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## Introduction and History of Endoscopy

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### 1.1 Introduction

When I first started talking about my use of endoscopy in small animal practice, I described it as “a quantum leap forward in our diagnostic and therapeutic capabilities.” This continues to be true. A few years ago, I started stating in lectures that “A patient comes into every small animal veterinary practice every day that would benefit from a minimally invasive procedure.” This is true and whenever I am in any practice, I can find a patient who would benefit from endoscopy for diagnostic or therapeutic indications. I also believe that I can push this statement a little further to “Every patient that comes into every small animal practice every day would benefit from a minimally invasive procedure.” Unreasonable? Not really. Otoscopy is indicated as part of a proper physical examination of every patient. Why not video endoscopy on every patient so the client can see what you see?

By benefitting the patient, endoscopy allows us to practice better medicine and this makes us feel better about what we are doing, so we enjoy our work more. Endoscopy also has the same effect on all of the staff when they see the procedures on the video monitors. The only downside is that you may find the entire staff watching what you are doing while oohing and aahing. This does generate enthusiasm in the staff and encourages them to promote endoscopy to clients. Clients love to have minimally invasive procedures performed on their pets. Endoscopy is also the best burnout protection you can buy allowing us to see what we have never seen before, magnified and in color (Videos 1.1–1.7). So you can see that this is a win, win, win from all directions. Endoscopy is fun and exciting. Oh, and endoscopy does make money.



### 1.2 The History of Endoscopy

Reviewing the history of endoscopy is an interesting but frustrating endeavor. Most names and dates listed are taken from publications citing other publications without finding, reading, or confirming the original work. Publications from different modern specialties reference different people and dates for events for early endoscopes and procedures with conflicts over who did what and when to advance the development of instrumentation. A few important dates are listed from a consensus of historical reviews and original references are listed if they were found. I cheated like everyone else in taking listed early references from more recent publications. I did go to the original publications in a few cases where this was possible and found interesting disagreements. As an example, the French Academy of Sciences does not have any listing for A.J. Desormeaux in 1853, the year listed for presentation of his endoscope design in many references. This presentation was actually published in 1855 (Desormeaux 1855). I would attempt to find all the original early references to confirm their accuracy but researching this is far beyond the scope of this publication and would delay its publication beyond my life expectancy.

Endoscopy was first suggested on Egyptian papyrus before 1000 years BCE and was first reported in “modern” human medicine over 200 years ago. In 1805, the first endoscope was designed by a German physician Phillip Bozzini using a candle and a mirror to project light into a metal tube for examination (Figure 1.1) with the first endoscopic procedure using this instrument, examination of the lower urinary tract, reported in 1806 (Bozzini 1806). He named the instrument “lichtleiter” or light conductor. This



**Figure 1.1** The first rigid endoscope, built by Bozzini in the early 1800s. The light source was a candle directed by a mirror into a metal tube. (Source: Downloaded from the European Museum of Urology Website.)

concept was criticized so severely that further development of endoscopy was delayed for 50 years. The next attempt at an endoscope design was made by a French surgeon Antonin Jean Desormeaux in 1855 using a system of mirrors and lenses with an alcohol turpentine mix for a light source (Desormeaux 1855). A rigid gastroscope was developed in 1868 by Adolf Kussmaul (Killian 1901) using the alcohol turpentine mixture for a light source with sword swallows as test patients. The first successful cystoscope was designed by German Physician Maximilian Nitze and he is considered the father of cystoscopy (Nitze 1879). This system added telescopic lenses to improve the image with light from an exposed heated wire and a cooling mechanism to decrease thermal damage from the heated wire. Shortly after Edison invented the light bulb, this technology was used for endoscopes. This was a major and significant step with a light bulb placed at the tip of rigid endoscopes to improve illumination and reduce thermal injury (Figure 1.2). This technology still produced limited illumination and risk of thermal injury to tissue from the heat of the bulb. This advance allowed endoscopy to progress in some areas but was significantly impaired in others by inability to deliver adequate lighting. This design was state-of-the-art for almost 100 years.

George Kelling reported visualizing the abdominal contents of a dog by using a cystoscope in 1902 (Kelling 1902; Barringer 1947). H.D. Jacobaeus first described thoracoscopy in human medicine in 1910 and proposed the term *laparoscopy* for examining the abdominal cavity (1910). Laparoscopy was first reported in the United States in 1911

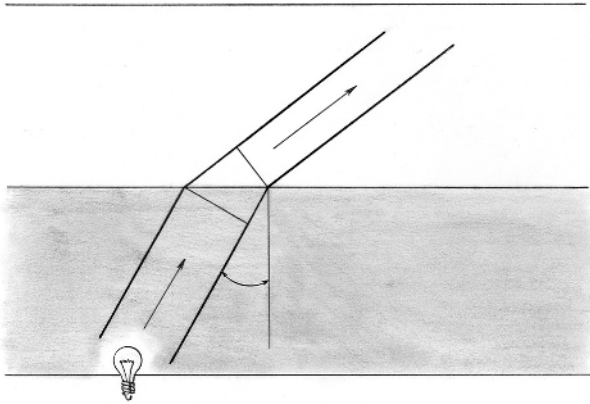


**Figure 1.2** A major step in advancing technology or endoscope development was placing the exposed wire filament in an enclosed bulb. This improved the quantity of light and decreased the risk of tissue burning. This picture is of a standard endoscope bulb connected to an ACMI 120° cystoscope. The bulb is 4 mm long and 2 mm wide.

