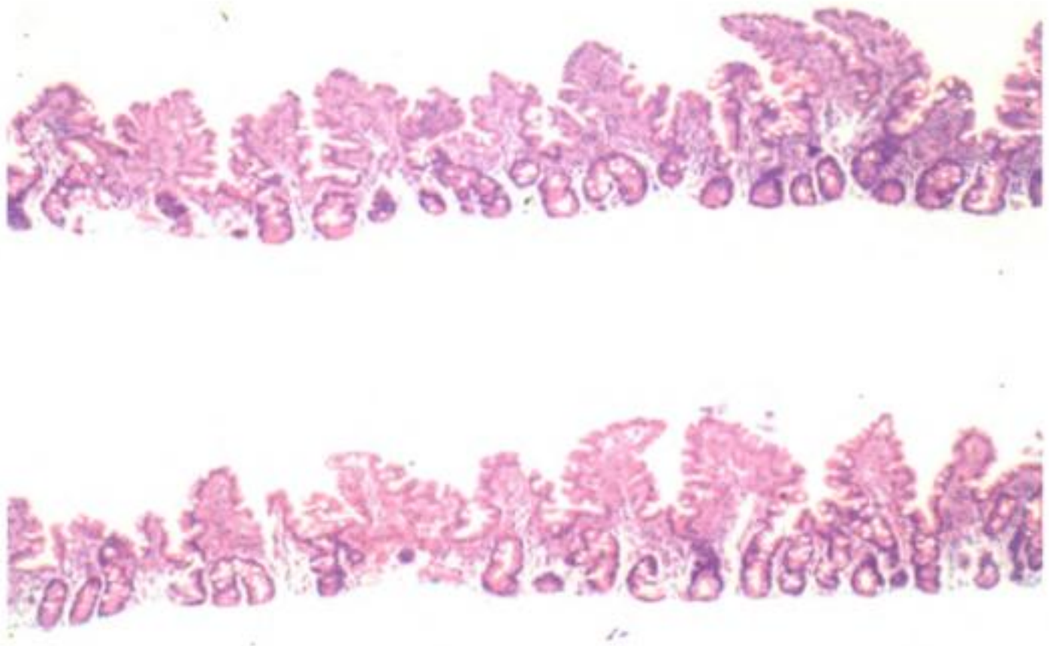
Anderson's Disease



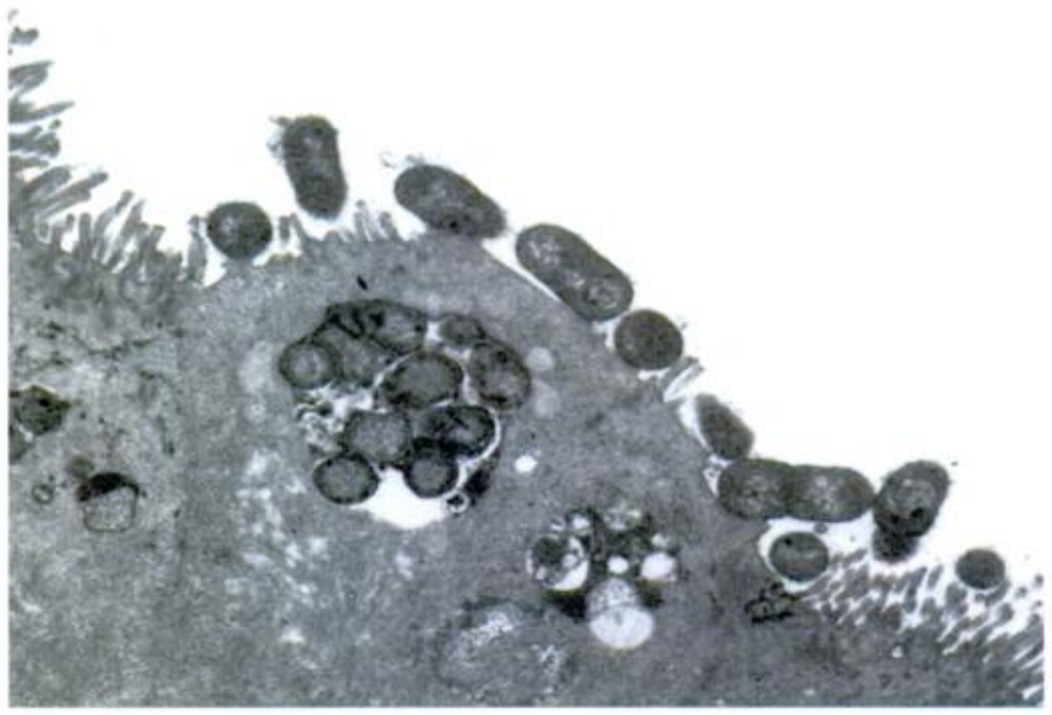
209. Enterocytes showing vacuolization and marked lipid staining. (Image courtesy of M.E. Samson Bouma, MD.)

Infectious Enteropathies

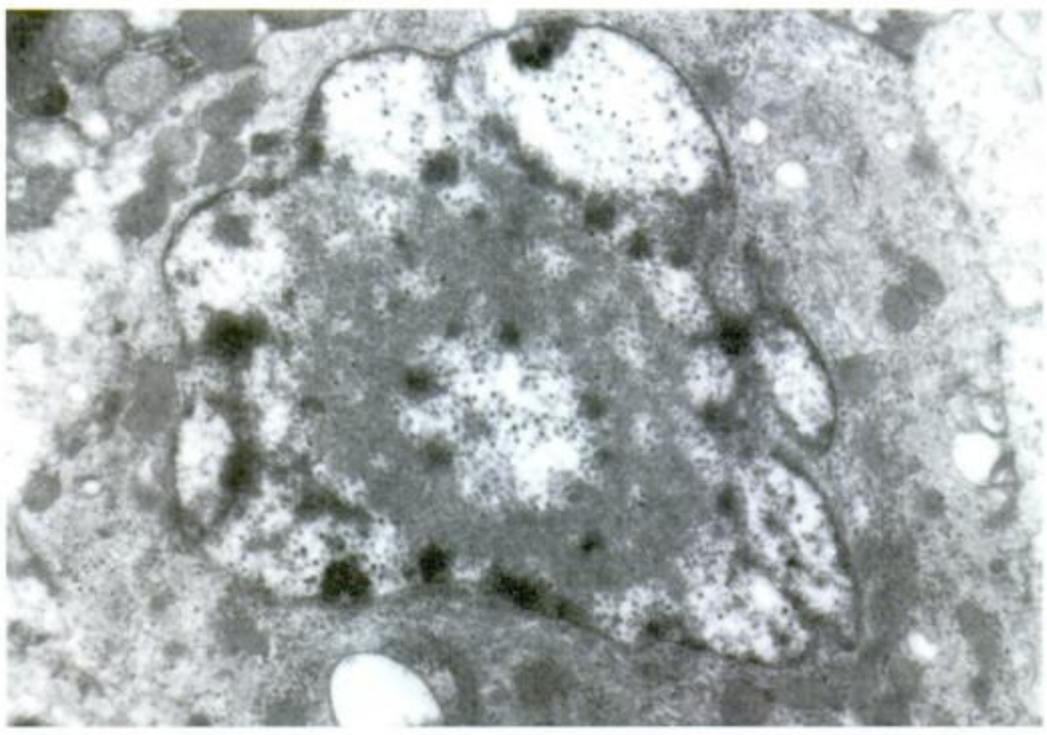
210. *A*, *Giardia lamblia*. *B*, Scanning EM of *Giardia lamblia* on mucosal surface, ventral surface upwards showing sucker disc and flagella. (Images courtesy of Alan Phillips, PhD.)



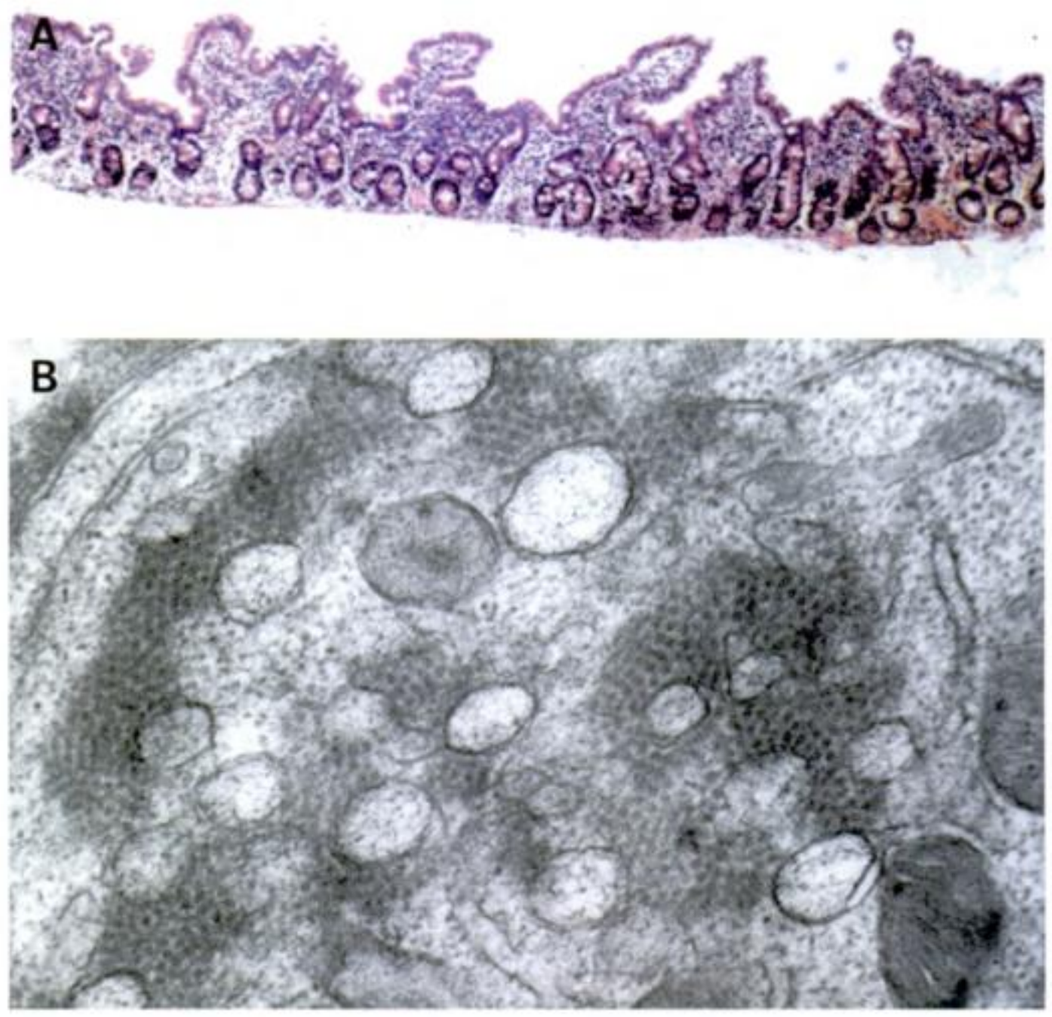
211. Cryptosporidium with partial villous atrophy. (Image courtesy of Alan Phillips, PhD.)



212. Transmission EM if enteropathogenic *Escherichia coli*. (Image courtesy of Alan Phillips, PhD.)

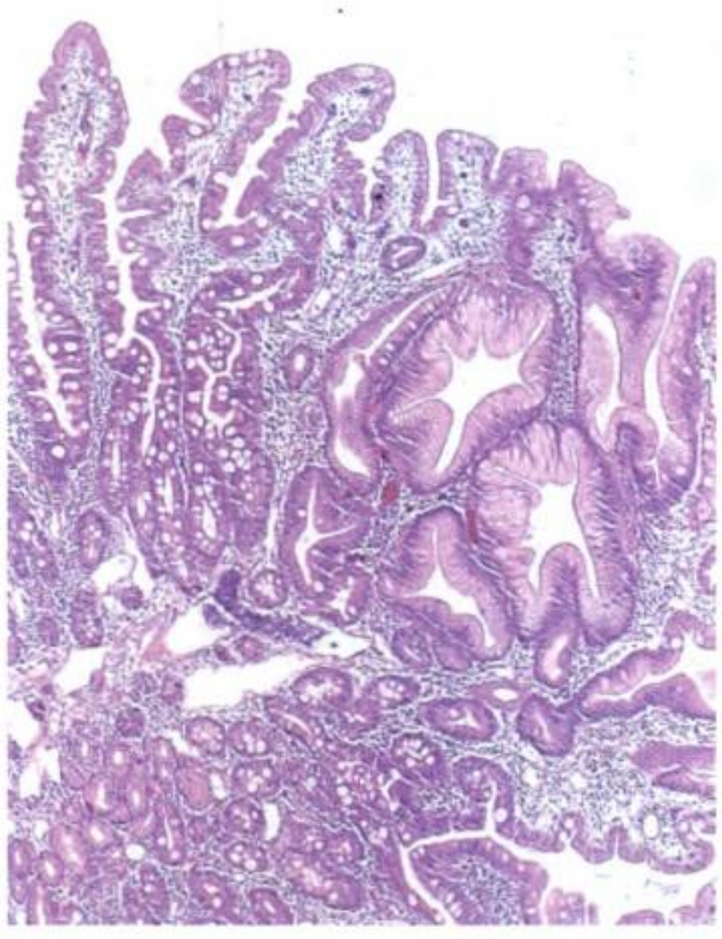


213. Transmission EM of adenovirus particles within the enterocyte nucleus. (Image courtesy of Alan Phillips, PhD.)



214. *A*, Astrovirus enteropathy. *B*, Transmission EM astrovirus particles in cytoplasm of enterocyte, in child with persistent diarrhea and nosocomial astrovirus infection. (Images courtesy of Alan Phillips, PhD.)

Cowden's Syndrome



215. Juvenile polyp with focal area of low grade dysplasia. (Image courtesy of Nicole Brousse, MD.)

8 Enteroscopy: Push and Intraoperative

George Gershman and Mike Thomson

Endoscopy of the small bowel, although not a routine procedure may play a leading role in the diagnosis and treatment of occult gastrointestinal bleeding, polyposis syndromes and other rare vascular malformations in adults and children.[1-6] Currently, enteroscopy is the only non-surgical method to obtain a jejunal biopsy, achieve hemostasis or perform a polypectomy in the small bowel.

With the introduction of wireless capsule endoscopy, enteroscopy may diminish as a useful adjunctive diagnostic and therapeutic procedure. Historically, four types of enteroscopy were developed in the 1970's and 1980's:

1. Guidewire enteroscopy[7] requires the successful passage of an intestinal string or guide wire from mouth to anus. One or two days prior to the procedure, the patient swallows the guide to which the the enteroscope is then attached and then pulled through the entire gastrointestinal tract. This type of enteroscopy was never used in children because of high risk of complication.
2. The Sonde-type enteroscopy relies on peristalsis to propel the enteroscope and the attached balloon down the gastrointestinal tract. Because the instrument is passed through the nose and advanced intermittently, there often is significant discomfort. Some successful attempts in children were made,[8] but because of the difficulty in controlling the pain, the method did not become popular among pediatric gastroenterologists.
3. Push type enteroscopy enables examination of at least two feet of the proximal jejunum and was adapted for pediatric patients.[9-12] Initially, standard pediatric endoscopes or colonoscopes were used. The average length of jejunal intubation was 50cm with a range from 30 to 100cm. Despite the obvious limitations with the area of the small bowel that may be examined, enteroscopy using standard endoscopes has several advantages. First, the average time for the procedure is 10 to 15 minutes. Second, there is no additional expense for costly equipment. Third, an over tube which increases the risk of complications is not needed.[13-15] Most of the complications with this technique occurred prior to the development of a flexible tip to the overtube. As improved and longer enteroscopes became available, they enabled deeper intubation of the small bowel. However, longer instruments resulted in prolonged procedures and they required the use of an overtubeto reach the more distal areas of the jejunum.
4. Intraoperative enteroscopyis performed by the preoperative insertion of the endoscope into the proximal jejunum followed by the intraoperative movement of the small bowel by the surgeon over the enteroscope. This technique has been used successfully in infants and children with partial small bowel obstruction, recurrent gastrointestinal bleeding, intussusception and Peutz-Jeghers syndrome.[16–18] The most recent modification of this method utilizes laparoscopically-assisted guidance.[19]

Figure 8-1. Normal jejunum with prominent Kerkring's folds.

Many push type enteroscopies have been performed successfully in children.[20] Recently, a steerable double balloon method has been developed for total enteroscopy in adults.[21] Future studies are required for validation of this technique in children.

In this chapter, the following topics will be covered:

- Indications
- Equipment
- Technique
- Diagnostic comparison with other small-bowel assessment techniques
- Complications

INDICATIONS

Potential indications for push enteroscopy in the pediatric population are outlined in Table 8-1. Occult bleeding from the GI tract, is a major indication for enteroscopy in adults, and a bleeding source may be identified in 60 to 70% of patients who are examined by experienced endoscopists (Figure 8-2).[4] Nonsteroidal drugs may cause acute and chronic small-bowel hemorrhage, perforation, obstruction, or a specific ulcerative enteropathy.[22] Because these medications are used less frequently in the pediatric population, there are no data regarding the association of nonsteroidal antiinflammatory drugs and small-bowel disease in children. Enteroscopy has been used to identify abnormalities in patients with Crohn's disease,[23] lymphangiectasia (Figure 8-3 and 8-4) and celiac disease. In addition to establishing a diagnosis, enteroscopy allows therapeutic intervention such as cautery of angiodysplastic or hemorrhagic lesions in the jejunum. Graft survival following small-bowel transplantation has been assessed by push enteroscopy (Figure 8-5); however, advancing an enteroscope or simply using a standard endoscope through a jejunostomy is much easier.[24] Biopsies evaluated for histology and disaccharidase activity are also helpful in the early detection of small-bowel allograft rejection. A zoom endoscope has been used to detect the early structural changes associated with graft rejection.[25]

Direct percutaneous jejunostomies can be placed using enteroscopy and the same pull-through technique employed in percutaneous gastrostomy insertion. Nasojejunal tubes can be placed accurately using a guidewire-assisted technique. Finally, polyps can be removed with a normal snare technique (Figure 8-6).

Table 8-1. Indications for Enteroscopy in Children and Adolescents

Diagnostic
Obscure gastrointestinal bleeding
Iron-deficiency anemia (especially if history of nonsteroidal drug use)
Extent of Crohn's disease
Polyposis syndrome surveillance
Lymphoma (suspicion or follow up post-treatment)
Lymphangiectasia
Intestinal obstruction
Graft assessment after small bowel transplantation
Enteroclysis
Therapeutic
Therapy of hemorrhagic lesions (eg, cauterizing angiodysplasia)
Polypectomy
Stricture dilatation
Nasojejunal tube placement
Percutaneous jejunostomy tube placement

EQUIPMENT

Although a pediatric colonoscope can be used for enteroscopy, specifically designed enteroscopes up to 230 cm in length are now available. The Olympus SIF Q140 has a diameter of 10.5 mm and is 250 cm long. A push enteroscope, like a colonoscope allows four-way tip deflection to 160° to180°. There are no enteroscopes or overtubes specifically designed for pediatric application. An overtube, typically 60 to 100 cm in length with a soft Gortex tapered tip, stiffens the enteroscope within the stomach and upper duodenum limiting looping and thereby allowing deeper advancement into the small bowel.

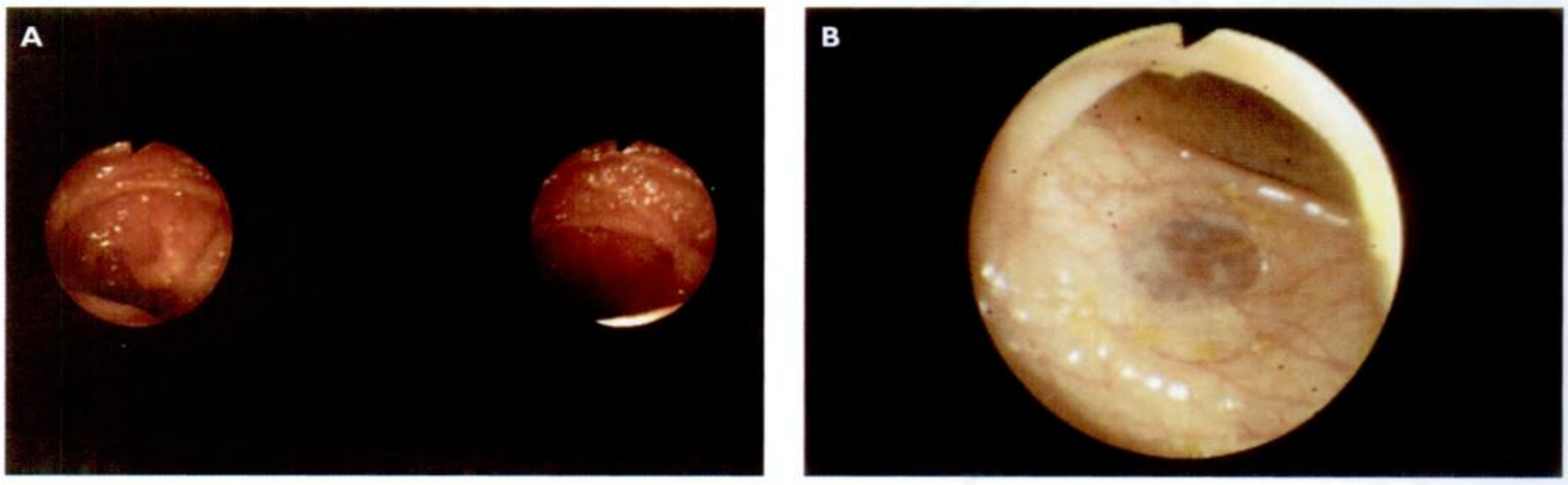


Figure 8-2. *A*, Isolated jejunal hemangioma. *B*, Hemangioma in the jejunum.

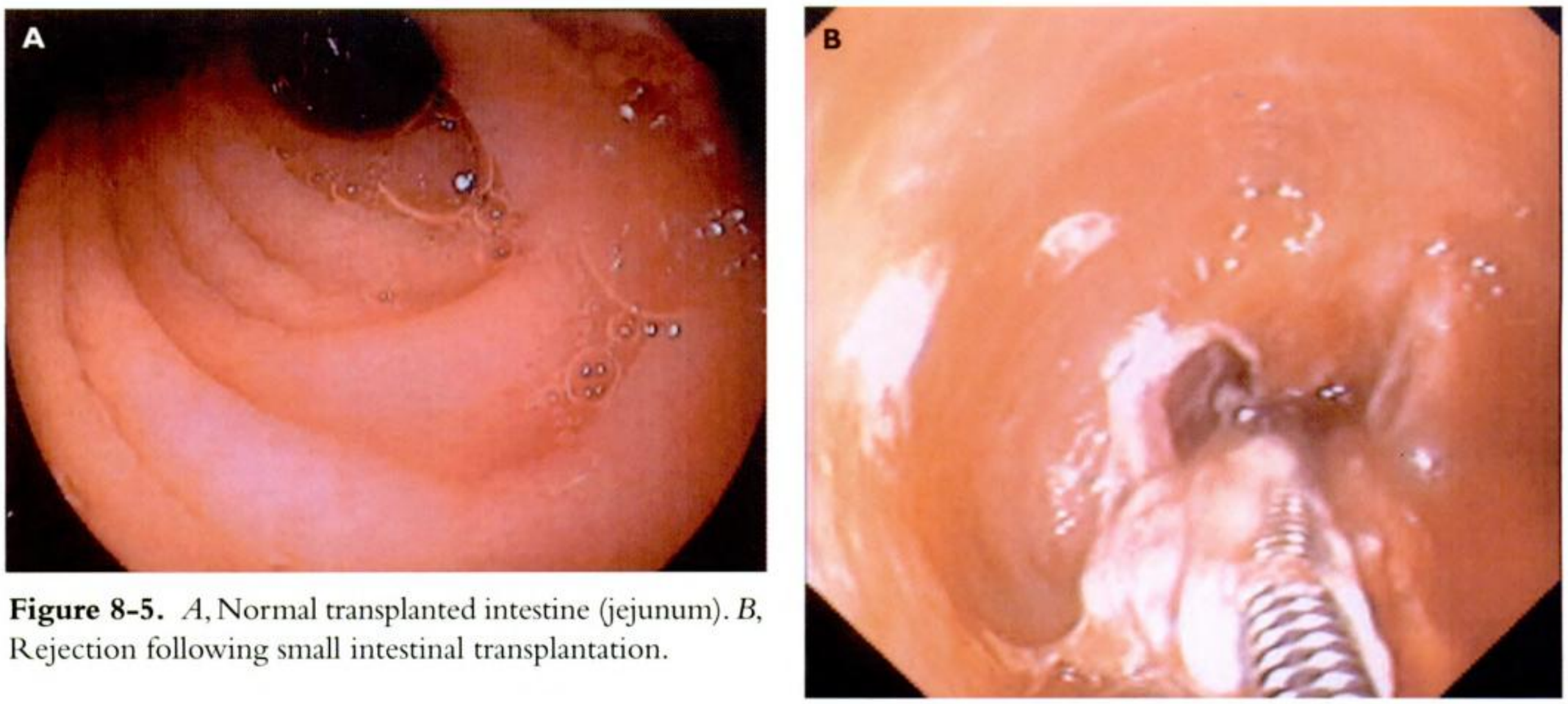


Figure 8-5. *A*, Normal transplanted intestine (jejunum). *B*, Rejection following small intestinal transplantation.

TECHNIQUE

Push Enteroscopy

An enteroscope can be advanced to between 120 and 180 cm beyond the ligament of Treitz, and with laparoscopic assistance, even the terminal ileum can be reached, allowing lesions such as a Meckel's diverticulum to be found.

Preparation for enteroscopy is the same as for upper GI endoscopy, although the procedure may be substantially longer and more uncomfortable. For these reasons, general anesthesia even in adolescents is often used. Patients are positioned in the left lateral position. As the endoscope is advanced into the stomach, the natural tendency is to move along the greater curvature, distending the stomach as the instrument is advanced into the duodenum. At some point, in the descending portion of the duodenum, paradoxical movement of the endoscope occurs impeding advancement into the third and fourth portion of the duodenum. To avoid this situation from occurring, the instrument should be advanced through the stomach as close as possible to the lesser curve. Lifting the flexible tip of the endoscope steeply upwards as soon as the incisura of the stomach is seen will create a condition in which the antrum of the stomach and the duodenal bulb approach a position in a straight line with the cardioesophageal junction. Simultaneously, the instrument should be rotated clockwise and withdrawn. As the scope is withdrawn, the lumen will be lost momen-

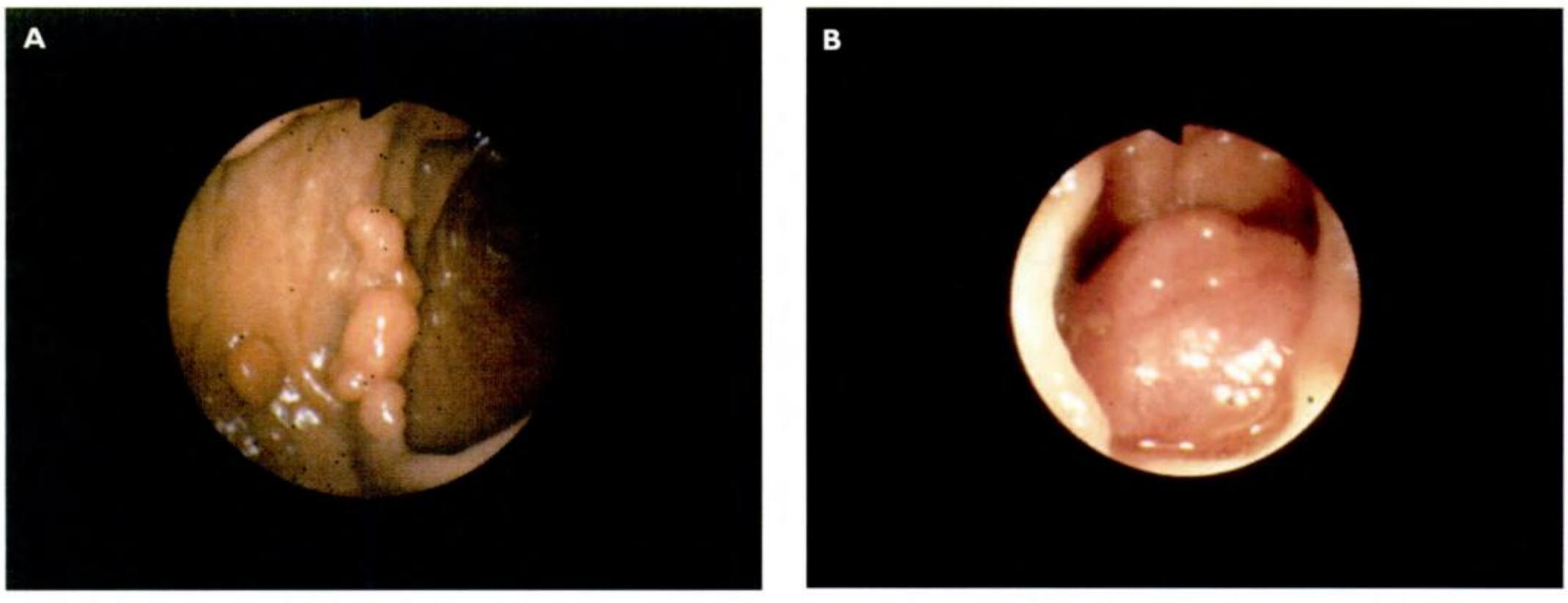


Figure 8-6. *A*, Jejunal polyp in Peutz-Jeghers syndrome. *B*, Giant polyp in jejunum in Peutz-Jeghers syndrome.

tarily until the prepyloric folds are seen directing the endoscope to the pylorus. As the scope is slowly withdrawn, it should approach the pylorus and slip into the duodenum (Figure 8-7A). Continuing the clockwise rotation and continuing to withdraw should lower the tip of the fiberscope and advance it beyond the bulboduodenal junction (Figure 8-7B). Continual rotation will cause the scope to move into the descending portion of the duodenum.

If the duodenum is not successfully intubated using this technique, with the tip of the scope at the incisura, a slight counter-clockwise turn while lifting up the tip followed by a push forward and simultaneous clockwise rotation and elevation of the tip, may enable intubation of the duodenum without forming a loop of scope. When resistance is felt, the instrument should be slightly withdrawn and the maneuver repeated until the duodenum is reached. The lower horizontal and ascending portions of the duodenum are easily inspected once the descending portion is traversed. The duodenojejunal junction is reached even in the adolescent patient with less than 80 cm of the instrument inserted. Throughout these maneuvers, insufflation should be kept to a minimum.

If one fails to reach the duodenojejunal junction, the instrument should be withdrawn to the descending portion of the duodenum and by rotating counter-clockwise and simultaneously lifting the tip up and to the left one can maneuver into the distal duodenum. The difficult part of the procedure is to synchronize the two manipulations. The velocity of the rotation and the degree of lifting and turning to the left are determined by the proximity of the intestinal wall and the amount of resistance. During this maneuver, the lumen narrows gradually and at one point disappears completely permitting only visualization of one or two Kerkring's folds. At the end of the maneuver, the lumen is restored and at this moment, the endoscope should be advanced forward while simultaneously rotating it clockwise. As one approaches the duodenojejunal junction, the tip of the

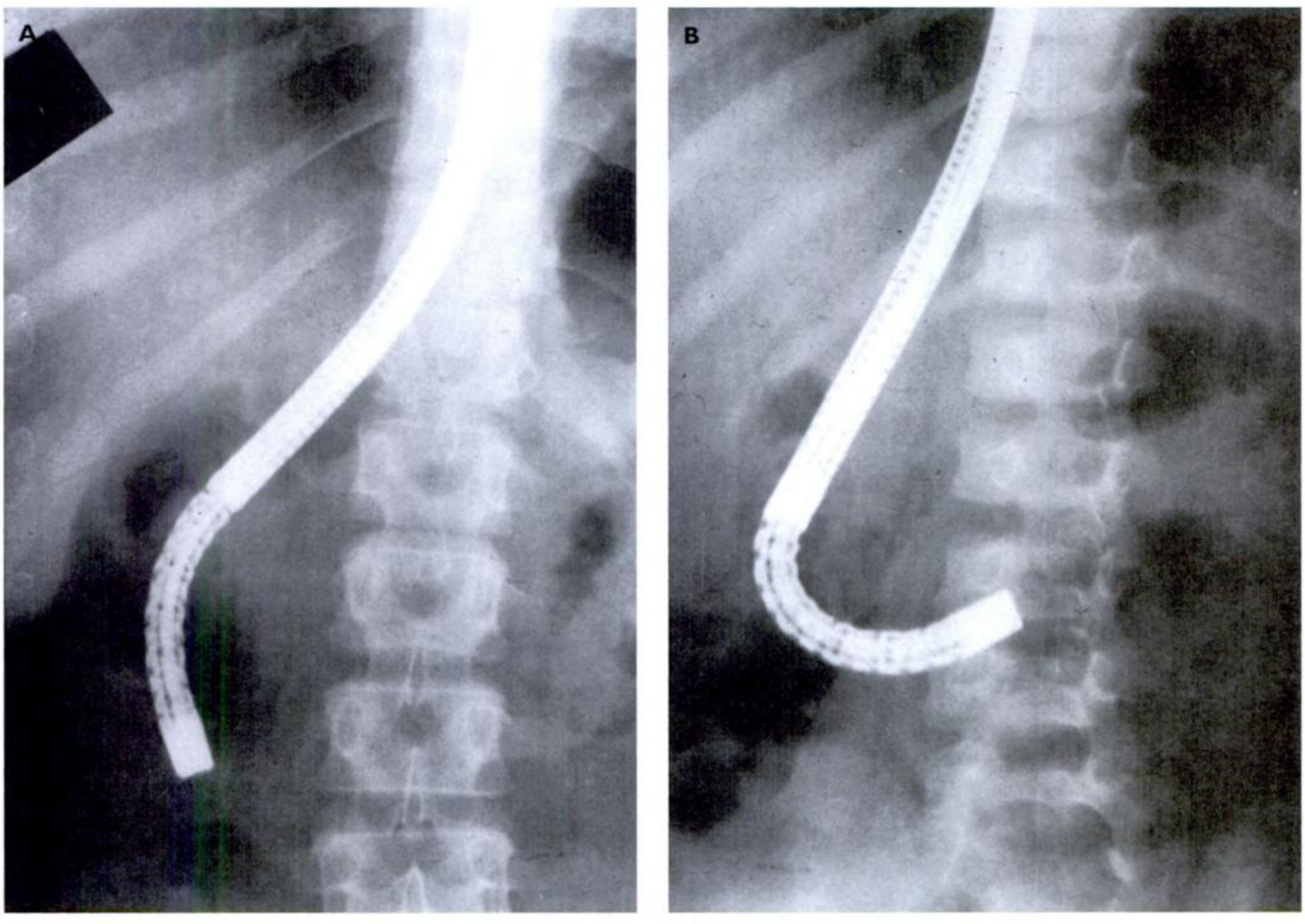
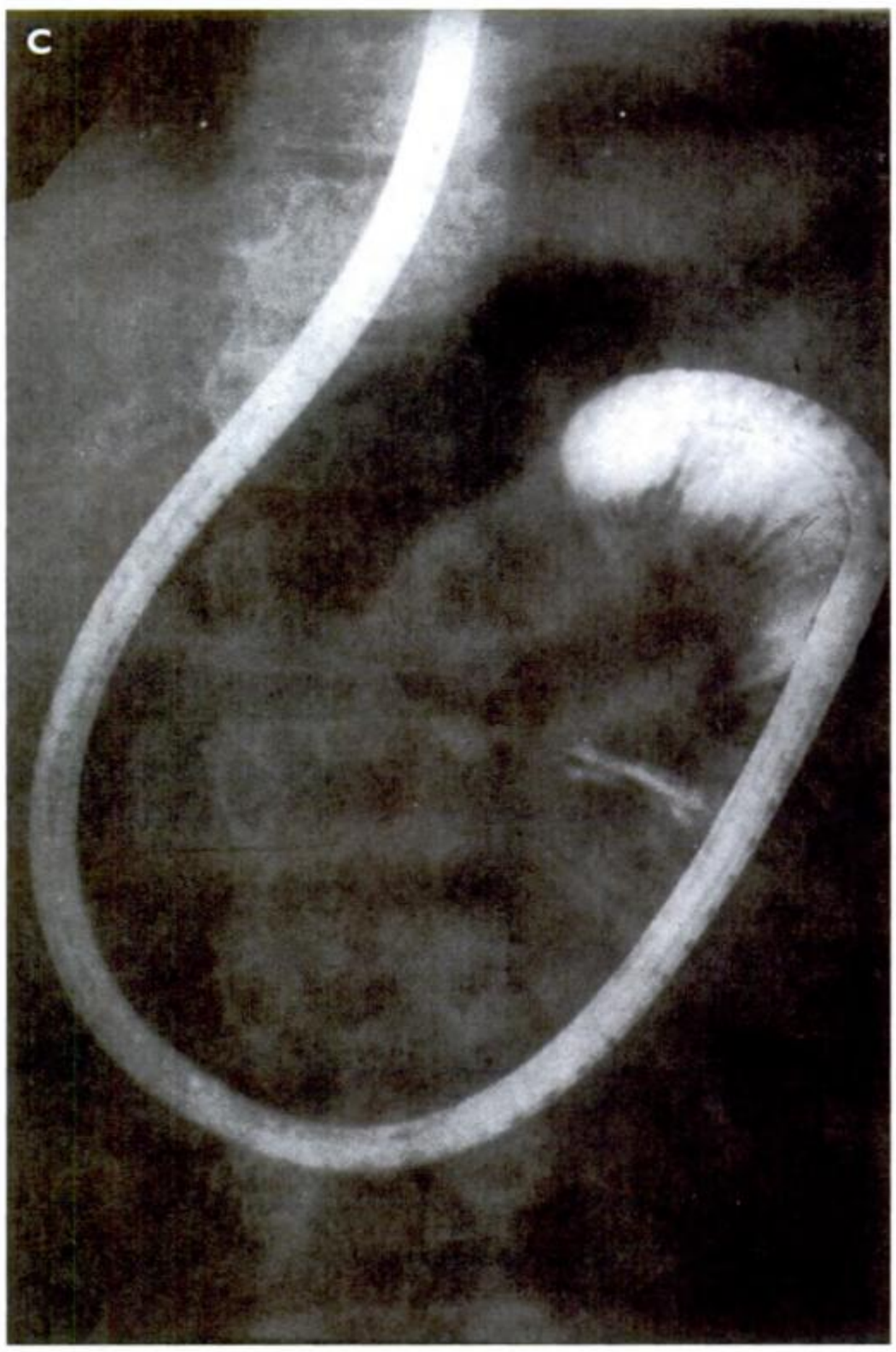


Figure 8-7. Radiology series showing technique of jejunal intubation. *A*, Endoscope in second portion of duodenum in good position along the lesser curve of the stomach. *B*, Endoscope in third portion of duodenum with the instrument remaining along the lesser curvature of the stomach. *Continued on the next page.*



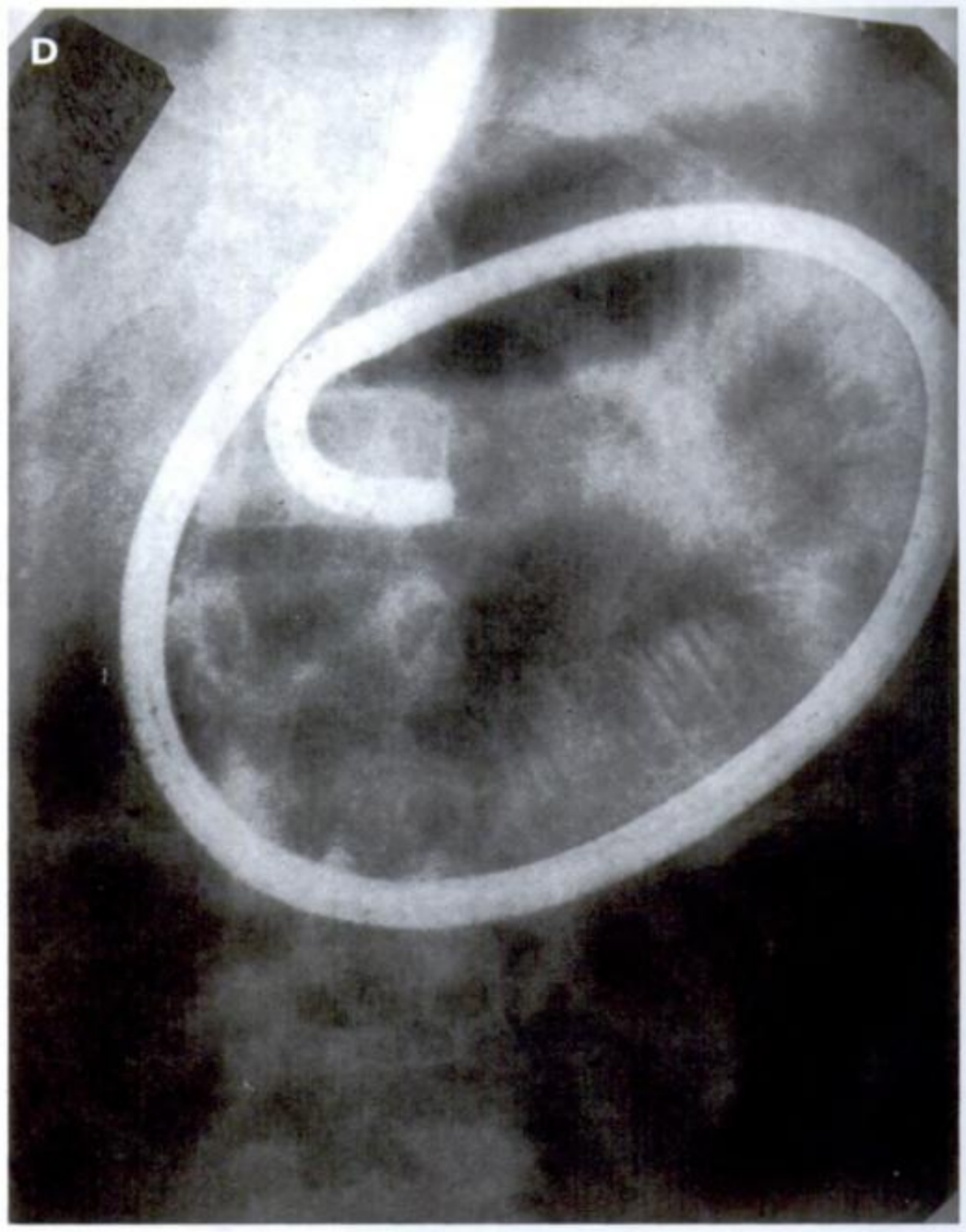


Figure 8-7. *Continued.* Radiology series showing technique of jejunal intubation. *C*, Endoscope in proximal jejunum (20–30 cm). *D*, Endoscope in proximal jejunum (30–40 cm). *Continued on the next page.*

scope will need to be lowered. At the point when the duodenojejunal junction is passed, only the lower right wall will be visible. The orifice of the jejunum appears after additional clockwise rotation and movement of the tip to the right. Pressure in the right hypochondrium by the assistant may facilitate downward movement of the endoscope. The first jejunal loop is more readily identified because it is straighter and travels down to the pelvis (Figure 8-7C). Moving the overtube, if one has been threaded over the enteroscope prior to oral insertion, into the second part of the duodenum will facilitate distal movement of the enteroscope and deeper small bowel penetration (Figures 8-7D, 8-7E). Some endoscopists use fluoroscopy to aid in overtube tip positioning. When advancing the overtube, the enteroscope should be straightened by pulling back with a clockwise rotation. This maneuver is similar to the one used to achieve the shortened scope position during endoscopic retrograde cholangiopancreatography. Variable-stiffness enteroscopes may soon be developed that may eliminate the need for an overtube.

Intraoperative or Laparoscopic-Assisted Enteroscopy

Intraoperative or laparoscopic-assisted enteroscopy starts with conventional enteroscopic jejunal intubation followed by surgical assistance. The endoscopist's role is relatively passive, deflecting the tip of the instrument whilst the surgeon, either with hands or with laparoscopic instruments, concertinas the examined parts of the small bowel over the enteroscope. Both the mucosal and serosal surfaces can be examined. Very little air is insufflated into the bowel to avoid hindering the surgeon. Dimmed lights in the operating field also help to identify the position of the tip of the instrument. In experienced hands, all of the small bowel is examined in 60% of cases, taking up to 2 to 3 hours (Figure 8-8).

In some situations, an enterotomy may be used to insert a sterilized enteroscope. Lesions can be marked by injection of ink or placement of a suture. Intraoperative or laparoscopy-assisted enteroscopy is

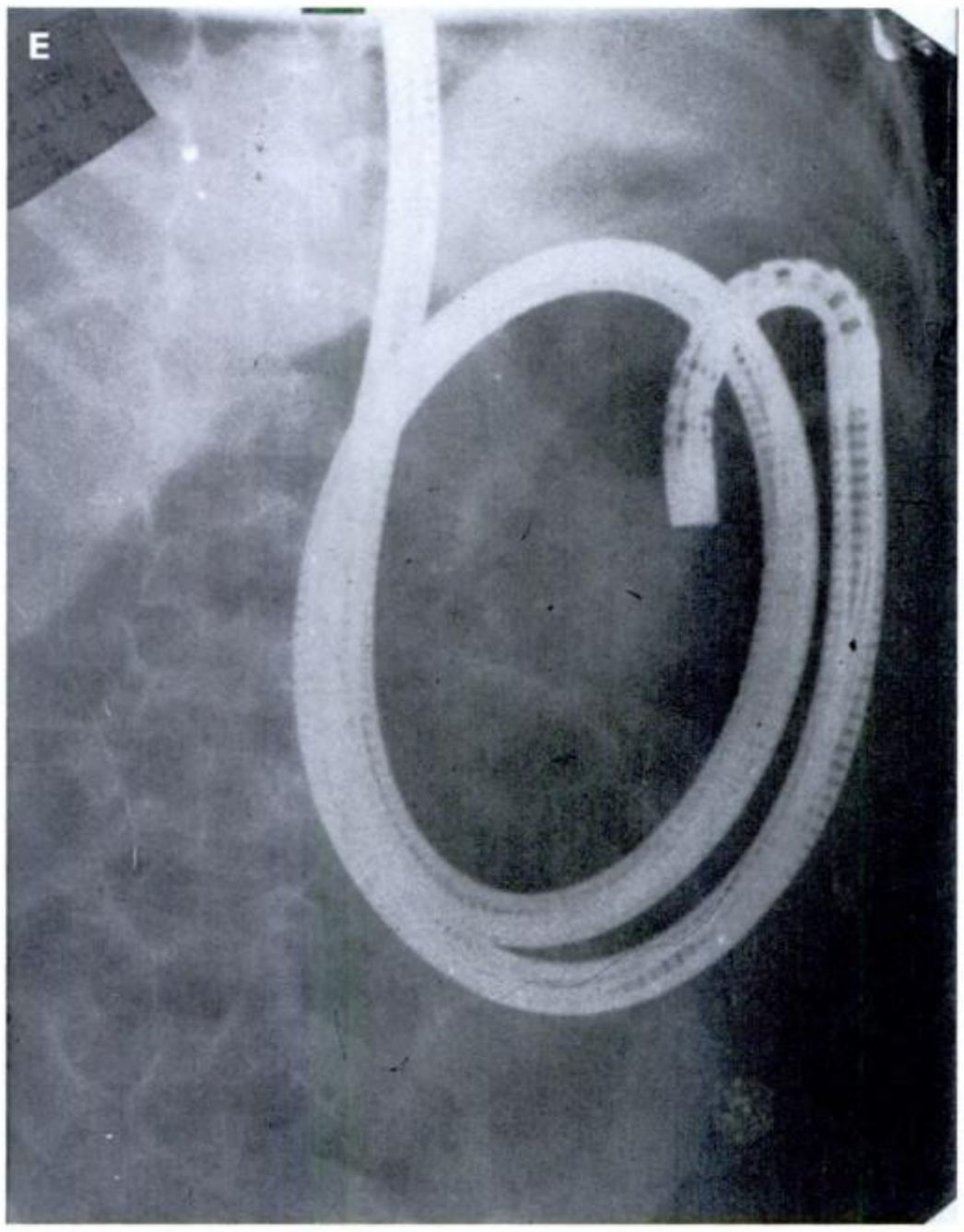


Figure 8-7. ***Continued.*** *E*, Endoscope in distal jejunum (80–100 cm beyond the ligament of Treitz).

