The endoscope

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This article is an overview of the development of modern endoscopes, beginning with the introduction of fiber-optic endoscopes in the 1960s. Starting in the early 1990s, fiber-optic imaging was rendered largely redundant by ''video chip'' endoscopes with charge coupled device (CCD) sensors. Videoendoscopy freed the endoscopist from the slavery of the eyepiece and the teaching head, an attachment screwed onto the instrument to allow others (one at a time) to share the experience. The image quality of CCD-based instruments has undergone progressive refinement that parallels the development of digital cameras. The modern digital cameras, available everywhere for prices starting at a few hundred dollars, have amazing resolution, thanks to the progressive miniaturization of the light-sensing ''chip.'' The early limitations of color imaging with CCD chips, which required synthesis of primary colors produced by a rotating wheel, have given way to true ''color chips.'' A recent modification of CCD technology (complementary metal oxide semiconductor [CMOS]) may reduce the cost and increase the quality of video imaging. A growing number of image manipulation techniques, from magnification and chromoscopy to optical biopsy and confocal microscopy, will be discussed in subsequent articles. These technologies are designed to increase the diagnostic yield (''extend the reach'') of modern GI endoscopy. GI endoscopy has come a long way: happily, there is no argument about the influence of ''intelligent design'' in this particular evolution!

IN THE BEGINNING . . .

In the 1840s, it was demonstrated that light could be guided along curving jets of water for fountain displays. In 1854, the British physicist John Tyndall popularized ''light guiding'' by making light follow a jet of water flowing from a tank. Around 1900, bent quartz rods were found to carry light, and these were marketed for dental illumination. During the 1920s, John Logie Baird in Scotland and Clarence W. Hansell in the United States patented the idea of using transparent rods to transmit images for television. In 1954, Professor Harold Hopkins and Dr Narinder Kapany of Imperial College, London, described ''imaging bundles'' in the journal *Nature.* They found that thin glass fibers were able to ''carry'' light because of the physical property of total internal reflection. The light needs to travel in a medium that has a relatively high refractive index, higher than that of the surrounding medium. Water, glass, and certain plastics exhibit this ability when they are surrounded by air. When light inside the fiber is reflected off the inner surface at a shallow angle, all of the light remains contained within it until it exits at the far end (Fig. 1). Covering the fibers with a coating of a different refractive index enhances internal reflection and allows the light to be propagated further. The development of glass-clad optical fibers was a major advance in fiber-optic technology and led directly to the development of the first prototype gastroscope, which was subsequently demonstrated by Dr Basil Hirschowitz (Fig. 2). Then, optical fibers received a further coating, a so-called buffer, to protect them from wear and moisture. When large numbers of flexible optical fibers are bound together, such that the spatial orientation of individual fibers is the same all along the ''optical bundle,'' a ''coherent image'' can be obtained, despite bends in the insertion tube. Coating on the fibers and the small space between them gives rise to the ''packing fraction,'' a fine reticular pattern that distinguishes fiber-optic from videoendoscopic images. The image quality of a fiber-optic bundle is limited by the number of fibers (''pixels'') and cannot match that created by a CCD chip.

The typical optical bundle in a fiber-optic endoscope is 2 to 3 mm in diameter and contains 20,000 to 40,000 glass fibers with a diameter of approximately 10 μm. A tiny lens focuses the ambient light onto the end of the optic bundle; the depth of focus ranges from a few millimeters to 10 to 15 cm. An adjustable focusing lens in the eyepiece reconstructs the image for the observer. To illuminate the target area, high-intensity light, typically from a halogen source (eg, xenon), is transmitted by using separate fiber-optic ''light guides'' to the tip of the endoscope. Because an image is not being transmitted, the light bundle does not have to be ''coherent.'' Apart from the ergonomic disadvantages of fiber-optic endoscopes, they are easily damaged. One bite on the endoscope shaft by an agitated patient whose mouthpiece has slipped can seriously