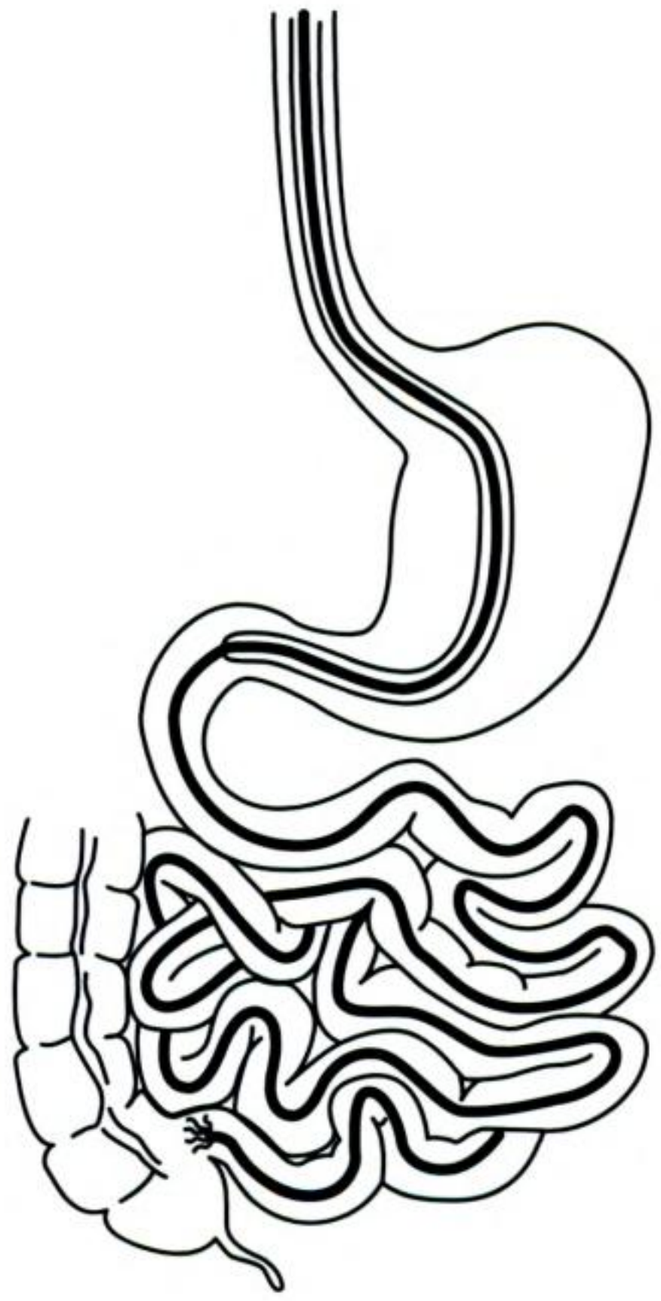


Figure 8-8. Intraoperative or laparoscopic-assisted enteroscopy may permit examination of the entire length of the small intestine.

the most successful technique for identifying sites of obscure GI bleeding with diagnostic yields of 60 to 100%. Laser or bipolar coagulation can be used, but resection of lesions is recommended if the procedure is done intraoperatively.

Enteroscopy has demonstrable advantages in the assessment of many conditions that affect the jejunum as well as other parts of the gastrointestinal tract. The extent of polyposis syndromes may be more accurately determined by "on-table" enteroscopy at laparotomy than by external transillumination and palpation. Up to 65% of patients with Crohn's disease, have had lesions not previously identified in the small bowel by other investigations including direct visualization of the serosal surface. Occult Crohn's disease can be identified in children using enteroscopy. Partial intestinal obstruction and Meckel's diverticulum have also been identified with intraoperative enteroscopy.[17] Small-bowel neoplasia is the second most common reason for obscure GI bleeding accounting for 5 to 10% of the cases in young adults. Exploratory laparoscopy and enteroscopy are important diagnostic tools in evaluating these patients who often have many tests prior to finding a cause for their symptoms.

Complications

Complications are not often encountered with simple push enteroscopy, but when the overtube is employed, significant patient discomfort has been described. Other rare complications associated with the use of the overtube include pharyngeal tear, Mallory-Weiss tear, gastric mucosal stripping, pancreatitis, and duodenal perforation. Intraoperative enteroscopy has a 5% incidence of perforation and, in one series, a 50% incidence of mucosal laceration. Prolonged ileus has been occasionally described. Polypectomy during enteroscopy may have a higher probability of perforation than during colonoscopy because the small bowel wall is thinner. None of these complications have been reported in the limited numbers of studies in children.

Diagnostic Colonoscopy

9

Mike Thomson and M. Stephen Murphy

This chapter focuses on the clinical application and technique of diagnostic colonoscopy. The practice of pediatric colonoscopy has evolved significantly over the past 20 years with improvements in technique and advances in technology (see Chapter 2, "Endoscopic Equipment").

Indications

There are numerous conditions that can be identified with colonoscopy (Table 9-1). The atlas section following this chapter illustrates the normal endoscopic appearances of the colon, and also shows many of the disorders which may be identified during colonoscopy.

Inflammatory Bowel Disease

The most common indication for diagnostic colonoscopy in children is the suspicion of inflammatory bowel disease (IBD).[1] Patients with bloody diarrhea are likely to have some form of colitis. Nowadays it is common to perform both upper gastrointestinal (GI) endoscopy and colonoscopy when investigating children for possible IBD. This helps to establish disease distribution and can assist in distinguishing between ulcerative colitis and Crohn's disease. The macroscopic and histological features of these conditions are highlighted later in this chapter. The specific changes seen and their distribution can be crucial in distinguishing between these disorders. Examination of the entire colon with intubation of the ileum provides the best chance of establishing the diagnosis. Examination of the distal ileum is important and may add considerably to the value of pediatric colonoscopy.[2,3] It can detect evidence of Crohn's disease that would otherwise be overlooked. In some cases it may be the only means of establishing a histological diagnosis of Crohn's disease. It can sometimes help to distinguish between Crohn's disease and the potentially confusing changes often noted on barium contrast radiology due to the normal entity of lymphoid nodular hyperplasia in the terminal ileum. Finally, it could help in the diagnosis of other forms of ileitis (see below). In patients with IBD, therapy is often influenced by knowledge of the

Table 9-1. Disorders in Which Diagnostic Colonoscopy May Play a Primary Role

Colitis
- Ulcerative colitis
- Crohn's colitis
- Infectious colitis
- Allergic colitis
- Breast milk colitis
- Neutropenia or neutrophil dysfunction
- Lymphocytic colitis
- Collagenous colitis
- Diversion colitis

Protracted diarrhea of infancy
- Microvillus inclusion disease
- Autoimmune enteropathy

Graft-versus-host disease

Vascular anomalies
- Portal hypertensive varices
- Angiodysplasia
- Hemangiomas
- Blue rubber bleb syndrome
- Vasculitis

Polyps
- Juvenile polyp
- Cloacogenic polyp
- Adenoma
- Hyperplastic polyp

Polyposis syndromes
- Familial adenomatous polyposis
- Gardner's syndrome
- Peutz-Jeghers syndrome
- Juvenile polyposis coli
- Turcot's syndrome
- Cronkhite-Canada syndrome

Malignant tumours
- Leiomyosarcoma
- Gastrointestinal lymphoma
- Colonic carcinoma

disease location, extent, and severity. In some cases follow-up colonoscopy may be helpful in assessing the response to treatment, and it is our practice (MT) to repeat the examination after treatment as a matter of routine. Children and their parents often find it helpful to have visual evidence of mucosal healing. In those with long-standing colitis histological evidence of dysplastic change may be detected.

Although colonoscopy can sometimes reveal complications of IBD, such as strictures or fistulas, these are more reliably demonstrated using other techniques such as contrast radiology imaging. The role of the barium contrast enema is now very limited in children with IBD, and it should rarely be required. It is associated with significant radiation exposure. Although other radiological techniques such as abdominal ultrasound, computerized tomography (CT), and ^{99m}TC-HMPAO (technetium-99m hexamethyl propylene amine oxime) leucocyte scintigraphy may be helpful in the investigation of some children with suspected colitis, colonoscopy is the gold-standard test for the diagnosis of ulcerative colitis and Crohn's disease. The objective should always be to obtain histological confirmation of the diagnosis.

Other Forms of Colitis

Although ulcerative colitis and Crohn's disease are important causes of chronic inflammation it is necessary to consider other possibilities in the differential diagnosis. Ulcerative colitis and Crohn's disease are rare in children below the age of 2 years, and in such cases it is especially important to consider other possible explanations for bowel inflammation. A relatively short history might suggest an infectious etiology.

Infections such as amebic dysentery, campylobacter, salmonella, and shigella can cause colitis. Yersinia and tuberculosis can cause ileitis and can mimic Crohn's disease. Detection of tubercle bacilli may be improved by cutting thick histology sections (5 μm) for Ziehl-Neilson staining, and by PCR analysis of tissue samples. Parasitic infestation with *Enterobius vermicularis* (pinworm) is common and often observed at colonoscopy. Some have suggested that this may be a rare cause of ileocolonic ulceration, though this is controversial.

Allergic enterocolitis usually presents in infancy and may be associated with bloody diarrhea. It is most often due to cow's milk allergy, but it may occur in the exclusively breast-fed infant. Breast milk colitis is thought to be due to the transfer of maternal dietary antigen to the infant through the milk. Colitis may occur in infants with protracted diarrhea, for example, due to autoimmune enteropathy.

Bowel inflammation may occur in neutropenic patients or in disorders associated with neutrophil dysfunction, such as chronic granulomatous disease, glycogen storage disease types 1b and 1c, or defective neutrophil chemotaxis.

In adults there is a disorder known as collagenous colitis that presents with watery diarrhea and abdominal cramps. The diagnosis is based on distinctive histological changes: there is a chronic inflammatory infiltrate in the lamina propria, increased intraepithelial lymphocytes and a characteristic subepithelial collagen band. There are a few reports of this condition in children. Lymphocytic colitis (or "microscopic colitis") presents in a similar manner and is again of unknown cause. The histology is similar but the collagen band is not seen. This entity is also rare in childhood.

Diversion colitis (or "disuse colitis") may occur in a segment of colon surgically excluded from contact with the fecal stream. The incidence increases with time and patients may first develop symptoms after months or years. The associated histological changes consist of nonspecific inflammation.

Graft-versus-Host Disease

Graft-versus-host disease with GI involvement may occur following solid organ and especially bone marrow transplantation. The gut disease may be acute or chronic. It is important to distinguish between graft-versus-host disease and other causes of diarrhea or GI bleeding in these patients, such as infectious colitis or chemotherapy induced mucositis. Focal apoptosis of the glandular epithelium is a characteristic histological finding in acute graft-versus-host disease.

Vascular Anomalies

Vascular anomalies are an occasional cause of colonic bleeding in infancy and childhood. Disorders such as "blue rubber bleb nevus syndrome" or angiodysplasia may be recognized at colonoscopy. In some cases the lesions may be subtle and easily overlooked, especially if bowel cleansing has been unsatisfactory. Vasculitis can masquerade as colitis with a similar mucosal appearance. In some cases it may be suspected due to involvement of other organ systems. Celiac axis, renal, and mesenteric angiography may reveal the characteristic microaneurysms of vasculitis.

the up/down control and, if necessary, to the left/right controls. The index finger operates the air, suction, and water buttons. The right hand is then free to hold the shaft of the instrument close to the patient and to control insertion and withdrawal as well as rotation. It is held between thumb and fingers of the right hand (rather than in the palm), giving delicate control and allowing easy rotational movements.

Finding the Way Forward and Negotiating Bends

Generally the direction of the endoscope tip is controlled using a combination of shaft rotation and up/down movements, with only occasional need for left/right adjustments. It is very useful to imagine the endoscopic field of view as a clock face so that directions can be represented in terms of the hours of the clock. For example, it is possible to move in any direction between 9:00 and 12:00 and between 12:00 and 3:00 using a combination of upward deflection and anticlockwise or clockwise rotation. Similarly, downward deflection with clockwise or anticlockwise rotation allows movement in directions lying between 9:00 and 6:00 and between 6:00 and 3:00. This approach is useful for developing a sense of three-dimensional orientation during colonoscopy.

Marked twisting of the instrument shaft greatly impairs the effectiveness of these movements and should be reduced to a minimum. The shaft of the instrument outside of the patient should be as straight as possible, and internal looping should be minimized (see below). Over-bending with the controls should also be avoided because if the tip is sharply angulated, forward movement is usually impossible.

Throughout the procedure it is important to try to maintain a clear view of the lumen close to the center of the image. Air is insufflated from time to time, gently dilating the bowel in order to obtain a clear view of the direction ahead. Insufflation should not be overdone, however, and when possible any excess air should be aspirated. Some endoscopists employ carbon dioxide insufflation. Carbon dioxide is rapidly absorbed and may reduce patient discomfort due to persistent distension. If the colon is excessively distended with air, forward progress of the instrument may be impaired. If the direction of the lumen is difficult to determine it is often suggested by the presence of a relatively dark (more distant) area towards the edge of the field of view. The correct way forward can also be suggested by the longitudinal direction of the submucosal vasculature. If there is a sharp change of direction ahead, the lumen usually appears as a dark crescentic shadow. If, despite looking in all directions, the way ahead cannot be determined, the instrument is withdrawn a short distance, immediately allowing the endoscopist to regain orientation. This is a basic and very important principle of colonoscopy. Experienced operators withdraw the instrument in this way at frequent intervals. Beginners are often reluctant to do so because they fear "losing ground." This is one of the major reasons for slow progress with the procedure. Finally, if at any point during the procedure a maneuver results in loss of the luminal view, then reversal of the action just performed should restore it. Again, careful withdrawal of the instrument combined with minor tip deflections using the controls or minor rotatory movements can also restore the view.

Before attempting to maneuver the instrument tip around an acute bend it is important to view the bend from a reasonable distance in order to decide the precise direction of the turn. Inspection from close up often leads to a false impression, and so the colonoscope should be withdrawn a few centimeters if necessary. It is very helpful to rehearse the actions needed to achieve the desired directional movement of the tip because these are not always readily predictable. The tip is then advanced up to the bend, and the appropriate combination of controlling actions is performed as the instrument is carefully advanced. It is sometimes unavoidable that the luminal view is briefly lost while passing around a sharp bend. The endoscopist can then briefly employ a "slide-by" technique. Gentle forward pressure is applied and forward progress is confirmed by observing the movement of the submucosal vasculature across the lens. Anything more than brief "side-viewing" of the bowel wall in this way is not desirable.

Loop Formation

One of the major difficulties encountered in colonoscopy is that forward pressure often results in sideways bending of the shaft rather than forward movement of the instrument tip. Both the sigmoid and transverse colon lie suspended from a loose mesenteric attachment (mesocolon) and there is consequently a tendency for the advancing colonoscope to stretch the colon in these segments, producing the problem of "looping." The descending colon and ascending colon are generally fixed to the retroperitoneum, although quite frequently this is not the case and fixation of these segments may be partial in more than one-third of

patients. Such variation in mesocolon anatomy is a significant factor in the unpredictable loop conformations that are often encountered. If a loop forms, forward pressure on the shaft of the instrument may not translate into forward movement, but rather leads to progressive enlargement of the loop. If the patient is awake they will usually experience discomfort. The use of excessive force in these circumstances could result in injury to the bowel, especially in those examined under general anesthesia, given the absence of patient discomfort as a warning sign. Manual compression of the abdomen is often employed to prevent or control looping. This is usually done by an assistant standing behind the patient and to the left of the endoscopist.

Large loops must be reduced by withdrawal of the instrument. As a general principle it is important to withdraw the instrument immediately after negotiating each sharp bend in the colon. Passage around such bends often begins the process of looping, and the colonoscope is straightened by withdrawing until the angulated tip catches on the bend.

Choice of Instrument

The endoscopist should first decide whether to use an adult or pediatric colonoscope (see Chapter 2). In general, it is better to use an adult colonoscope if possible. Adult instruments can be used for children down to 3 years or 15 kg. The choice may be influenced by instrument availability and by personal preference. The larger diameter of the adult instrument can reduce maneuverability in the relatively small bowel lumen, but this is not usually a significant problem. An advantage to using a larger instrument is that it has more stiffness, which reduces the tendency to loop. Although there is no evidence that the use of a larger instrument increases risk in small children, care should be taken to avoid using excessive force. The introduction of pediatric colonoscopes with operator-controlled variable stiffness may be a useful development. A control dial on the instrument is used to increase stiffness, for example, when advancing through the sigmoid or transverse colon.

Antispasmodic Agents

Some endoscopists like to administer an intravenous antispasmodic agent such as merbentyl. This is said to make it easier to view the lumen but it may increase the tendency to loop formation. Antispasmodics may facilitate ileal intubation if the ileocecal valve is contracted (see below), and may help with visualization of polyps concealed behind haustral folds. These agents are short-acting and re-administration may be required. Alternatively, they may be administered once the cecum is reached.

Patient Positioning and Initial Preparation

The examination is usually carried out with the patient lying in the left lateral position with hips and knees flexed (Figure 9-1). During the procedure it is important that the surface on which the colonoscope rests is flat and clear of all impediments. This avoids confusion if the endoscopist, while intent on viewing the image, detects resistance to forward movement due to snagging of the instrument on such obstacles. If this is avoided, resistance due to obstruction or loop formation can be readily recognized. If the direction of advancement is correct and there is no loop formation gentle forward pressure is normally all that is required.

Commencing the Examination

The instrument is checked to ensure that the suction, lens washing, and air insufflation facilities are all functioning normally. The lens washing jet should spray laterally and not merely drip water, and when the tip of the instrument is held under water, air insufflation should produce a rapid stream of bubbles (see Chapter 7, "Diagnostic Upper Gastrointestinal Endoscopy"). If insufflation is not fully functional the procedure will prove difficult or impossible, and those unfamiliar with the problem often imagine the bowel to be narrowed or noncompliant, resulting in misleading reports.

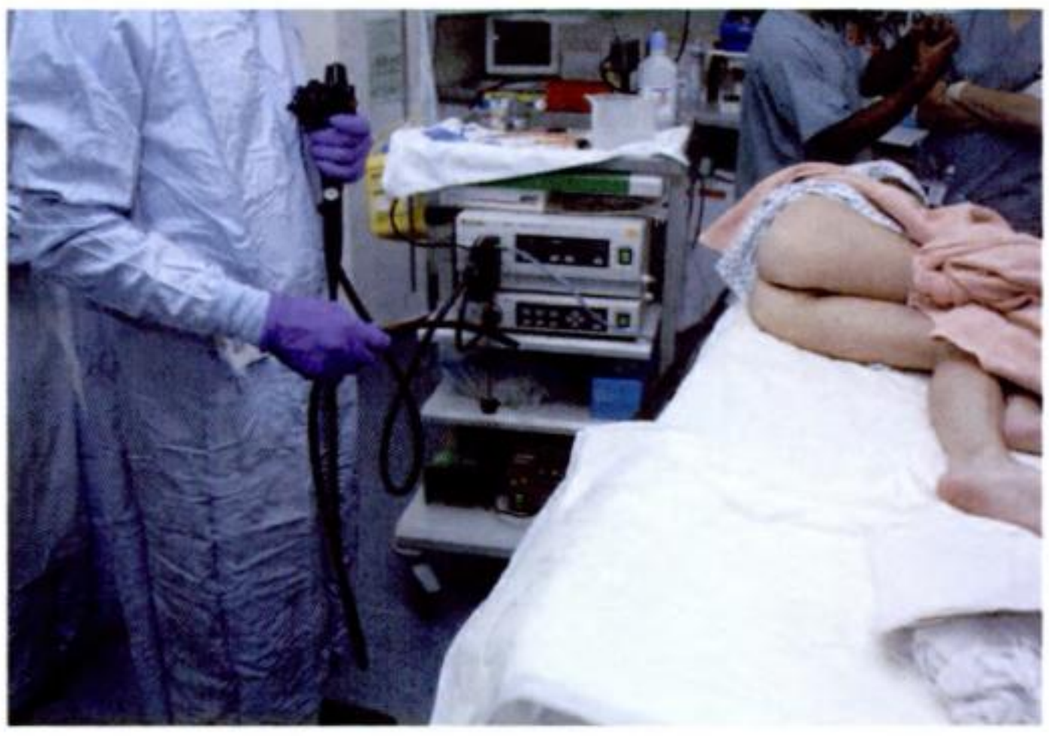


Figure 9-1. Left lateral position with hips and knees flexed.

The perianal area should be carefully inspected. It is common practice to perform a digital rectal examination prior to colonoscopy. This can detect lesions such as polyps in the distal rectum, and the lubricant introduced on the finger may help with subsequent passage of the instrument. Double gloving of the right hand facilitates this process, the outer glove being discarded before starting the colonoscopy.

The distal end of the colonoscope is now thoroughly coated with a water-soluble lubricant, while avoiding contamination of the lens at the tip of the instrument (Figure 9-2). From time to time, the shaft of the instrument may require further lubrication during the procedure. The tip is inserted carefully into the anal canal with or without digital guidance with the index finger (Figures 9-3 and 9-4). Usually, following insertion the instrument makes contact with the rectal mucosa so that the view is obscured. If it is withdrawn slightly and the direction adjusted while a little air is insufflated, the rectum can be inspected. The instrument should be rotated so that any free fluid present lies at the bottom of the image. The fluid is aspirated. The distal rectum is carefully examined before proceeding further. In the mid-rectum the ampulla is seen as a relatively wide region. The normal rectal mucosa is pink and smooth, readily reflecting the light from the colonoscope. The network of submucosal vessels is clearly seen. The semilunar folds (valves of Houston) are seen in the proximal rectum.

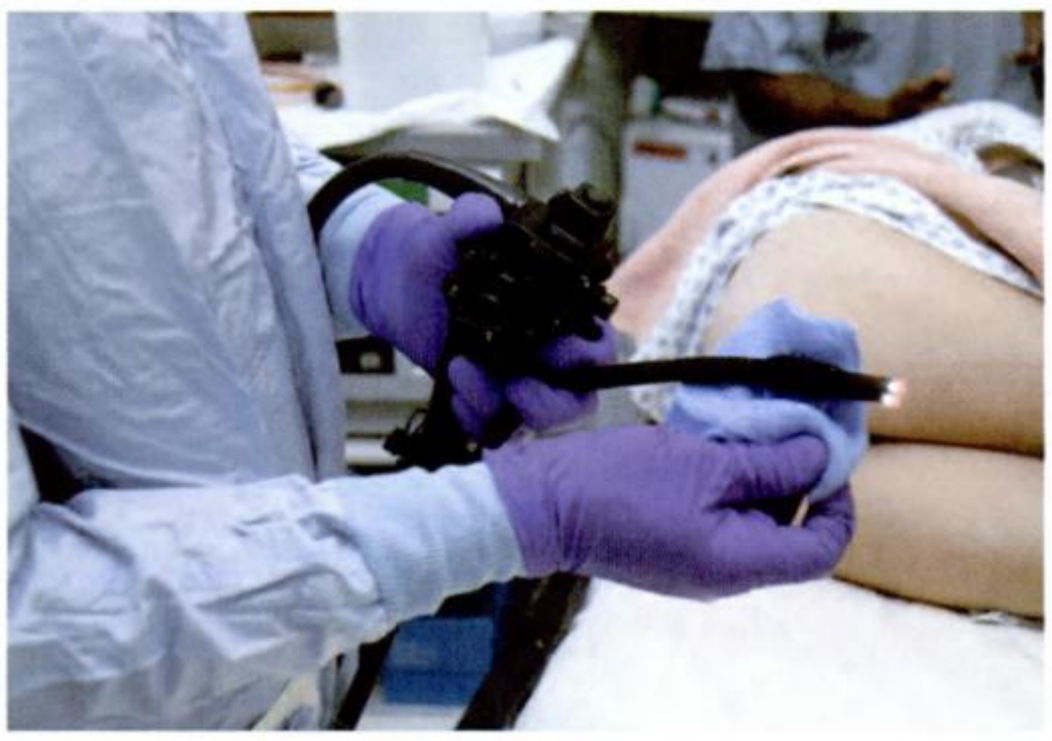


Figure 9-2. The distal end of the colonoscope is coated with a water-soluble lubricant.

Sometimes the bowel cleansing regimen is not satisfactory, and solid fecal residue may be present. It is usually possible to continue the examination despite this through a judicious combination of air insufflation, careful steering of the instrument, and, if necessary, lens washing.

It is possible, if required, to perform a retroflexion maneuver of the instrument tip in order to examine the distal rectum more thoroughly. This is done by deflecting the tip of the instrument, while advancing slightly. If retroflexion has been successful, the shaft of the colonoscope is seen entering the rectum through the anal canal from below. Using a combination of rotatory movements and minor adjustment of the degree of insertion, thorough examination of the distal rectum bowel is possible.

Sigmoid and Descending Colon

The mesenteric attachment of the sigmoid lies along the pelvic brim and varies considerably in length. Correct negotiation of this segment is often the most

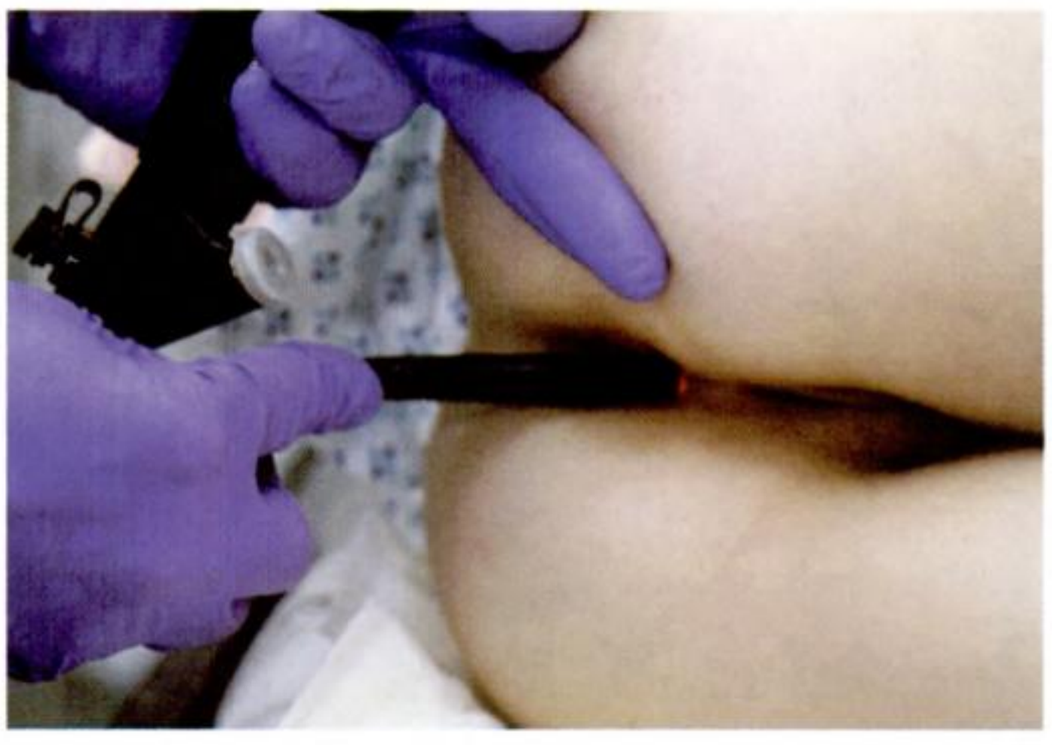


Figure 9-3. Insertion of the colonoscope into the anal canal.

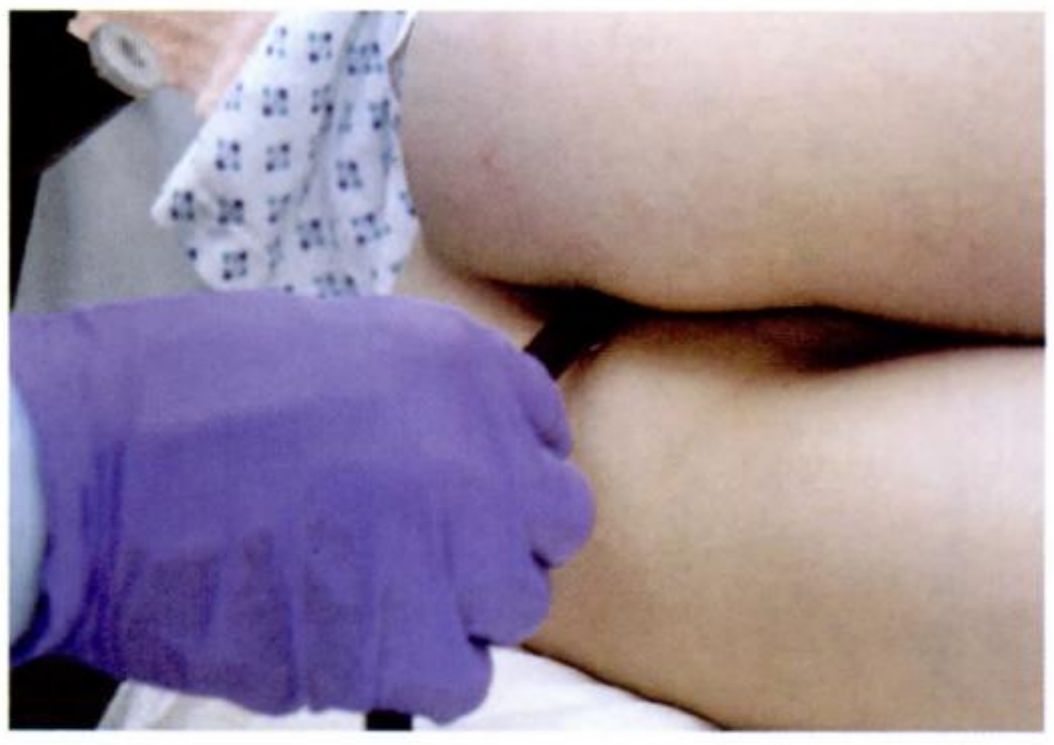


Figure 9-4. Advancing the instrument into the rectum.

difficult challenge for the colonoscopist. Loops forming in this region may prevent passage of the instrument into the descending colon. Even if the sigmoid is successfully negotiated and the looping controlled, there is a tendency for a sigmoid loop to recur at a later stage in the procedure, again causing difficulties with advancement of the colonoscope. The sigmoid colon is normally pushed forward by the sacral promontory and then curves posteriorly to the (usually fixed and laterally placed) descending colon. Thus, in effect, it usually forms a clockwise spiral. This is very important in understanding the rationale for various maneuvers often applied to facilitate this phase of the procedure. At the proximal end of the sigmoid the junction with the descending colon often presents as an acute bend.

To negotiate the sigmoid colon the examiner applies gentle forward pressure along with a combination of shaft rotation and up/down tip deflections to maintain a view of the lumen. Because the patient is lying on the left side, pools of fluid are often present within the dependent loops of the left colon, but usually it is possible with judicious air insufflation to pass the instrument over these rather than spend time attempting to aspirate them.

As the colonoscope advances, an upward and outward loop may often form so that the instrument now descends down at an unfavorable angle, forming an even more sharply angulated junction between the sigmoid and descending colon. This sharp bend may be difficult or impossible to negotiate. Anatomically this is more likely to prove difficult if the descending colon is fixed low down in the pelvis or if the sigmoid colon is unusually long. The two-dimensional radiological appearance of the loop has given rise to its description as an "N-loop" (Figure 9-5). Applying manual pressure to limit anterior curving can often control an N-loop. Sometimes, especially if the sigmoid is unusually long, a different loop may form—the so called "α-loop" (Figure 9-6). Here the loop actually twists around its relatively short pelvic mesenteric attachment. The colon then loops right in a continuous sweep so that there is no sharp angulation at the junction with the descending colon. The α-loop is therefore less troublesome and the instrument can often be advanced through it and on into the descending colon. Although the instrument moves forward, it should be apparent to the endoscopist that due to the α-loop the length of colonoscope inserted is more than would be expected (see expected lengths below). The loop can be removed subsequently by clockwise rotation of the colonoscope, followed by slow withdrawal while keeping the lumen in view. This maneuver may not be effective until the colonoscope has entered the distal transverse colon, when it can be assisted by hooking the tip of the instrument over the splenic flexure. Paradoxical forward movement of the tip is often seen as the instrument is withdrawn because the bowel "concertinas" back over the shaft of the colonoscope. Manual compression of the abdomen may again be helpful.

The common clockwise spiral loop conformation can often be controlled using clockwise twisting of the

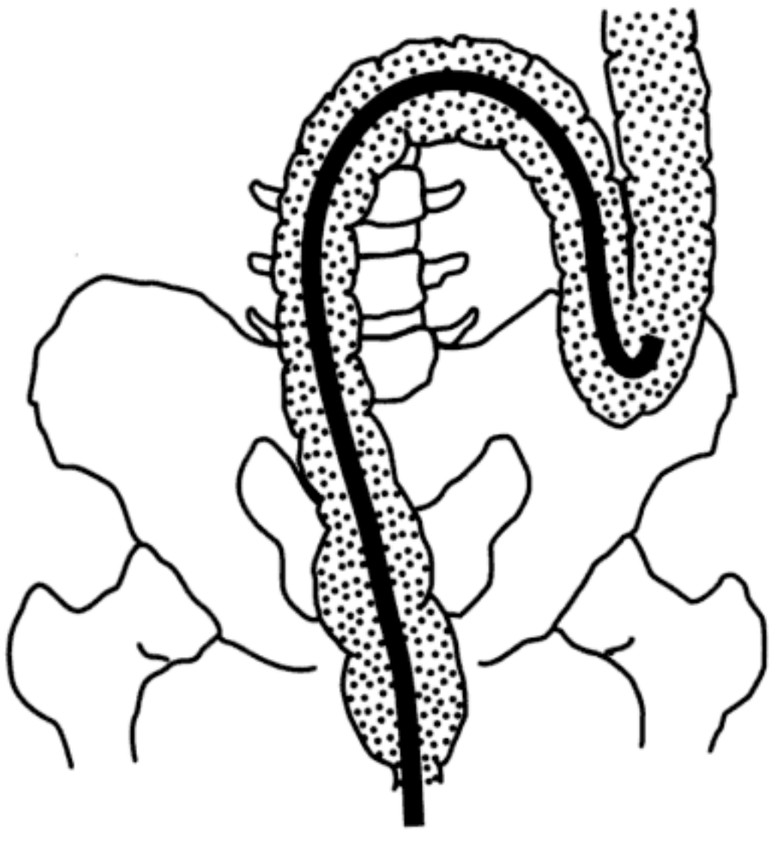


Figure 9-5. The N-loop.

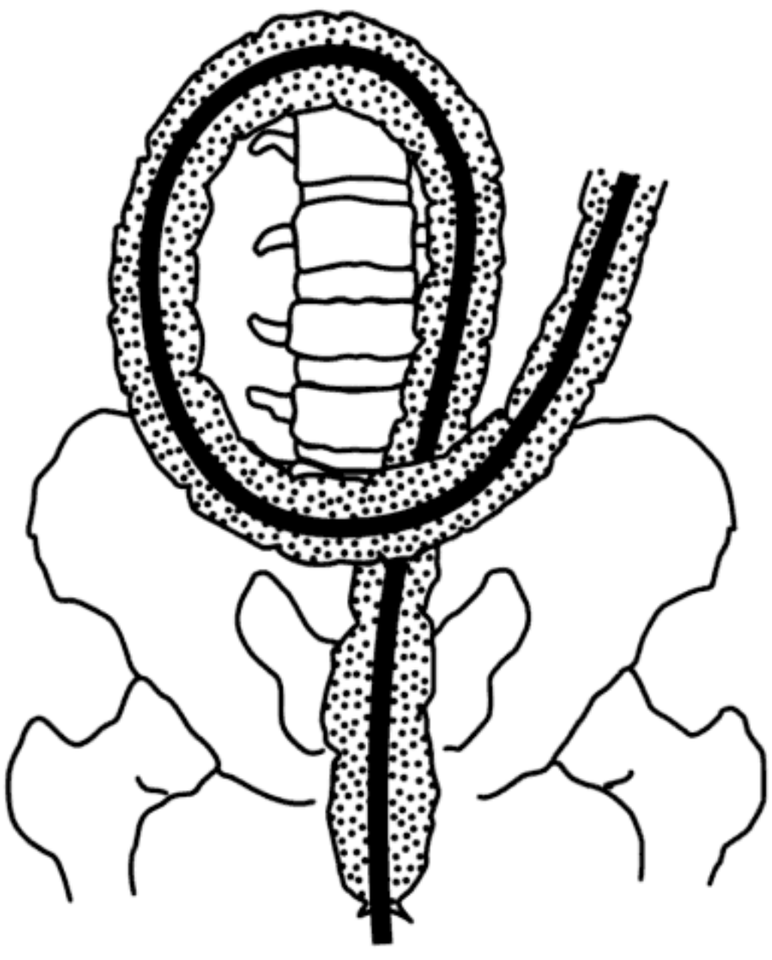


Figure 9-6. The α-loop.

shaft, which tends to encourage the sigmoid colon to slide back along the colonoscope in concertina fashion, thereby shortening itself. The tip will then be seen to move up along the colon. In many cases maintaining a clockwise twist, while advancing through the sigmoid colon, reduces the tendency of loop formation. Hard and fast rules cannot be provided, however, given the potential anatomical variations.

Passing the instrument from the sigmoid colon round to the descending colon is often the most difficult challenge in colonoscopy. The junction is usually recognized as an acute bend, and a longitudinal fold (taenia coli indentation) may be seen on the outer side of the curve. The tip of the instrument is passed round the bend and immediately the instrument is withdrawn to straighten the colon and improve the angle of the junction. If the bend proves unusually difficult then moving the patient onto the right side may sometimes help. Once the instrument passes beyond this last turn the descending colon is usually recognized by its straight tubular appearance. The left colon has relatively few haustral folds. Provided there is no looping, progress along the descending colon is usually easy.

Splenic Flexure and Transverse Colon

On reaching the splenic flexure, provided there is no loop, it can be expected that the colonoscope will be inserted to about 40 cm in an older child or as little as 20 cm in a young child. Although these figures are approximate they are helpful in deciding if a loop has formed. At the splenic flexure the spleen may be seen through the bowel wall as an area of bluish discoloration. Further confirmation of the position can be obtained by looking for a point of transillumination on the abdominal wall behind the left mid-axillary line and close to the costal margin. It is useful to reduce the ambient lighting to help with this, and it may be necessary to adjust the tip of the instrument in order to direct the light towards the surface.

The instrument is now advanced around the splenic flexure. At this point the shaft is again straightened. Any sigmoid loop present is removed by pulling back with the tip hooked around the flexure. The tip of the instrument is now straightened somewhat, and with clockwise rotation of the straightened shaft the colonoscope can usually be advanced slowly into the transverse colon. This may require a combination of right and upward tip deflection. If occasionally this maneuver fails then moving the patient onto their right side may help by opening up the splenic angle. The transverse colon is often recognized by its characteristic triangular appearance caused by the indentation of the taenia coli. Unlike the descending colon it is usually empty of fluid contents.

Provided there is no significant loop it is usually easy to advance along the transverse colon towards the hepatic flexure. Aspiration of excess air helps to shorten the colon so that it tends to concertina back over the instrument. In children the transverse colon does not usually loop down towards the pelvis on its suspending mesentery to the degree that is common in adults, but there may be a noticeable sharp bend in the mid section. If the transverse colon is very long a "γ loop" may occasionally form around a twisted mesentery (Figure 9-7). This is analogous to the sigmoid α-loop. This is uncommon in children, but if this should happen it is very difficult to remove and often prevents subsequent ileocecal intubation.

Hepatic Flexure and Ascending Colon

On reaching the hepatic flexure, provided there is no loop, it can be expected that the colonoscope will be inserted to about 60 cm in an older child or 40 cm in a young child. At the hepatic flexure a gray-blue shadow is usually obvious where the liver lies adjacent to the bowel wall. If there is any doubt about the tip location it is worth looking for a point of transillumination on the abdominal surface close to the right anterior axillary line at the costal margin (Figure 9-8). Moving the child to the supine or right decubitus position is occasionally helpful if there is real difficulty in identifying the direction of the lumen. When

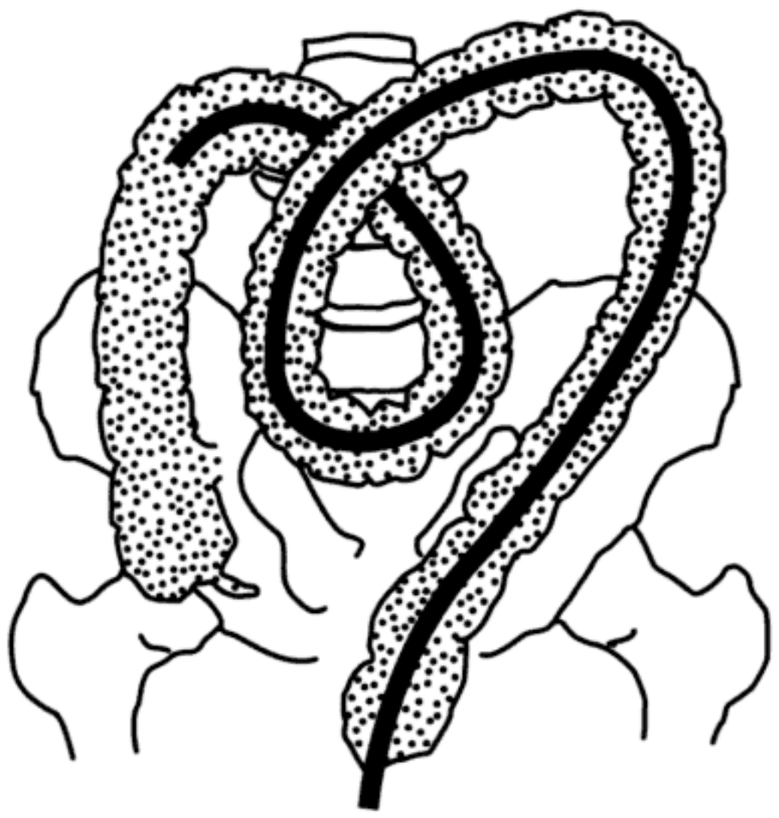


Figure 9-7. The γ-loop.

that ileal intubation can be difficult and repeated attempts may be necessary. The difficulty with this technique is that ileal intubation is being attempted without a direct view of the valve.

The alternative, which may be preferred, is as follows. With the valve again at the 6:00 position a biopsy forceps is advanced so that it is visible just a few millimeters beyond the tip of the instrument so that only the jaws can be seen (Figure 9-9) .The colonoscope is then advanced just beyond the ileocecal fold and gently deflected down so that the forceps presses a little into the lip of the valve, thereby opening its "mouth" (Figure 9-10). As the tip is deflected the endoscope will marginally "foreshorten" and, consequently, slight simultaneous advancement may be necessary. Minor maneuvers such as slight left deviation or withdrawal may be required to help open the valve orifice. Once it opens the tip is passed into the ileum with further downward deflection (Figure 9-11). Often the maneuver is helped by small right and left deflections while an assistant applies abdominal pressure to support the transverse colon and prevent loop formation. With practice this technique permits ileal intubation in most cases. It has the advantage that the endoscopist is able to see the ileocecal valve orifice.

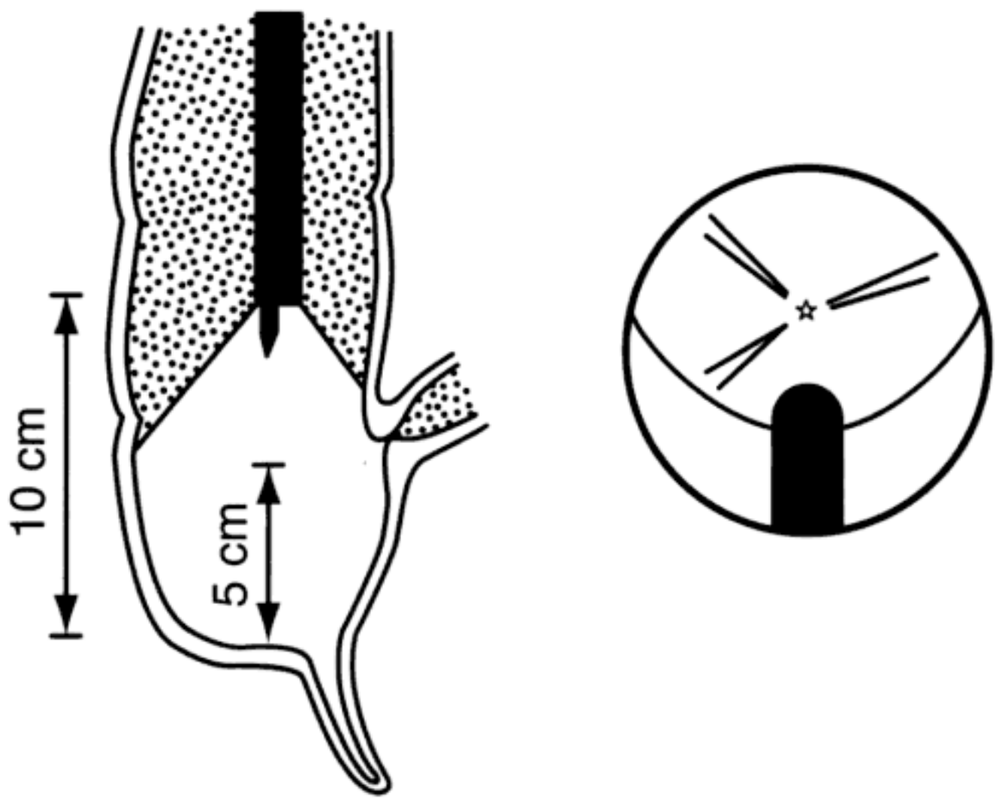


Figure 9-9. Ileal intubation using the forceps technique to provide a direct view. The biopsy forceps are visible just beyond the tip of the colonoscope.

The ileum may be examined for a distance of up to 40 cm. The mucosa has a characteristic velvet-like appearance, and Peyer's patches may be seen as raised smooth areas. Varying degrees of lymphoid nodular hyperplasia occur. The ileal villi can be seen more clearly if the lumen is flooded with water, allowing them to float up from the surface. The surface can be shown in greater relief using a spray of standard blue/black ink or methylene blue in a 1 in 20 dilution.

Withdrawing the Colonoscope

The colon is now thoroughly and systematically examined as the instrument is gradually withdrawn. The endoscopist is no longer focused primarily on the process of advancing the instrument and full attention can be given to the examination. Moreover, it is often found that residual contamination in the lumen has

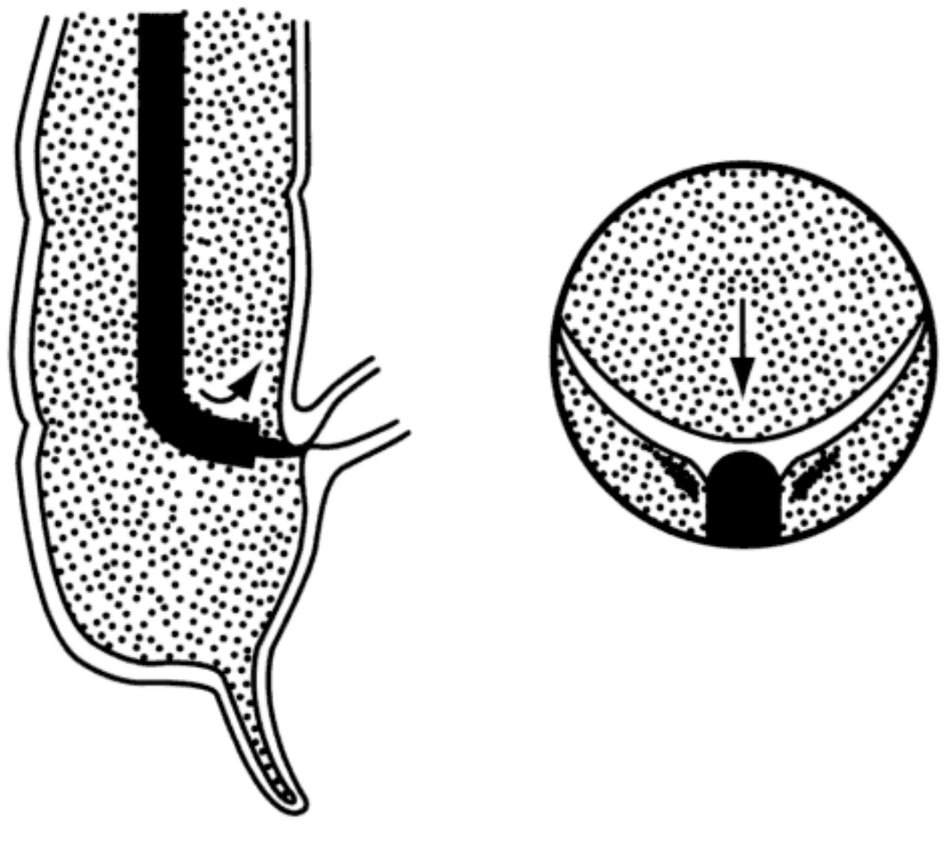


Figure 9-10. As the colonoscope is deflected down, the forceps press into the lip of the valve.

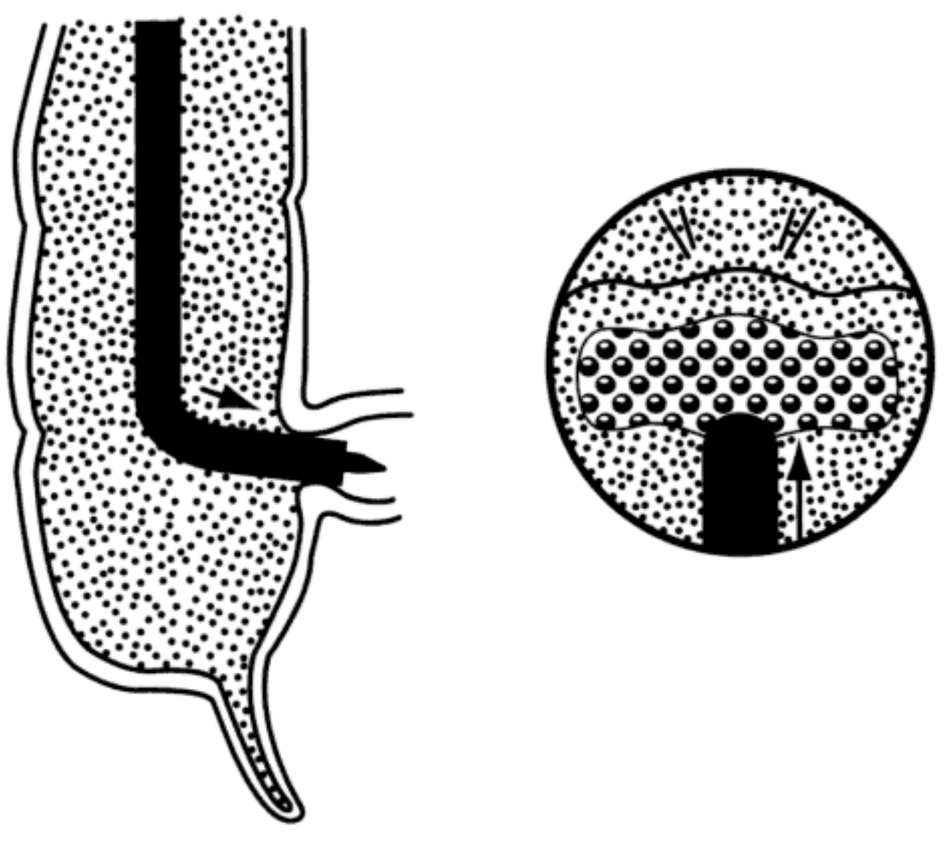


Figure 9-11. Once the valve orifice opens, the tip is passed into the ileum with further downward deflection.

largely cleared, giving a better view. Air can be insufflated when necessary and then aspirated before moving distally to the next segment of the bowel. Special care is needed if polyps are not to be overlooked because these can lie hidden behind the haustral folds.

Mucosal Biopsy

It is standard practice to take mucosal biopsies from the distal ileum and from each segment of the colon. In addition, if abnormal features are noted targeted biopsies are usually obtained. The technique for obtaining biopsies is described elsewhere (see Chapter 7, "Diagnostic Upper Gastrointestinal Endoscopy"). Some colonoscopy forceps are designed so that more than one biopsy can be obtained with each passage of the forceps in order to save time.

Complications

Diagnostic colonoscopy is not a high-risk procedure; complications related to therapeutic colonoscopy are discussed elsewhere. The main serious complication is that of bowel perforation. Most patients who suffer a perforation are likely to require a laparotomy and surgical repair of the bowel.

Various studies have been published describing the complication rate in very large numbers of adults undergoing colonoscopy. Reported incidences for perforation have ranged from 0.06 to 0.4%. Nowadays, with improved instrumentation, the incidence may be nearer to the lower end of this range.[4] The published data in relation to pediatric colonoscopy are more limited, but there is little reason to suppose that the risk is greater than in adult patients. Most perforations during diagnostic colonoscopy are due to mechanical pressure, and about 70% of these occur in the sigmoid colon. The risk of perforation is increased in the presence of serious bowel pathology, such as severe colitis, and it is greatly increased in those with underlying connective tissue disease, such as Ehlers-Danlos syndrome. Seromuscular tears have been reported following colonoscopy, but because these can only be seen at laparotomy, the incidence of this type of injury is unknown.

In one report on 3,000 pediatric colonoscopy examinations there were 5 perforations, but 4 of these occurred following polypectomy. Ten minor complications occurred, including 4 small hemorrhages (postpolypectomy), 3 cases of transient abdominal pain, 1 common peroneal nerve palsy, and 2 cases of unexplained postprocedure fever. The overall complication rate for simple diagnostic colonoscopy was 0.05%.

Rare complications in adults have included splenic rupture or avulsion and pancreatitis. Splenic injury presents within 24 hours of the procedure with evidence of hypovolemia and abdominal or shoulder-tip pain. Pancreatitis may be due to mechanical injury to the pancreatic tail.

Although bacteremia has not been reported in association with colonoscopy in children, it is presumably a risk because it has been shown to occur in adults. The use of prophylactic antibiotics in high risk patients is discussed in detail elsewhere (see Chapter 5, "Patient Management").

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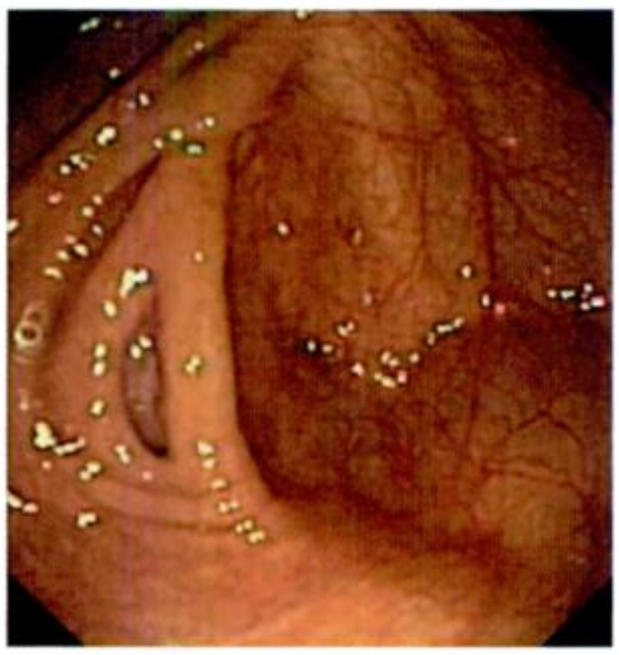
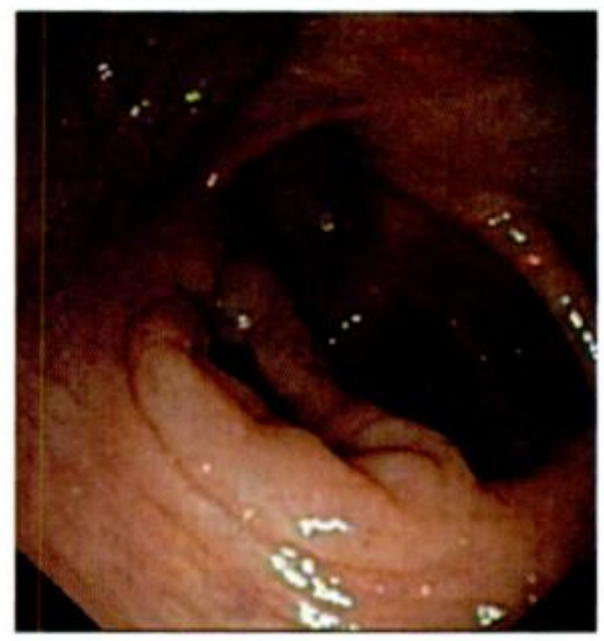
9. Gedebou TM, Wong RA, Rappaport WD, et al. Clinical presentation and management of iatrogenic colon perforations. Am J Surg 1996;172:454–7.

Atlas Part II

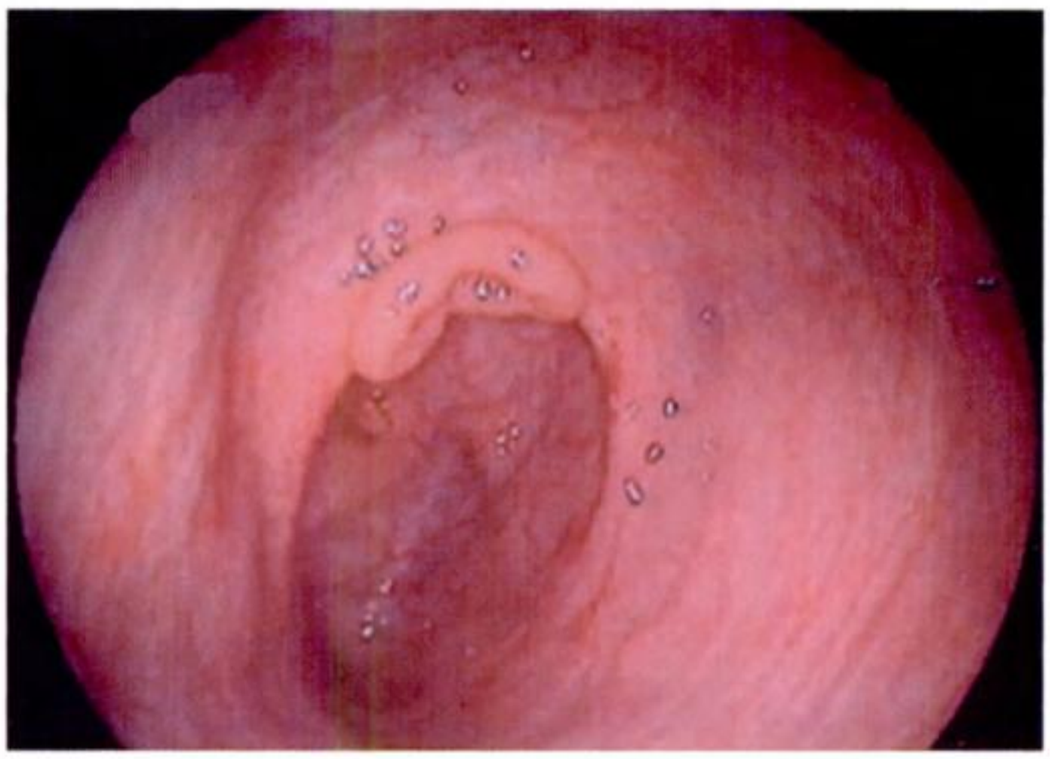
Normal colon



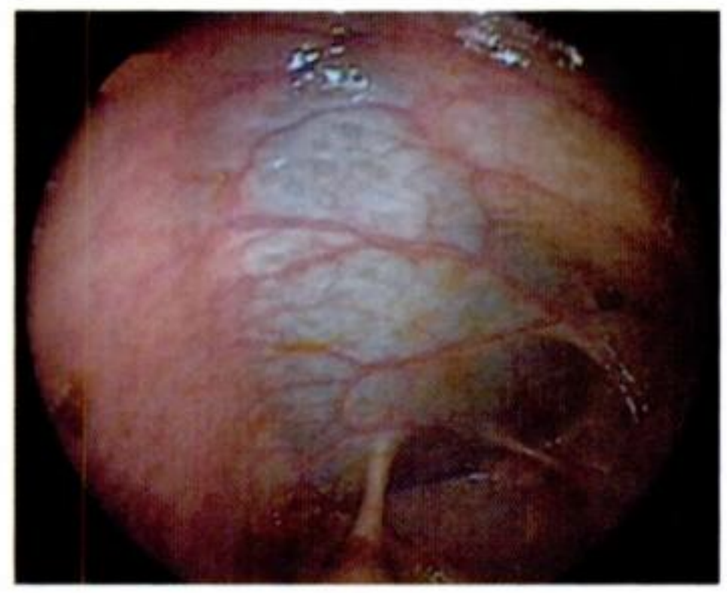
1. Appendiceal orifice.



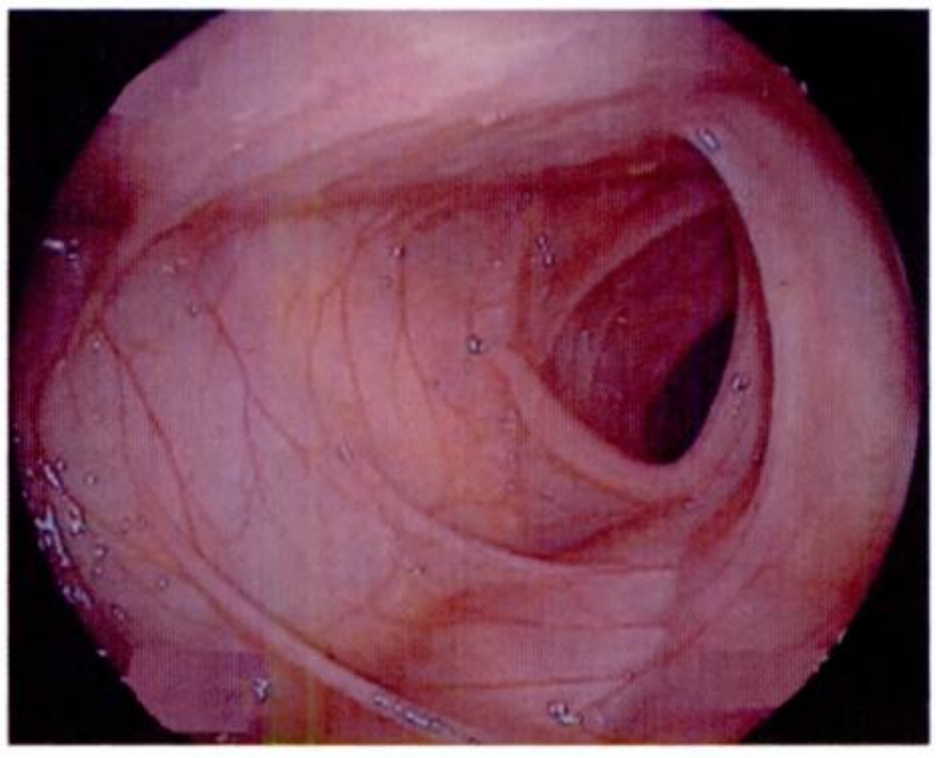
2. Ileocecal valve.



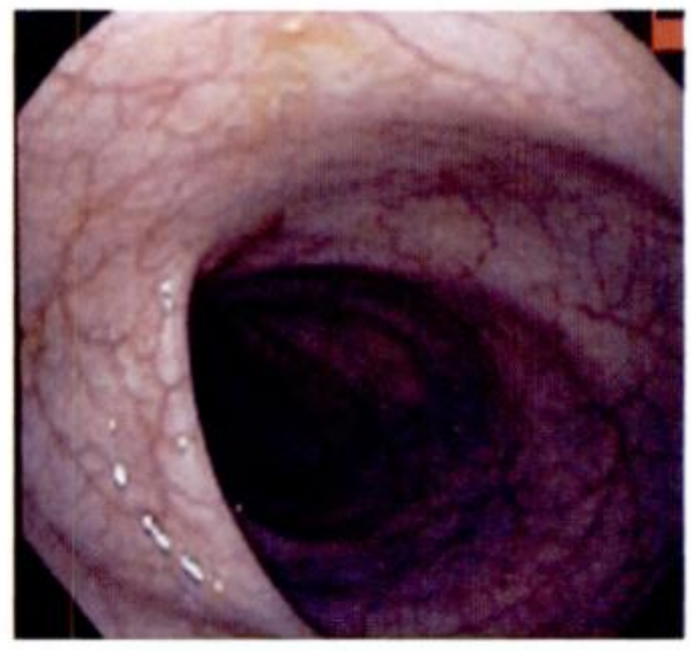
3. Typical appearance of the ileocecal valve fold.



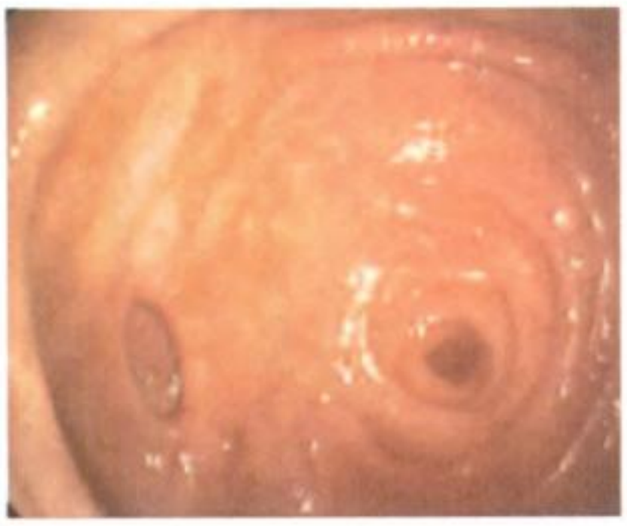
4. Hepatic flexure with blue appearance of the adjacent liver as a useful landmark. Prominent lymphoid nodules are more easily seen in contrast with the liver.



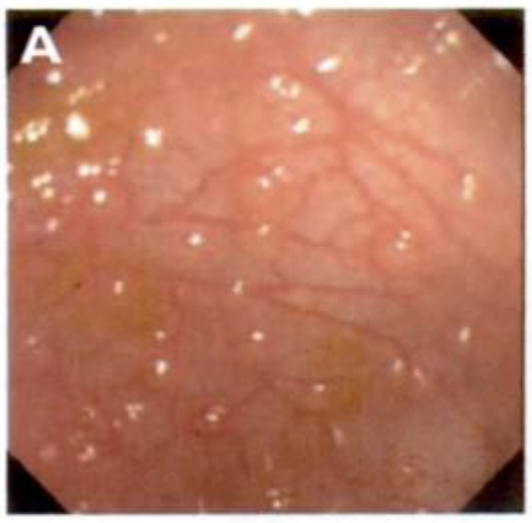
5. Transverse colon with triangular pattern of the semilunar folds.

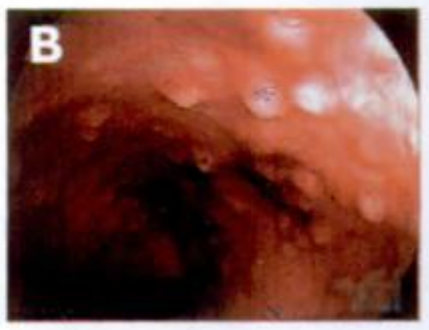


6. Left colon with clear vascular pattern.



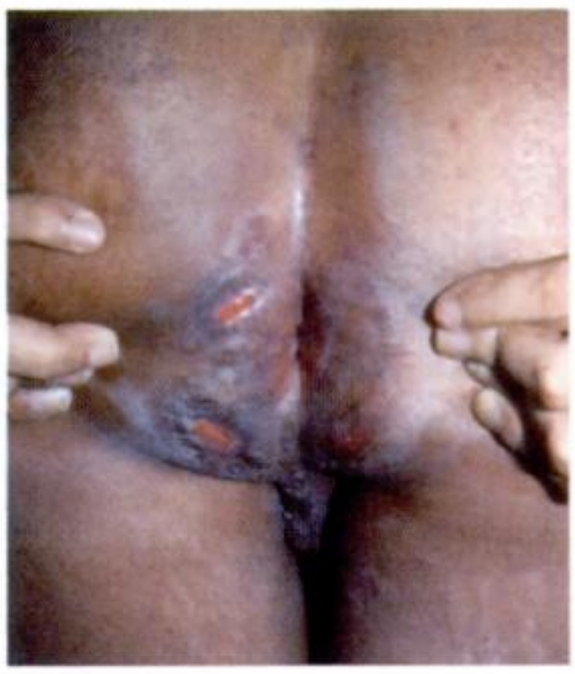
7. Incidental finding of a cecal diverticulum in a child with an otherwise normal colonoscopy.



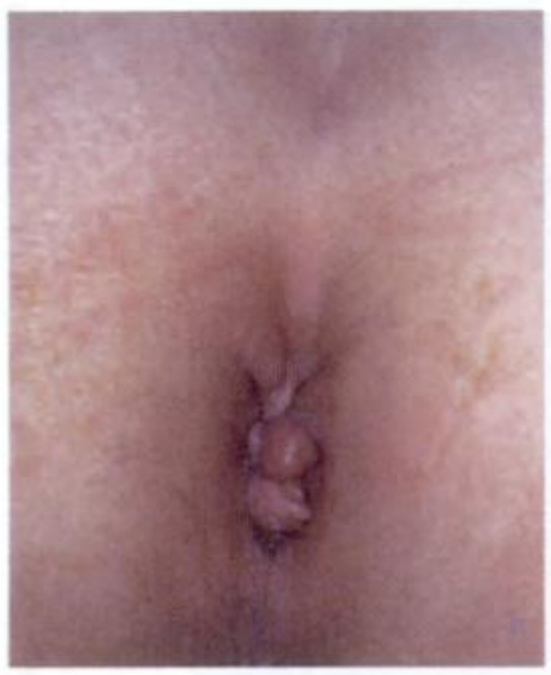


8. *A, B,* Nodular lymphoid hyperplasia of the colon. (*B,* Image courtesy of Jorge Oscar Donatone, MD.)

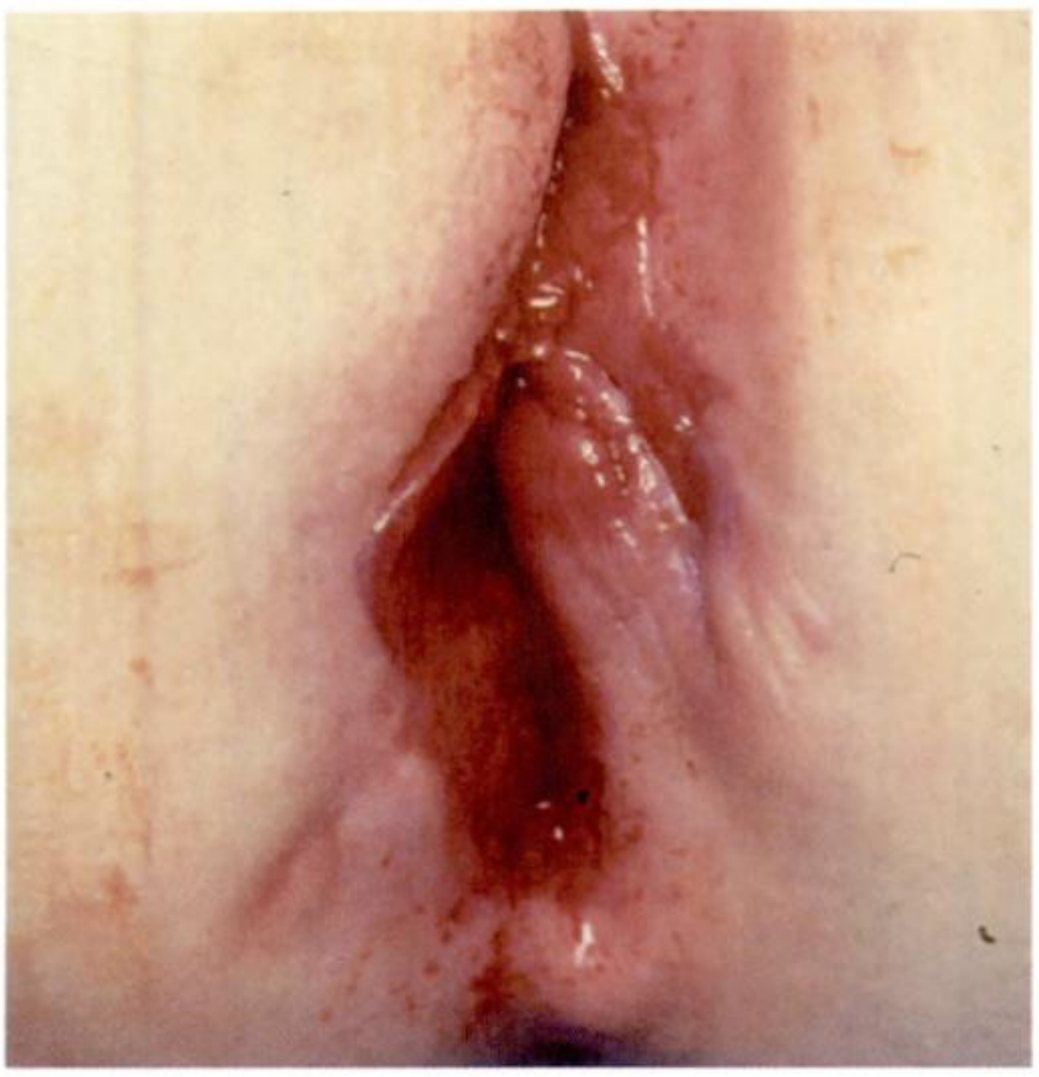
Crohn's Disease



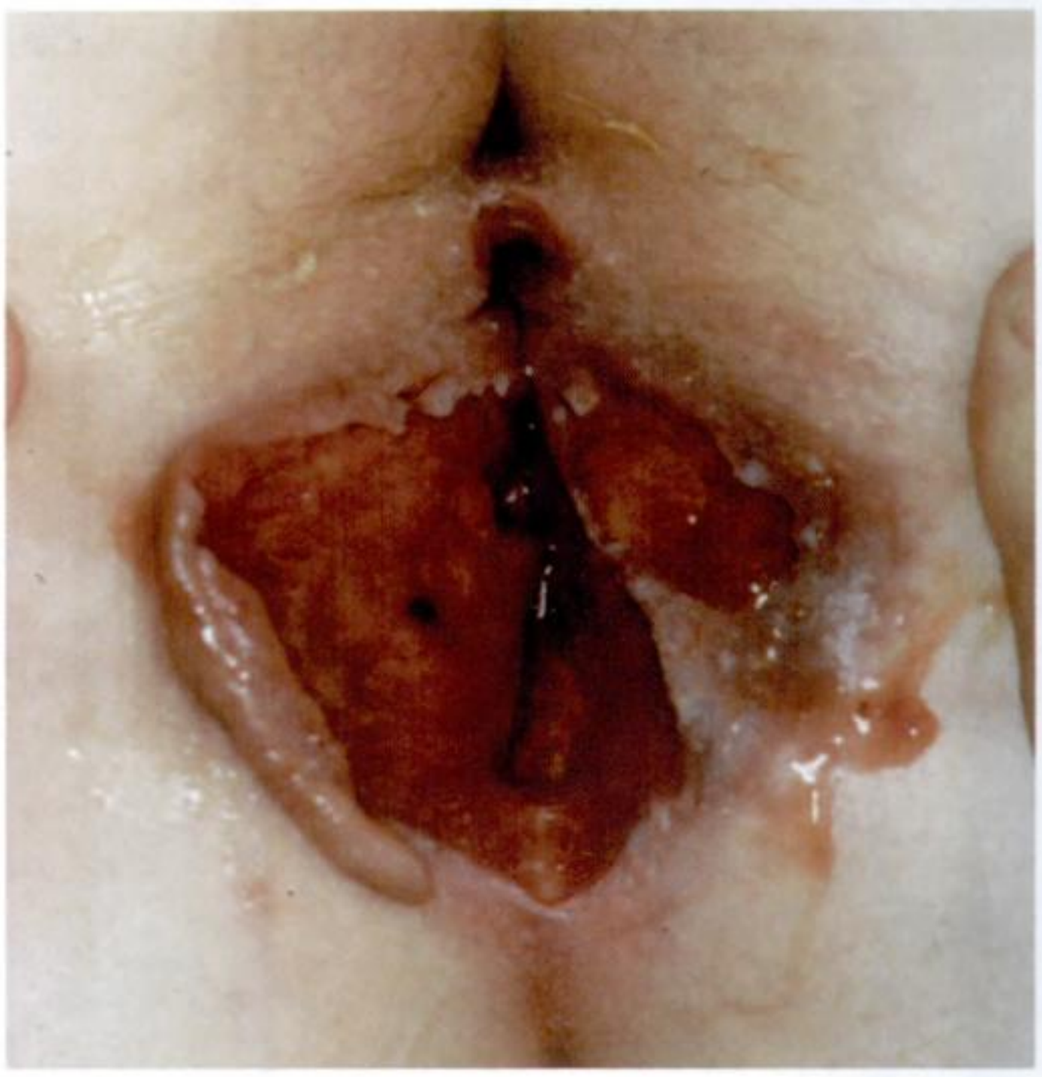
9. Perianal satellite ulcers. (Image coutesy of Gabriel Dinari, MD.)



10. Noninflamed perianal skin tags.

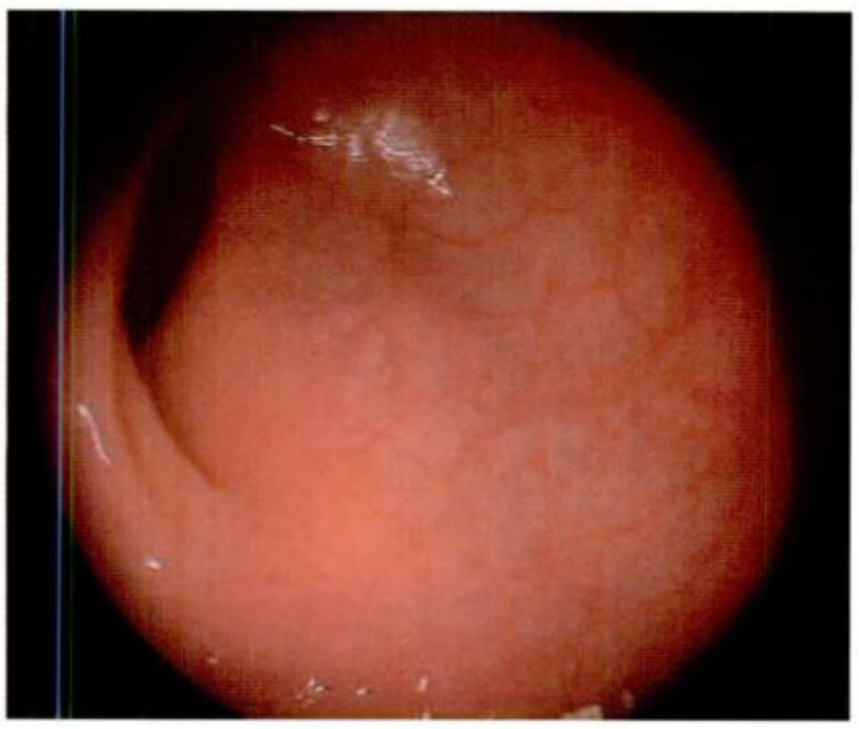


11. Severe fissuring perianal disease.

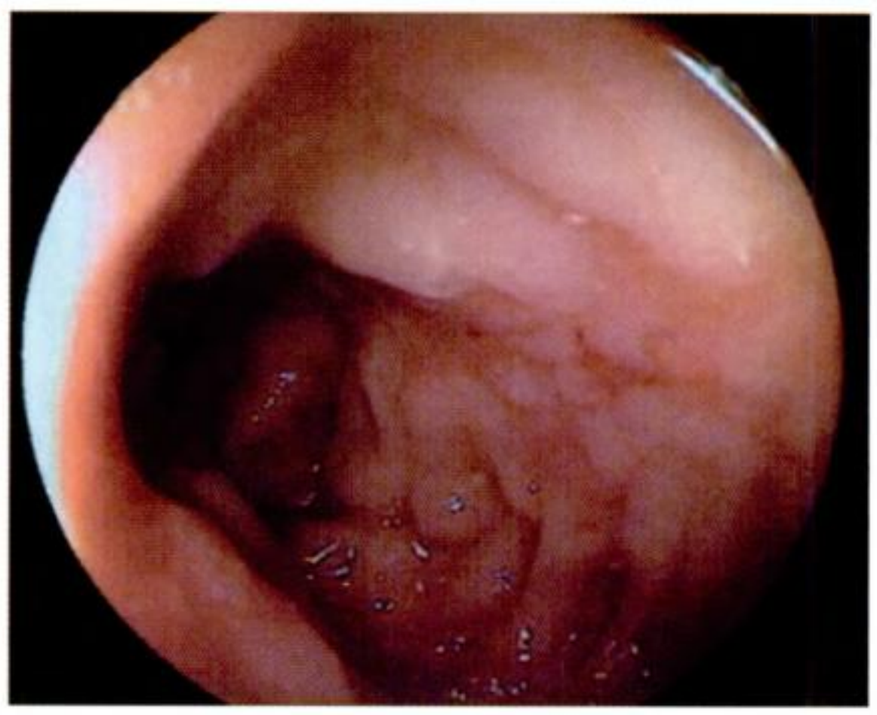


12. Destructive ulcerating perianal disease.

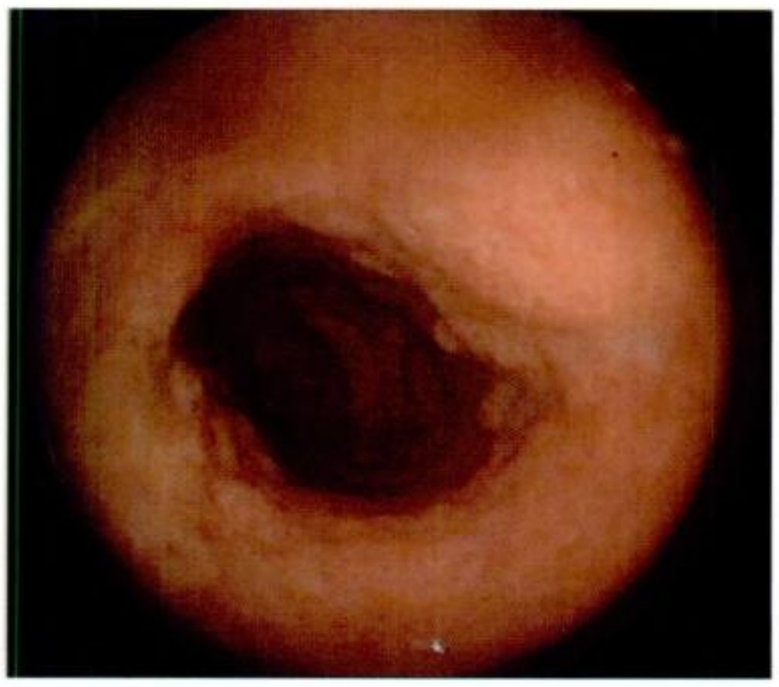
Plate 69



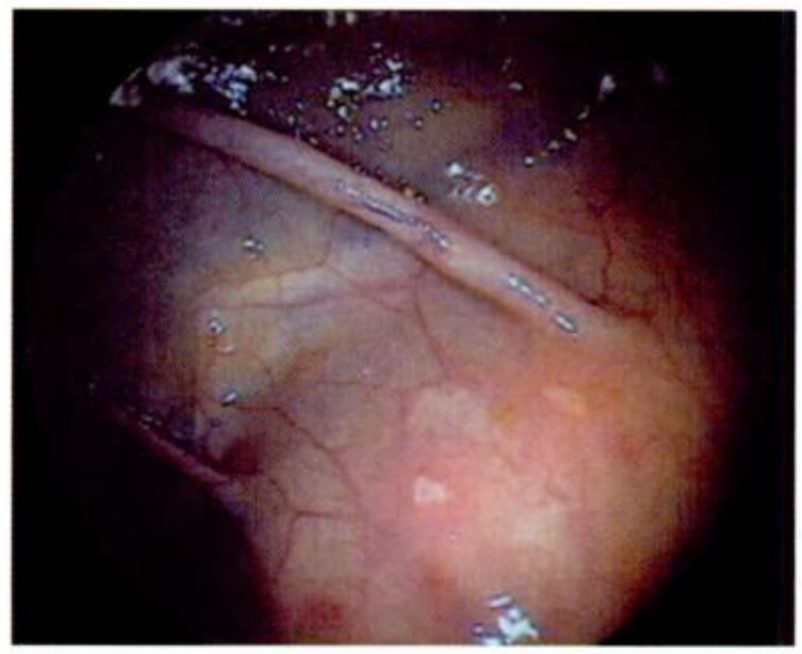
13. Focal erythema.



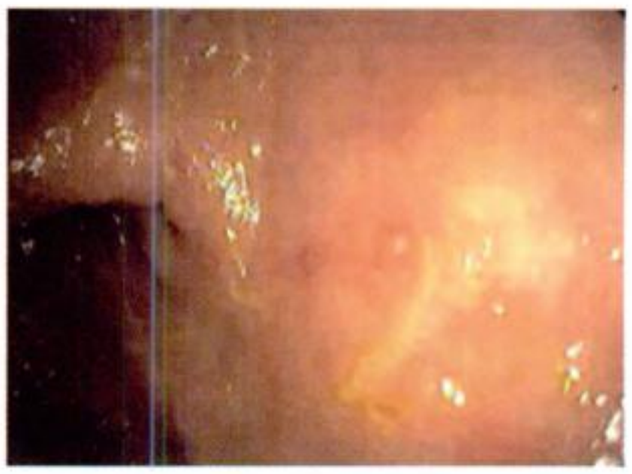
14. Mild focal area of nodularity



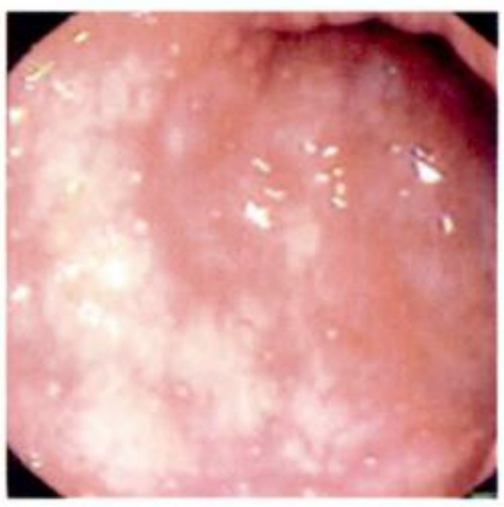
15. Diffuse colitis with nodularity.



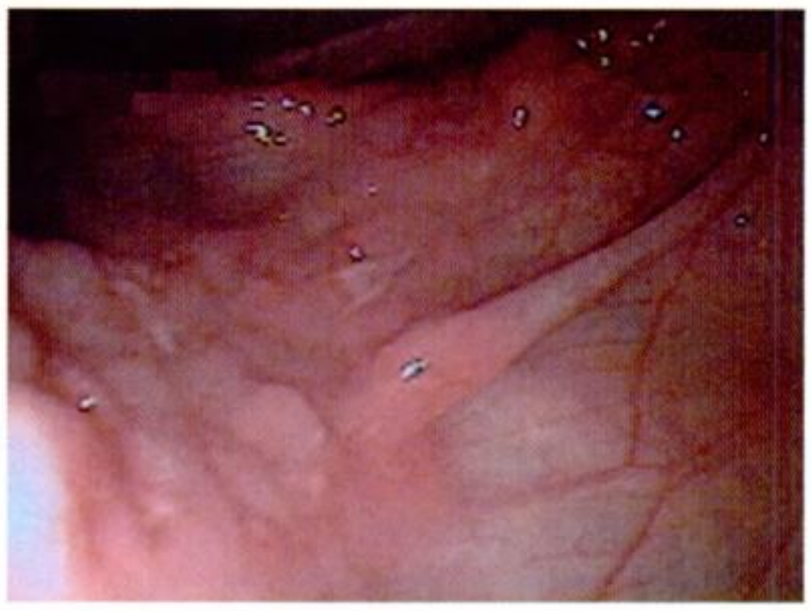
16. Aphthoid lesion.



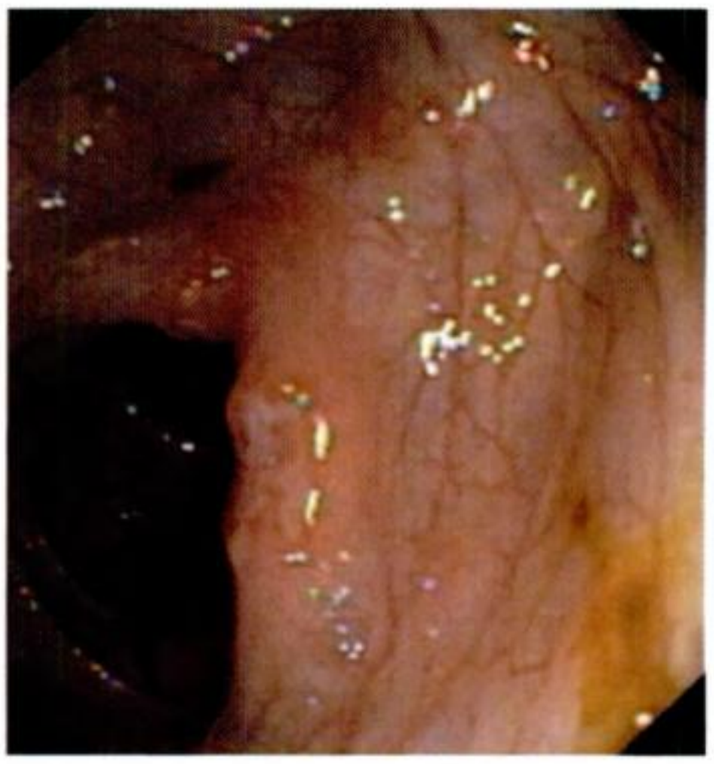
17. Aphthoid-like lesion resembling Crohn's disease seen in the colon following preparation with phosphosoda.



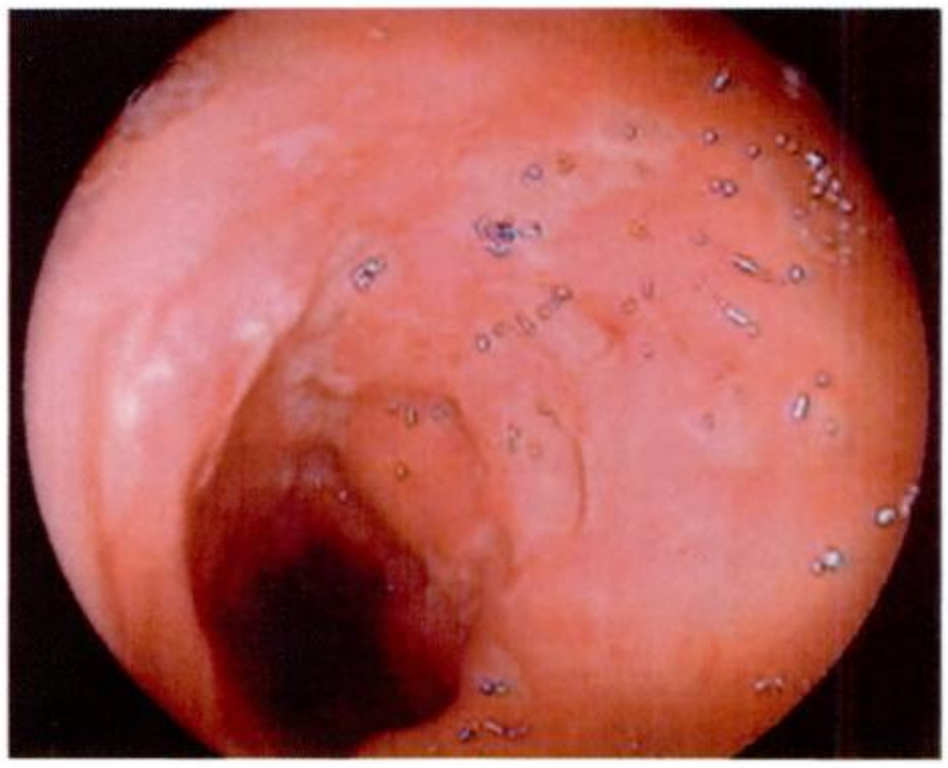
18. Multiple aphthae in Crohn's colitis.



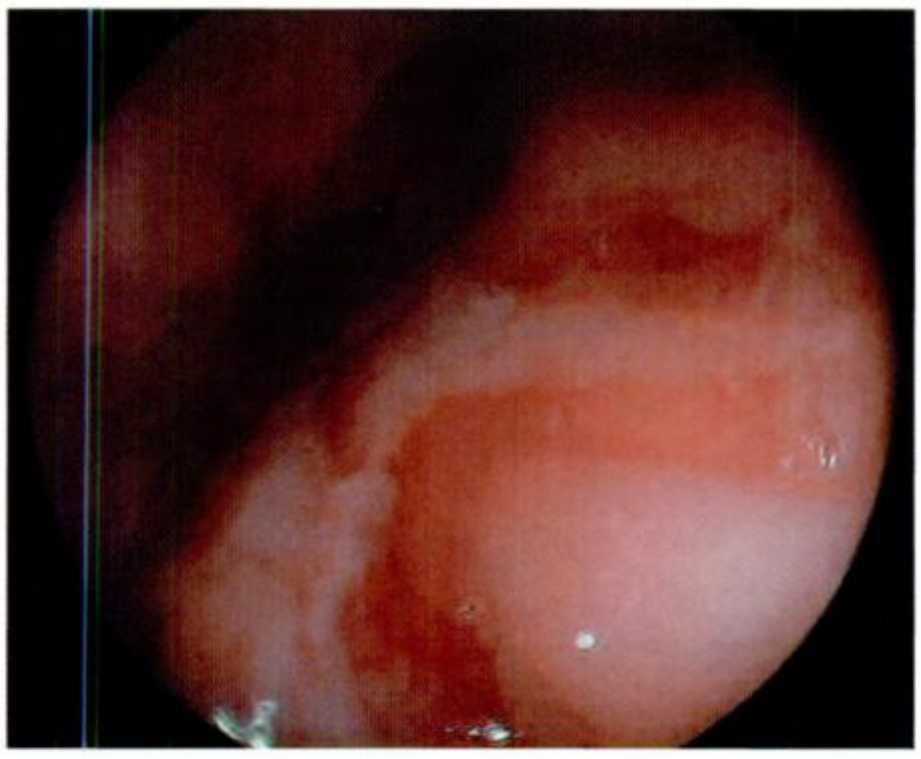
19. Multiple focal ulcers with adjacent normal appearing area.



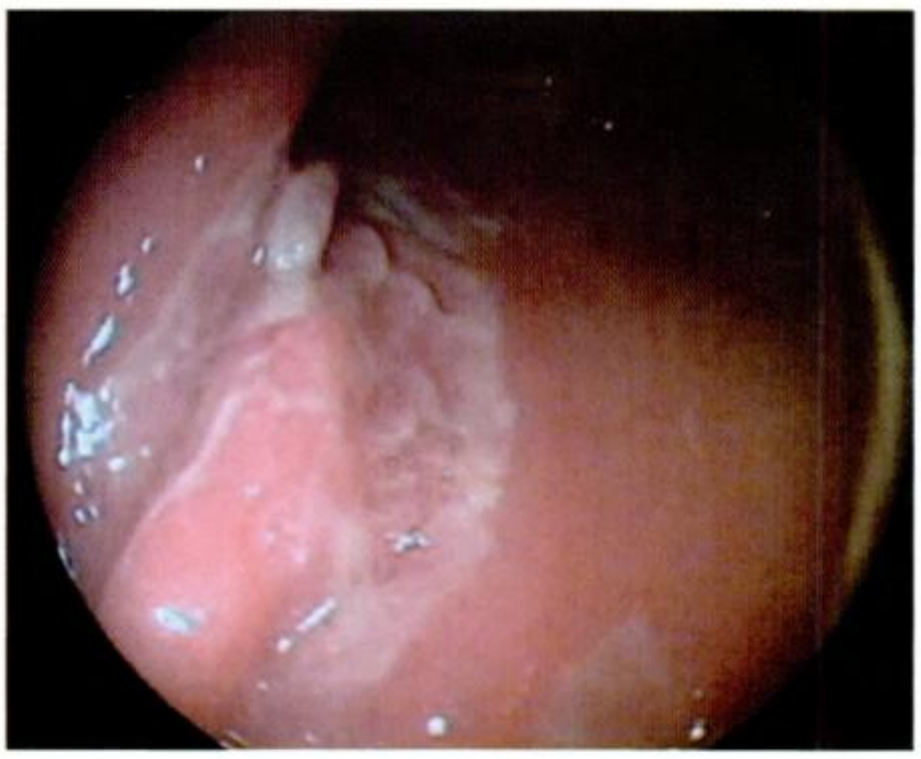
26. Ulceration with intense surrounding erythema and adjacent normal mucosa.