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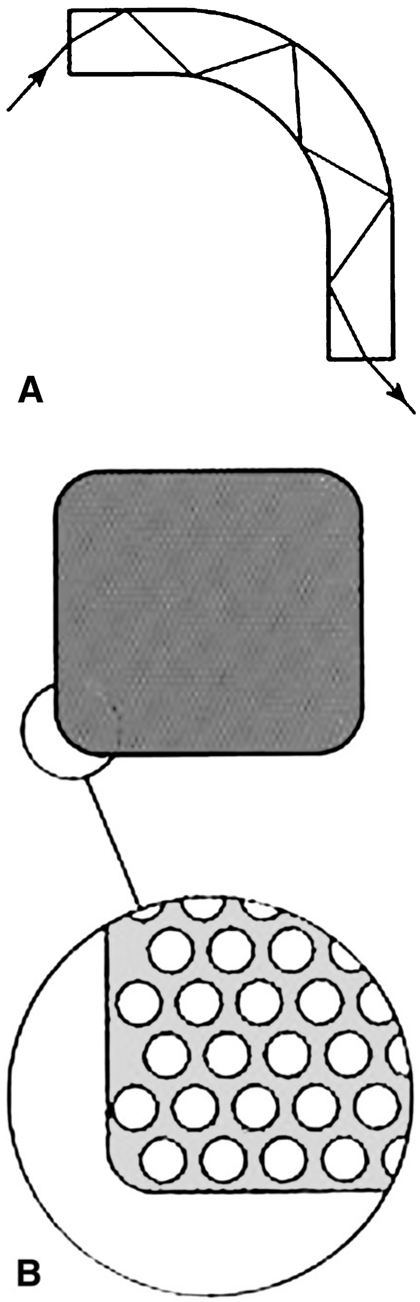

Figure 1. Diagram of how fiber-optic light transmission works. **A,** Total internal reflection of light down a glass fiber. **B,** Fiber bundle, showing the ''packing fraction'' or dead space between fibers. (From Cotton PD, William CB, editors. Practical gastrointestinal endoscopy. Malden [Mass]: Blackwell; 2003). Reprinted with permission from the ASGE.

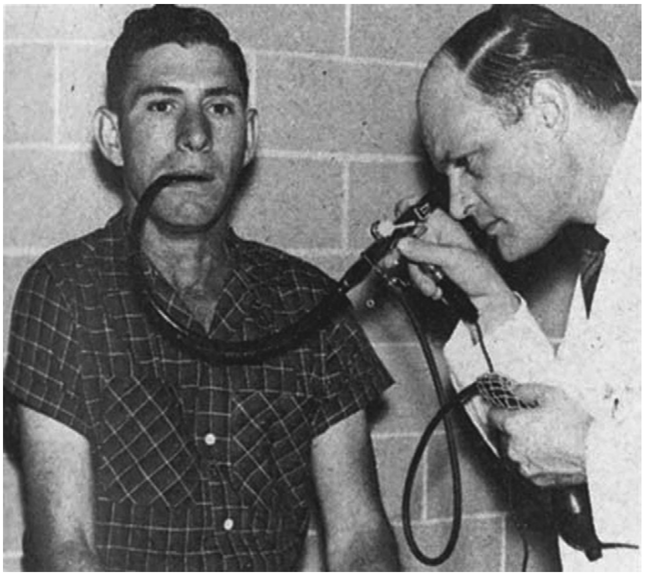

Figure 2. Dr Basil Hirschowitz. The Dittrick Medical History Center, Case Western Reserve University, Cleveland, Ohio. Available at: http://www.cwru.edu/artsci/dittrick/site 2. Accessed December 15, 2006.

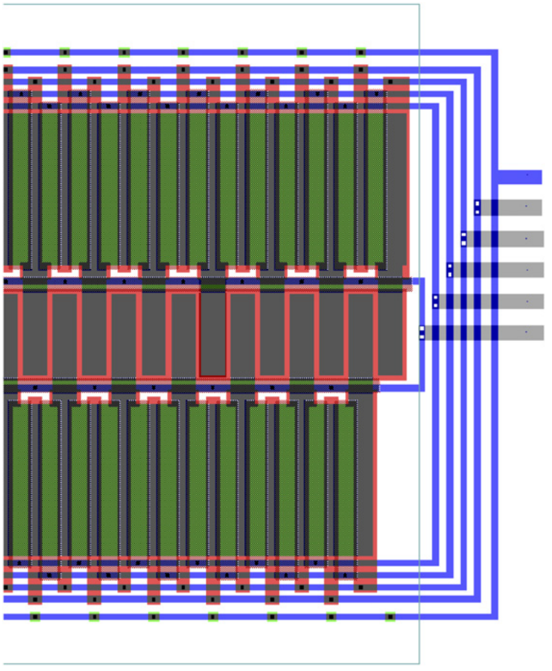

Figure 3. Architecture of a CCD chip. Available at: http://www.ece.cmu.edu/dwg/course/CCD.html. Accessed December 15, 2006.

damage the light bundle, requiring a very expensive repair. The light-carrying fibers degrade with time and lose their light-carrying properties. This process is accelerated by exposure to ionizing radiation. Endoscopes used routinely for procedures done under fluoroscopic control, eg, ERCP, are particularly affected. Physically broken fibers cannot transmit light; they are visible as tiny black dots scattered around the fiber-optic image.

VIDEOENDOSCOPES

Videoendoscopes use CCDs, often referred to as ''CCD chips,'' to capture images. The beauty of CCD endoscope technology is that it relieves the endoscopist of the need to hold the instrument to his or her eye. Apart from being