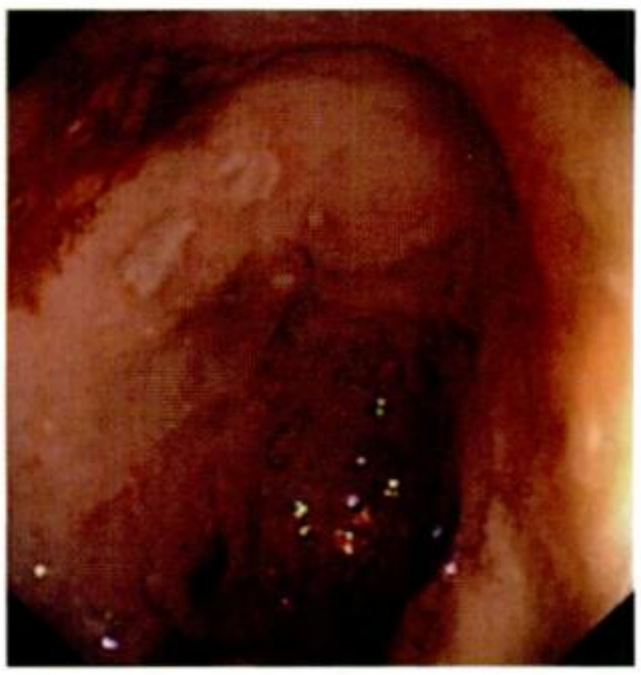
27. Multiple irregular deep ulcerations.



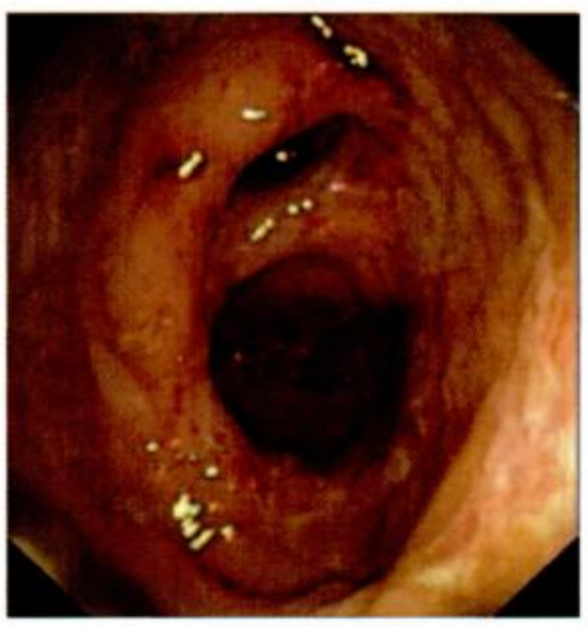
28. Linear ulceration.



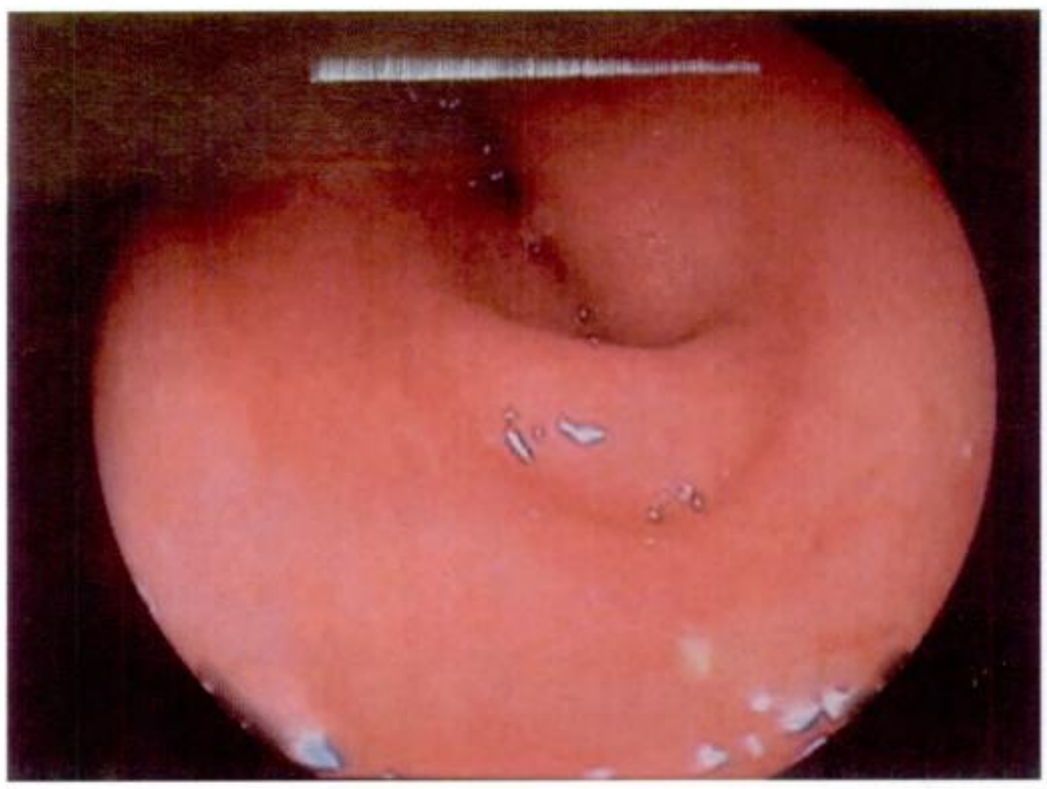
29. Longitudinal ulcer.



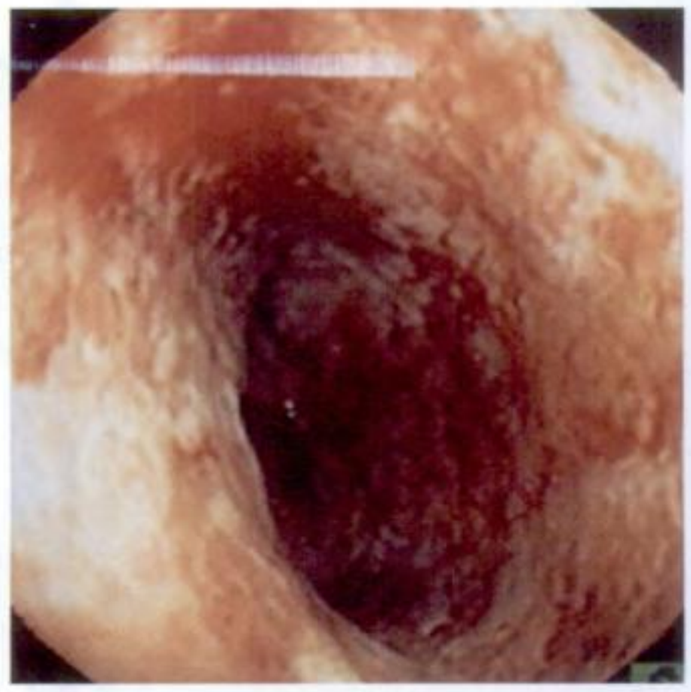
30. Deep focal ulceration.



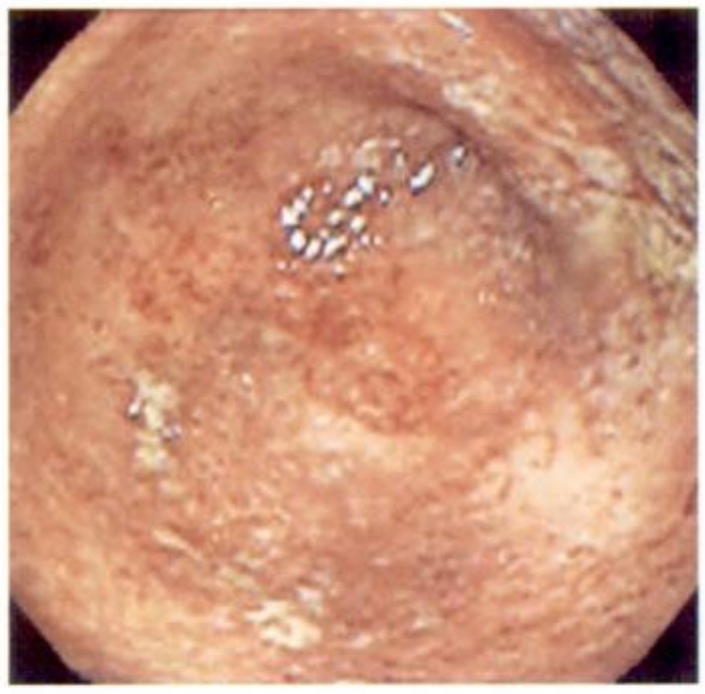
31. Thickened patulous ileocecal valve with surrounding superficial ulceration.



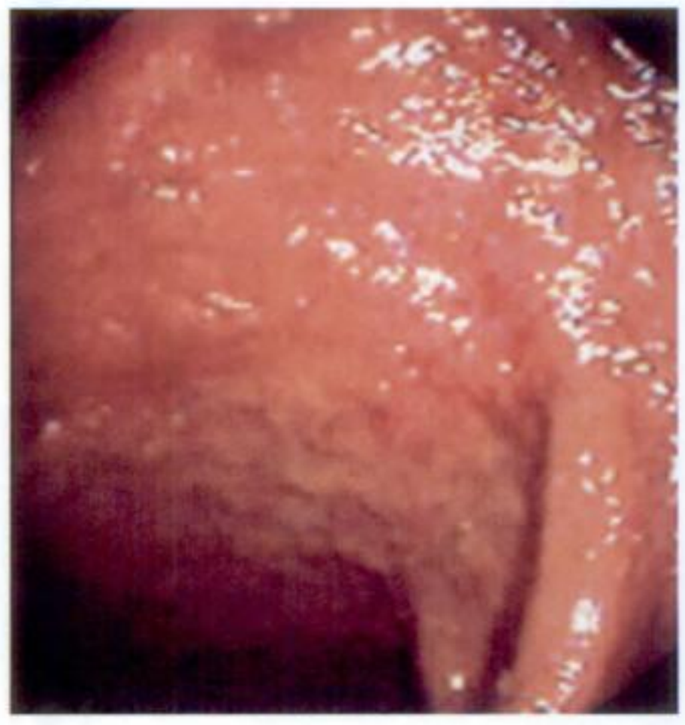
56. Loss of vascular pattern.



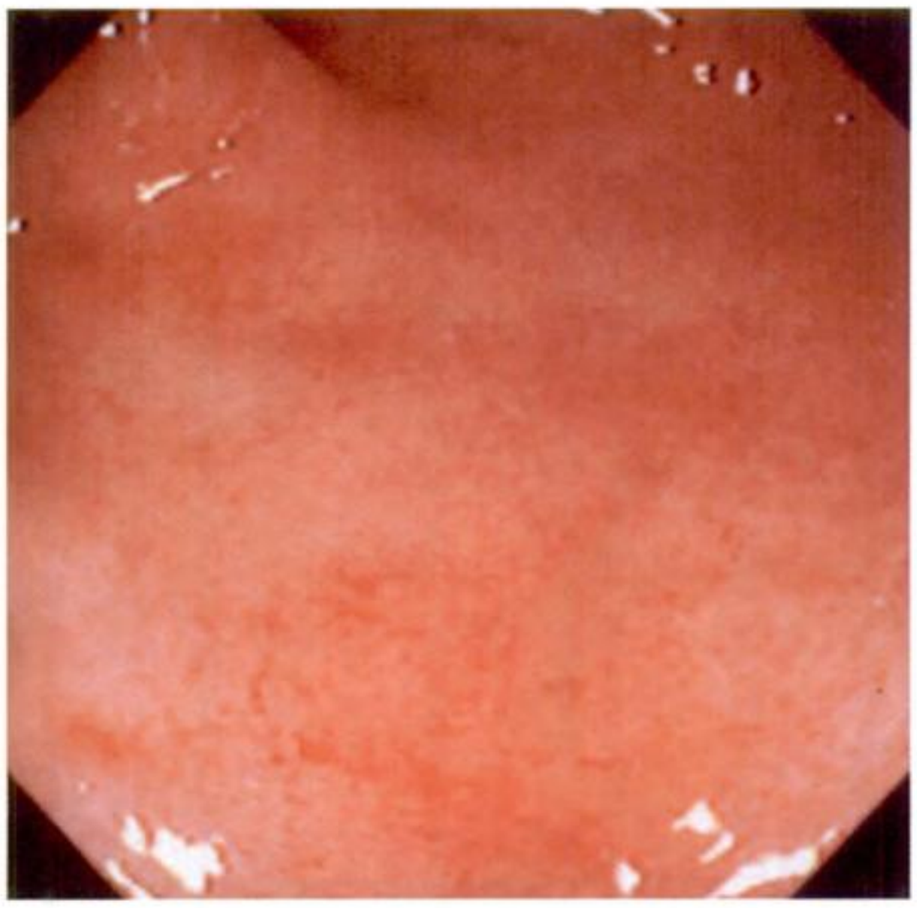
57. Diffuse granular and hemorrhagic mucosa.



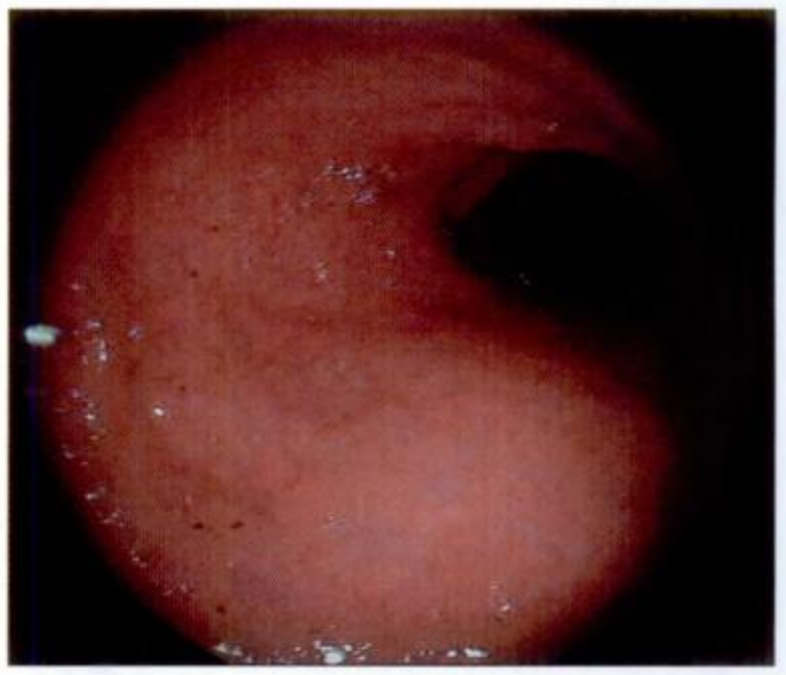
58. Diffuse erythema and granularity.



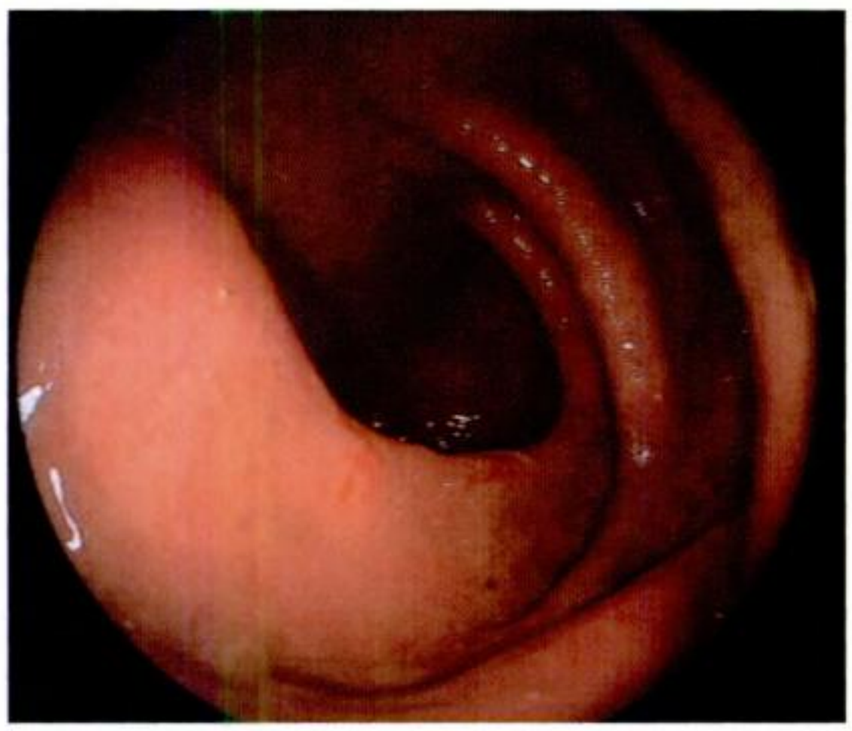
59. Diffuse erythema and granularity with small erosions.



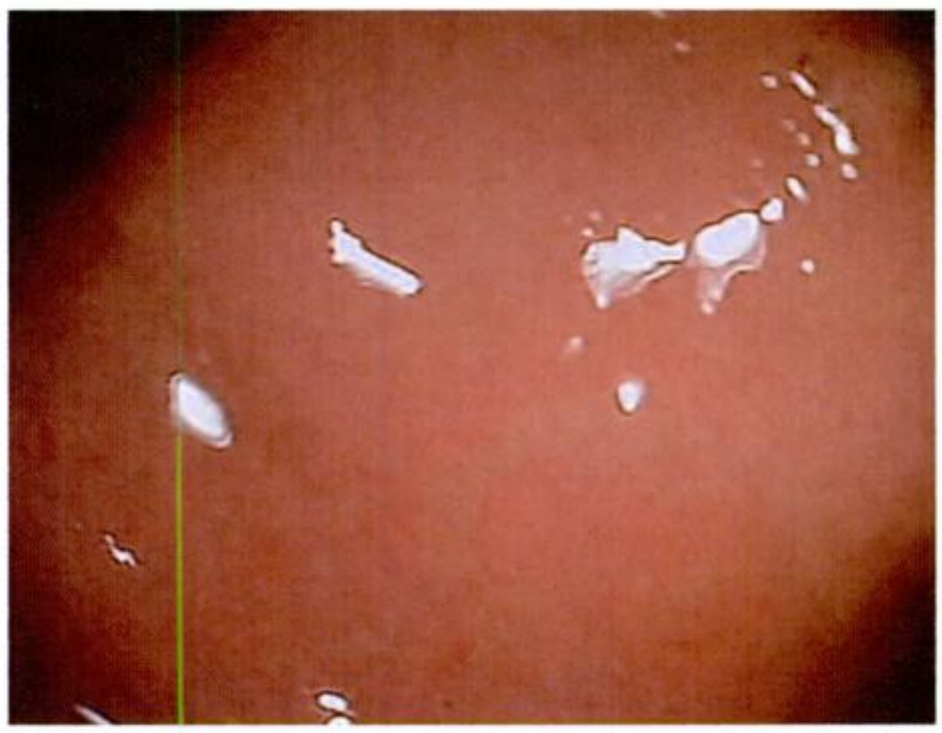
60. Mild ulcerative colitis showing diffuse erythema, loss of vascularity and patchy subepithelial hemorrhage.



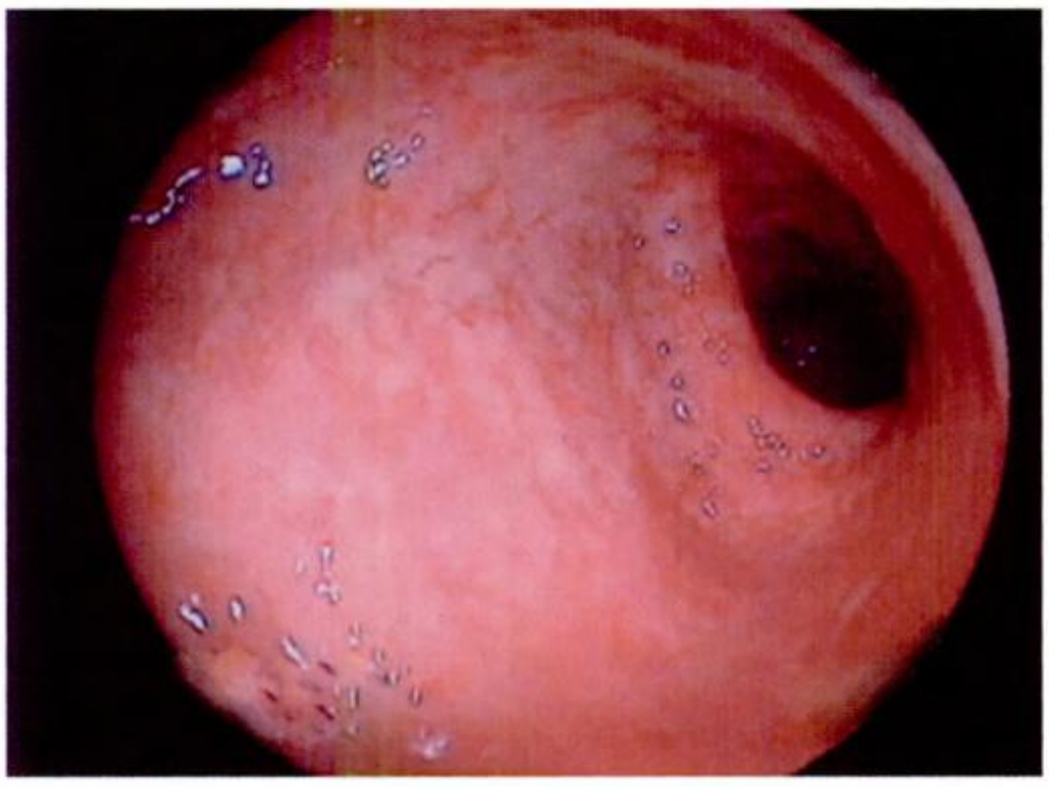
61. Acute ulcerative colitis with erythema and diffuse granular appearance.



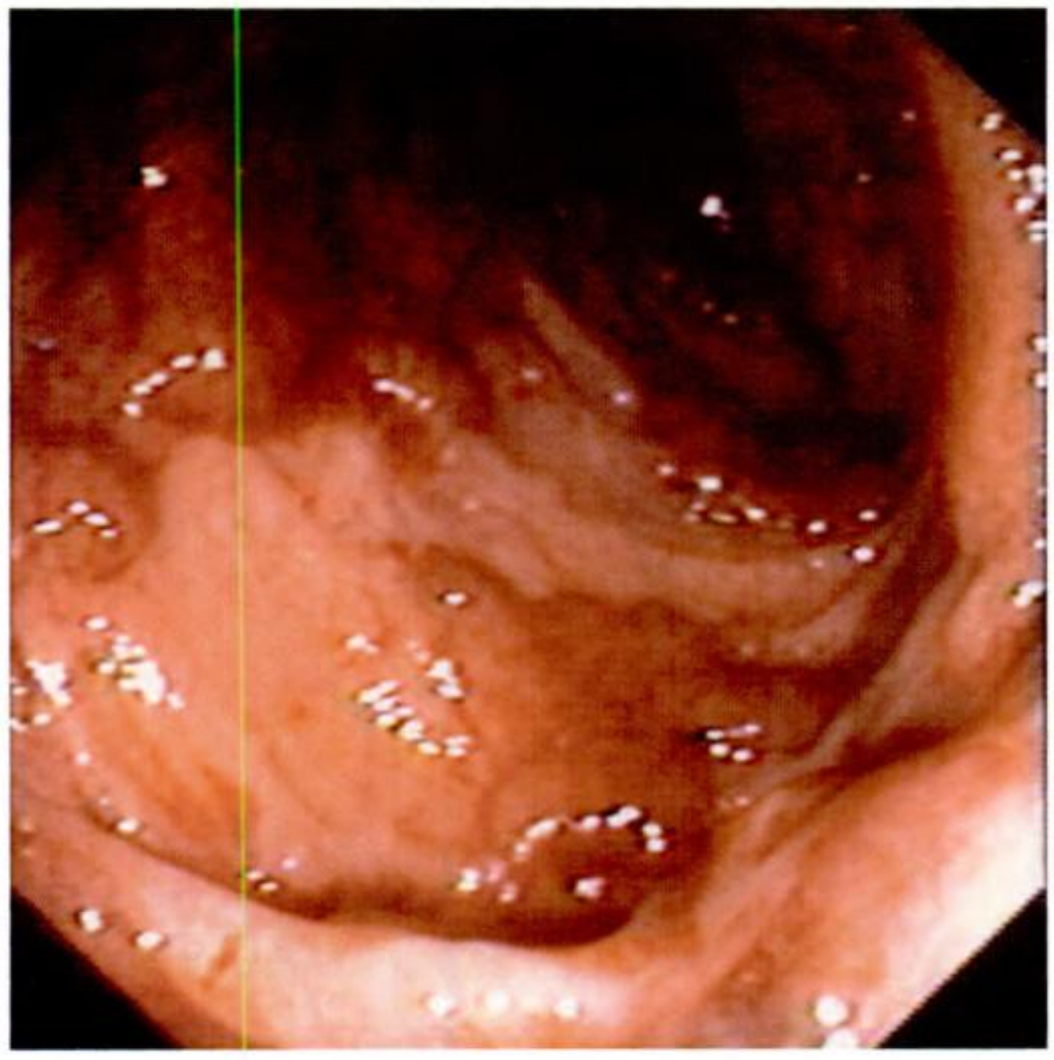
62. Diffuse erythema with superficial ulcerations.



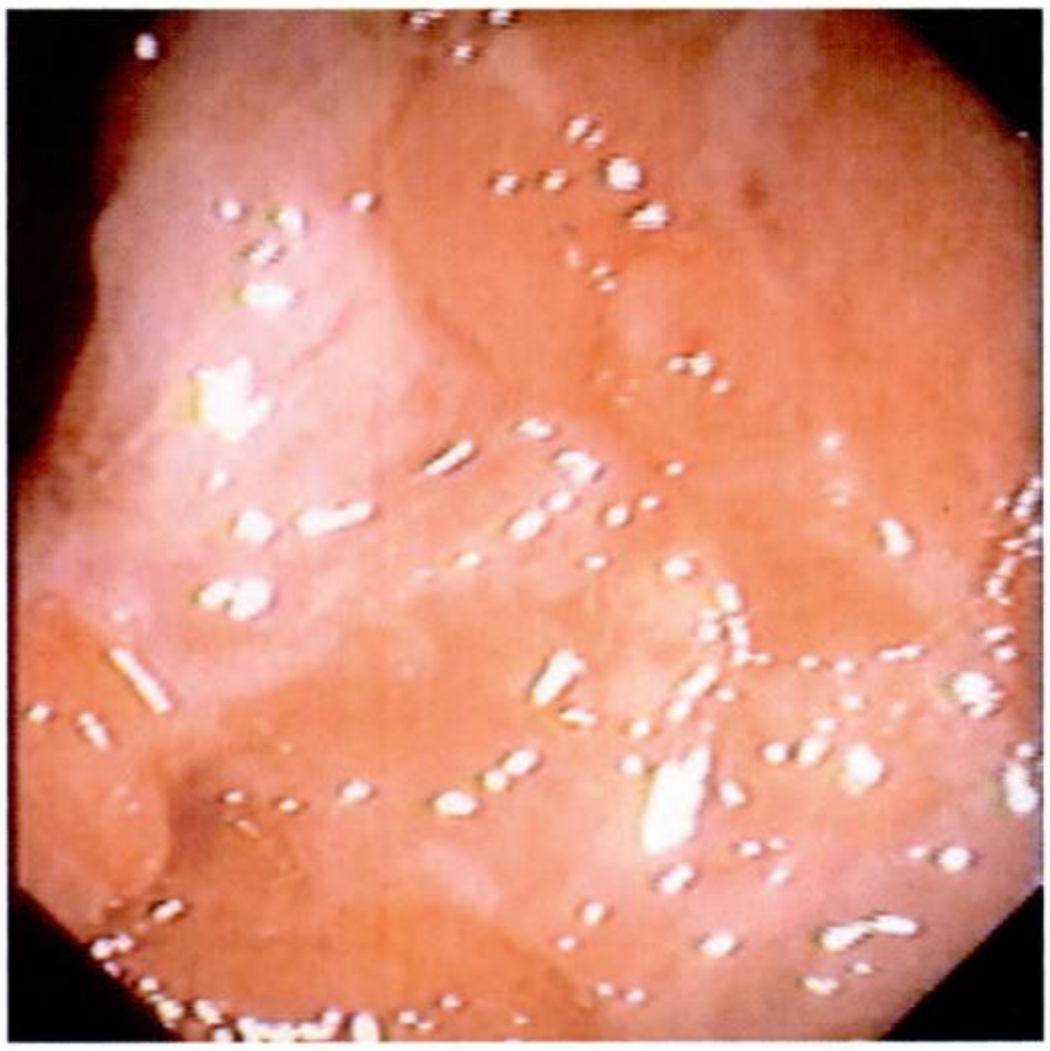
63. Digital magnified view showing diffuse erythema with mucopurulent exudate.



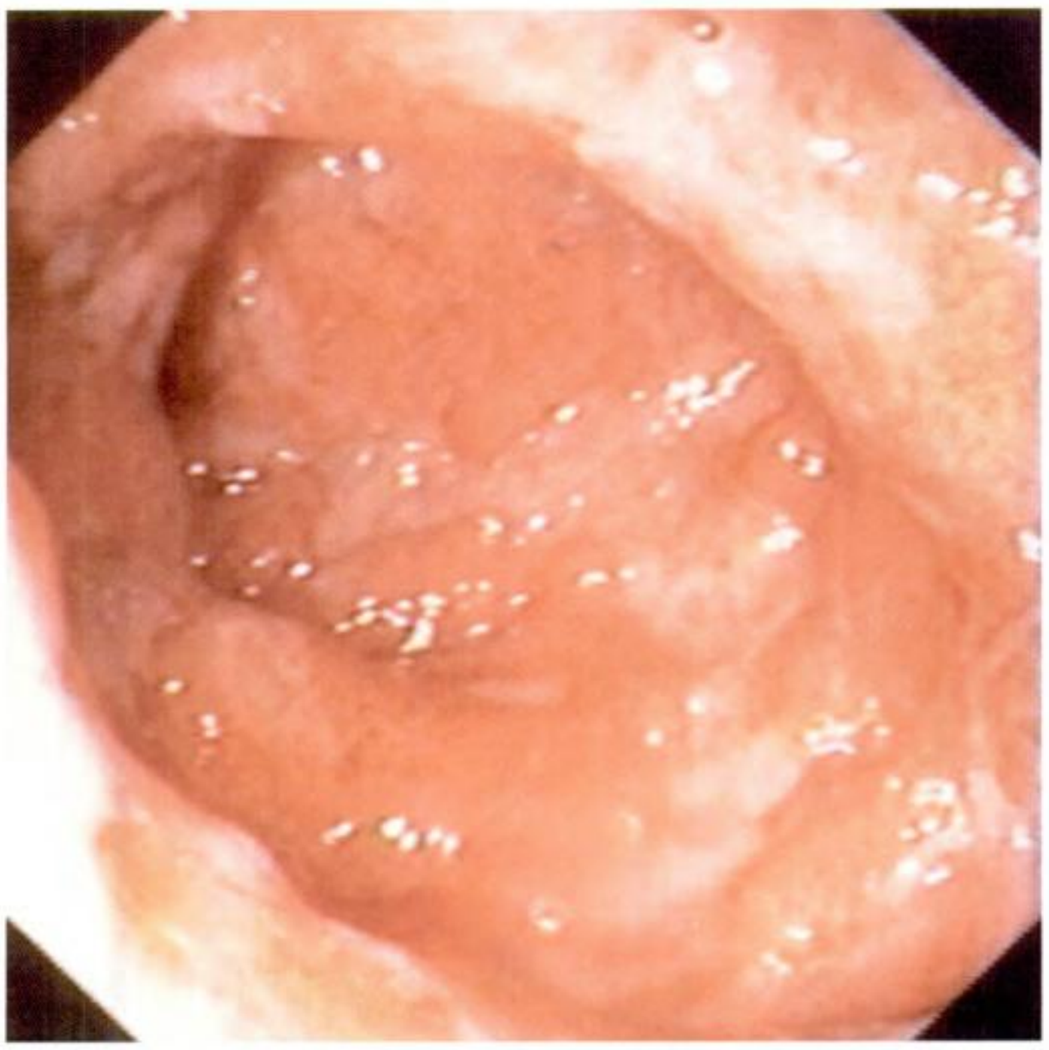
64. Diffuse erythema and mucopurulent exudate.



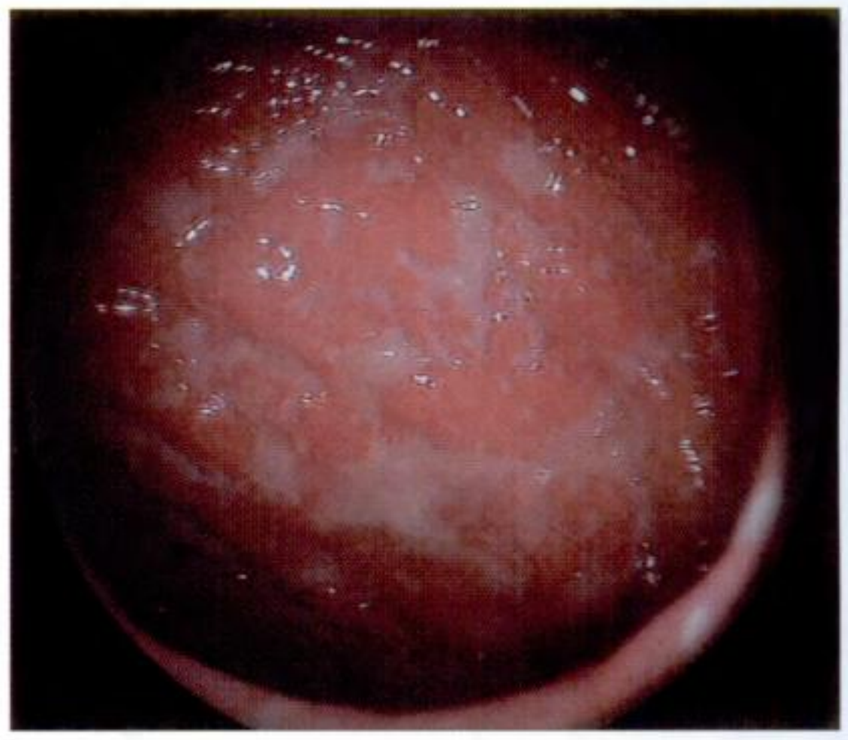
65. Severe ulcerative colitis with deep, confluent ulcerations reaching the muscle layer with some islands of remaining inflamed mucosa.



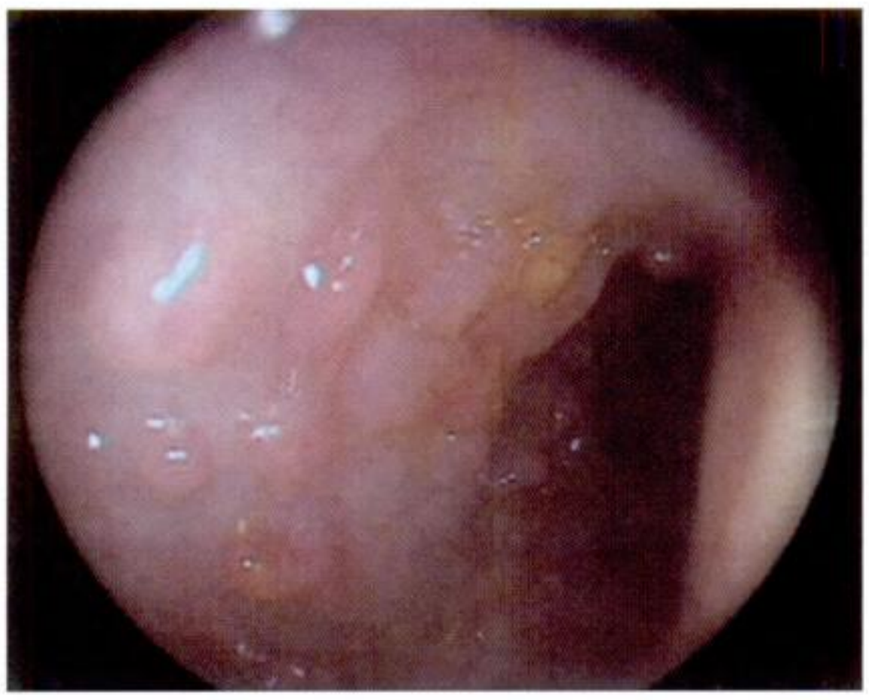
66. Severe ulcerative colitis with large and deep total mucosal abrasion surrounded by residual inflamed and erosive mucosa.



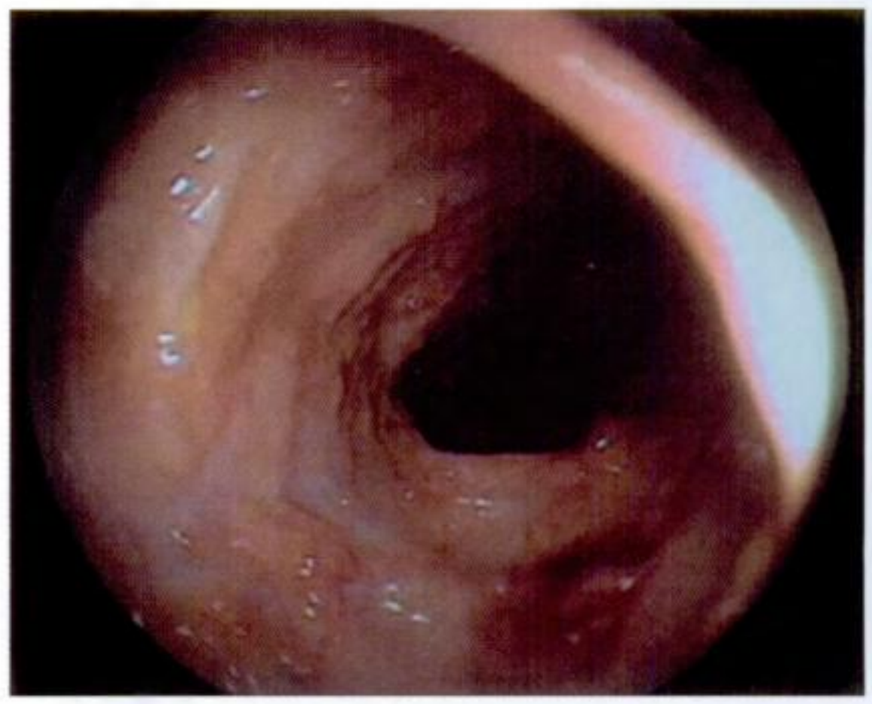
67. Severe ulcerative colitis with congestive mucosa around deep and large linear ulcerations.



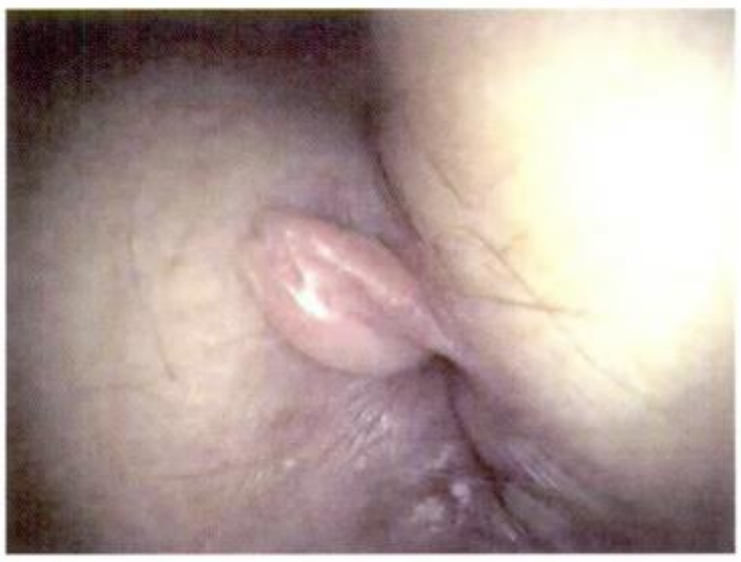
68. Severe ulcerative colitis with ulceration and extensive mucopurulent exudate.



69. Ulcerative colitis with pseudopolyps.

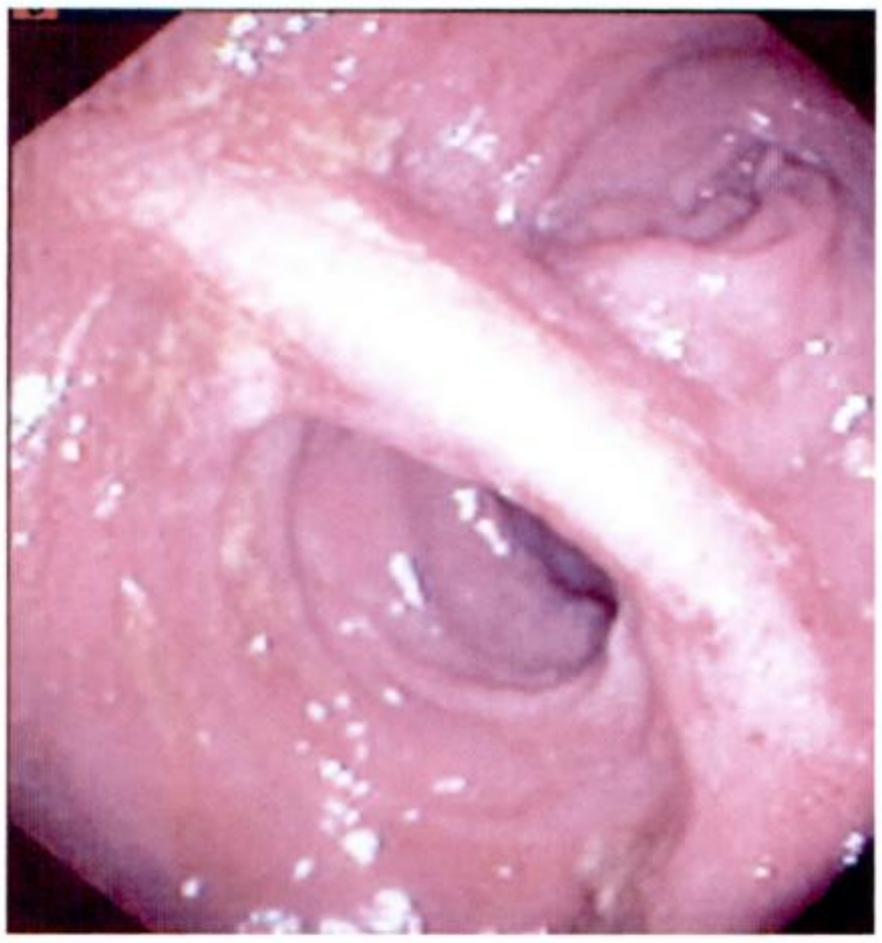


70. Chronic ulcerative colitis with pseudopolyps and intervening relatively spared mucosa.

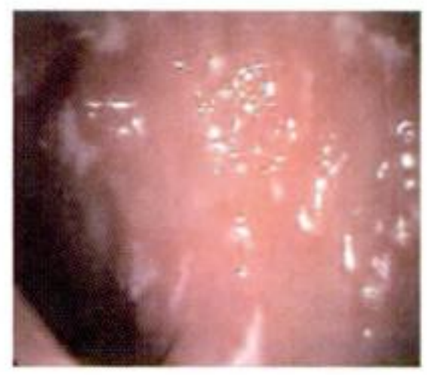


71. Single perianal skin tags may be seen in ulcerative colitis.

Pouchitis



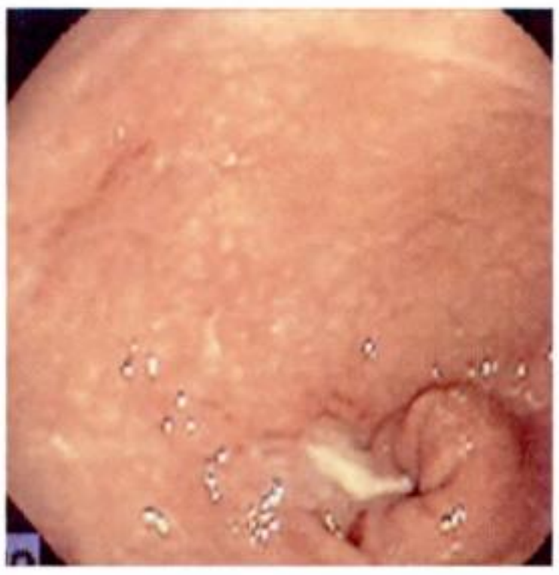
72. J pouch in patient with previous ulcerative colitis. Note the septum separating the two limbs.



73. Erythematous mucosa with loss of vascular pattern and mucoid exudate caused by pouchitis following endorectal pullthrough for ulcerative colitis.

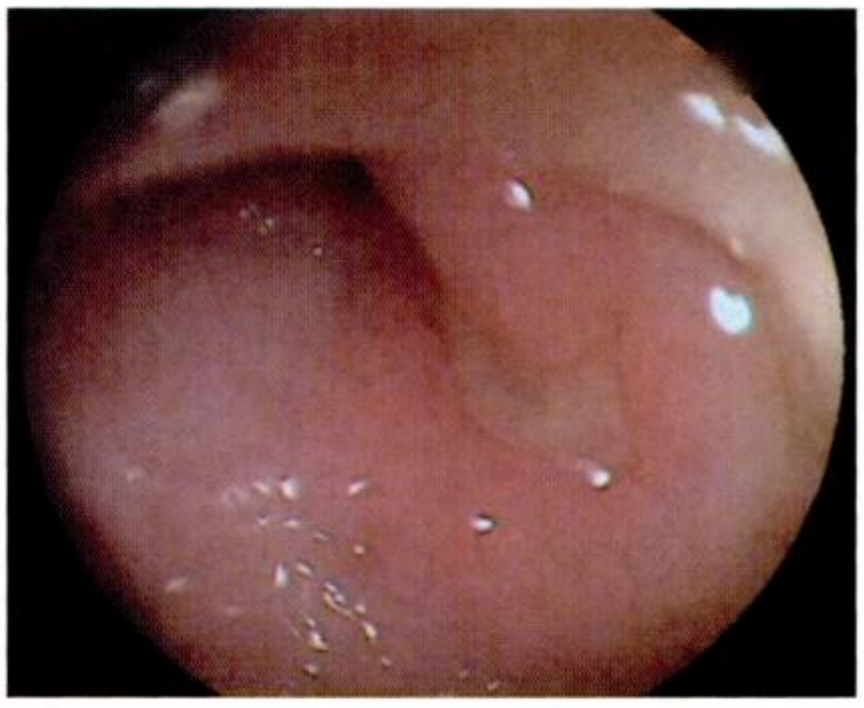
Conditions Associated with Colitis

Chronic Granulomatous Disease



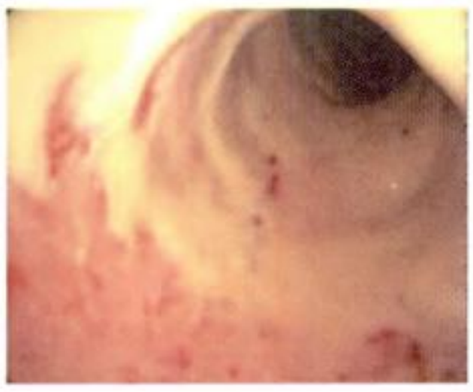
74. Mild colitis in chronic granulomatous disease.

Glycogen Storage Disease type 1b



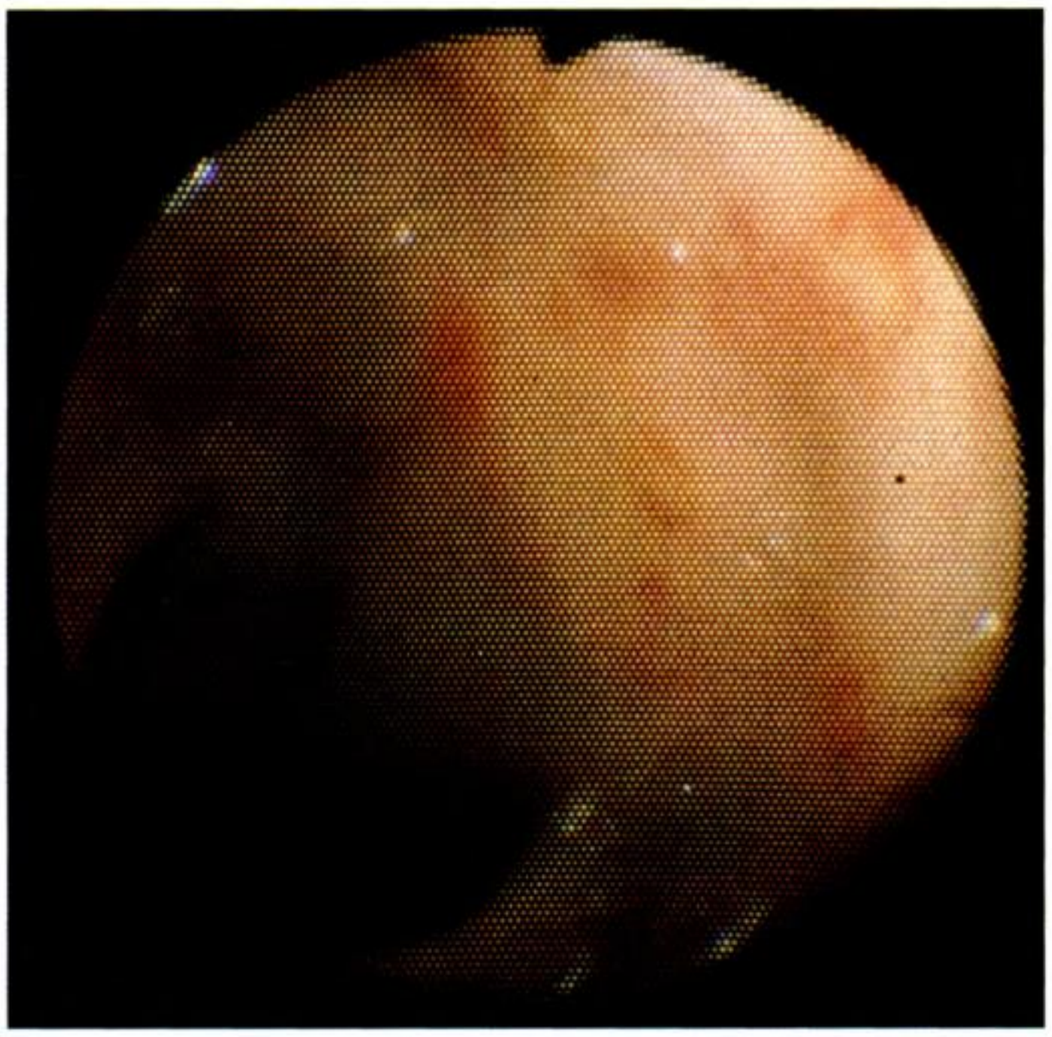
75. Deep ulceration with surrounding edema and erythema.

Diversion Colitis

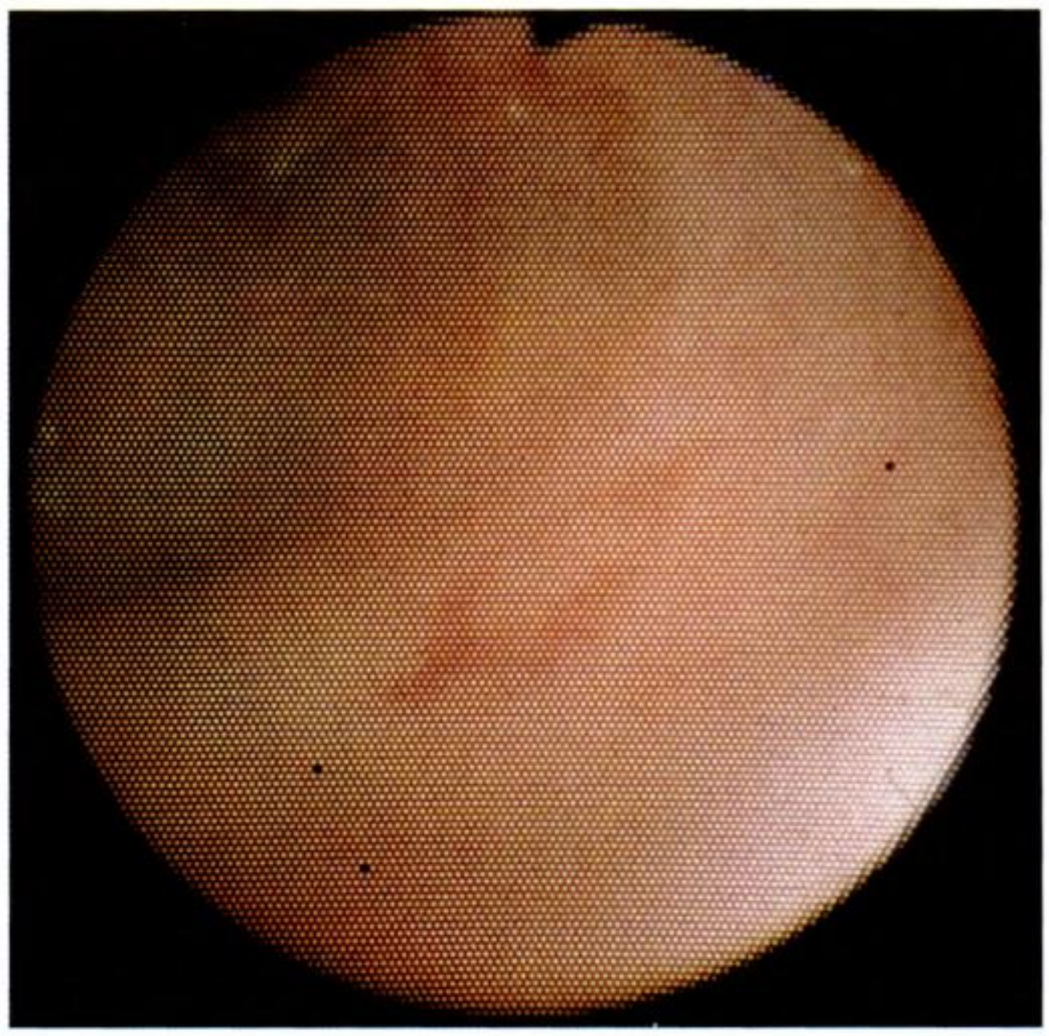


76. Mucopurulent discharge suggestive of diversion colitis in a segment of left colon in a child with Crohn's disease and diverting ileostomy.

Breast Milk Associated Colitis

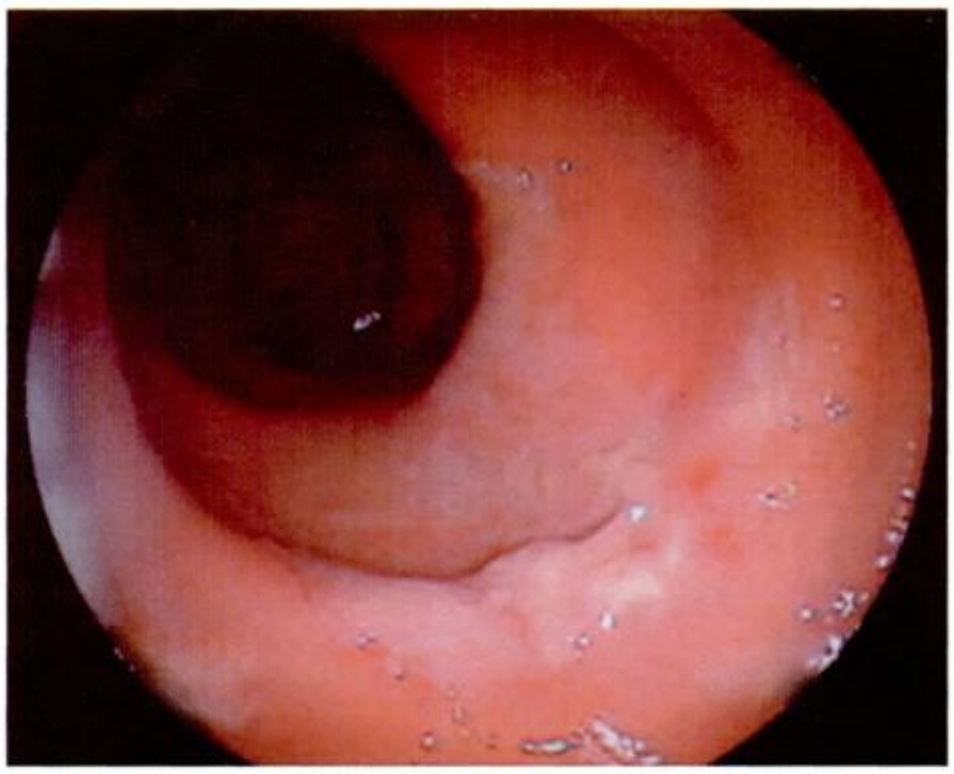


77. Focal erosions in a breast-fed infant with bloody diarrhea.

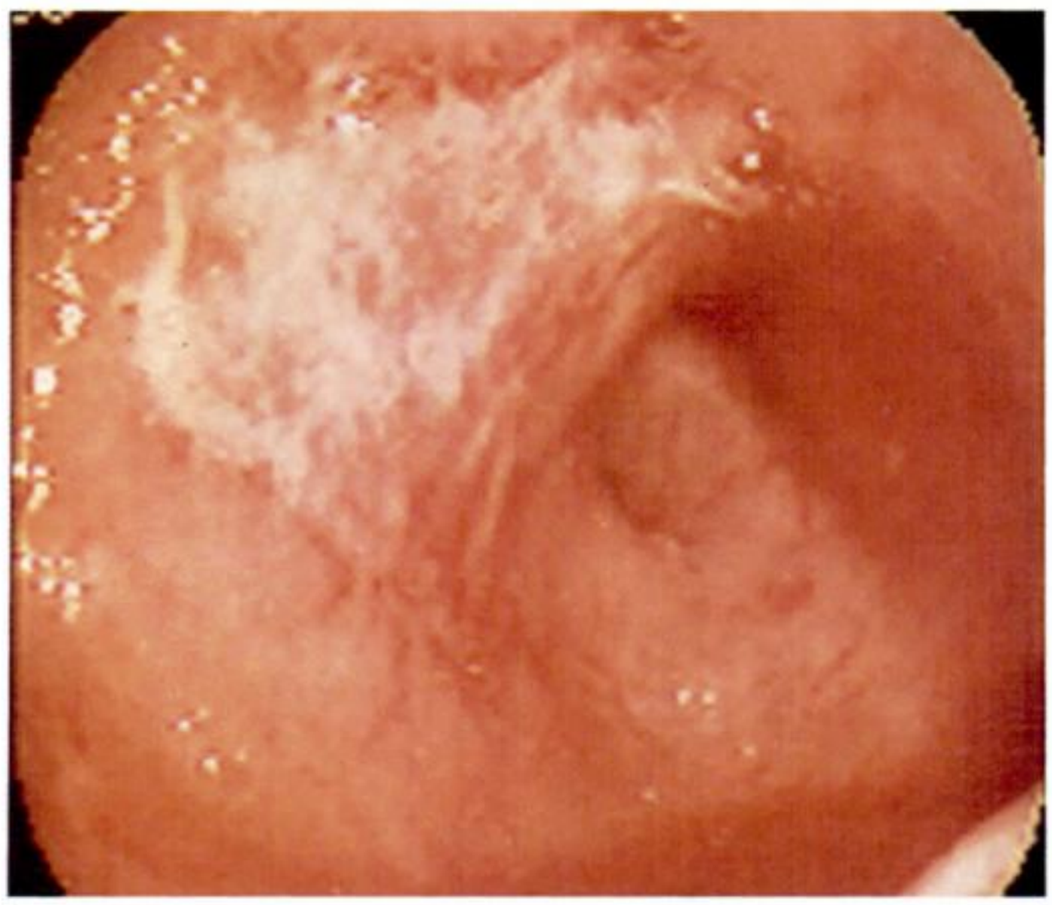


78. Close view of focal erosion in breast fed infant with bloody diarrhea.

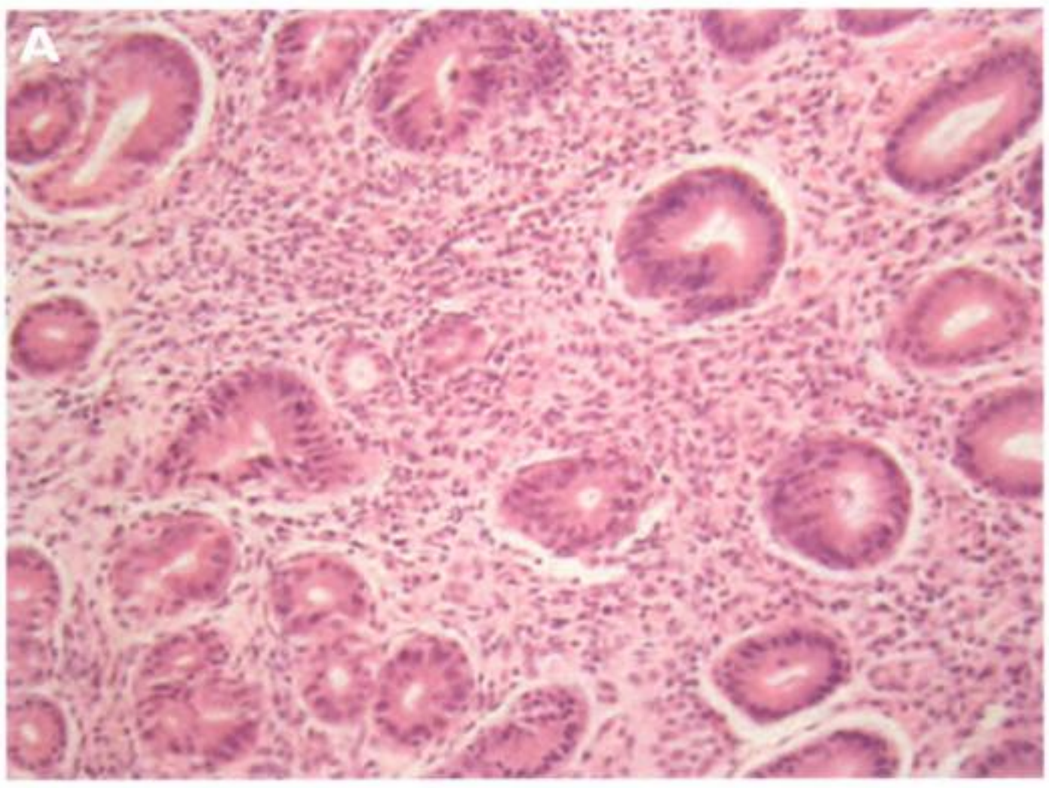
Rectal Ulcer

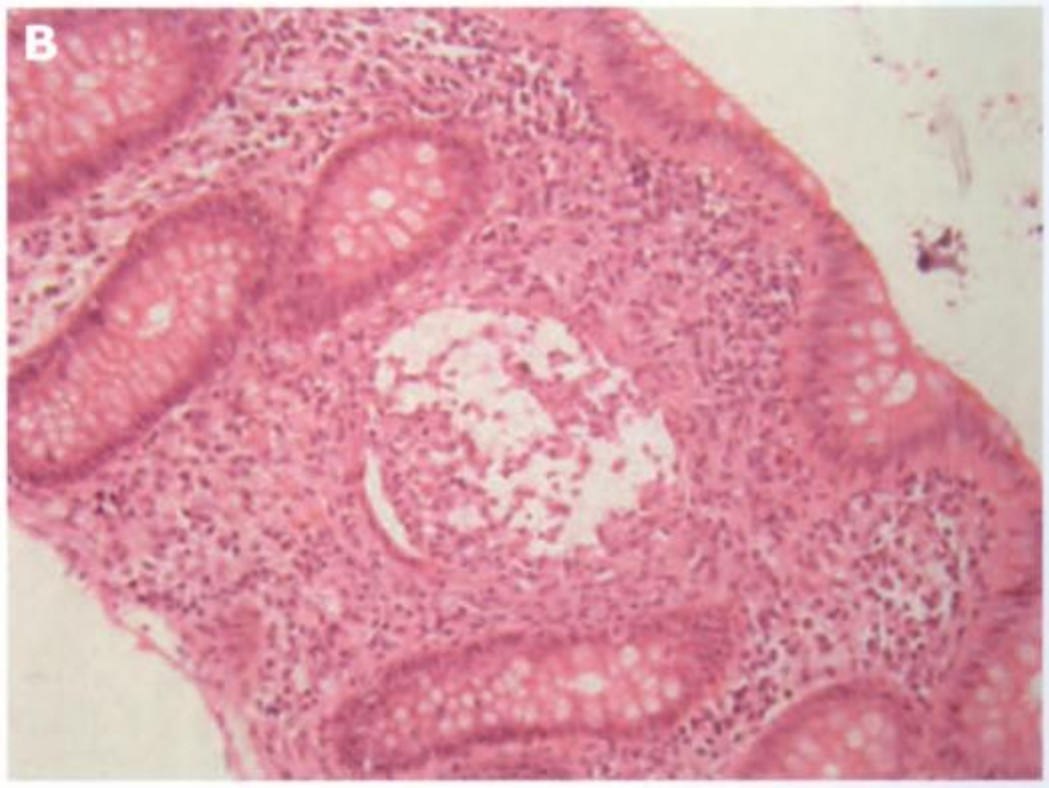


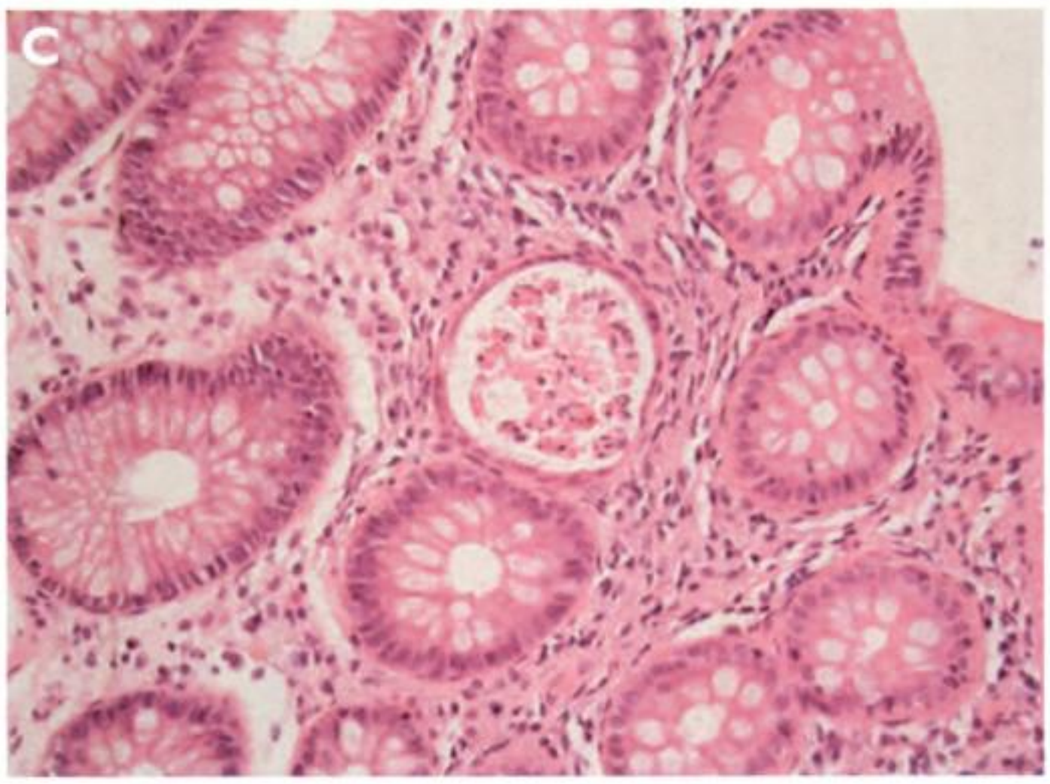
79. Solitary rectal ulcer.

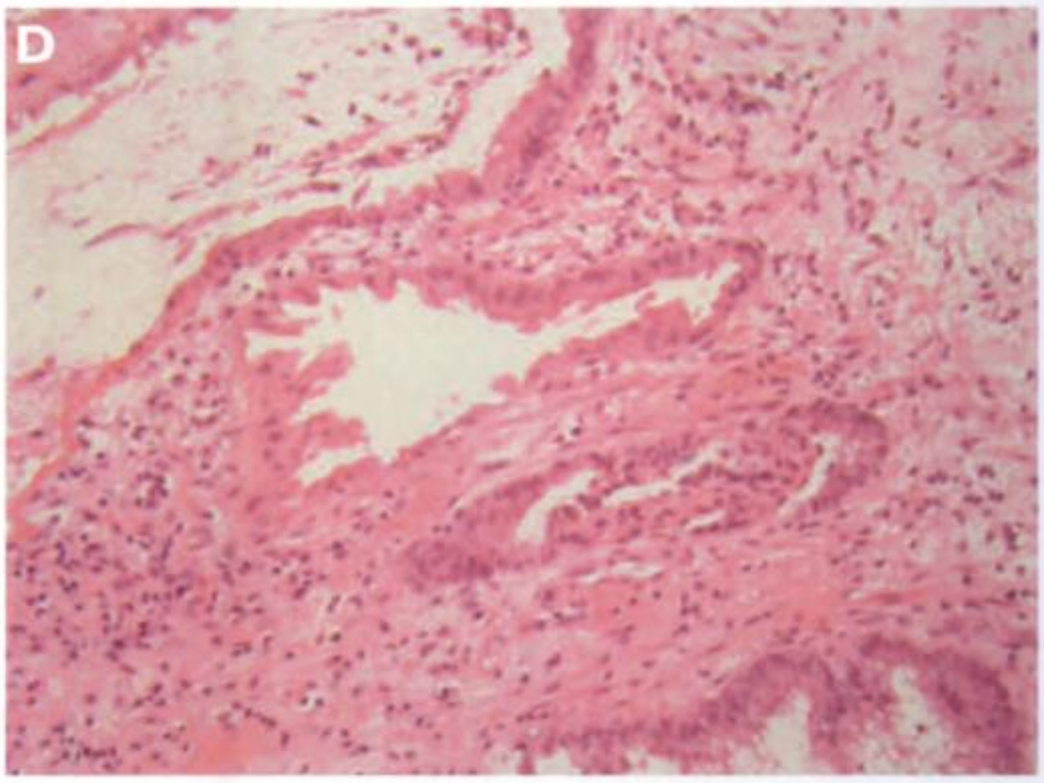


80. Large 'solitary rectal ulcer'.









138. *A, B, C,* Diffuse chronic and focal active inflammation in Glycogen Storage Disease Type 1b, a disease that clinically may closely resemble Crohn's disease. *D,* Glycogen Storage Disease Type 1b with active inflammation is accompanied by crypt distortion similar to that seen in Crohn's disease. (Images courtesy of Rachel Brown, FRCPath.)

13 Endoscopic Retrograde Cholangiopancreatography

Claude Liguory, Gustavo Andrade de Paulo, and Jean-François Mougenot

Endoscopic retrograde cholangiopancreatography (ERCP) has become an accepted diagnostic and therapeutic modality in pediatrics.[1–2] The limited use of this technique in children is related to the relatively low incidence of pancreatic and biliary diseases in childhood, limited availability of specific pediatric instruments, and lack of expertise among pediatric gastroenterologists to perform ERCP. Indications for ERCP in children are becoming better defined, but because of limited series of patients, the evaluation of therapeutic intervention remains difficult.[3–8]

Table 13-1. Pediatric Endoscopic Retrograde Cholangiopancreatography Series

Author, year	Patient	Procedure (*n*)	Success (%)	Age		GA (%)
				Range	Mean	
Riemann and Koch, 1978[88]	18	18	100	6–17 y	NR	11
Cotton and Laage, 1982[27]	20	25	96	7–16 y	NR	65
Guelrud et al, 1987[89]	23	23	96	19–150 d	67 d	26
Allendorph et al, 1987[97]	39	39	92	6 m–18 y	12.5 y	46
Heyman et al, 1988[30]	12	12	33	3–58 w	11.6 w	100
Buckley and Connon, 1990[46]	42	42	97	1–19 y	10.5 y	38
Guelrud et al, 1991[13]	32	32	94	16–150 d	49 d	19
Putnam et al, 1991[90]	38	42	93	14 m–19 y	12.3 y	32
Dite et al, 1992[91]	19	19	100	4–16 y	11.9 y	68
Brown et al, 1993[5]	92	121	94	4 m–19 y	10.9 y	54
Brown and Goldschmiedt, 1994[51]	25	42	100	22 m–19 y	NR	NR
Richieri et al, 1994[92]	19	19	100	1–18 y	9.6 y	58
Guelrud et al, 1994[67]	51	NR	98*	1–18 y	NR	0
Derkx et al, 1994[93]	20	22	90	4–19 w	12 w	100
Mitchell and Wilkinson, 1994[94]	40	40	90	6–80 w	12 w	100
Abu-Khalaf, 1995[63]	16	16	100	2 m–18 y	10.5 y	31
Ohnuma et al, 1997[95]	73	75	88	8–300 d	71 d	100
Tagge et al, 1997[11]	26	26	96†	6 m–19 y	10 y	58
Tarnasky et al, 1998[48]	10	10	100	0.5 –16.9 y	8.8 y	80
Graham et al, 1998[68]	17	17	94	3 –16 y	11.2 y	88
Hsu et al, 2000[75]	22	34	100	1.5 –17 y	10.7 y	68
Teng et al, 2000[43]	42	50	100	57 d–15 y	NR	80
Poddar et al, 2001[4]	72	84	97	11 m–14 y	9 y	0
Pfau et al, 2002[96]	43	53	94.3	1–18 y	13.5 y	60.4
Liguory et al, 2001[98]	51	51	92	6m–15 y	8 y	100

Adapted from Fox et al,[14] Liguory et al[98]

d = day; GA = general anesthesia; m = month; NR = not reported; w = week; y = year.

* 83% of success in therapeutic exams.

† 87% of success in therapeutic exams.

Technical Considerations

ERCP is a complex, combined endoscopic and radiographic procedure and requires the collaboration of skilled members from the departments of gastroenterology, radiology, surgery, and pediatrics.[9–11]

Sedation or General Anesthesia

The relatively large diameter of standard duodenoscopes may cause discomfort and compress the soft-walled trachea in young children. Prone position during ERCP also compromises chest and lung excursion and may result in hypoventilation and hypoxia in a sedated child. For these reasons general anesthesia is almost always mandatory and endotracheal intubation might be appropriate for children (Table 13-1).[7,12,13]

Equipment

Fluoroscopic equipment that is suitable for children of all ages should be used to minimize radiation exposure.

Indications (%)				Complications (%)			
Biliary	Pancreatitis	Pain	Therapy (%)	Pancreatitis	Hemorrhage	Perforation	Infection
17	83	0	0	0	0	0	1 (death)
20	50	30	5	0	0	0	0
100	0	0	0	0	0	0	0
28	54	18	10	10	0	0	0
100	0	0	0	0	0	8	0
36	43	21	12	5	2	0	0
100	0	0	0	0	0	0	0
36	64	0	0	8	0	0	0
5	68	26	0	0	0	0	0
20	77	3	16.5	3	0	0	2.5
64	36	0	68	8	0	0	0
58	42	0	5.3	5.3	0	0	0
0	100	0	35	8	0	0	0
100	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0
56	25	19	25	0	0	0	0
100	0	0	0	0	0	0	0
92	8	0	61.5	4	0	0	0
100	0	0	100	0	0	0	0
0	100	0	53	13	0	0	0
0	100	0	67.6	6	0	0	0
64	36	0	12	0	0	0	2
61	28	11	30.6	7	0	0	1.4
47	53	0	45.2	3.8	1.9	0	0
29.4	54.9	15.7	43.1	2	0	0	0

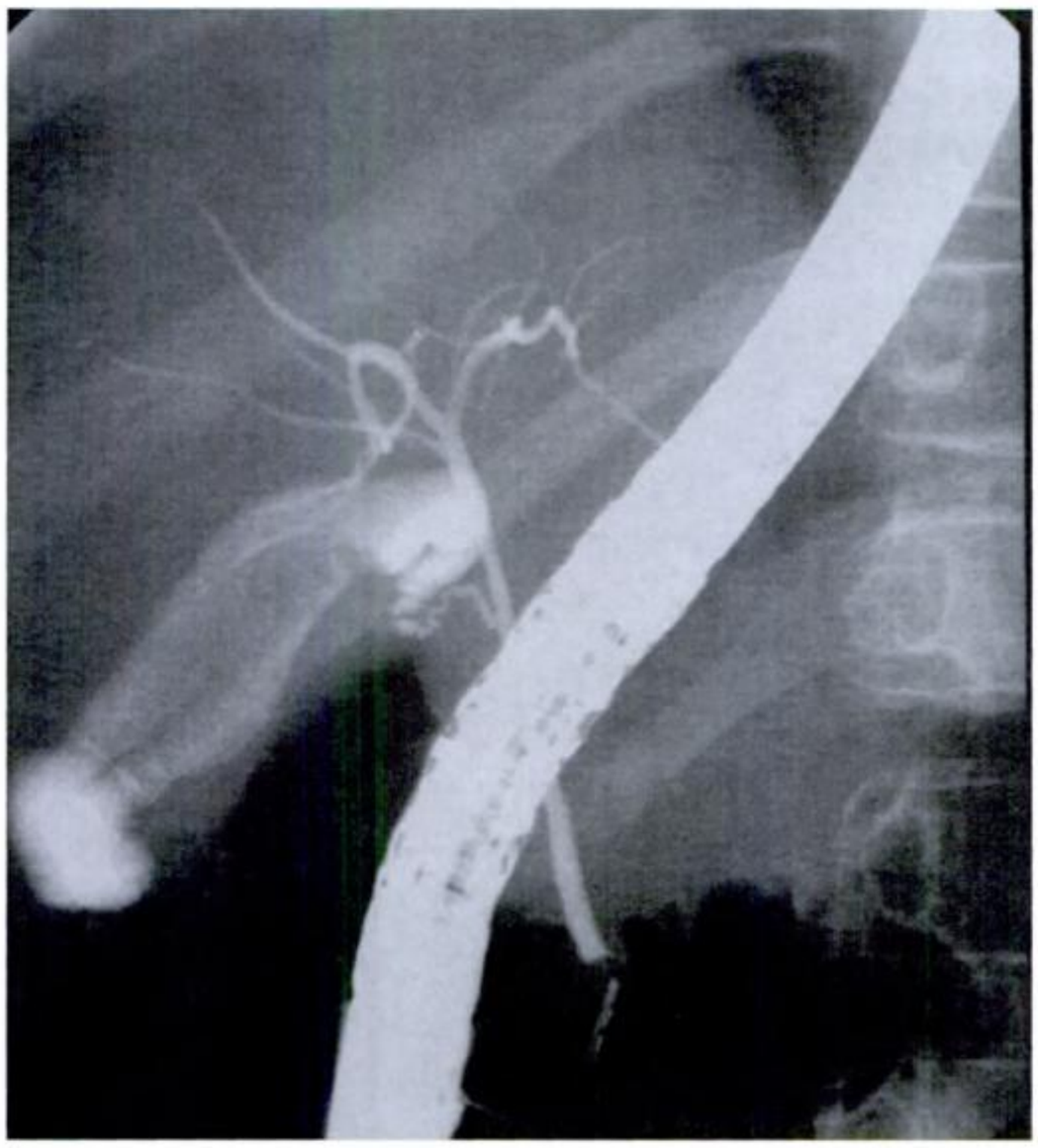


Figure 13-2. Normal retrograde cholangiogram in an 8-year-old child.

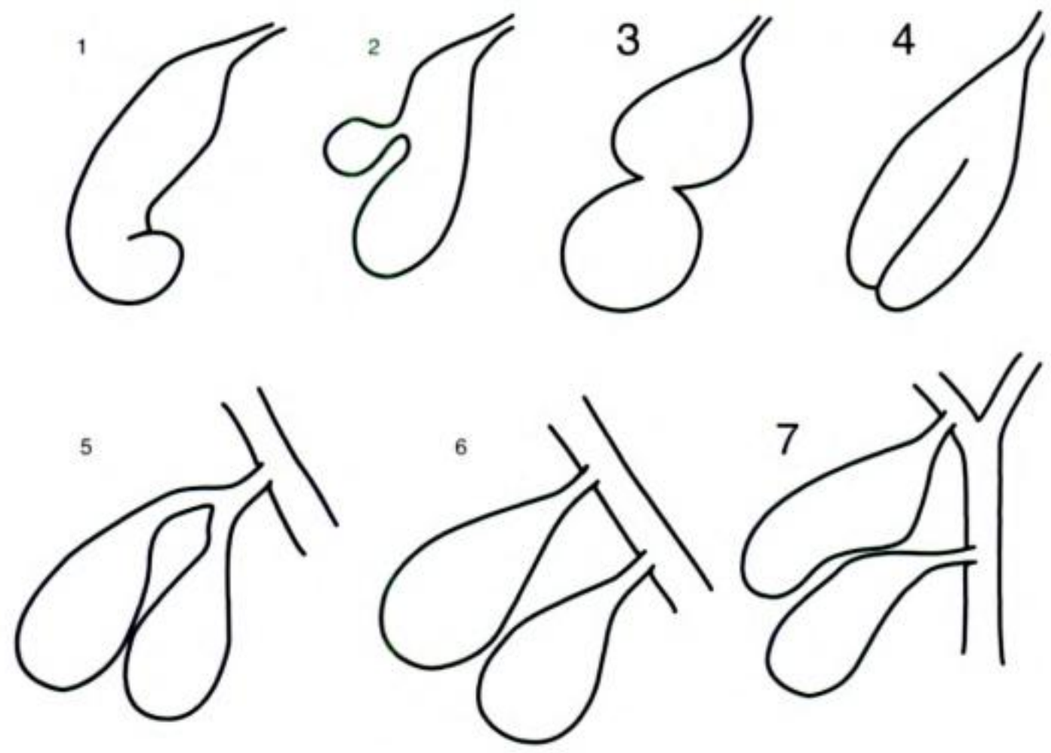


Figure 13-4. Congenital variations of the gallbladder: 1, phrygian cap deformity; 2, diverticulum; 3, hourglass; 4, septum; 5, double gallbladder with single cystic duct; 6, double gallbladder with two cystic ducts draining into common bile duct; 7, double gallbladder with two cystic, one of which drains into the right hepatic duct. Adapted from Hand BH.[26]

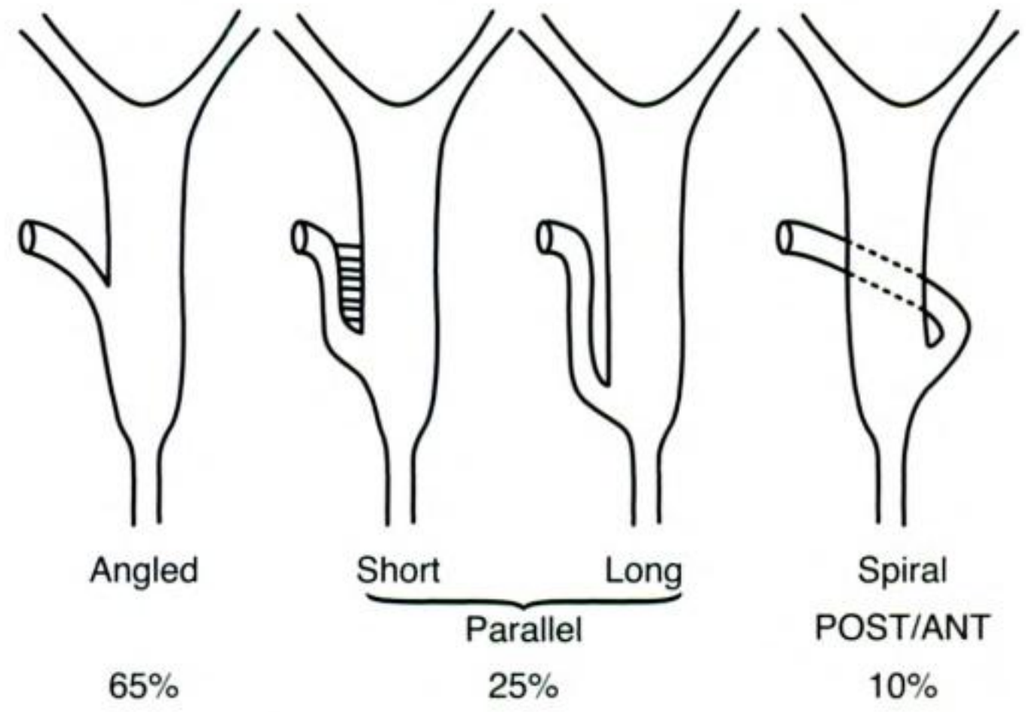


Figure 13-3. Modes of entry of the cystic duct and the approximate percentage of incidence. ANT = anterior; POST = posterior. Adapted from Hand BH.[26]

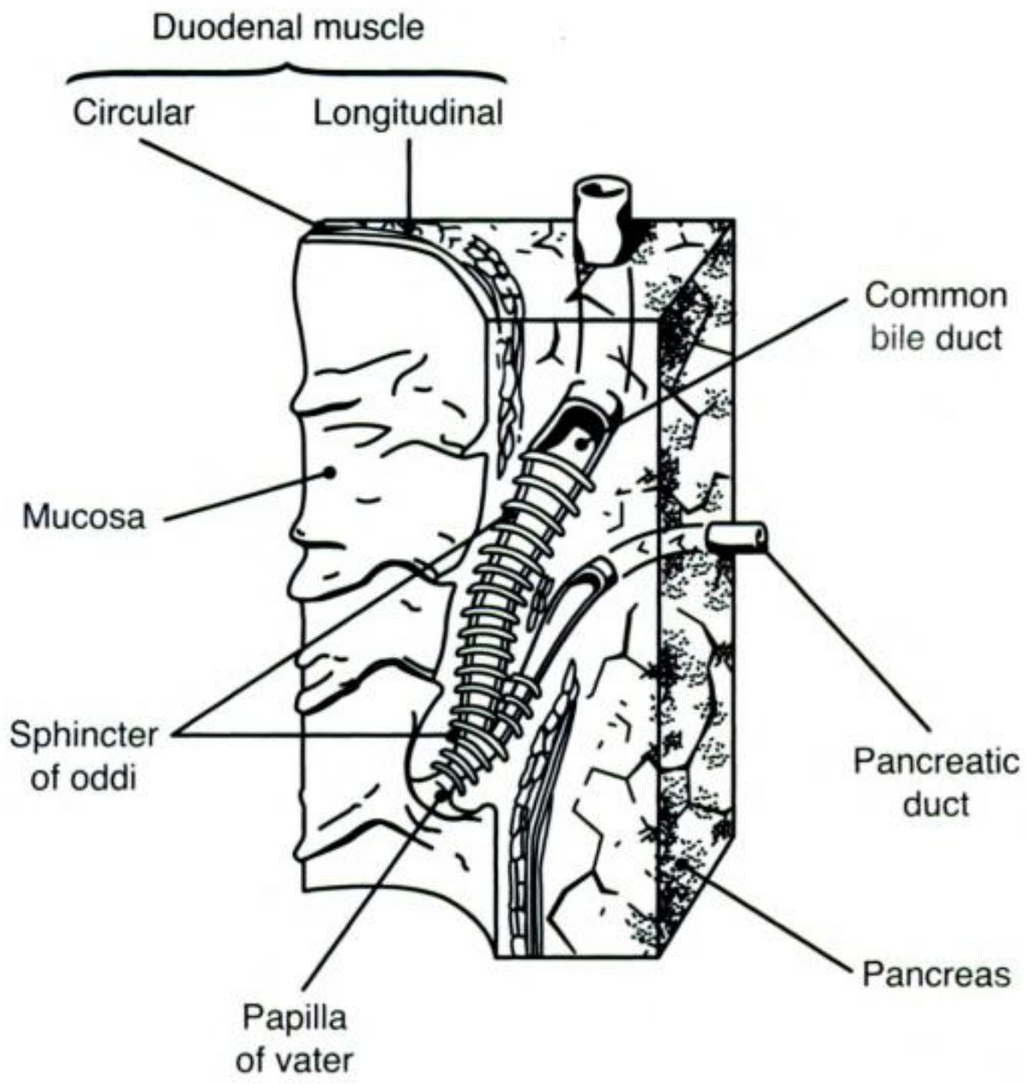


Figure 13-5. Schematic representation of the human sphincter of Oddi. Most of the sphincter of Oddi is situated within the wall of the duodenum. The part of the sphincter of Oddi surrounding the terminal bile duct is longer than that surrounding the terminal pancreatic duct. (From Lindner HH. Clinical Anatomy. East Norwalk: Appleton and Lange; 1989.)

pancreatogram (Figures 13-3 to 13-5).[26] The size of the normal common bile duct (CBD), measured in children between 7 and 16 years, varies from 2.1 to 4.9 mm just below the entry of the cystic duct. The diameter of the pancreatic duct in the head ranges from 1.4 to 2.1 mm, and in the body from 1.1 to 1.9 mm.[27]

Diagnostic and Therapeutic Indications

Indications for diagnostic and therapeutic ERCP in pediatrics (see Table 13-1) are, for the most part, similar to those established for the adult population. However, the relative frequency of each indication differs.[1-6,8,11-14,27,28]

Choledochal Cysts

Choledochal cysts are uncommon anomalies of the bile ducts, associated with congenital anomalous pancreaticobiliary junction (APJ) in 80 to 90% of the cases.[31–33] They are usually found during infancy or childhood, but 20% of patients are older than 10 years old.

The most recently accepted classification was proposed by Todani and colleagues (Figure 13-7).[34]

- Type I cysts (80 to 90% of cases) are classified according to the shape of the affected segment. Type IA cyst involves cystic dilation of the CBD, with marked dilation of part or the entire extrahepatic biliary tree. The gallbladder commonly arises from the cyst, and the intrahepatic biliary tree is normal. Type IB cyst involves focal, segmental dilation of the CBD, usually of the most distal part of the duct. A normal segment of CBD is present between the cyst and the cystic duct. Type IC cyst involves fusiform dilation of the CBD, along with diffuse, cylindric dilation of the common hepatic duct. The gallbladder arises from the dilated CBD and the intrahepatic biliary system is not dilated.
- Type II cyst is a true choledochal diverticulum (2% of cases).
- Type III cyst is a choledochocele (1.5 to 5% of the patients) involving only the intraduodenal portion of the CBD. The papilla appears as a hemispherical cystic structure protruding into the duodenal lumen. The terminal end of the CBD is blunt and bulbous, unlike the normal tapered appearance. The cystic structure enlarges further during injection of contrast material into the distal CBD.[35]
- Type IV cysts are subclassified into 2 groups. Type IVA cysts (in up to 20% of patients) involve dilation of the intra- and extrahepatic bile ducts. Cholangiogram shows gross cystic dilation of the extrahepatic biliary tree, with extension of the cystic dilation into the intrahepatic biliary tree. The intrahepatic dilation may affect multiple segments, be smooth and fusiform, or be irregular. Much less common type IVB cysts also involve dilation of multiple segments, but are confined to the extrahepatic bile duct. The intrahepatic biliary tree is normal.
- Type V cysts (Caroli disease) involve dilation of one or several segments of the intrahepatic bile ducts.[34,36]

The presenting symptoms and signs of choledochal cyst are abdominal pain, jaundice, and abdominal mass. Unusual presentations include rupture of the choledochal cyst causing bile peritonitis, pancreatitis, or bleeding esophageal varices due to biliary cirrhosis.[37] Many complications have been associated with choledochal cyst including cholelithiasis, choledocholithiasis, cystolithiasis, biliary cirrhosis, portal hypertension, pancreatitis, intrahepatic abscesses, and biliary carcinoma.[32] Although cyst excision eliminates the potential site for neoplasia, it does not exclude the possibility of developing cancer in the intrahepatic ducts. Long-term follow up is always mandatory.[38]

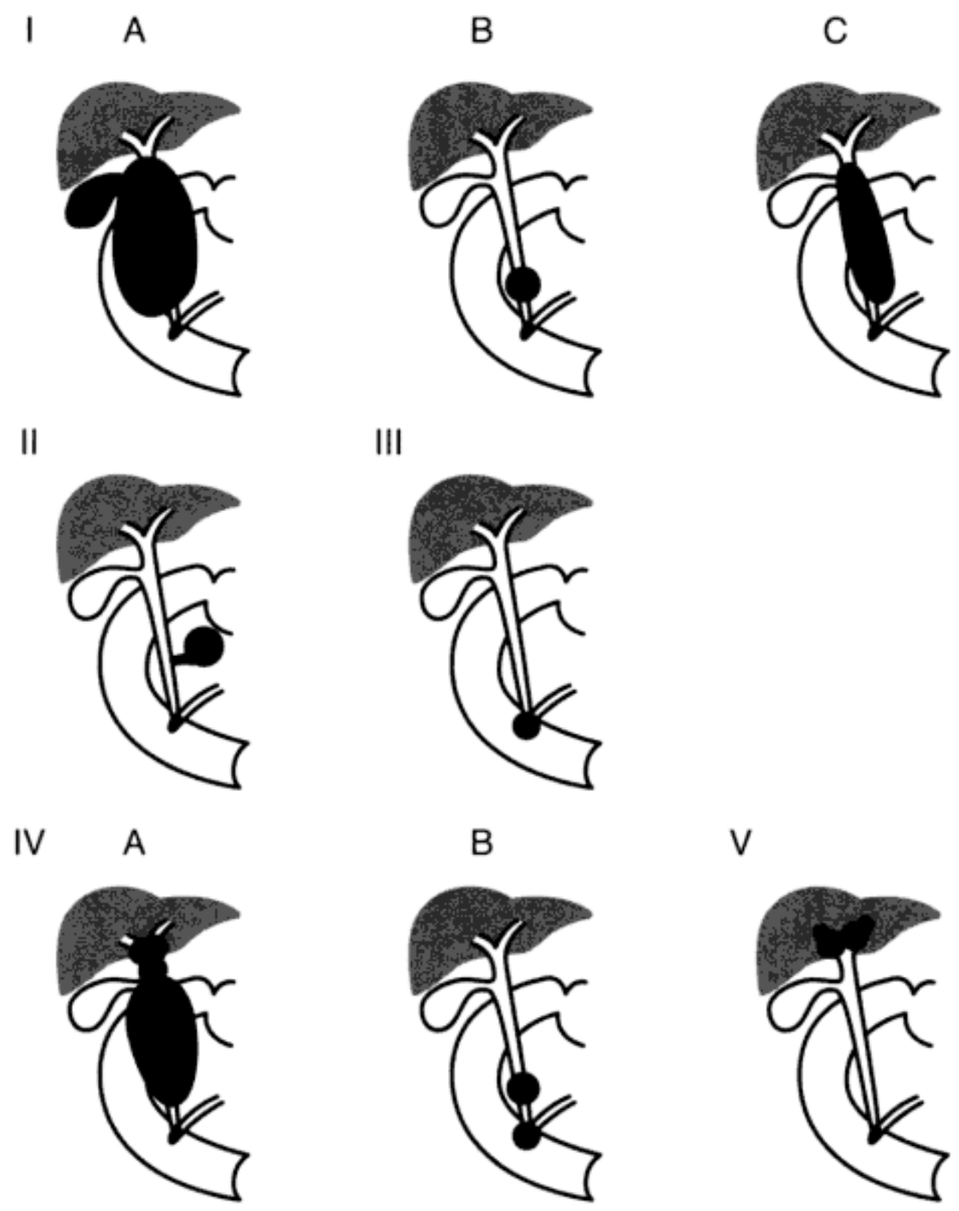
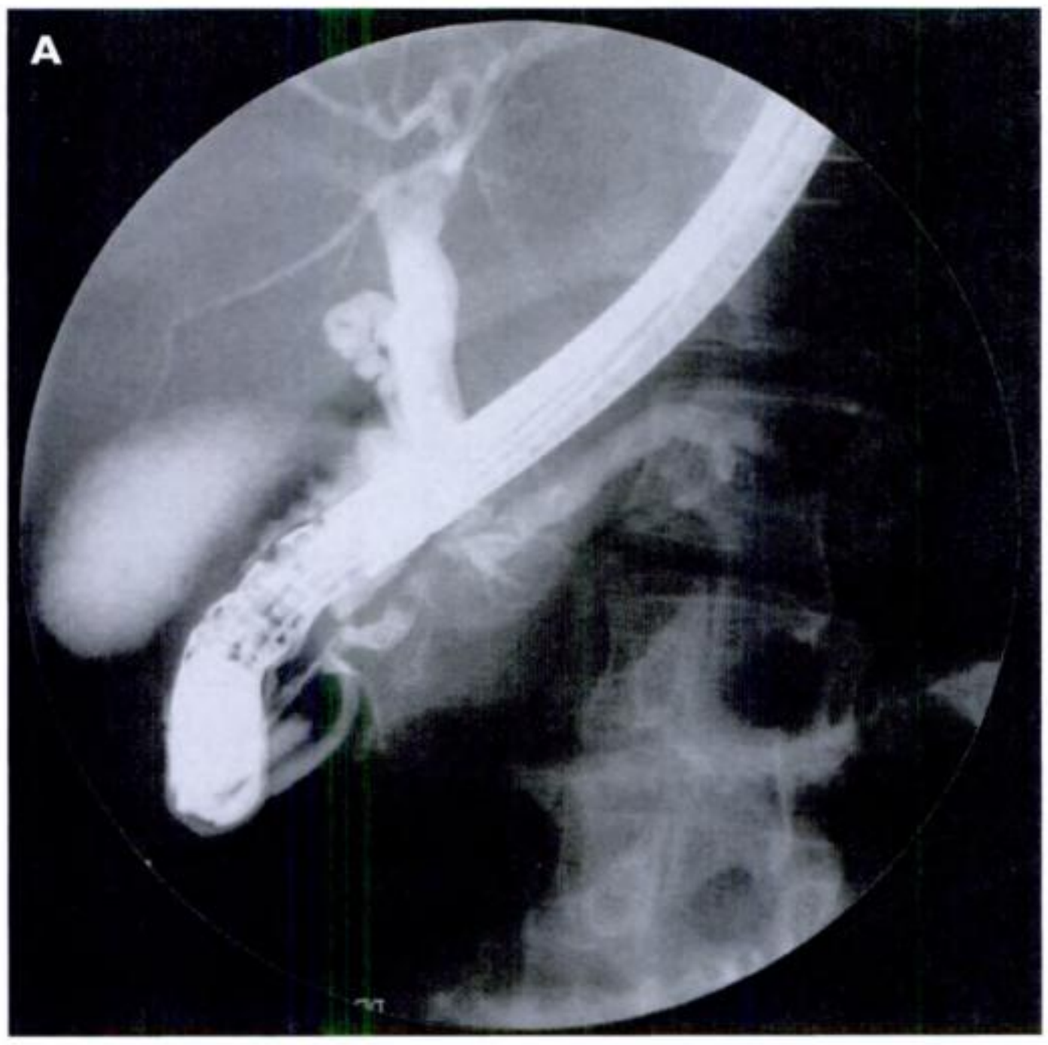
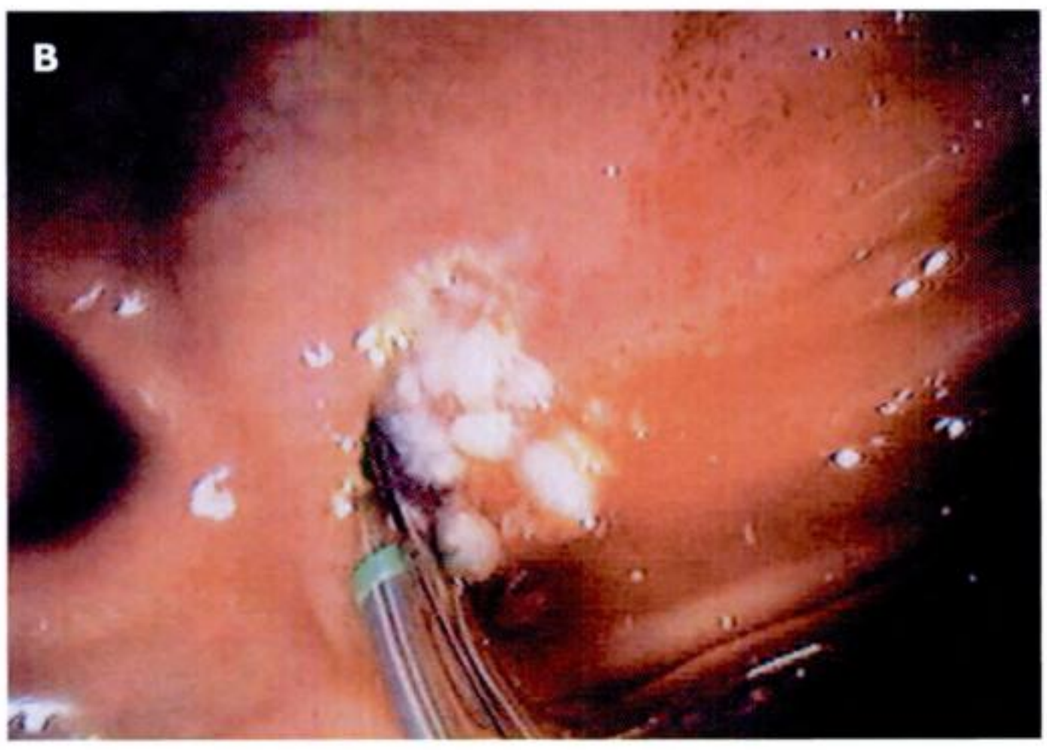


Figure 13-7. Schematic representation of the Todani anatomic classification of choledocal cysts (Adapted from Guelrud M, et al. ERCP in pediatric practice: diagnosis and treatment. Oxford; Isis Medicam Media; 1997.)

Abdominal US and CT scans are important in diagnosing cystic masses in close proximity to the pancreatic head and hepatic hilum. MRCP can identify APJ in up to 82% of the cases. It also shows good correlation with ERCP with regard to choledochal cyst and APJ diagnoses.[39,40] Endoscopic ultrasonography can be useful to detect small stones and gallbladder lesions.[41]

ERCP is the most sensitive method to define the anatomy of the biliary system, depict APJ, and identify biliary malignancies.[42] However, in this setting, ERCP has been associated with a particularly high risk of pancreatitis, probably related to the fact that cyst opacification often requires repetitive injections involving the pancreatic duct. Owing to the high potential of complications, including malignant degeneration, the treatment of choice is always surgery. Depending upon the anatomy, a choledocho-jejunal anastomosis can be performed although cyst excision and Roux-en-Y hepaticojejunostomy is preferred.





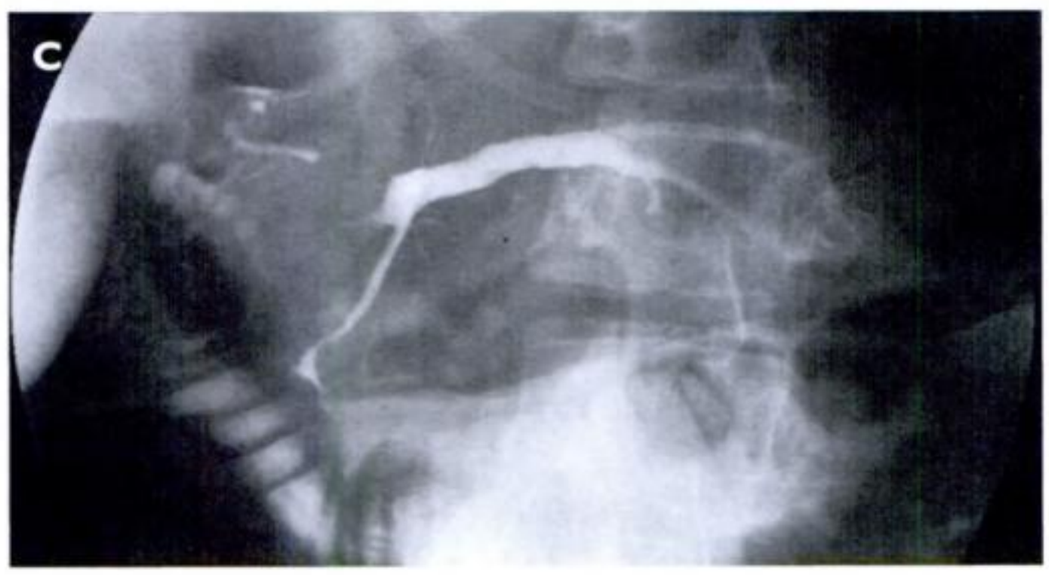


Figure 13-12. Recurrent pancreatitis in an 11-year-old girl. *A*, Endoscopic retrograde cholangiopancreatography showed dilated main pancreatic duct with multiple filling defects due to protein plugs. The common bile duct was also dilated. *B*, Stones were extracted after pancreatic duct sphincterotomy. *C*, Postoperative opacification showed that the Wirsung duct was clear of stones.

Acute Pancreatitis

The most common causes of acute pancreatitis in children are drugs, infectious agents, hypertriglyceridemia, trauma, biliary tract anomalies, and pancreatic ductal obstruction.[64] In most noncomplicated cases, noninvasive imaging studies such as abdominal US, CT scan, and MRCP can define the extent of the disease, diagnose and quantify necrosis, and determine whether pseudocysts are present.[1]

In patients who present with acute pancreatitis, ERCP has no role except when the diagnosis of acute biliary pancreatitis with concomitant cholangitis is suspected. Indications for ERCP in acute biliary pancreatitis should be

- before cholecystectomy: in the presence of concomitant cholangitis, obstructive jaundice, and severe disease or in patients who suffer an in-hospital exacerbation; and
- after cholecystectomy: in patients with unsuccessful laparoscopic or open CBD exploration or patients with smoldering disease (± sphincter dysfunction or ductal disruption).

Anecdotal reports of therapeutic ERCP in acute biliary pancreatitis in children have been published.[65]

Recurrent Pancreatitis

Recurrent pancreatitis can be divided into two groups, nonobstructive or obstructive pancreatitis (Figures 13-12 and 13-13).[66] Obstructive causes include choledochal

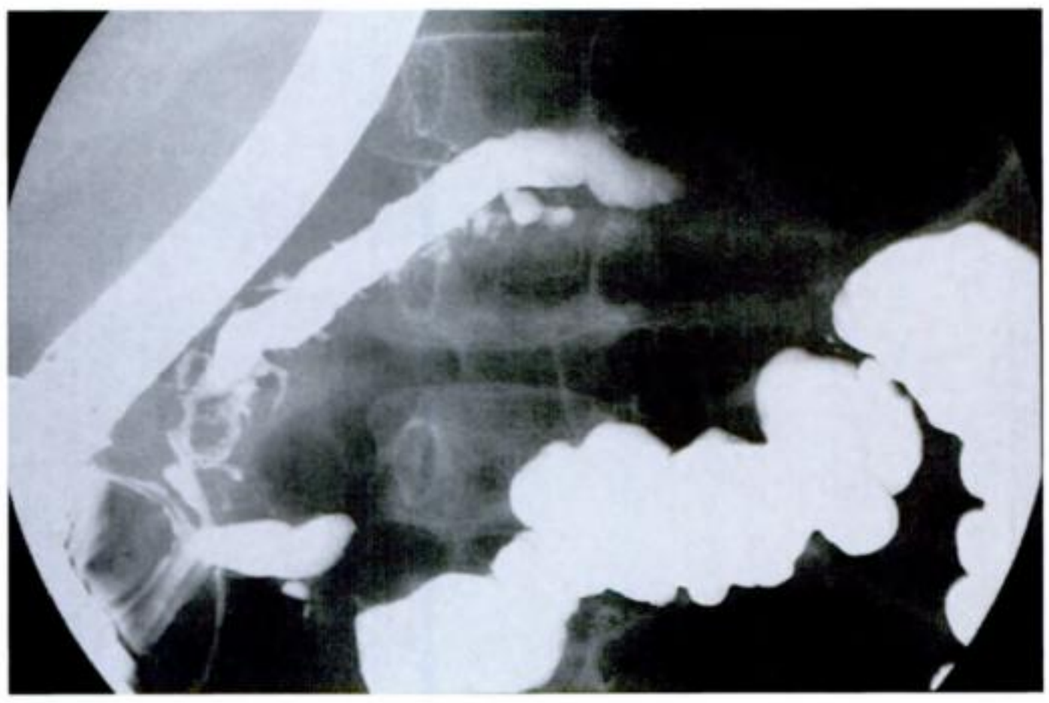


Figure 13-13. Recurrent pancreatitis in an 8-year-old boy is treated by cystoduodenostomy and cholecystectomy. A recurrent bout of acute pancreatitis, one month later, leads to endoscopic retrograde cholangiopancreatography. Selective cannulation of the main pancreatic duct shows a prepapillary stenosis of Wirsung duct with upstream dilatation. Endoscopic papillotomy of the pancreatic sphincter and stenosis dilation are performed.

cysts, pancreas divisum, duodenal diverticulum, duodenal duplication, parasitic infestation, and anomalous pancreaticobiliary junction. Whatever the underlying cause of pancreatitis, the possibility that there may be an anatomic abnormality amenable to endoscopic therapy or surgery should always be considered.[64,67,68] ERCP has been found useful in the identification of treatable causes in 40 to 75% of children with recurrent pancreatitis.[3]

Endoscopic therapy in recurrent pancreatitis includes: standard biliary sphincterotomy, dual sphincterotomy of the pancreatic duct sphincter and the CBD sphincter, minor papilla sphincterotomy, pancreatic stone extraction, pancreatic endoprosthesis insertion, cystogastrostomy, and cystoduodenostomy.

Pancreas Divisum

Pancreas divisum (PD), the most common congenital variant of pancreatic ductal anatomy caused by failure of fusion of the dorsal and ventral endodermal buds during gestation, has been found in approximately 5 to 14% of autopsy series and 0.3 to 8% of ERCP studies. When patients with unexplained recurrent pancreatitis are studied, the incidence is 25%. Each duct drains via its own separate orifice, the major papilla of Vater for the ventral duct of Wirsung, and the minor papilla for the dorsal duct of Santorini (Figures 13-14 and 13-15).[67,69]

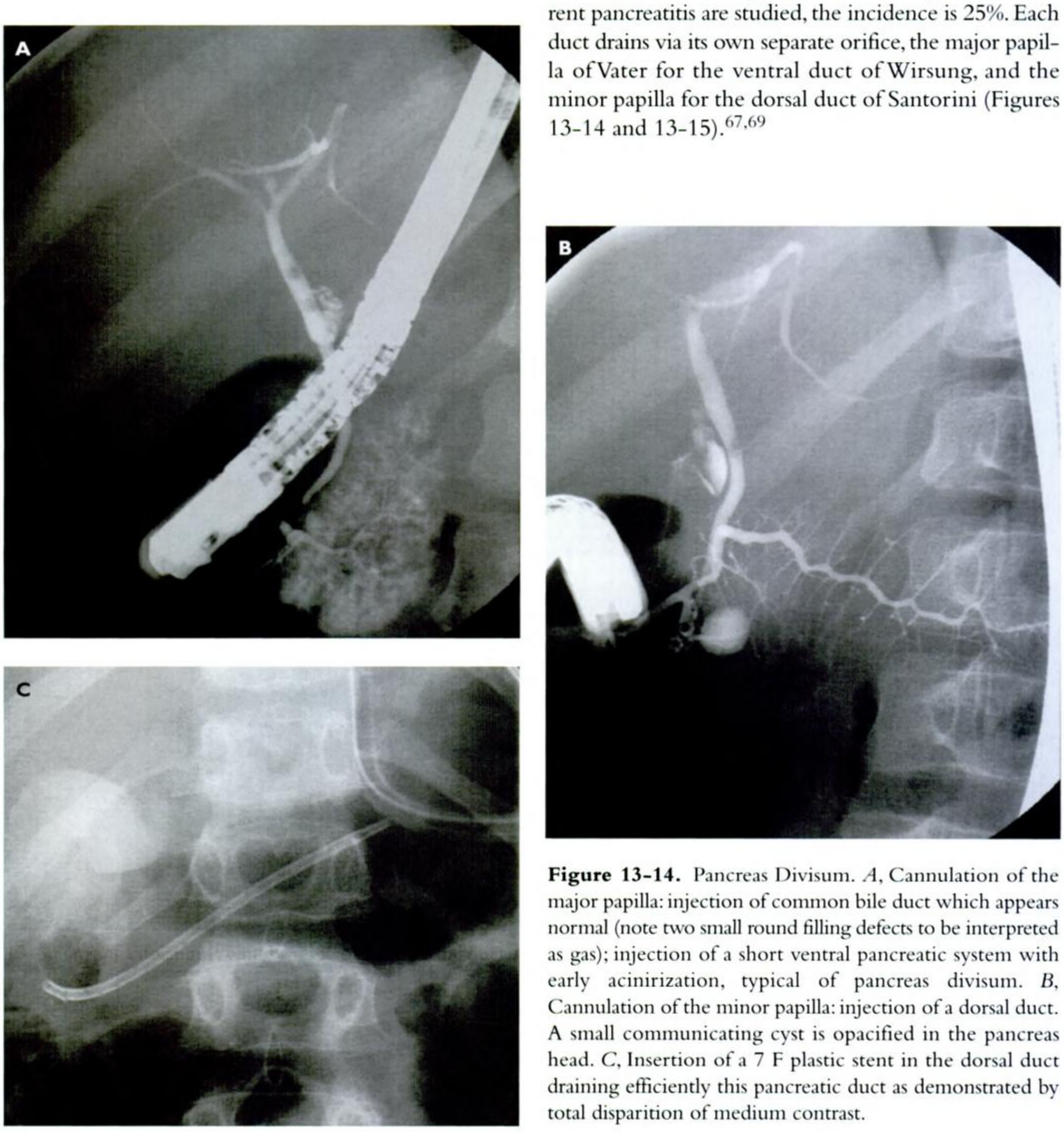


Figure 13-14. Pancreas Divisum. *A*, Cannulation of the major papilla: injection of common bile duct which appears normal (note two small round filling defects to be interpreted as gas); injection of a short ventral pancreatic system with early acinirization, typical of pancreas divisum. *B*, Cannulation of the minor papilla: injection of a dorsal duct. A small communicating cyst is opacified in the pancreas head. *C*, Insertion of a 7 F plastic stent in the dorsal duct draining efficiently this pancreatic duct as demonstrated by total disparition of medium contrast.

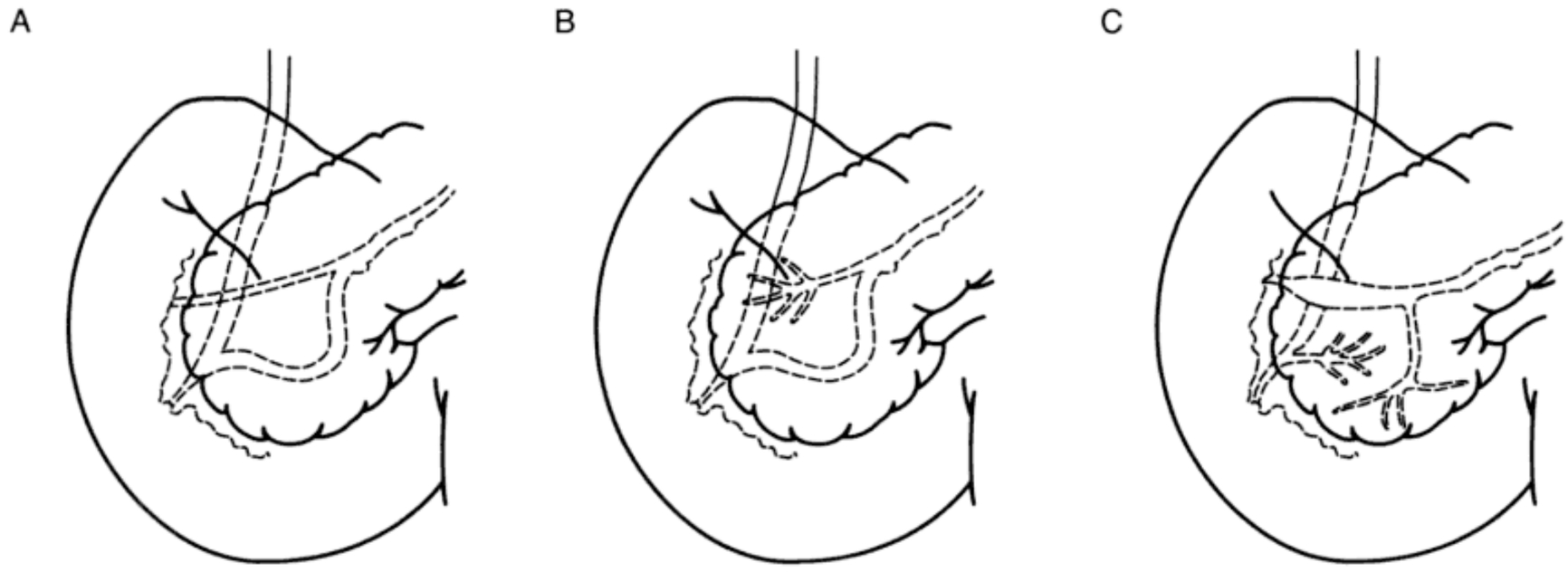


Figure 13-15. Diagrams of variant forms of pancreatic ductal anatomy. *A*, The main pancreatic duct drains through the major papilla. The accessory duct is patent and drains through the minor papilla. *B*, Same as *A*, except that the minor papilla is not patent and the accessory duct and branches terminate near the duodenal wall. *C*, Typical pancreas divisum, with a small ventral duct draining through the major papilla. There is a large dorsal duct draining through the minor papilla. Courtesy of the Department of Medical Illustration, Indiana University School of Medicine.

In 272 cases of successful ERCP performed in children, PD was found in 9 (3.3%).[69] In children with recurrent pancreatitis, the incidence ranges between 7 and 22%.[67] The relationship between PD and recurrent pancreatitis is not known, but many believe that the minor papilla is too small to allow for adequate drainage.[70] However, others have considered PD to be an incidental finding. In recent years, endoscopic therapy has permitted insertion of an endoprosthesis into the dorsal duct, dilation of the minor papilla, or sphincterotomy of the minor papilla with or without stent insertion. Overall, improvement is seen in 70 to 90% of the cases.[70]

Guelrud and colleagues have treated 3 children with PD by endoscopic sphincterotomy of the minor papilla.[67] In one child, a pancreatic stent was placed for 2 weeks. Two children were asymptomatic during follow-up of 10 to 17 months and one child had recurrent episodes of abdominal pain without enzyme elevation. Similar results were seen in another 3 patients treated surgically in the same series.[67]

Other Congenital Anomalies

Annular pancreas, short pancreas, cystic dilation of the pancreatic duct, duodenal or gastric duplication, and duodenal diverticulum have been reported in association with recurrent pancreatitis. When less invasive tests such as CT scans and MRCP are inconclusive, ERCP might be useful.[66]

Anomalous Pancreaticobiliary Junction

APJ is a congenital malformation defined as a communication of the CBD with the pancreatic duct to form a long common channel outside the duodenal wall and therefore not under the influence of the sphincter of Oddi. During an ERCP, APJ is considered to be present when the common channel measures more than 15 mm or when its extraduodenal portion is more than 6 mm long.[70–72] This anomaly has been implicated as a cause of choledochal cyst, bile duct and gallbladder carcinoma and recurrent pancreatitis.[71]

According to the classification of Kimura and colleagues there are 2 types of APJ:

- Type PB: when the pancreatic duct appears to join the CBD (Figure 13-16).
- Type BP: when the CBD appears to join the pancreatic duct (Figure 13-17).[73]

Guelrud and colleagues have proposed a third type, the "long Y," where there is only a long common channel without CBD dilation.[72]

It seems that recurrent pancreatitis is more directly associated with the type PB than the BP.[72] One case of balloon dilation has been reported as an alternative to surgical anastomosis in a child with long common channel, choledochal cyst, and multiple biliary stenoses.[74]

Sphincter of Oddi Dysfunction

Sphincter of Oddi dysfunction (SOD), an abnormality in the contractility of this sphincter, is a benign, noncalculous obstruction to flow of bile or pancreatic juice through the pancreaticobiliary junction. Rare pediatric patients, like adults, can have pancreatitis secondary to SOD.[14] They do not respond as well to endoscopic treatment, for which the complication rate tends to be higher than that for adults.[75]

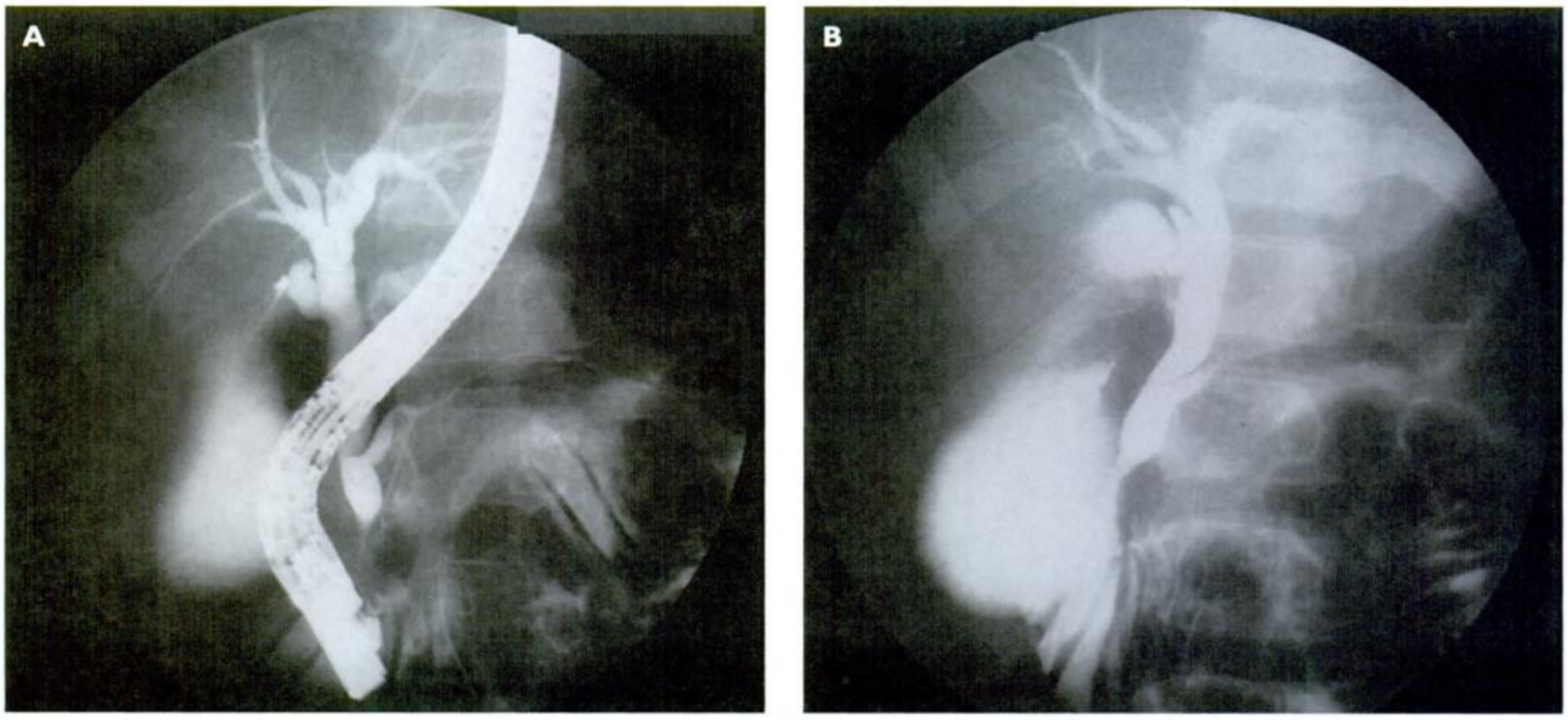


Figure 13-16. Anomalous Pancreaticobiliary Junction. Severe acute pancreatitis in a 13-year-old boy. *A*, Cannulation of the major papilla; injection of common bile duct and Wirsung duct reveals an anomalous pancreaticobiliary ductal junction type PB: long common channel with pancreatic duct joining the common bile duct. Note the diffuse dilatation of the biliary tract. *B*, After retrieval of duodenoscope, X-ray of the patient in dorsal decubitus better demonstrates the long common channel cephalad to the sphincter of Oddi.

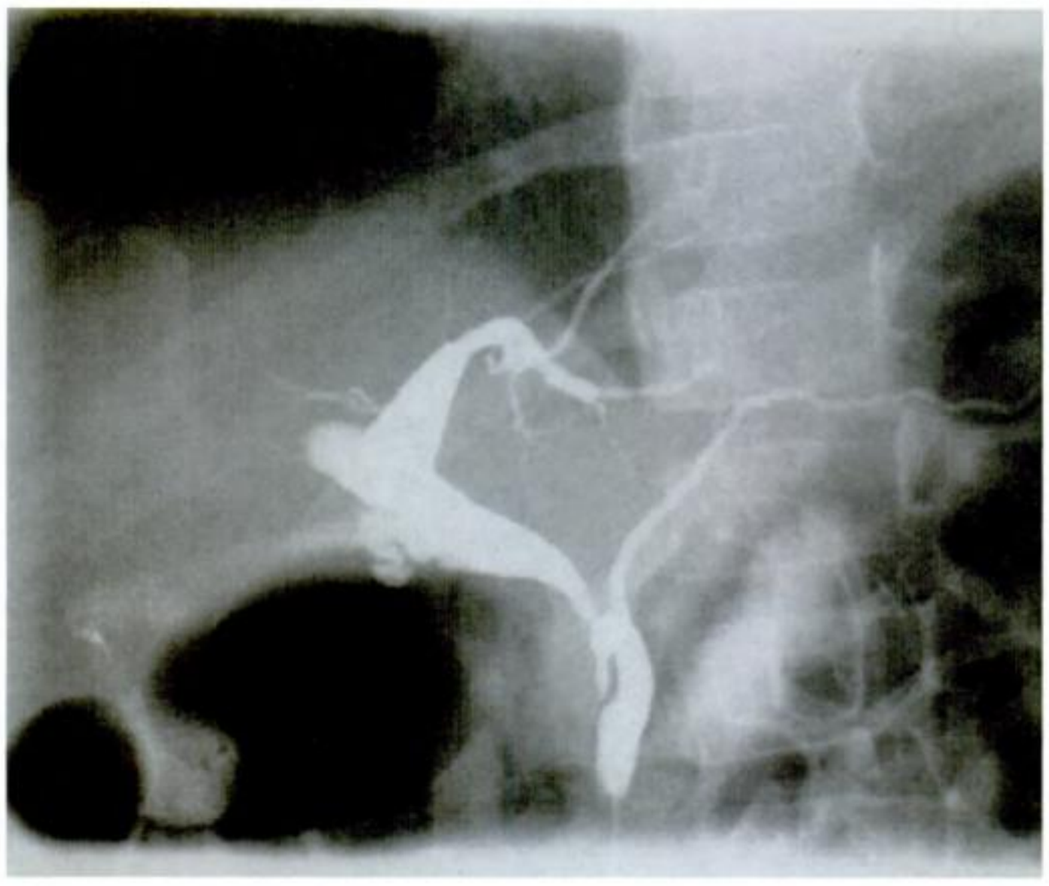


Figure 13-17. Anomalous Pancreaticobiliary Junction. Recurrent acute pancreatitis in a 6-year-old child. Endoscopic retrograde cholangiopancreatography demonstrates an anomalous pancreaticobiliary ductal junction type BP: long common channel with common bile duct joining pancreatic duct.

Chronic Pancreatitis

Chronic pancreatitis is characterized by fibrosis, destruction of exocrine tissue, and, eventually destruction of endocrine tissue (Figures 13-18 to 13-20). Both parenchymal and ductular tissue may be involved. Three subgroups of chronic pancreatitis are delineated[76]: (1) chronic calcifying pancreatitis characterized by sporadic parenchymal fibrosis associated with intraductal protein plugs, intraductal stones, and ductal injury; (2) chronic obstructive pancreatitis, resulting from obstruction of the main pancreatic duct, characterized by uniform ductal dilatation and atrophy with eventual replacement of acinar cells by fibrous tissue; (3) chronic inflammatory pancreatitis, characterized by fibrosis, mononuclear cell infiltration, and atrophy, associated with autoimmune diseases such as Sjogren's syndrome and primary sclerosing cholangitis. New etiologies for chronic pancreatitis have been recently defined: eosinophilic pancreatitis, genetic pancreatitis (1. mutation in the trypsinogen cationic gene responsible for familial pancreatitis with autosomal dominant inheritance; 2. recessive mutations in the *SPINK1* gene [serine protease inhibitor Kazal type 1] or in the *CFTR* gene [cystic fibrosis transmembrane conductance regulator] observed with high frequencies in patients with "idiopathic" pancreatitis). Before performing invasive tests such as ERCP, genetic testing for these entities is mandatory if the first bout of pancreatitis occurs before the age of 20 years.[77,78]

Abdominal pain is the most serious clinical problem in chronic pancreatitis. The later stages of chronic pancreatitis are characterized by spontaneous remission of abdominal pain and the appearance of signs of full-blown insufficiency of both the exocrine and eventu-

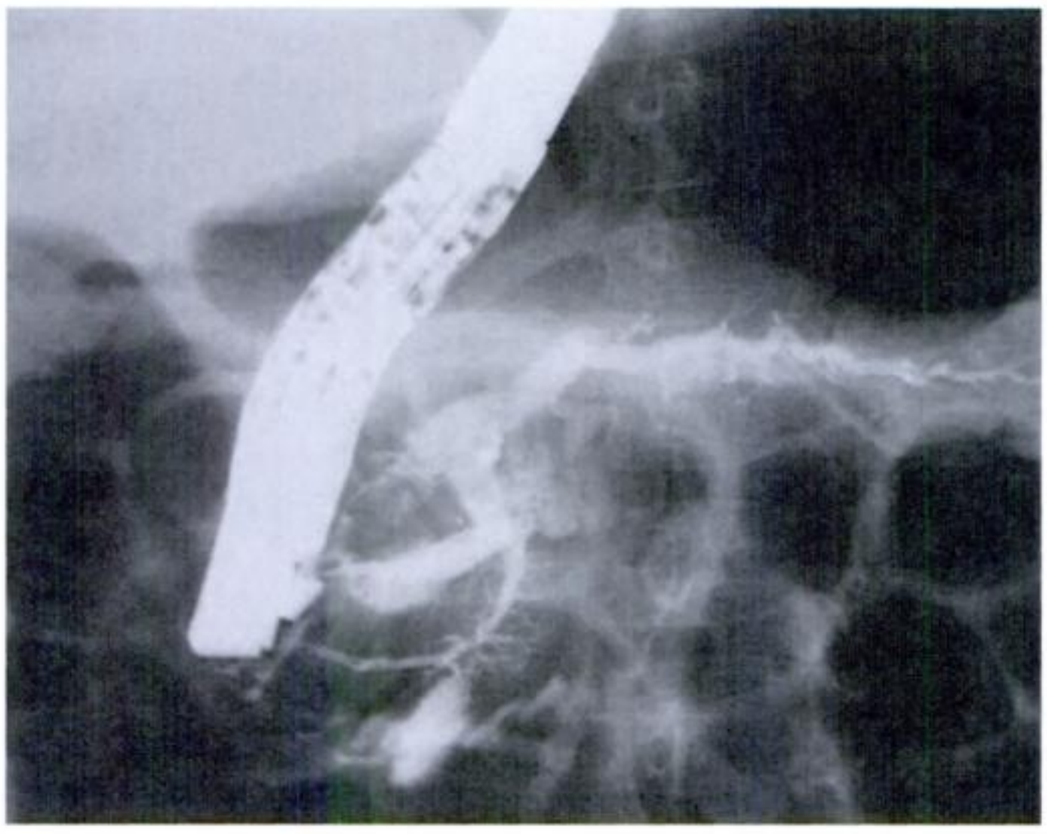


Figure 13-18. Chronic calcifying pancreatitis in a 6-year old-girl. Pancreatic ducts are irregularly dilated with intraductal filling defects.

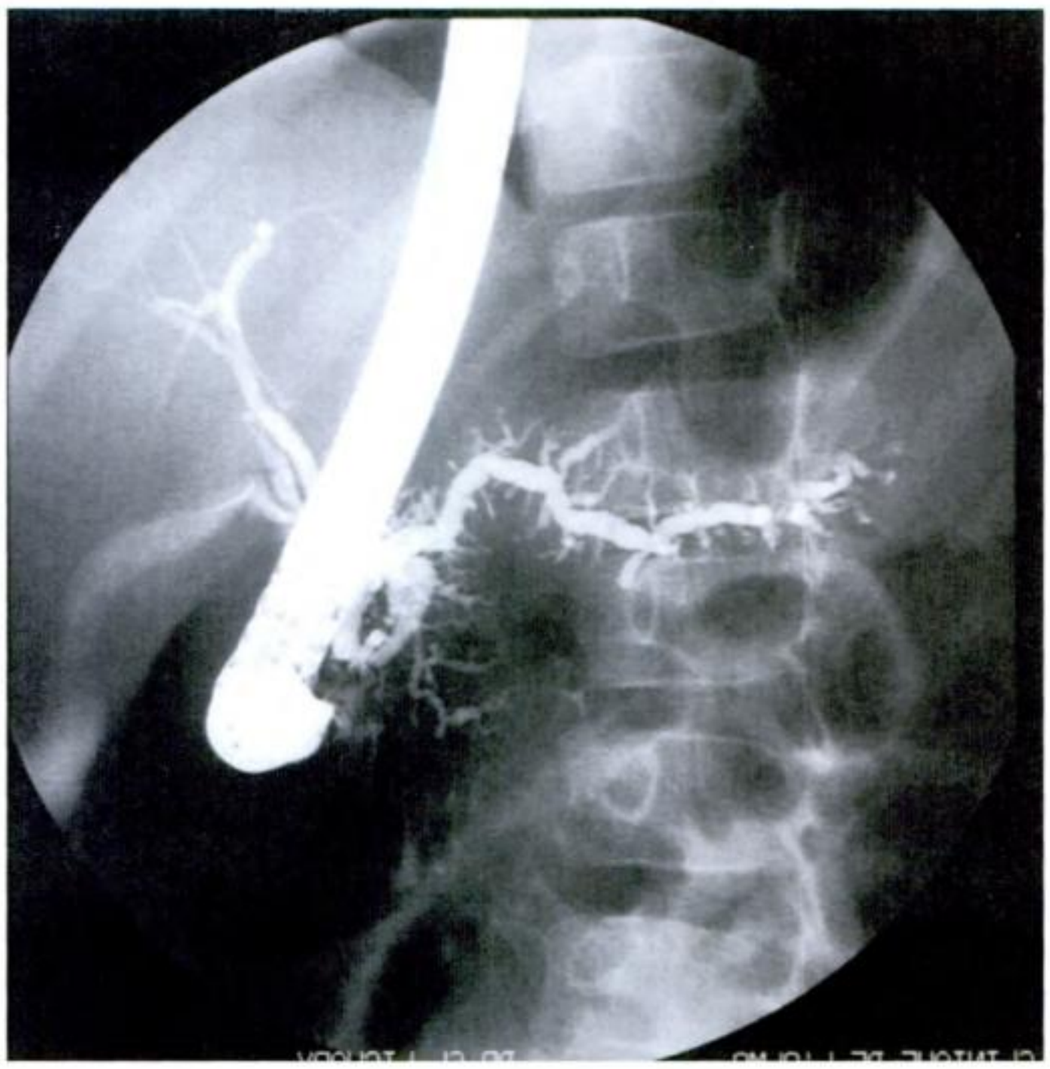


Figure 13-19. Chronic calcifying pancreatitis in a 6-year old-child. Endoscopic retrograde cholangiopancreatography shows important pancreatographic changes consisting in irregular dilatation of both main pancreatic duct and branches and calculi. Biliary tract is normal.

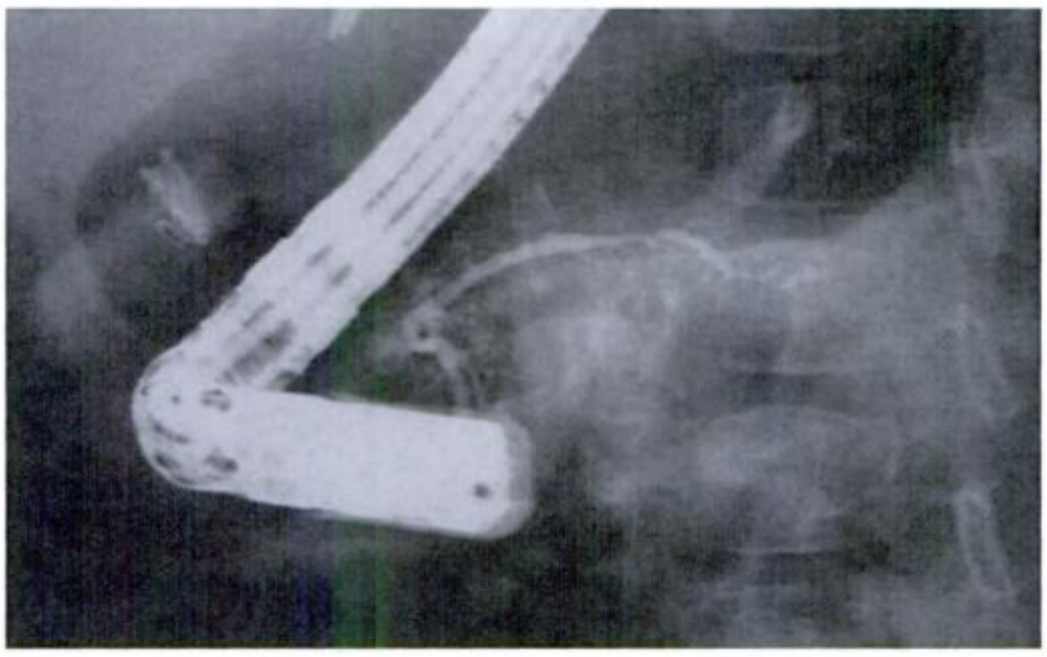
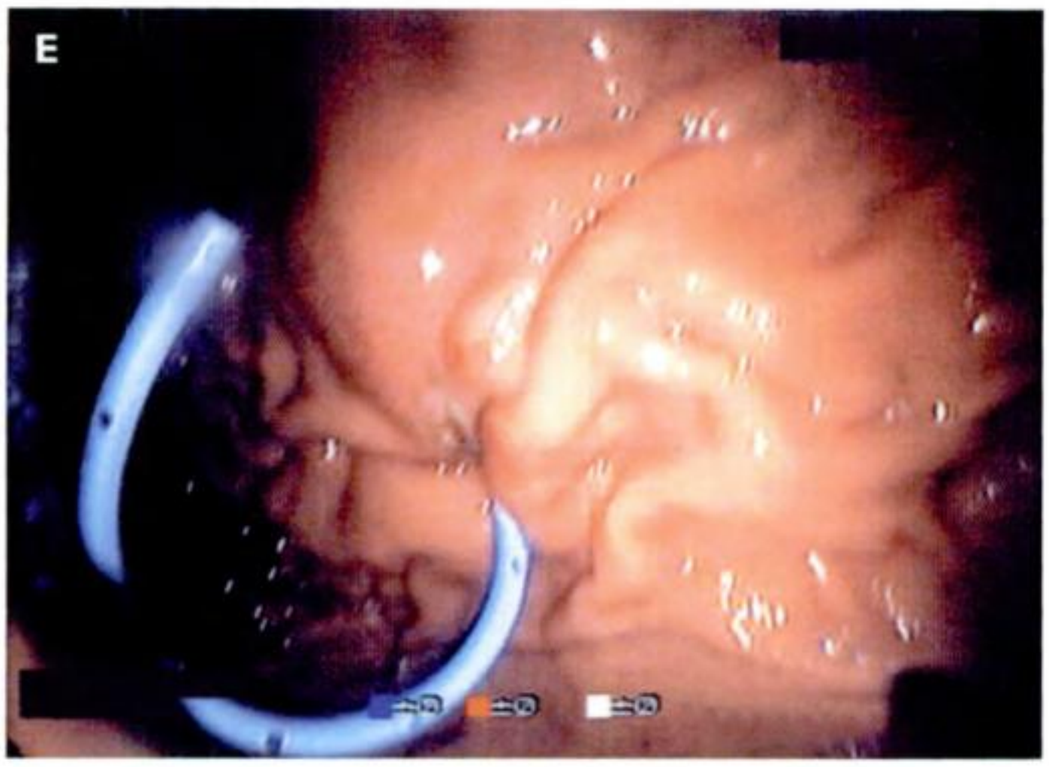


Figure 13-20. Chronic pancreatitis in a 3-year-old child suffering from intractable diarrhea (primary epithelial dysplasia) under parenteral nutrition. Recurrent bouts of pancreatitis following a cholecystectomy are not elucidated by ultrasonography and magnetic resonance cholangiopancreatography. Endoscopic retrograde cholangiopancreatography shows moderate irregularities of the main pancreatic duct better seen in the tail.

ally the endocrine pancreas. Treatment is aimed at producing stable remission of painful symptoms, prevention of complications (cystic lesions, stenosis of the main bile duct), and halting or slowing the progression of the disease. These objectives are particularly important when the disease appears early in life because it can interfere with the psychophysical development of the child.

Therapeutic endoscopy is useful in treating local complications such as pancreatic pseudocysts and biliary strictures. Endotherapy is also effective in treating postsurgical complications such as pancreatic leakage after pancreaticojejunostomy. However, the main indication is to control painful chronic pancreatitis resistant to medical treatment, or recurrent attacks of acute pancreatitis, which frequently appear in the course of chronic pancreatitis. This goal can be achieved by endoscopic drainage procedures in cases of outflow obstruction caused by pancreatic ductal stones, strictures of the main pancreatic duct, or a compressing pseudocyst, all resulting in upstream dilation. Drainage procedures include pancreatic sphincterotomy, stone extraction, balloon dilation of strictures, usually followed by stent insertion, and pseudocyst drainage.[79,80]

The pain experienced by children with chronic idiopathic pancreatitis appears to be more commonly caused by the transient occlusion of the sphincter of Oddi by protein plugs. In these cases, the most effective approach to restore the flow within the duct is to reduce the resistance to the passage of these plugs by sphincterotomy. In a study involving 22 children with pancreatitis treated endoscopically, Hsu and colleagues observed significant improvement in all six outcome parameters analyzed, especially in the frequency and severity of pain, decrease in health care encounters, and general well-being.[75]



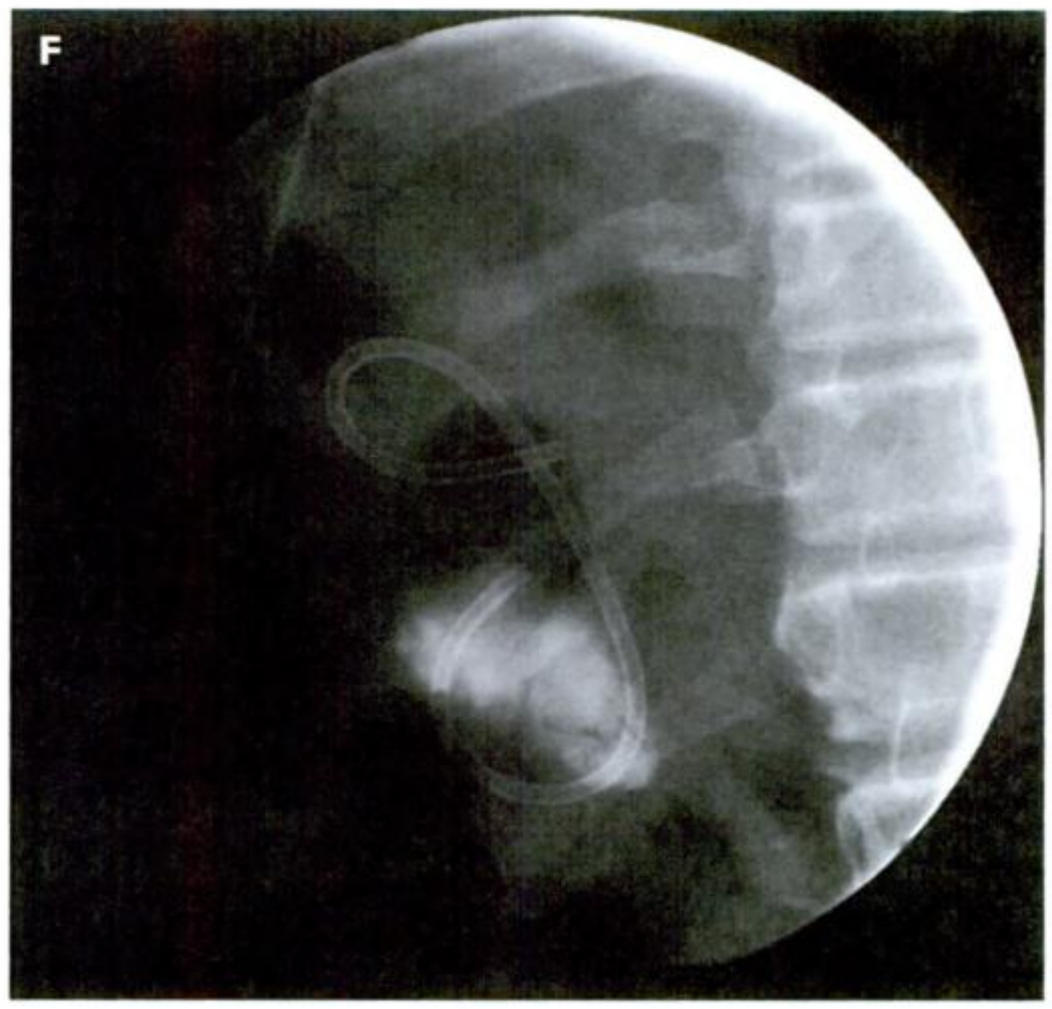


Figure 13-22 ***Continued.*** *E*, Endoscopic view of the stomach after placement of a pigtail stent. *F*, Radiologic view of the pigstail stent allowing communication between cystic cavity and stomach.

Conclusions

ERCP may be a safe and valuable diagnostic and therapeutic procedure in children with presumptive pancreaticobiliary disease. Considerable experience with this endoscopic procedure is a prerequisite before undertaking cannulation in this young age group.[85–96] The performance and interpretation of biliary endoscopy in children requires an adequate knowledge and understanding of pediatrics. In order to provide appropriate care for each child, a team including a pediatric gastroenterologist, surgeon, and adult endoscopist should be involved. Endoscopic competence in pediatric ERCP is difficult to define and almost impossible to quantitate.[86] Since every procedure has the possibility of requiring therapeutic intervention, unless skills are maintained by managing adults, pediatric endoscopists rarely have the expertise to perform complex interventional procedures.

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14 Endoscopic Management of Portal Hypertension

M. Burdelski

Portal hypertension is defined as a portal vein pressure greater than 10 to 15 mm H_2O, or a portal pressure gradient exceeding 10 to 12 mm Hg. The cause of portal hypertension may be prehepatic, intrahepatic or posthepatic. In those with prehepatic obstruction, there may be proximal extension into the liver. In intrahepatic obstruction, increased intrahepatic vascular resistance due to cirrhotic or fibrotic transformation of the liver may cause increased vascular resistance, usually associated with increased hepatic blood flow and expansion of the splanchnic blood volume. Posthepatic obstruction of the hepatic venous outflow may affect either the small or large hepatic veins, or the suprahepatic inferior vena cava.

Epidemiological studies are lacking; therefore, the incidences of the various types of portal hypertension are uncertain. Based on pediatric liver transplantation data, it is estimated that the incidence of portal hypertension due to intrahepatic obstruction is about one per million per annum.[1,2] With reduced use of umbilical vein catheterization in the neonate, prehepatic portal hypertension has become much less common. However, with increasing use of ultrasound techniques, the detection rate may have increased, especially in early cases. Posthepatic obstruction, including Budd-Chiari syndrome and veno-occlusive disease, is rare. In order to manage these cases correctly, a proper understanding of the pathophysiology is important.

Pathophysiology

Prehepatic

Prehepatic obstruction may be caused by thrombophilic states, umbilical vein catheterization, and congenital portal vein malformations. In about 50 percent of cases, however, the cause is uncertain.[3] It leads to the formation of collateral veins, which bypass the otherwise normal liver. The resultant esophageal and gastric varices and portal hypertensive gastropathy may require interventional endoscopic treatment. Hepatic atrophy may occur due to hypoperfusion of the liver. Metabolic disturbances such as hyperammonemia may also be associated with collateral formation.[4] Blood flow from the superior mesenteric vein is a major contributor to hyperammonemia. In some patients, inferior mesenteric vein dilatation may result in venous valvular incompetence leading to the development of secondary pararectal collaterals, and this may be associated with hemorrhoidal bleeding. Most patients are likely to develop bleeding from esophageal and gastric varices within months or years. In some cases, secondary bleeding disorders may arise, including hypofibrinogenemia, prolonged prothrombin time, and thrombocytopenia. Hypersplenism may be profound, requiring intervention if the platelet count is very low or if there is persistent leukopenia. Encephalopathy may occur in late adolescence, especially in those who have undergone a shunt procedure.[5]

Intrahepatic

Important causes of intrahepatic portal hypertension include cholestatic disorders, viral hepatitis, autoimmune hepatitis, and hepatic metabolic disorders. Congenital hepatic fibrosis is rare, but should be considered in patients with multicystic or polycystic kidney disease. Cholestatic liver disorders may be rapidly progressive in children. Extrahepatic biliary atresia may cause cirrhosis, portal hypertension and liver failure within months, sometimes despite the infant undergoing a Kasai procedure.[6,7] Rapid disease progression may also occur in other neonatal cholestatic disorders. Severe hypersplenism may occur, and also manifestations of liver failure including encephalopathy, hepatopulmonary syndrome and hepatorenal syndrome, clotting disorders, hypoalbuminemia, and malnutrition.[6,7] The hyperkinetic cardiovascular syndrome associated with intrahepatic and prehepatic shunting may cause bleeding from the upper airway, which must be distinguished from variceal hemorrhage. The multisystem involvement in these children places them at high risk when undergoing anesthesia and invasive endoscopic procedures.[4]

Posthepatic

A wide range of disorders may cause posthepatic venous obstruction.[8] Blockage of the hepatic veins may occur in patients with myeloproliferative syndrome.

Concentric obstruction of the terminal venules may occur following chemotherapy and bone marrow transplantation (veno-occlusive disease). It can also occur with alkaloid poisoning, aflatoxins, vitamin A toxicity, radiation, inflammatory bowel disease, and sickle cell anemia. The suprahepatic inferior vena cava may be obstructed as a result of cardiac abnormalities or venous malformations, or there may be no obvious explanation. If possible, the primary cause should be identified because specific therapy may be required. Posthepatic venous obstruction may rapidly induce complications. Patients may develop marked hepatosplenomegaly and refractory ascites. Budd-Chiari syndrome often causes acute liver failure.Veno-occlusive disease following chemotherapy, radiation, or bone marrow transplantation may cause hepatic fibrosis. In patients with malignant disease the option of liver transplantation may not be available.

Symptoms and Signs

The aim in managing portal hypertension is to prevent variceal hemorrhage.[9] Splenomegaly is present in all three types of portal hypertension. Hepatomegaly occurs in cholestatic liver disorders with cirrhosis, in hepatic fibrosis, and in Budd-Chiari syndrome. In contrast, in noncholestatic cirrhosis the liver may not be significantly enlarged. In patients with intrahepatic obstruction, the presence of ascites indicates decompensated cirrhosis, but it also occurs with posthepatic obstruction. Hypersplenism is seen in patients with both prehepatic and intrahepatic obstruction. In contrast, in posthepatic obstruction due to myeloproliferative syndrome, thrombocytosis is present. A coagulopathy may occur in both intrahepatic and posthepatic obstruction, and in prehepatic obstruction if it is associated with massive splenomegaly leading to a consumptive coagulopathy. The liver test abnormalities in the various forms of portal hypertension are summarized in Table 14-1.

Imaging

Technical advances have made ultrasound imaging an indispensable investigative tool in portal hypertension. It can demonstrate both hepatomegaly and liver atrophy. Spleen size can be measured accurately. Doppler ultrasound can demonstrate portal vein obstruction and cavernous transformation.[4] In cirrhosis, reduced portal venous blood flow is compensated for by an increase in arterial flow. Collateral channels at the splenic hilum occur in those with gastroesophageal varices.[4] Hepatic venous outflow obstruction is indicated by the presence of a band-like flow pattern instead of the normal three-phase pattern.[4] In veno-occlusive disease, if the large hepatic veins are still patent and only small veins are

Table 14-1. Classification of Portal Hypertension

	Location of Venous Obstruction		
	Prehepatic	**Intrahepatic**	**Posthepatic**
Clinical signs			
Splenomegaly	+	+	+
Cutaneous manifestations		+	+
Ascites		+	+
Caput medusae	+	+	+
Laboratory findings			
Hypersplenism	+	+	+
Coagulopathy		+	+
Low cholinesterase	(+)	+	+
Raised transaminase levels		+	+
Ultrasound			
Atrophic liver	+	(+)	
Hepatomegaly		+	+
Splenomegaly	+	+	+
Splenic hilum collaterals	+	+	+
Hepatofugal portal blood flow		+	+
Ascites		+	+
Impaired hepatic outflow			+
Cavernous transformation	+		

in this context has been studied in a randomized, controlled trial and is effective.[11] A prospective study has also shown band ligation to be effective in preventing bleeding in children irrespective of the cause of portal hypertension.[17] The benefits of primary prophylaxis are enhanced by the use of nonselective β-blockers.[18]

Secondary Prophylaxis

This refers to the use of prophylactic endoscopic therapy in patients who have already experienced variceal bleeding. Only one randomized controlled trial of band ligation versus sclerotherapy and one prospective study of ligation in children has been published.[16,19] The randomized trial showed a significantly lower bleeding rate in the post-endoscopy phase with ligation. The prospective study reported a much lower incidence of bleeding following ligation compared with published data for sclerotherapy.[19]

Aims of Endoscopic Treatment

Prevention of bleeding is a major objective of endoscopic treatment. This is especially important in young children in whom the treatment of active bleeding is particularly difficult. Unfortunately, the small endoscopes used for infants lack double instrument channels, which is a disadvantage in the emergency setting. There are also technical difficulties with band ligation in small children (see below).[19] There are also limitations with the use of agents such as polyalcohols in sclerotherapy. The dose of aethoxysclerol (polidocanol) should not exceed 0.4 mL/kg, a volume which in a small infant is likely to be insufficient to control bleeding. Prophylactic endoscopic therapy has the potential to completely eradicate varices.

Band Ligation

Variceal rubber band ligation is now generally considered the preferred technique for both esophageal and gastric varices in children. Randomized, controlled trials indicate that, regardless of etiology, this technique can prevent bleeding and can achieve eradication of varices.[16,17,19] Bands may be applied singly or, using a multiband applicator, up to 6 bands may be applied with a single passage of the endoscope. The diameter of the multiband applicator may pose difficulties for young children, in whom there is a risk of injury to the pharynx and esophagus.[19] Band ligation is effective and the complication rate is lower than that with sclerotherapy. The interval between ligation sessions can be 4 to 6 days and typically 4 to 6 therapeutic sessions are needed for variceal eradication.[19,20]

Sclerotherapy

Esophageal varices may be treated with sclerotherapy using polidocanol (1% solution), a polyalcohol sclerosant. This is injected both adjacent to and into the varix.[21] The volume injected is determined by the endoscopist based on the changing appearance of the varix, which should be pale and swollen after treatment. As mentioned earlier, the maximum total volume permitted is 0.4 mL/kg body weight per treatment session. The varices are consecutively treated around the esophageal circumference just above the Z-line. Subsequently, the more proximal varices are treated. The interval between treatments should be at least 2 weeks so that previously injected varices are readily distinguished. It is important to avoid unnecessary reinjection because this increases the risk of esophageal stenoses and of ulceration with secondary hemorrhage. Typically a total of 4 to 6 therapeutic sessions are necessary. It appears that the risk of complications is increased if sclerotherapy is performed in an emergency setting or by an inexperienced operator. Potential complications include pleural effusion due to the irritant effect of the solution, esophageal stenosis as a result of circumferential necrosis, esophageal dysmotility, hemorrhage from deep ulceration, and metabolic acidosis from excessive sclerosant administration. Residual varices present after band ligation may be treated using sclerotherapy.[10]

Sclerotherapy for gastric varices, including those in the fundus, should be carried out using cyanoacrylate.[22,23] Polidocanol should not be used because it does not sclerose the multiple sponge-like collaterals that occur in this location, and so there is a risk of bleeding from deep collaterals when the ulcer scab is shed. Cyanoacrylate is injected into the varix and acts as a "tissue glue," affecting the surrounding varices. It is administered as a cyanoacrylate-lipiodol solution. The maximum permitted dose is 1 mL for a gastric varix and 0.5 mL for an esophageal varix. A "second-look" endoscopy is performed 4 days later to look for treatment-induced necrosis and to detect varices that may require further treatment. There are reports of cerebral and pulmonary embolism associated with the use of cyanoacrylate.[23] Unintended aspiration of cyanoacrylate may cause blockage of the endoscope's instrument channels. To avoid damaging the instru-

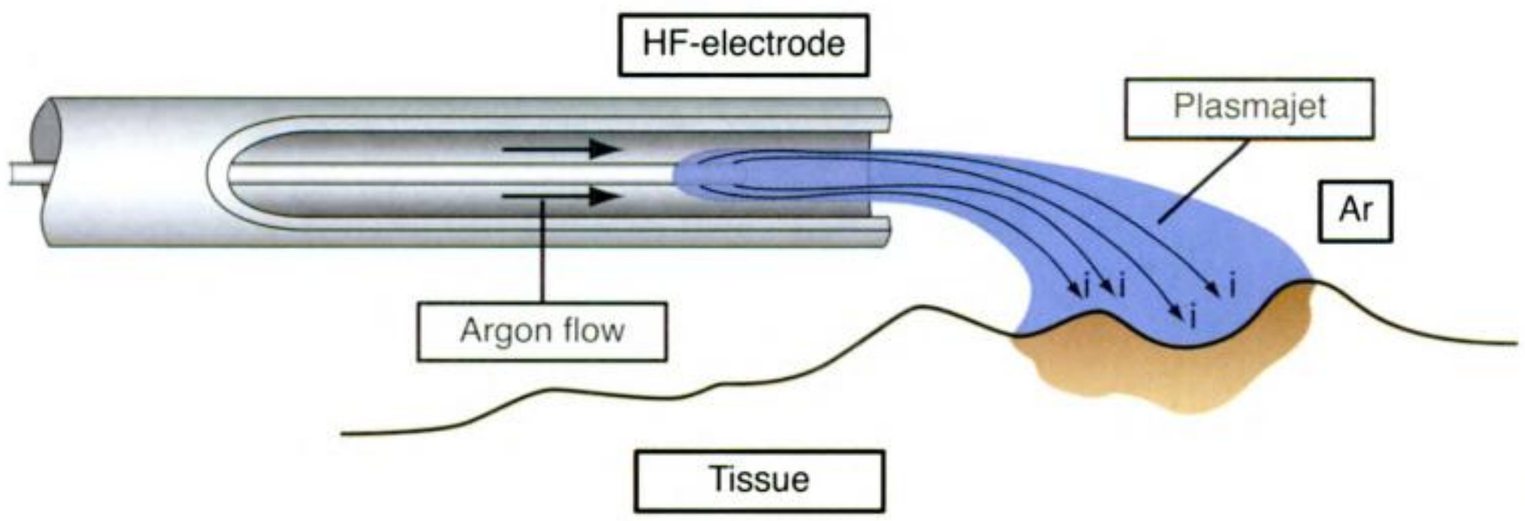

Figure 15-3. Tangential application of argon plasma coagulation.

dren less than 12 years of age. In adults, they can reliably seal arteries up to 2 mm in diameter.

Jensen and Machicado recommended the following settings for the treatment of a bleeding peptic ulcer: (1) firm tamponade, (2) four 30-J pulses applied per area of tamponade before repositioning the probe.[11] Based on experimental findings, coagulation using the side of the probe is at least as effective as en-face coagulation. Irrigation of the ulcer bed is important before and after the procedure to allow accurate positioning of the probe and to float the probe away from the tissue without lifting of the coagulum.

Bipolar or Multipolar Electrocoagulation

Bipolar electrocoagulation is widely used in North America, but less often in Europe.[12] Monopolar electrocoagulation is no longer used. Bipolar probes are now more rigid, facilitating tamponade, which is particularly helpful for tangentially approaching bleeding ulcers. Large and small probes are available. This method can achieve permanent hemostasis in arteries up to 0.5 mm in diameter.

Detailed endoscopic technical parameters have been established for bipolar electrocoagulation and for heater probe treatment by the Center for Ulcer Research for various hemorrhagic lesions.[11]

Argon Plasma Coagulation

Argon plasma coagulation (APC) (Figure 15-3) is the method of choice for actively bleeding nonvariceal lesions of the upper and lower GI tract.[13] It is effective for both oozing and pulsatile arterial bleeding. It can be used for hemostasis of localized bleeding spots and for larger surfaces (Figure 15-4). APC is a no touch technique that is both effective and safe, inducing only superficial effects with a low risk of perforation.

Technique

Before APC, the usual endoscopic preparations are needed. Special attention is required for the colon owing to the risk of gas explosion.

In children, a 2.3 mm diameter flexible delivery catheter filled with argon gas is passed through the operating channel. The tip of the probe is placed close to the lesion but without touching it. The distance at which the coagulating gas flow is activated depends on the power setting: the lower the output power, the closer the probe has to be to the tissue. When the coagulating arc is established, it is possible to move the coagulating action to adjacent areas by adjusting the tip of the probe. Therefore the endoscopist must keep a constant distance between the probe and the tissue. This is not easy in children due

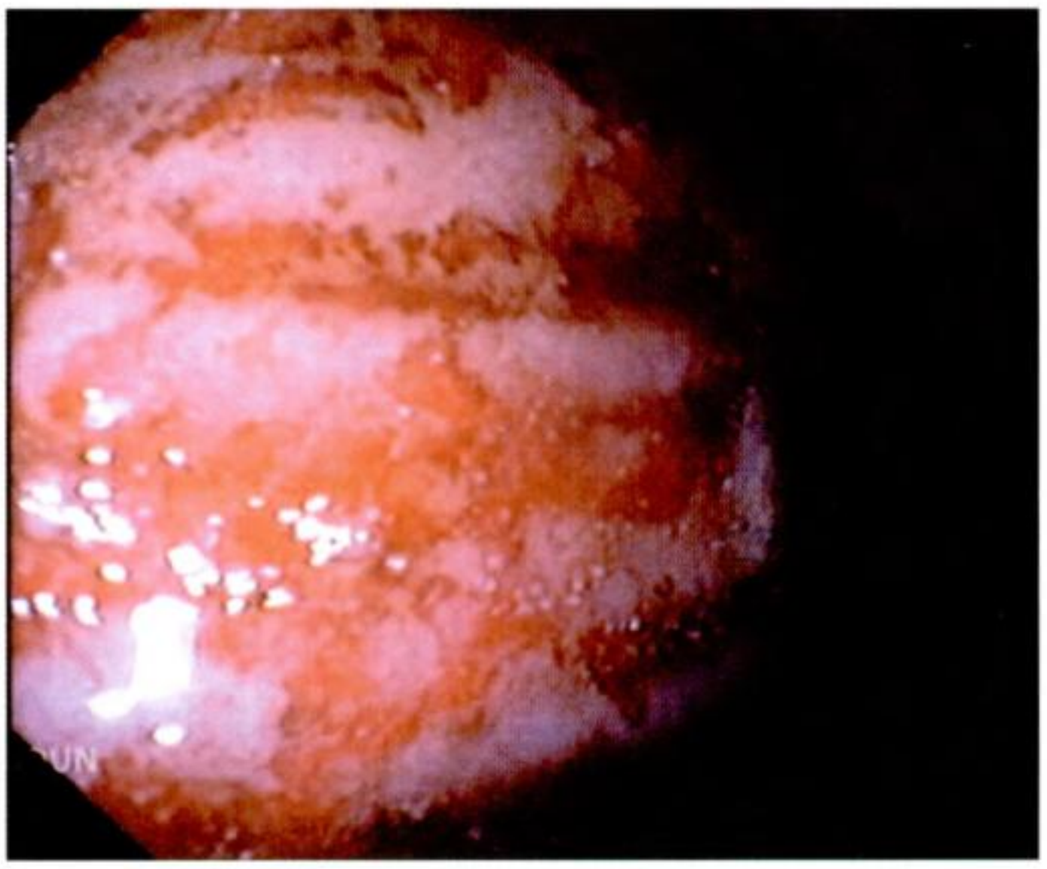

Figure 15-4. Linear hemorrhagic mucosal lesions in the gastric corpus associated with persistent vomiting followed by hematemesis.

to the higher respiratory rate. Once the targeted tissue is desiccated, the argon plasma flow automatically shifts to an adjacent area that is still electrically conductive. This provides a safety feedback effect preventing deep injury. APC can be delivered in various ways: point-by-point, strip, and paintbrush techniques.

Farin and Grund in their "10 commandments of APC in flexible endoscopy" outlined the main rules for safe APC. [13]

1. You shall not confuse APC with argon laser.
2. You shall always test argon plasma ignition and the electric arc outside the endoscope before inserting the APC probe into the working channel.
3. You shall insert the APC probe at least far enough into the working channel of the endoscope for the first distal black ring to become visible.
4. You shall always carry out APC under visual control.
5. You shall take care that the APC probe does not touch the organ wall during activation; however, your application shall be near enough to ensure argon plasma ignition.
6. You shall never press the activated probe into tissue or against the organ wall, since this can lead to emphysema or wall damage.
7. You shall not touch metal stents directly with the APC probe; here, too, you shall maintain an adequate distance.
8. You shall avoid distention caused by inflowing argon by aspirating repeatedly and placing a decompression catheter if necessary.
9. You shall set the power limit of the electrosurgical unit and the activation duration based upon the wall thickness in the affected organ (eg, a maximum upper limit of 40 W in the right colon).
10. You shall deliver several short-duration activations rather than a few long-duration activations.

Overnight observation in hospital is advisable in children who have undergone APC.

Indications

The safety and effectiveness of APC has been shown to be equivalent to the heater probe in a randomized series of adults with peptic ulcer hemorrhage.[14] APC is also used in rare conditions such as angiodysplasia (Figure 15-5) and watermelon stomach. In these arteriovenous abnormalities, APC not only achieves hemostasis, but also tends to eradicate the lesions, thus reducing recurrent bleeding.

In the lower GI tract, APC is a valuable technique for bleeding after procedures such as polypectomy or mucosal biopsy. It may be used in the right colon provided overinflation with gas and thermal injury to the bowel wall are avoided.

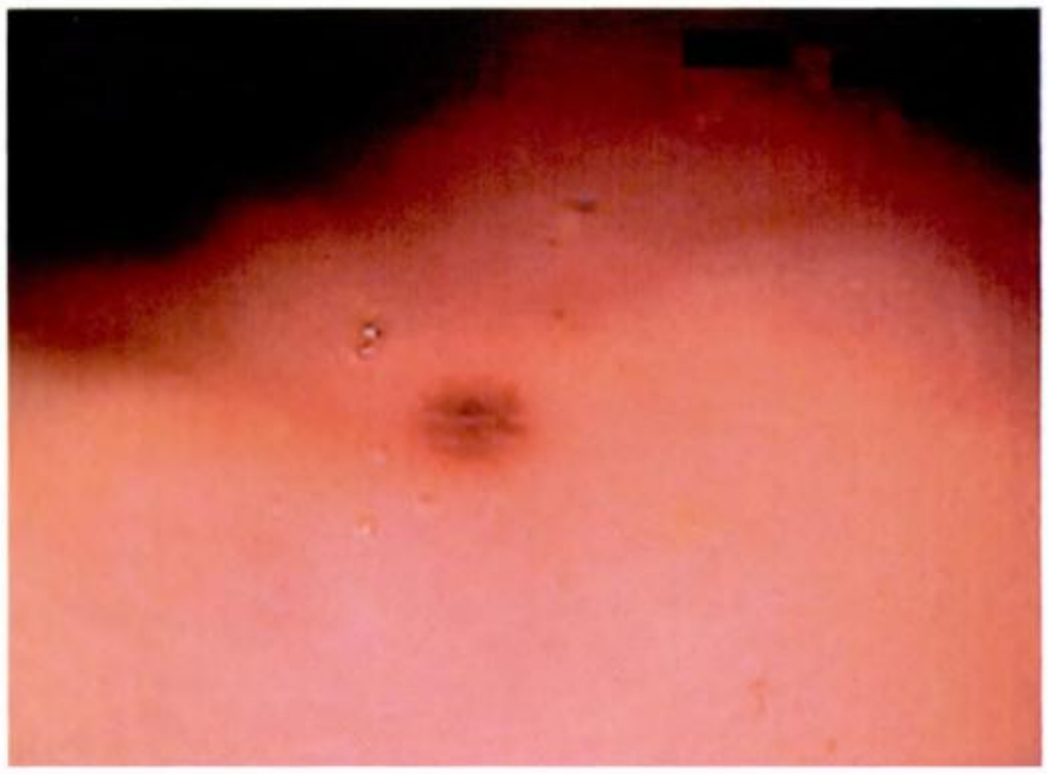

Figure 15-5. Gastric angiodysplasia in a girl with Rendu–Osler's disease.

Combination Treatment and the Limits of Endoscopic Therapy for Bleeding Peptic Ulcer

In actively bleeding ulcers, initial injection with dilute epinephrine reduces blood flow and allows time to determine whether further intervention is needed. For pulsatile arterial bleeding, subsequent thermal treatment is generally considered advisable not only for hemostasis, but also to prevent rebleeding. In other conditions, epinephrine injection is recommended. In all bleeding related to acid injury, treatment with an intravenous proton pump inhibitor should be given.[15]

Hemorrhage from major arteries are not suitable for endoscopic therapy and immediate surgery is essential. Failure of endoscopic therapy and rebleeding are more likely in hypovolemic shock, large ulcers, and ulcers on the lesser curvature of the stomach or on the posterior wall of the duodenal bulb.[16]

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16 Endoscopic Management of Stenosis and Achalasia

Adolfo Bautista Casasnovas, Jesus Broto Manques, and Samy Cadranel

Congenital Esophageal Stenosis

Recognition of congenital esophageal stenosis may be difficult because peptic esophageal strictures can occur in young children. Congenital stenosis is defined as an intrinsic stenosis, caused by a congenital malformation of the esophageal wall.[1] There are three types (Table 16-1). The first is due to a membranous web or diaphragm, probably analogous to other gastrointestinal webs. The second, is referred to as "idiopathic muscular hypertrophy" or "fibromuscular stenosis", and is due to segmental hypertrophy and fibrosis of the muscular and submucosal layers. The third is the most common, the best understood, and is due to the presence of tracheobronchial remnants—cartilage, respiratory mucous glands, ciliated epithelium—in the esophageal wall. Unlike the other types, which can be dilated, this usually requires surgical resection. In some cases tracheobronchial remnants are associated with esophageal atresia and so can be explained on an embryological basis.[2] About 25% of patients with congenital stenosis have associated anomalies. Congenital esophageal stenosis is reportedly more common in Japan.[3]

Clinical Presentation

Symptoms of esophageal stenosis such as progressive dysphagia, regurgitation, vomiting and coughing, typically emerge when weaning begins. Impaction of food is common when children begin to transition from liquid to more solid diets. Others present with symptoms of regurgitation, respiratory distress, aspiration, or apnea in the newborn.[1] The differential diagnosis includes acquired stricture, extrinsic esophageal compression, and esophageal achalasia.

Diagnosis and Treatment

Diagnosis may be difficult. A contrast cine-esophagram typically reveals an abrupt narrowing in the distal esophagus taht may be easily mistaken for a peptic stricture associated with gastroesophageal reflux disease. Esophagoscopy, however, reveals narrowing without signs of esophagitis. A 24-hour esophageal pH study may be performed to look for evidence of acid reflux.

Congenital webs can be treated with dilatation or by endoscopic resection.[4] Stenosis due to fibromuscular hyperplasia often responds to dilatation, but if symptoms remain after 4 to 6 treatment sessions, surgical treatment is necessary. If dilatation is unsuccessful in infants with stenosis associated with tracheobronchial remnants, a segmental resection and end-to-end anastomosis is performed. Following treatment the long-term prognosis is generally excellent.

Acquired Esophageal Strictures

Acquired strictures may occur due to chronic reflux esophagitis (peptic strictures), scarring at the site of surgical anastomoses, chronic foreign body entrapment, or following ingestion of a caustic substance. In children, stricture caused by malignancy is rare (see Table 16-1). Anastomotic and corrosive strictures may be aggravated by secondary gastroesophageal reflux. Anastomotic strictures are short, whereas those due to corrosive ingestion are often long and irregular. Peptic strictures are usually located in the distal third of the esophagus, and are generally quite short. They are therefore easier to manage than those due to caustic injury. Whatever the cause, however, the treatment of acquired strictures is similar. This chapter provides detailed description of the endoscopic management of strictures due to caustic ingestion, but the principles described apply for acquired strictures as well.

Table 16-1. Types of Esophageal Stenosis

Congenital
Membranous web or diaphragm
Fibromuscular thickening
Tracheobronchial remnants
Acquired
Anastomotic scarring
Chronic foreign body entrapment
Chronic peptic esophagitis
Caustic ingestion

Strictures Associated with Caustic Ingestion

Despite efforts at prevention, ingestion of caustic substances by children remains a common event. Although safety regulations have reduced the incidence in developed countries, the danger still exists and the variety of hazardous cleaning materials available has increased. In the developing world caustic ingestion represents a major public health issue. Injury is usually caused by strongly alkaline substances such as drain cleaners or gel products for dishwashers. These often have a sweet odor and attractive packaging, and are readily swallowed by young children. The consequences may be devastating esophageal scarring that prevents normal feeding. This has a huge and lasting impact on both child and family (Figure 16-1).[5]

The initial management is aimed at determining the extent and severity of injury (Table 16-2). All patients with suspected caustic ingestion should undergo an endoscopic examination of the esophagus under general anesthesia. This is carried out within 24 hours before edema and friability have become severe. Treatment depends on the degree and extent of injury. Patients with grade 1 injury do not require any specific therapy. Those with grade 2 or 3 injury should be observed closely in the hospital and require active management. There is controversy about the optimal treatment in such cases. The administration of prednisone (2 to 2.5 mg/kg/d for 3 weeks), although common practice, does not appear to prevent strictures.[6] Some have reported a moderately beneficial effect on inflammation and stricture prevention with dexamethasone (0.75–1mg/kg/d) and antibiotics (ampicillin 50 mg/kg/d).[7,8] If esophageal perforation occurs, then thoracotomy, esophagectomy, and subsequent esophageal replacement are necessary. About 20 to 30% of children with grade 2 or 3 injury develop esophageal strictures. The initial treatment for strictures is based on dilatation. All require long-term follow-up because esophageal carcinoma may occur later in life.

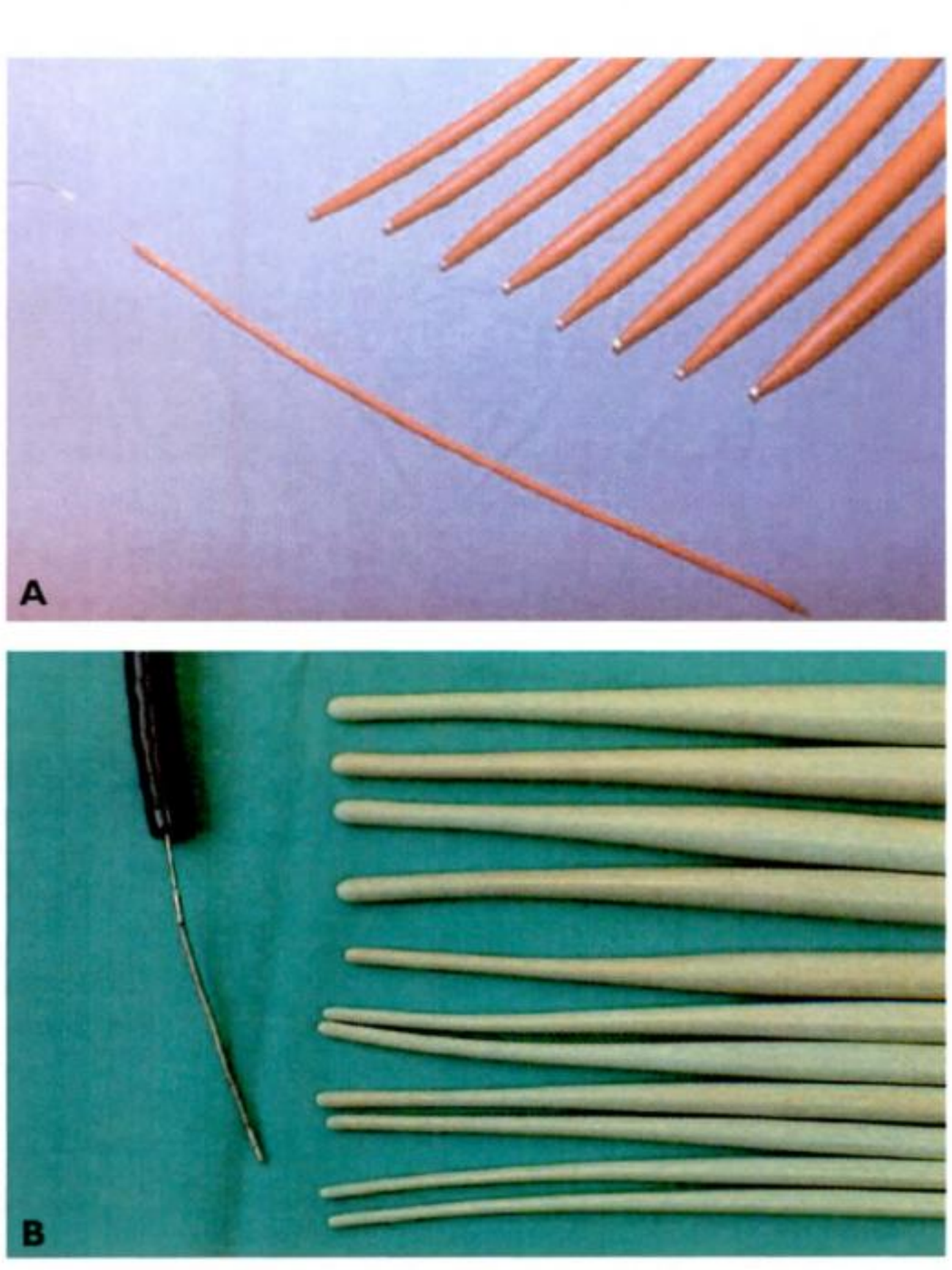

Figure 16-1 Dilatation bougies. A, Tucker rubber bougies. B, Savary bougies and their wire guide passing through the operating channel of the endoscope.

Development of Esophageal Dilatation

The use of esophageal dilatation was first described in the early 1700s when primitive dilating devices such as greased whale bone were employed. In 1837, Goodyear invented the technique for hardening rubber, and rubber dilators came into use. In 1902 Chevalier Jackson devised a rigid esophagoscope that allowed dilatation under direct vision. In 1924, Gabriel Tucker of Jefferson University in Philadelphia devised the technique of string dilatation, so that both antegrade and retrograde dilatation became possible. String dilatation is now a widely used method.[9]

Numerous dilators and techniques have been devised over the years. These include the mercury-filled dilators of Hurst and Maloney, Tucker retrograde bougies, Jackson silk-woven bougies, metal olives passed over a string or guidewire (as in the Plummer or Eder-Puestow method), Celestin neoplex dilators, Emerson Teflon dilators, Savary-Gillard dilators and Rehbein (Rush) dilators, and the American Dilatation System (Bard).

Table 16-2. Grading Severity of Caustic Injury

Grade I	Erythema and/or edema of the mucosa
Grade IIa	Noncircumferential ulceration involving less than $\frac{1}{3}$ of esophagus
Grade IIb	Noncircumferential ulceration involving more than $\frac{1}{3}$ of esophagus
Grade III	Circumferential ulceration/necrosis involving less than $\frac{1}{3}$ of esophagus
Grade IIIb	Circumferential ulceration/necrosis involving more than $\frac{1}{3}$ of esophagus

For many, wire guided techniques are the method of choice because they are undoubtedly safer.[10] Thus, the Rehbein, Tucker, and Savary-Gillard and American Dilatation System dilators are most commonly used in children. Some authors advocate the use of pneumatic balloon dilatation, and have reported good results with this technique. This type of dilatation may prove more effective than either antegrade or retrograde bouginage because the balloon applies a radially directed force stretching the stricture without applying a shearing force that could lead to mucosal avulsion.[11] However, in a comparative study of Savary-Gillard dilators and balloon dilators, no significant differences were found and both techniques were highly effective.[12] Savary-Gilliard dilators are easier to use and do not generally require fluoroscopic control.

Dilatation is usually recommended if there are radiological signs of stenosis or if the patient develops dysphagia. It is usually well tolerated but may need to be repeated for years. The process ruptures scar tissue, so that the walls of the esophagus can lie in normal contact with one another.

Esophageal Dilatation Following Caustic Injury

Following caustic injury of the esophagus, early dilatation ultimately increases the risk of perforation and does not prevent stricture formation. Treatment should begin 21 to 45 days after the injury.

With simple dilators or bougies the technique is straightforward. Flexible dilators are available in a range of diameters. At each treatment session, one or more may be passed down the esophagus. With the Rehbein and Tucker dilators, a silk guide is passed up the esophagus from the stomach via a gastrostomy. The silk string is drawn out through the mouth and the dilator is then tied to it. Antegrade dilatation is then performed. Dilatation may also be performed using wire-guided bougies. A flexible guidewire is passed endoscopically through the stricture. The endoscope is removed, and the wire left in place. The dilator is then passed over the guidewire and down through the stricture. If necessary several dilators can be passed sequentially using the same wire. The guidewire is then withdrawn. This approach can also be carried out using fluoroscopic guidance. To perform pneumatic dilatation, the stricture is viewed endoscopically, and the balloon dilator is passed down the instrument channel and advanced through the stricture. The balloon is then inflated with water or radiopaque contrast medium. Because the balloon has an oblong shape, pressure is applied along the length of the stricture (Figure 16-2).

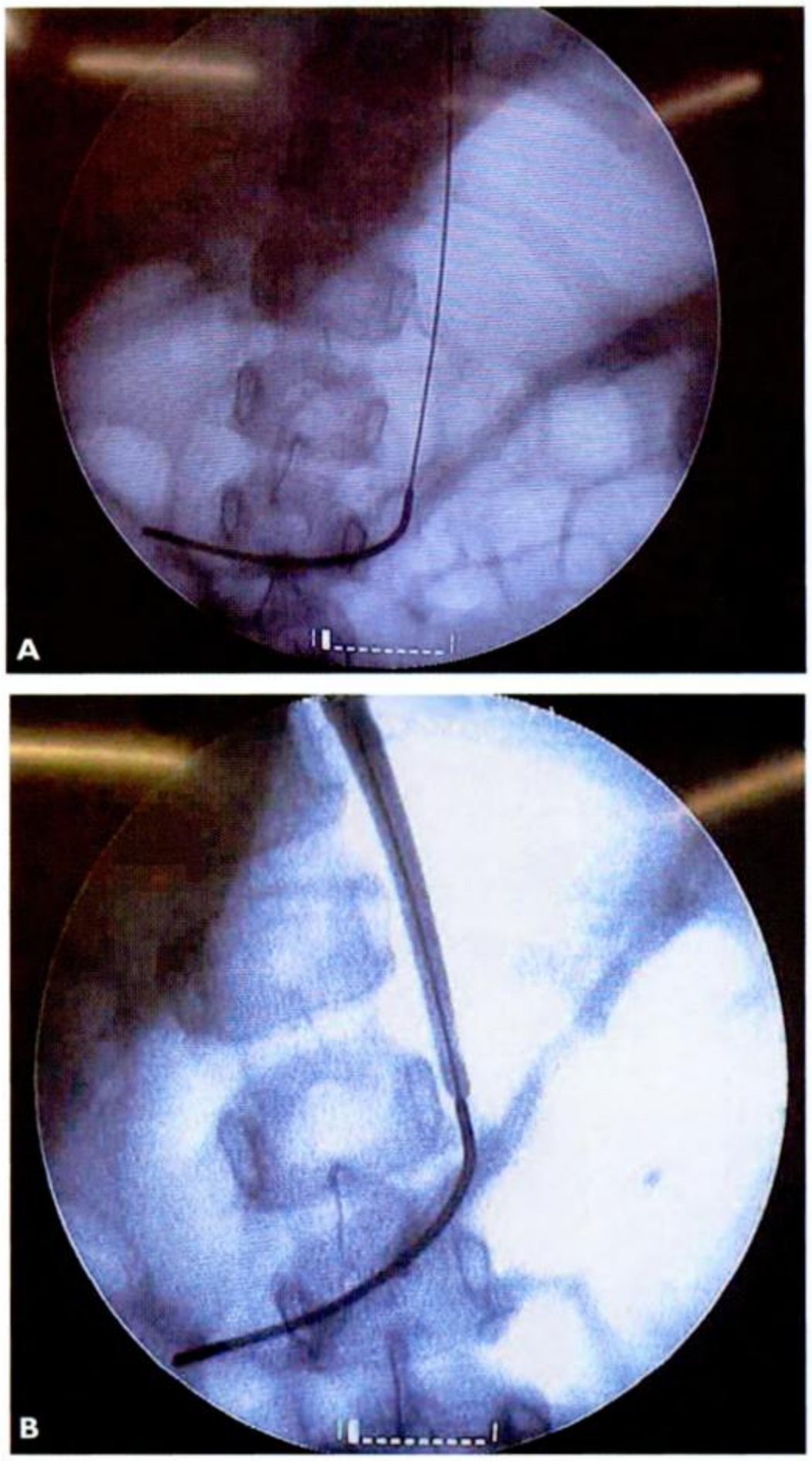

Figure 16-2 The dilatation of the stricture is checked fluoroscopically. A, Introduction of the wire guide into the stomach, beyond the zone of stricture. B, A Savary dilator is passed unto the wire guide.

Complications of Dilatation

Following dilatation of a caustic stricture, minor esophageal bleeding is to be expected. Low-grade fever often occurs immediately after the procedure. Mild chest or abdominal discomfortis common and does not necessarily indicate a significant complication.

Major complications are uncommon. If esophageal perforation occurs early recognition is crucial. The prognosis is generally favorable but antibiotics, restricting all oral intake, and providing parenteral nutrition are essential. If the diagnosis is delayed, there is a high risk that mediastinitis and pyothorax may occur and require surgical

drainage. If a perforation does occur, subsequent dilatations are permissable once healing has taken place.

Following severe caustic injury the esophagus may become shortened, pulling the gastroesophageal junction cephalad to the crus of the diaphragm. This alteration in anatomy may lead to secondary acid reflux. Furthermore, reflux may be increased by the need for frequent dilatation. Acid in the esophagus may interfere with healing and effective acid suppression with a proton pump inhibitor should be prescribed from the outset.

There are reports of brain occurring following dilatation.[13,14] Translocated bacteria may enter the cranium via the vertebral venous system—a known route for brain metastases.

Effectiveness of Dilatation

Dilatation is an effective management strategy for many patients with caustic strictures. Although results vary, up to 90% of patients have a satisfactory outcome, but many have undergone lengthy programs of dilatation with at least one dilatation annually. In a study of 932 children, 88% responded to dilatation, but the remainder required esophagoplasty.[15] When dilatation alone is ineffective, intramural steroid injection may be tried, but the outcome is without proven benefit. Local application of mitomycin immediately postdilatation may be an alternative means of reducing stricture recurrence.[16]

There is controversy regarding the appropriate criteria for surgical intervention and esophageal replacement. Some have suggested that those who require dilatation at intervals less than every 3 months should be considered for surgery;[15] whereas, others consider that surgery is indicated in patients who have failed a 6-month program of dilatation.[17]

Antibiotic Prophylaxis

Bacteremia was reported in 6 of 11 adult patients undergoing endoscopy with esophageal dilatation.[18] In another study that included 9 patients undergoing a total of 44 dilatations, bacteremia was detected following 33 procedures (75%).[19] However, in all but three patients, the bacteremia was transient and not associated with fever or complications. Alpha-hemolytic streptococcus (*Streptococcus viridans*) was the most commonly culterd organism. Despite the seemingly low risk of bacteremic complications, some consider antibiotic prophylaxis to be advisable.

Stenting

Stenting is a valuable technique for patients with severe and intractable esophageal stenosis. The development of self-expanding biocompatible stenting devices has greatly facilitated maintenance of esophageal patency.[20] The stent is placed using a specially designed preloaded applicator. The stent is loaded using a net-like device that compresses it within the applicator. A fine soft-tipped tube is inserted into the applicator to allow the passage of the guidewire. First, a routine dilatation is performed and the limits of the stricture are determined using fluoroscopy. Radiopaque markers are placed on the skin to check that the device will encompass the full length of the stricture. Radiologic guidance allows correct placement of the applicator and accurate release of the stent. Once the stent is open, the tube is extracted. Correct deployment is checked first using fluoroscopy and then endoscopy. Three days later a barium contrast study is performed. All patients are treated with acid-suppressing agents because acid reflux is known from esophageal pH studies to occur following this procedure. Three weeks later a second endoscopic examination is carried out to ensure that the stent is in the correct location and has remained patent. If there are no complications, the stent is left in place and the healing process continues with some variation up to 3 months.[20,21] Once the scarring process is complete, the stent is withdrawn using a foreign body forceps through either a rigid or flexible endoscope (Figure 16-3).

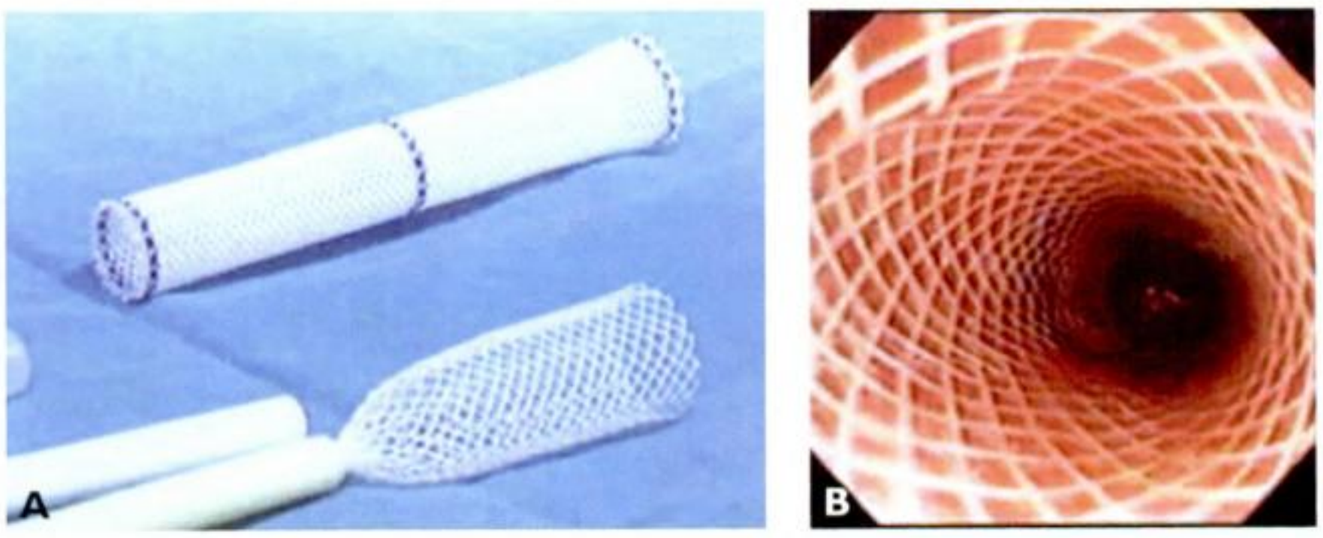

Figure 16-3 Stenting. A, Preparation: the stent is introduced into the applicator. B, The stent placed into the stenotic esophagus in a child with severe stricture due to the ingestion of caustics.

Achalasia

Achalasia is a primary motor disorder of the esophagus. Characteristically, the lower esophageal sphincter (LES) resting pressure is elevated, the sphincter fails to relax on swallowing, and esophageal peristalsis is impaired. These abnormalities are best demonstrated using esophageal manometry. In most cases the precise etiology is unknown. Inhibitory neurons in the myenteric plexus are lost resulting in unopposed stimulatory neural activity in the LES. Fewer than 5% of individuals with achalasia present before the age of 15 years and two-thirds of patients are male.[19]

Patients may complain of cough at night, dysphagia, and various other respiratory symptoms. Respiratory symptoms are particularly common in young children. The diagnosis may be suspected on a plain upright chest radiograph if an esophageal air/fluid level is present and there is no air in the stomach. Barium contrast radiology demonstrates esophageal dilatation, impaired peristalsis and a narrowing (beaked appearance) at the LES.

In children, balloon dilatation of the LES is often tried, but the results appear to be poor. If symptoms continue after 4 to 6 sessions of dilatation, surgery is required. Medical treatment with agents such as calcium channel blockers or botulinum toxin is of limited and temporary value.[22] Botulinum toxin has been widely used because it impairs the smooth muscle response to acetylcholine. Several controlled studies have shown that it is effective in the short term. It reduces lower esophageal sphincter pressure, improves esophageal clearance, and alleviates symptoms in up to 70% of patients; however, its effectiveness decreases with time and repeated injections are often necessary. It should therefore be reserved for children in whom the risk of surgery is high such as those with severe malnutrition. Most children with achalasia eventually require myotomy. Gastric fundoplication may also be perfromed along with the myotomy.

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Ingested Foreign Bodies

17

J.P. Olives

Infants and young children explore their environment by placing objects in their mouth; and consequently ingestion of foreign objects is common.[1–10] Most studies show that foreign bodies are ingested by an equal number of boys and girls[2] or a slight prevalence of boys;[3] although one prospective study did report that 60% were female.[5] About 10% of children are recidivists. In only 51% of the cases is ingestion witnessed,[5] and so the true incidence is probably underestimated. The majority of ingested foreign bodies do not cause symptoms. Death caused by foreign body ingestion is rare, as demonstrated in a large series reporting no deaths among 852 adults and only one death among 2,206 children.[7–10] Esophageal foreign body impactions should be dealt with without delay given the risks of aspiration or perforation, but objects that reach the stomach are likely to be eliminated within 30 days.[2,6] Complications are more likely with large (> 5 cm in length and > 2.5 cm in diameter) or sharp objects, and cetain specific objects such as batteries may pose a special hazard.[2,3] Passage of the object is more likely to be hindered at certain anatomical sites such as the cricopharyngeal ring, aortic arch, lower esophageal sphincter, pylorus, curve of the duodenum, ligament of Treitz, a Meckel's diverticulum, the ileocecal valve, appendix, or rectosigmoid junction.[2,3,9] Conditions such as esophageal stenosis, achalasia, or previous abdominal surgery may also impair spontaneous passage of foreign bodies.

Pharyngeal and Cricopharyngeal Foreign Bodies

Coins, tokens, toy parts, or fish bones often lodge in the pharynx, or at the level of cricopharyngeal ring.[2,11] Standard fluoroscopy is useful in detecting metallic objects, and a plain radiograph with both anterior-posterior and lateral views. Flat objects (such as coins or tokens) that lodge in the hypopharynx, are seen on edge in the lateral film of the neck, whereas those in the upper airway are seen on edge on the frontal film. Coins and flat objects often are easily removed using a Magill forceps, a Foley catheter, a magnet or by suction retrieval.[3,8,12–14] Fish bones can usually be extracted with a curved forceps or long tweezers.

Esophageal Foreign Bodies

Objects less than 2 cm in diameter, will usually pass readily into the stomach.[2,3,6,15,16] Long or sharp objects are most likely to be retained in the cervical esophagus, at the level of aortic arch or just above the lower esophageal sphincter. The type of ingested foreign body varies with age. In young children, coins, toy parts, crayons, jewelry, and ballpoint pen caps are more common; whereas, in older children, meat bolus or bone impaction are more common.[2–10,15–17]

Symptoms

Common symptoms of impaction include choking, hoarseness, refusal to eat, vomiting, drooling, sometimes with bloodstained saliva, or respiratory distress. Older children can usually state what they have swallowed and may point to the site of discomfort. In young children or those unable to communicate, sudden refusal to swallow, increased salivation, wheezing, or respiratory distress should raise concern. Long-standing esophageal impaction may present with a swelling in the neck, chronic cough, stridor, or dysphagia. Swelling, erythema, tenderness, or crepitus in the neck region should raise concern about oropharyngeal or proximal esophageal perforation.[2]

Diagnosis

Plain radiographs identify most foreign objects and the complications associated with ingestion. Plain films of the neck, chest, and abdomen should be taken, again in both anterior-posterior and lateral views. More than one object may be identified.[2,3,7,18,19] The lateral projection distinguishes objects lodged in the esophagus from those in the airway.

Handheld metal detectors may be useful in finding swallowed metallic objects and may be of use as a screening tool in pediatric patients.[20,21] In some cases contrast radiology may be helpful in demonstrating or locating a foreign body.[18] Computed tomography (CT) scanning may occasionally be necessary, but it may be misleading if the object is radiolucent. CT images may be enhanced by using 3D reconstruction.[9,19]

Treatment

The management of esophageal foreign bodies are influenced by the child's age, size, and by the shape, and number of ingested objects, and the anatomic location of objects. The technical capability of the endoscopist and the instruments available may also influence the management strategy. For ingestions of coins, nonintervention may be appropriate. Two studies proposed management based on the radiologic location of the coin.[22,23] If it is located in the upper third of the esophagus (including the cricopharyngeal region) it should be removed as soon as possible. If the child is asymptomatic and it is lodged in the lower esophagus, a repeat radiograph should be obtained in 12 to 24 hours because many enter the stomach within 24 hours.[24] Maksimak and colleagues reported that children without symptoms should be treated conservatively with observation and sips of water or clear liquid to promote passage of the coin.[25] This protocol was successful in 83% of patients (18/21 children).[25] If the coin remains in the esophagus after 24 hours, it should be retrieved. If the coin is located below the diaphragm, the child may be discharged with instructions to the family to examine the stools carefully to confirm passage of the coin. If after a week the coin has not passed an abdominal radiograph should be obtained to determine its location. If the coin remains in the stomach for 4 to 6 weeks, or if in the judgment of the endoscopist the location makes it unlikely that it will pass from the stomach, endoscopic retrieval should be performed.[2,3,24]

Endoscopic retrieval of a foreign body from the esophagus is best performed under general anesthesia with endotracheal intubation to protect the airway.[2,16] If this is not possible, the patient should be placed in theTrendelenburg position reduce the risk of items entering the trachea.[16] To grasp the object, the rat-tooth or alligator forceps is best. The use of a "through-the-scope" balloon is rarely necessary, but can assist removal of a foreign body. Blunt objects, such as marbles, that cannot be grasped may be removed easily under direct vision using esophageal dilating balloons or a Roth retrieval net—a polypectomy snare with a net that can also be used to capture round or oval objects.[2,15,16] If there is difficulty retrieving an esophageal foreign body of less than 2.0 cm diameter and 5.0 cm length, gently advancing the object into the stomach should allow it to pass through the gastrointestinal tract.[2,3,9] If endoscopy is not available, an alternative for coins and other blunt objects in the esophagus invloves the use of a Foley catheter.[26,27] A magnet may also be used for blind removal of metallic objects. The disadvantage with these techniques is that it may be dangerous with sharp objects. Blind retrieval without a protective overtube may damage the esophagus. Also, there is a risk that the object might enter the airway, if it is dislodged while being drawn through the cricopharyngeal sphincter. Nevertheless, one study reported successful removal of metallic foreign bodies in 34 of 36 patients using a magnetic orogastric tube.[28]

Sharp or elongated objects may be difficult to manage. The open safety pin is a potentially dangerous problem. If it lies in the esophagus with the open end facing proximally, it can be pushed into the stomach endoscopically, and then turned about for safe retrieval by grasping the hinged end. Placing an umbrella-type shield on the end of the endoscope will protect the esophagus. An alternative method is to attempt to close the pin using a polypectomy snare. The closed pin, once in the stomach, will pass without difficulty. A straight pin that is longer than 5 cm may fail to pass through safely, and duodenal perforation has been reported leading to hepatic hemorrhage or infection.[2,6] Methods used to assist in the removal of pins have included rigid esophagoscopy, the use of overtubes, rubber hoods and even a piece of rubber glove.[2,15,16]

Radiolucent objects such as glass, aluminum, plastic, and wood may be difficult to locate.[16] If the patient complains of persistent pain with swallowing despite a 6 hour fasting period, endoscopy should be performed.[16]

Complications

Examination of the esophagus in children with coin ingestions of less than 24 hours duration usually shows a normal mucosa or at most slight redness or abrasions.[2,3] The risk of complications, such as perforation, increases with time.[2,15,16] The symptoms of perforation may be acute and obvious or the process may be initially asymptomatic and so go unrecognized. A CT scan may be useful in locating impacted fish bones and radiolucent objects, as well as demonstrating tissue swelling or abscess formation.[19]

Gastric and Intestinal Foreign Bodies

Most gastrointestinal foreign bodies can be managed conservatively. Placing the patient in the right lateral

decubitus position for several hours may facilitate passage from the stomach. The progression of opaque objects can be followed by serial radiographic studies, but daily examination of stools using a strainer is important to demonstrate passage of radiolucent objects. Removal of sharp objects or those failing to progress from the stomach or proximal duodenum must be considered.

Disc Battery Ingestion

The disc or button battery is often found in many electronic products including watches, photographic equipment, toys, hearing aids, car keys, calculators, and even in musical greeting cards.[2,29] Although these are sealed, they contain corrosive and toxic chemicals. Prolonged contact with the esophageal mucosa can lead to mucosal damage. Exposure to gastric acid may increase the risk of leakage of the battery cell contents.[30] There are four main types—mercury, silver, alkaline manganese, and lithium. Lithium cells exhibit a higher potential of 3V compared with 1.5V for others, but lithium batteries are also more resistant to corrosion. Used batteries are potentially less toxic than new ones. Discharged cells are less likely to leak or cause tissue injury, and, in discharged mercury cells, the mercuric oxide is largely converted to non-absorbable elemental mercury.[22,31] Esophageal injury is attributable to (1) electrolyte leakage; (2) alkali exposure causing liquifaction necrosis; (3) mercury toxicity; (4) pressure necrosis; and/or (5) direct flow of current causing a low-voltage burn.[2] Esophageal damage occurs rapidly, potentiallywithin an hour of ingestion. Within 4 hours, there may be injury to all layers of the esophagus. More severe damage is produced by the lithium battery, and injury may occur within 15 minutes.[2]

Symptoms

Frequently there are no immediate symptoms following button battery ingestion. Some children may exhibit coughing or retching, nausea, vomiting or chest or abdominal discomfort.[2]

Diagnosis

The battery may be distinguished from a coin on a plain radiograph by a characteristic double-density shadow in the anterior-posterior view. On lateral films, the edges of the battery appear round with a step-off at the junction of anode and cathode.

Treatment

Vomiting should not be induced because this could lead to aspiration or to retrograde displacement of the battery from the stomach into the esophagus. Vomiting may also increase the risk of gastroesophageal perforation if the battery has already caused injury to the gut wall.[2] Administration of neutralizing solutions or charcoal is not beneficial. The treatment protocol recommended in one very large study (the Button Battery Study) advocates that nothing should be taken by mouth and a radiograph should be obtained to determine the location of the battery.[22] If it is lodged in the esophagus, it should be removed immediately.[2,22,30] Endoscopic retrieval success rates range from 33 to 100%. In children, endoscopic removal should be performed under general anesthesia using a polyp snare, a Roth retrieval net, a basket, or a through-the-endoscope balloon.[2] Endoscopy also permits an assessment of any esophageal injury. If endoscopy is not available, successful removal has been reported using a Foley catheter, balloon, or magnetized catheter. Batteries in the esophagus or the stomach have been extracted with a magnet attached to an orogastric tube.[30] Some recommend that if the battery has moved to the stomach or more distally in the gut, an expectant approach may be followed. The child is discharged from the hospital and allowed a normal diet. The family are advised however to report the development of any significant symptoms. The stools should be carefully examined using a strainer, to confirm passage of the battery. A prokinetic agent such as metoclopromide or a laxative may hasten transit. If the battery remains within the stomach for more than a week it should be retrieved by endoscopy. If it fails to move along the intestine or if significant symptoms develop then it may require surgical removal.[2]

Complications of Battery Ingestion

Complications of battery ingestion have included the development of a tracheoesophageal fistula, perforation and stricture formation, and fatalities have been reported.[2,22,32] Batteries have lodged in a Meckel's diverticulum leading to perforation.[2] Mercury toxicity is a potential risk, but appears to be rare, with only one mild case reported.[22]

Food Impaction

Food impaction may occur in children with an esophageal stricture or a motility disorder. This may lead

to distressing symptoms and an inability to swallow oral secretions, so that urgent intervention is necessary. If the child's symptoms are less severe it may be possible to defer treatment, because food impaction often resolves spontaneously.[16] However, if symptoms persist for more than 24 hours endoscopy is advised.[6,10,15] The initial examination verifies and locates the impaction. The food bolus may be removed, although this may have to be done in piecemeal fashion.[9] An endoscope overtube may facilitate repeated passage of the instrument, and may protect the mucosa and reduce the risk of aspiration. The application of a cautery current via a bipolar snare has been reported to facilitate cutting, grasping and retrieval of food boluses in the esophagus.[33,34] There is one report in which endoscopy was avoided by using a carbonated beverage (Coca Cola) to "digest" a food bolus trapped above an esophageal stricture.[35]

Conclusion

When children present following ingestion of a foreign body a careful and immediate evaluation is required. A decision should be made as to whether action is needed to retrieve the object, or whether an expectant approach may be safely followed. There are various techniques available for removal of foreign bodies, though endoscopy is often the preferred method. Advances in endoscopic equipment has made retrieval of foreign bodies easier. Knowledge of the object and the equipment that is available are critical factors in leading the endoscopist to making the decision about immediate retrieval or whether to let the object pass through the gastrointestinal tract.

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such as a disk is passed over the external tube, and this holds the tube at the abdominal wall so that it cannot slip back into the stomach. It is important to ensure that this device is not so loose as to be ineffective or so tight as to cause pressure damage.

The tube is now cut to the desired length and an adaptor plug is inserted. A small amount of iodinated disinfectant may be applied to the external retaining device. A dry dressing is applied to the site. Finally, the endoscope may be reinserted to confirm that the inner retaining device is functioning correctly, and to ensure that there is no bleeding.

Postoperative Management

In the immediate postoperative period the patient's general condition is monitored and the abdomen is examined for signs of peritonitis or pneumoperitoneum. Most children require some analgesia during the first two days. For one week, daily aseptic cleaning of the site is performed and a sterile dressing is applied. Subsequently, simple washing is sufficient and a dry dressing may be placed over the outer collar. Occlusive dressings are not recommended because they may increase the risk of local infection. The gastrostomy tube can be used within a few hours of insertion. In case of leakage, some prefer that the first infusion consists of sterile saline solution.

Patients and their families must be trained in the correct care of the gastrostomy (Table 18-2). The skin surrounding the stoma should be washed each day with warm water and a neutral soap. Afterwards the skin is carefully dried. Gastrostomy tubes should be rotated each day. Administration of medications and infusion of enteral feeds should take place separately. Drugs can be given either as liquid formulation or, if appropriate, as finely ground water suspensions. If the gastrostomy tube becomes blocked, an attempt may be made to gently force some warm water (40°C) through using a small syringe (eg, 10 to 20 mL).

Table 18-2. Practical Recommendations for Patients

A gastrostomy should not interfere with daily activities (feeding, washing, bathing, and swimming).
The gastrostomy site does not require daily dressing.
Children can safely lie prone and can move about normally.
After use the tube or button should be rinsed through with 10 to 20 mL of water to prevent blockage.
The gastrostomy site rarely becomes infected after the first 3 days. Redness or a serous discharge usually requires just simple dressing.
The gastrostomy tube or button should be rotated through 180 degrees each day.
Accidental dislodgement requires urgent replacement, because the fistula may close up within hours.
Keep a spare button available for urgent replacement if necessary.
Internal gastrostomy balloons should be filled with water (not air).

Long-Term Gastrostomy Management

A gastrostomy tube may last for a long time, but it is best to replace it every few months. Old tubes tend to deteriorate, becoming fissured and porous, colonized with organisms such as candida, and prone to obstruction. If a gastrostomy tube falls out or has to be removed, it should be replaced without delay because the tract very soon narrows—sometimes within hours. If this happens, dilatation of the tract may be necessary. Most replacement tubes are retained by a water-filled balloon. These balloons are prone to leakage and rupture, and this often requires frequent tube replacement.

If a gastrostomy tube is intentionally removed, spontaneous closure of the fistula usually occurs rapidly. The fistula closes in less than one month in about 75% of patients. Persistence of the fistula may occur in patients prone to aerophagy.

Replacing the Gastrostomy Tube with a "Button"

After a period of 2 months or more, when the gastrostomy tract has healed, the gastrostomy tube can be replaced by a more convenient device know as a "gastrostomy button." This device lies flush with the skin on the outside, and so provides a more acceptable and less obtrusive means for accessing the gastrostomy. It consists of a short tube, just sufficient to traverse the tract, with some form of internal retaining device. This may be an externally inflatable balloon, or alternatively a self-expanding dome-shaped retainer. When inserting the latter type of button, an obturator is pushed down into the button stretching it lengthwise, so that the dome narrows allowing passage of the device through the tract. Once the button is in place, removal of the obturator allows the dome to expand automatically, thereby holding the button securely in place. Buttons are available in a range of sizes and lengths.

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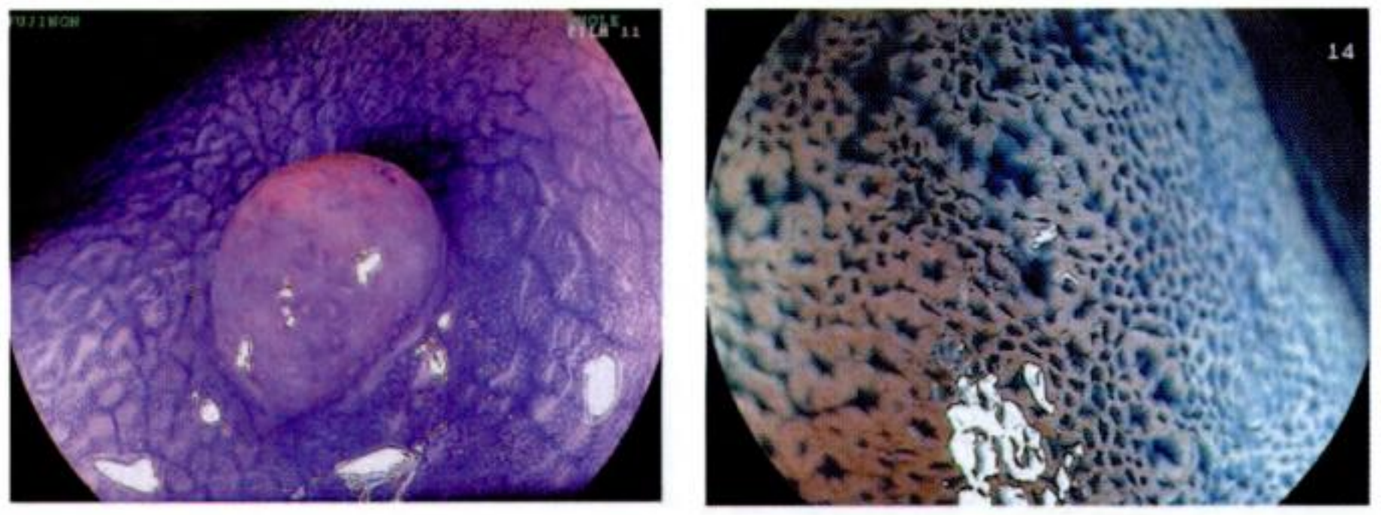

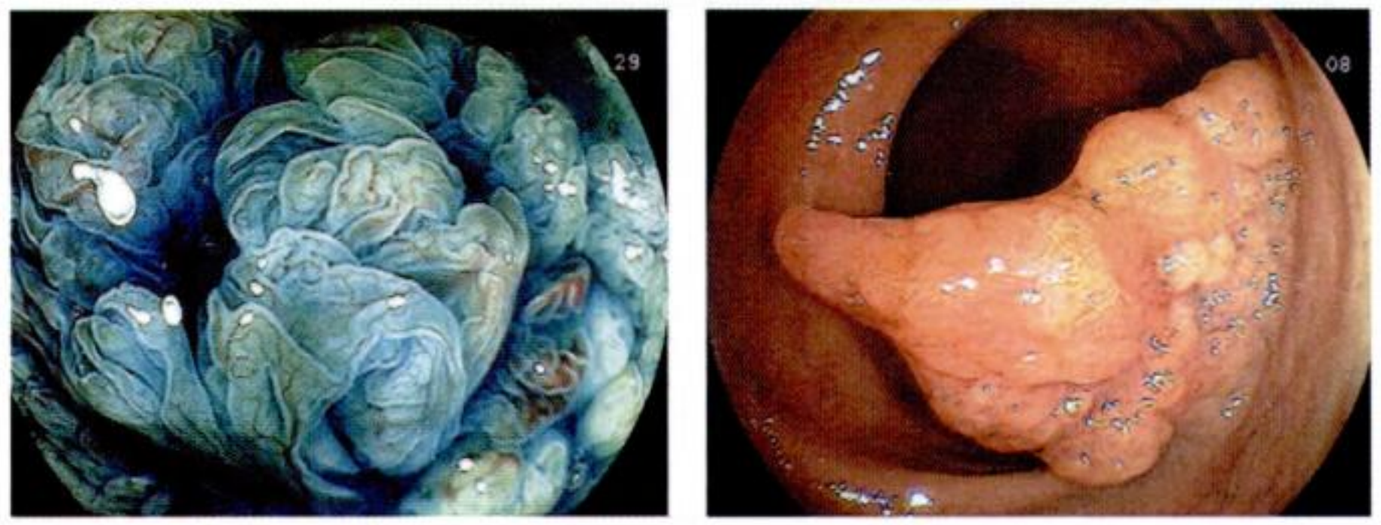

Figure 19-13. High resolution endoscopy of colonic polyps (Courtesy of Fujinon Inc).

Table 19-3. Pit Pattern Classification

Type	Pit Pattern
Type I	Round pits
Type II	Stellar or papillary pits
Type IIIS	Small tubular or roundish pits
Type IIIL	Large tubular or roundish pits
Type IV	Sulcus-, branch-, or gyrus-like pits
Type V	Irregular (type VI) or nonstructural (type VN) pits

Table 19-4. Postpolypectomy Surveillance Colonoscopy Recommendations of the Agency for Health Care Policy and Research Consortium

Findings at Index Examination	Surveillance
Single tubular adenoma	5 years
Multiple adenomas or villous histology	3 years
Numerous adenomas	Consider 1 year
Large sessile adenomas	3 to 6 months to examine the site

frequency monopolar or bipolar cutting and coagulation, the Endo-Cut mode permits controlled cutting during polypectomy. Cutting is divided by software into cuts and pauses in such a way that coagulation occurs during each pause (Figure 19-14). In addition, the Endo-Cut mode is supported by the power peak system, or PPS, which automatically releases dynamic, millisecond bursts of additional power as required; Endo-Cut allows a controlled section with reproducible coagulation effects. Once polypectomy has started, the delivery of energy must be continuous while the assistant slowly tightens the snare. Most electrocautery snares are monopolar because bipolar snares do not provide an important advantage.

Preparation Phase

Any personal or family history of a bleeding disorder should be identified. Information about the use of aspirin or anticoagulants should be sought. Platelet count, bleeding time, prothrombin time, and clotting time should be obtained. If a coagulopathy is present, it should be treated before polypectomy.[8] Polypectomy requires cleansing of the colon (Chapter 5, "Patient Management"). Fermentable sugars such as mannitol are contraindicated due to the risk of an intracolonic explosion.[9] Poor bowel preparation is also a contraindication to polypectomy.

Carbon dioxide insufflation prevents explosion.[9] With adequate bowel cleansing, however, most do not use CO_2.

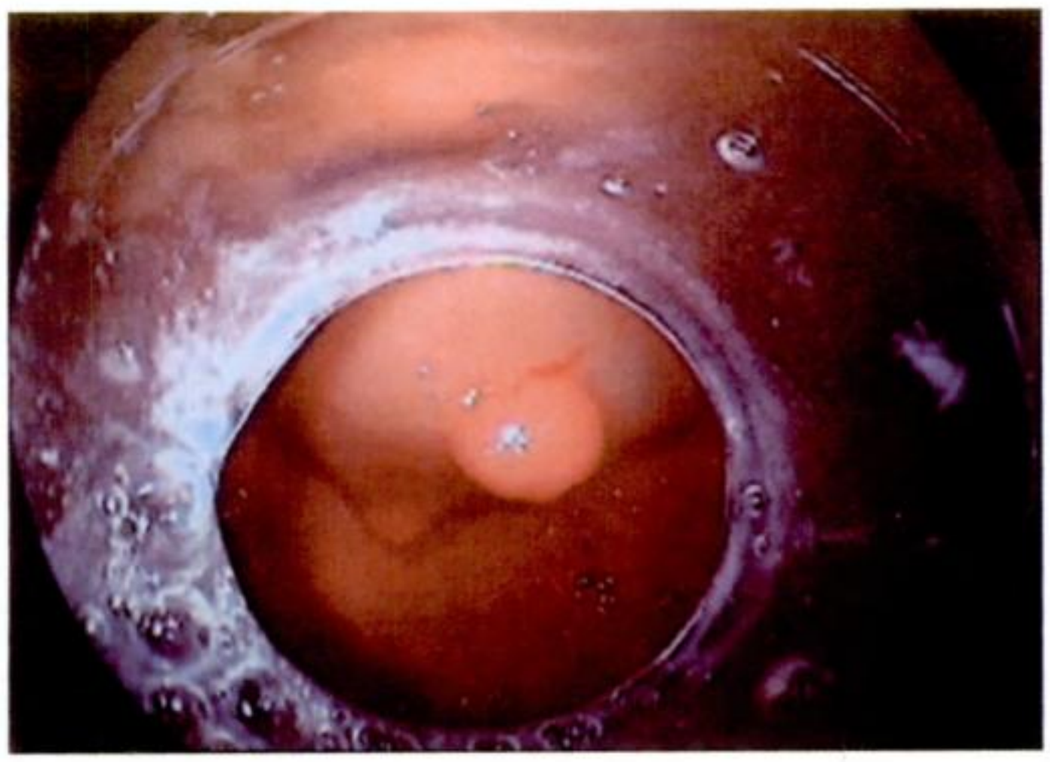

Figure 19-27. Endoscopic mucosal resection of a sessile gastric polyp using a transparent cap device: bleb after saline submucosal injection.

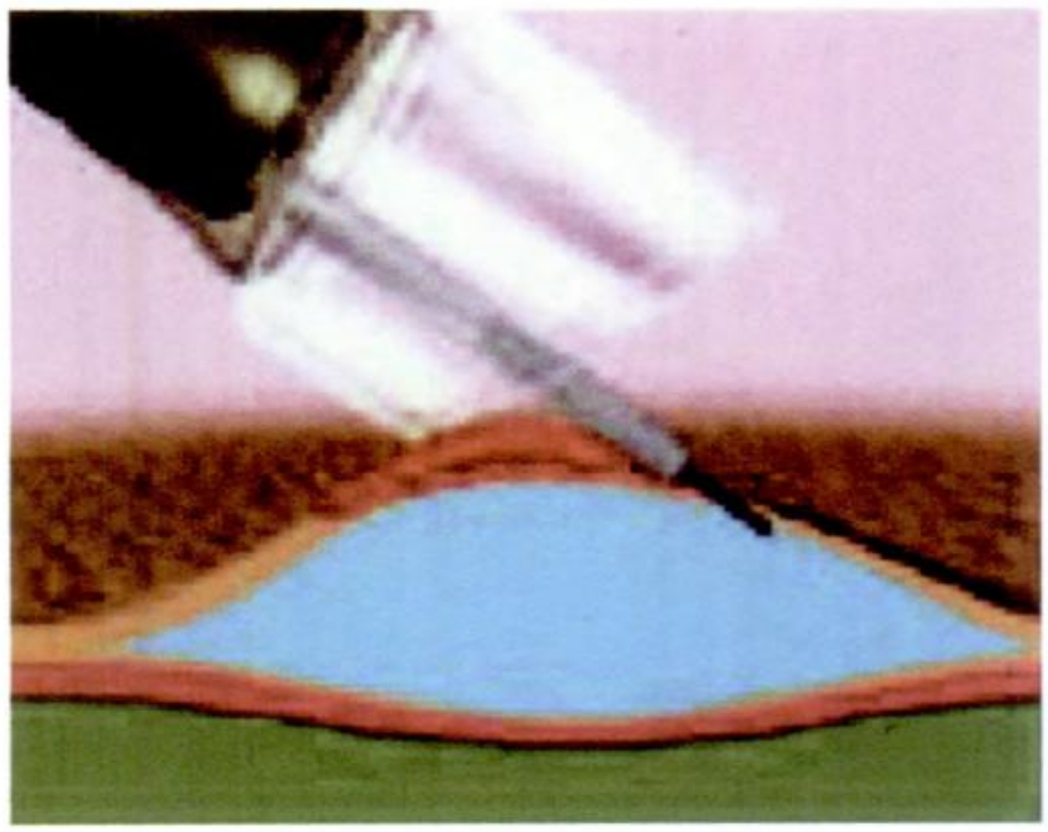

Figure 19-28. Endoscopic mucosal resection (EMR)-C step 3 (Olympus Inc).

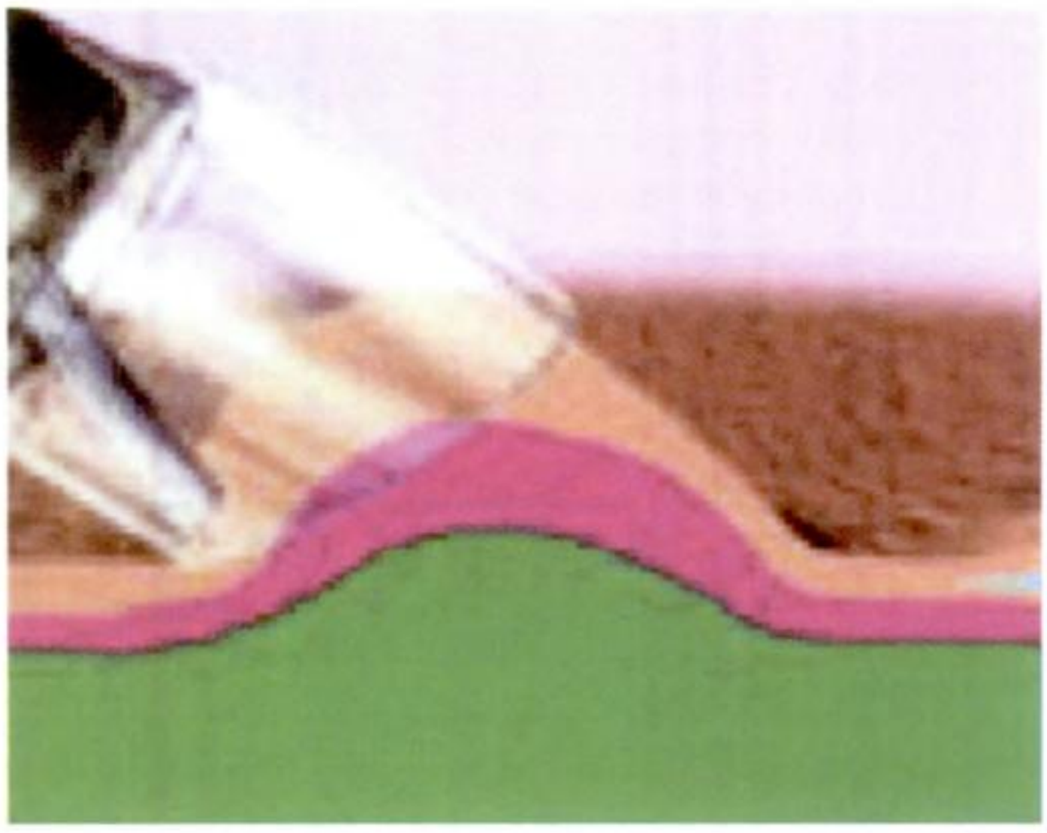

Figure 19-29. Endoscopic mucosal resection-C step 4 (Olympus Inc).

- Step 6: The pseudopolyp is cut using blended-current electrocautery (Figure 19-32). The resected specimen can be removed by retaining it in the cap.
- Step 7: The smooth surface of the muscularis propria layer is visible at the base of the ulcer. If a large vessel is seen, a hemostatic clip should be applied to prevent bleeding (Figure 19-33). Dye spraying is useful to confirm complete resection of the lesion.
- Step 8: If additional resection is necessary for complete removal, all of the above steps, including saline injection, are repeated. A straight-cut medium-sized cap with a rim (Olympus MH595) is used.

EMR Band Ligation Technique

EMR using a variceal ligating device (EMR-L) is derived from the endoscopic variceal ligation technique developed by Stiegmann and colleagues.[19] It is simple and safe, but is only suitable for resecting relatively small lesions (Figure 19-34) (about 10 mm), owing to the small capacity of the ligation cap.[20]

The initial steps, including mucosal staining, marking the area and creating a cushion by submucosal injection of normal saline are the same as that for the EMR-C procedure. Then the endoscope is withdrawn and fitted at the distal end with a ligation friction adaptor, preloaded with a rubber band. The abnormal mucosa is suctioned into the ligator device and the

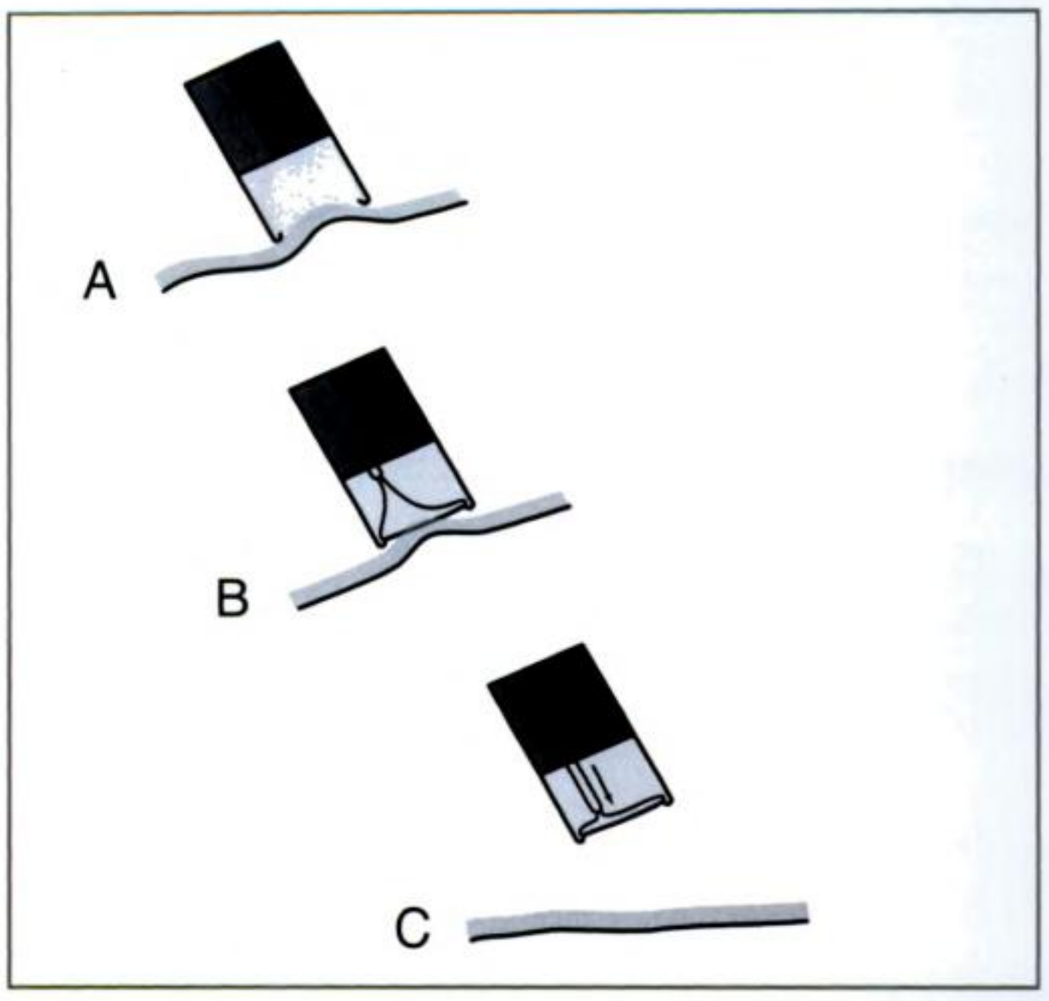

Figure 19-30. Prelooping process. *A*, aspirate the normal mucosa and seal the outlet of the EMR-C cap. *B*, open the snare wire as it passes along the rim of the cap. *C*, completion of the process.[18]

rubber band applied. The endoscope is again withdrawn to remove the ligator device. The pseudopolyp created by the rubber band is inspected endoscopically to ensure that it contains the lesion. An electrocautery snare is placed just above the rubber band and the pseudo-polyp removed as with standard polypectomy. Retrieval is carried out by suctioning the polyp onto the endoscope tip or by using the Roth basket or a grasping forceps. A disadvantage of this technique is that it requires repeated endoscopic intubation.

Histopathological Assessment

EMR procedures can provide the entire lesion for histologic evaluation. The resected specimen is stretched and fixed on a rubber plate using fine needles, and then immersed into a 10% formalin solution. Semi-serial sections allow determination of the depth of extension of the lesion. In EMR, the dissection plane usually includes two-thirds of the depth of the submucosal layer.

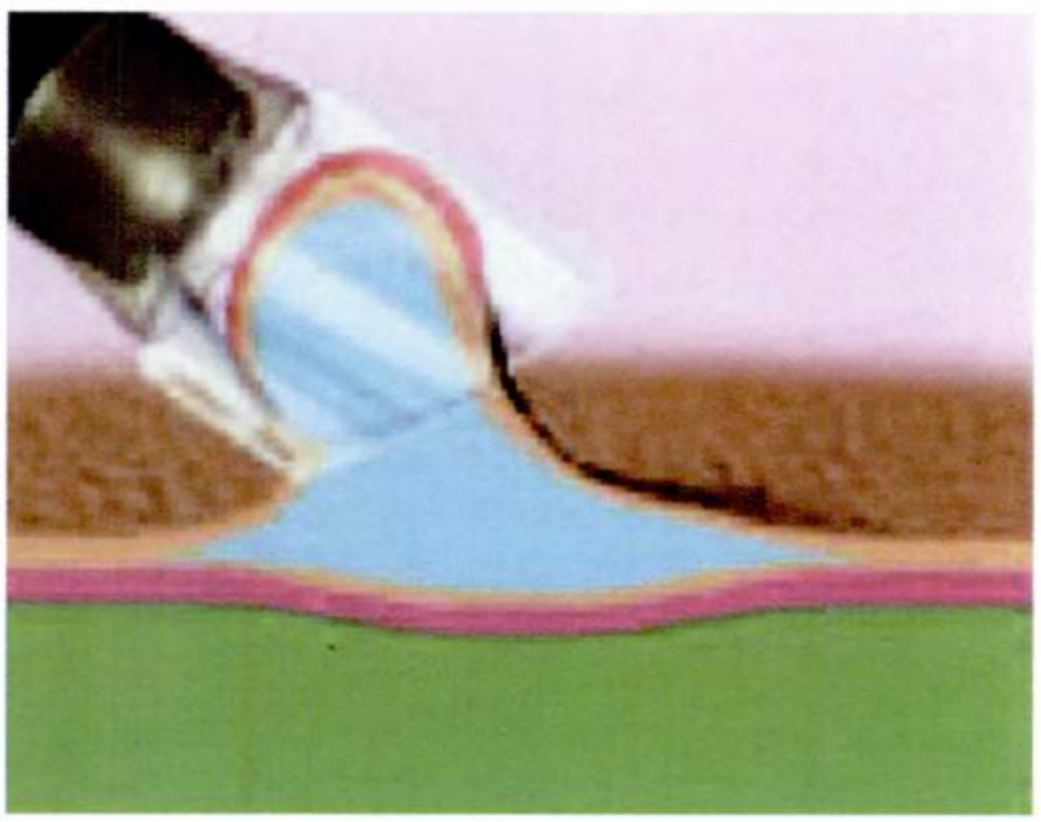

Figure 19-31. Endoscopic mucosal resection (EMR)-C step 5 (Olympus Inc).

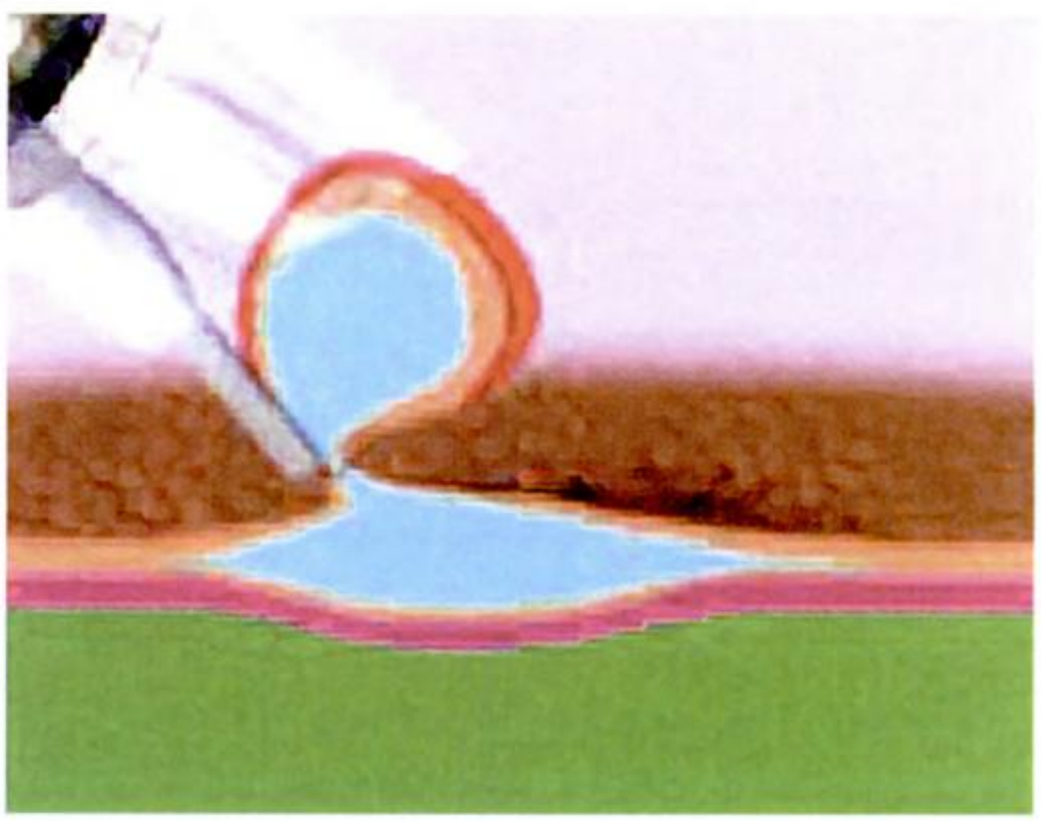

Figure 19-32. Endoscopic mucosal resection (EMR)-C step 6 (Olympus Inc).

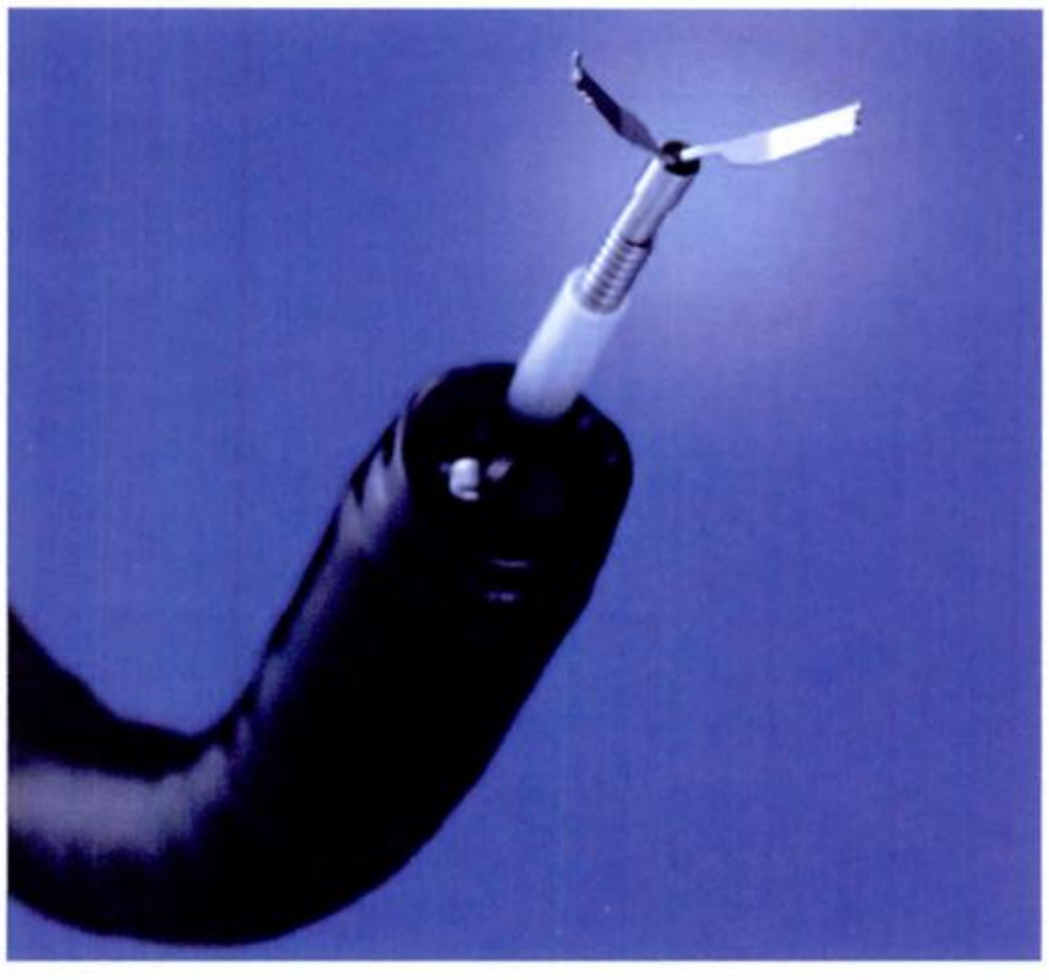

Figure 19-33. Endoscopic mucosal resection (EMR)-C: Hemostatic clips (Olympus Inc).

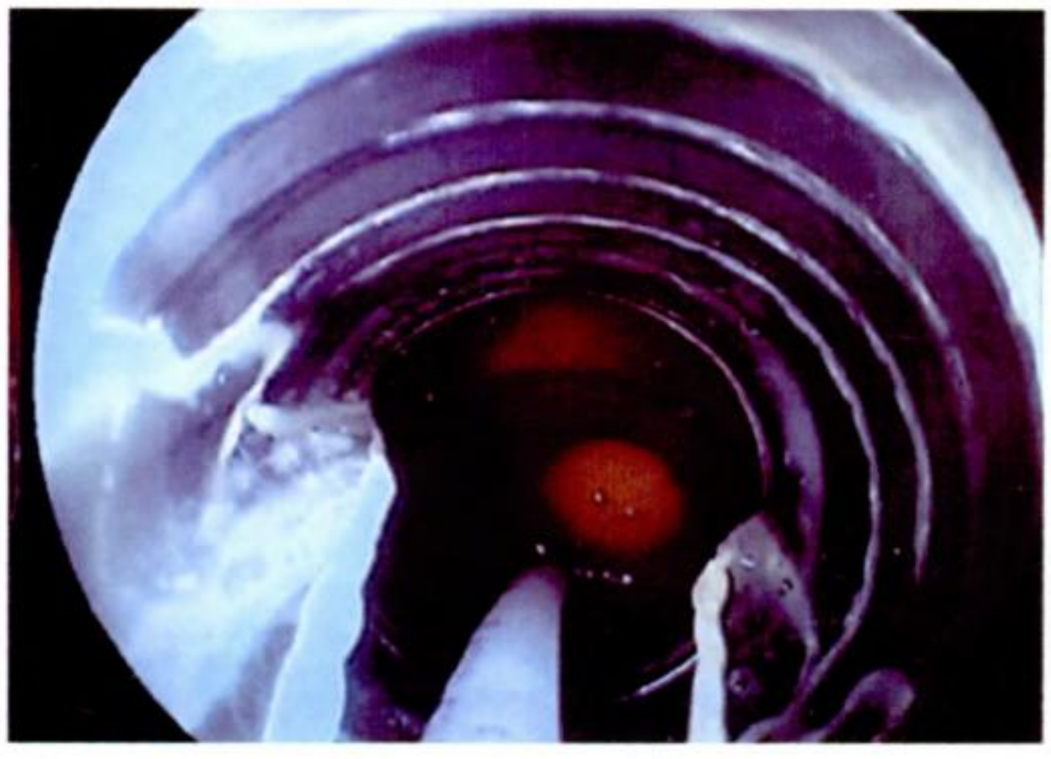

Figure 19-34. Endoscopic mucosal resection using variceal ligating device.

Healing After EMR

Immediately after the EMR procedure, treatment with a mucosal protective agent is started. Antibiotics are given intravenously for 2 days, and orally for 7 days. Mild retrosternal pain and throat pain resolve within a few days.

By day 3, a fibrinoid coat covers the ulcer. Within 4 weeks, the ulcer heals.

Prevention and Treatment of Complications

Perforation

Prevention of perforation requires placement of the saline injection to avoid muscle involvement. Only a large-volume injection will create a cushion sufficient for safe snaring of the mucosa. The elevated mucosa must not be snared at the base. Special care should be taken with EMR in certain areas of the GI tract. At the lesser curvature in the upper and middle thirds of the stomach, the mucosa has a limited capacity to stretch. This requires the use of a small-volume cap or reduced suction. In the colon, the muscle layer is thinner than in the other parts of the GI tract.

Bleeding from the Ulcer Bed

In the esophagus, submucosal injection of a low concentration epinephrine saline solution is recommended, whereas in the colon, pure saline is adequate to control bleeding. If arterial bleeding occurs, particularly in the stomach, hemostatic clips should be applied (see Figure 19-33).

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Pediatric Gastrointestinal Endoscopy

Textbook and Atlas

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Jean François Mougenot, MD
Samy Cadranel, MD

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Focusing on practical diagnostic and therapeutic endoscopy in children, this unique work perfectly integrates clinical gastrointestinal endoscopy with expert pathology. The extensive use of line diagrams, color illustrations of endoscopic appearances, and complementary histopathology creates a definitive reference resource for pediatric gastroenterologists and pediatric surgeons. The combined medical and surgical expertise of the authors, from renowned centers, provides both North American and European perspectives.

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