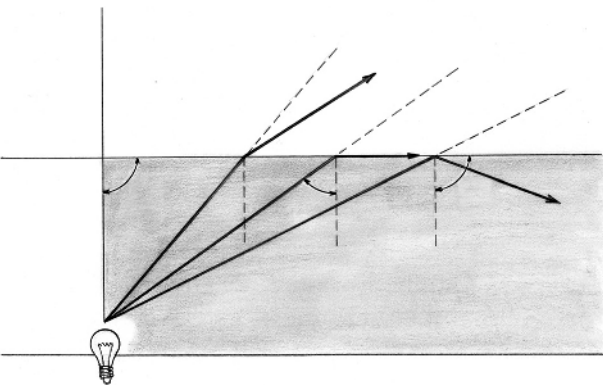
utilizing a proctoscope to visualize the gall bladder (Bernheim 1911).

What we consider to be modern endoscopy started with the paradigm changing development of “fiberoptics,” the technology that allows light transmission through bundles of very fine flexible glass fibers. Attempting an accurate historical record of the invention and development of fiberoptics is beyond the scope of this publication. In looking at the easily available material, there is more disagreement than consensus with different important time points and different names associated with significant events. Suffice it to say that fiberoptic technology does exist and has developed over a long period of time. The concept of guiding light by total internal reflection was first demonstrated in the 1800s and it was over 150 years before the combination of technologies required to make a functional flexible gastroscope occurred in the 1950s. This allowed a large bright light source to be used outside the body with transmission of adequate light while minimizing transmission of heat into the body. The term “Cold light source” was coined to describe this configuration. This also allowed an image to be transmitted from inside the patient to the outside where it could be seen by an observer.

The principal of “fiberoptics” is based on the phenomenon of refraction or light traveling at different speeds in different media so that light entering one end of a glass fiber is reflected internally until it is emitted at the opposite end of the fiber. Refraction is defined as the bending of light when passed from one medium to another medium possessing a different refractive index ( $n_i = \text{velocity of light in vacuum} / \text{velocity of light in substance}$ ) (Figure 1.3). When the angle of light hitting an interface of two materials with different refractive indices exceeds the critical



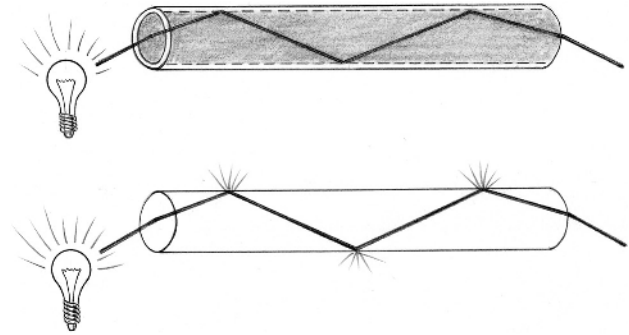
**Figure 1.3** Representation of a light beam being bent as it passes from one medium to another of lower refractive index. The darker medium has a higher refractive index (where light travels slower) than the lighter medium that has a lower refractive index (where the light travels faster). If the light wave goes through the interface of the two media at an angle, one edge of the light wave “ab” goes through the interface first and the other edge “eg” goes through the interface later. In the time that it takes the edge “fg” to reach the interface between the two materials, the other side of the wave has traveled the distance “bc.” The segment “bc” is longer than “fg” because light travels faster in the second less dense medium. This causes a bending or refraction of the light wave. The angle light that hits the interface is “ $\alpha$ ”.



**Figure 1.4** As the angle of incidence of the light waves “ $\alpha$ ” increases, so does the angle of the refracted light and the light beam will be bent to varying degrees, dependent upon the angle at which it hits the medium of lower refractive index. When “ $\alpha$ ” equals “c,” the refracted light travels along the interface of the two media. This angle is known as the “critical angle of incidence.” When the angle of incidence of the light beam hitting the interface is greater than the critical angle of incidence, the light reflects back into the original medium.

angle of incidence, it is reflected back into the original medium (Figure 1.4).

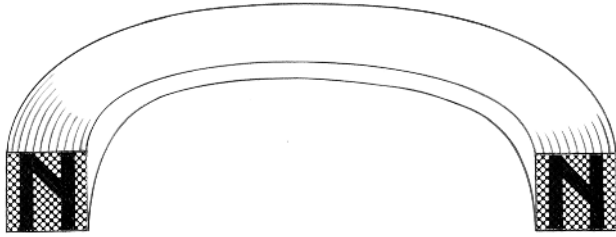
Light entering the end of a glass fiber will be transmitted through the fiber if its surface is clean and it is surrounded by a substance of a lower refractive index (Figure 1.5). This



**Figure 1.5** Total internal reflection of light in a fiberoptic glass fiber occurs if it is clean and is surrounded or “cladded” with a substance of a lower refractive index. The top drawing shows proper cladding of a glass fiber to minimize light loss along the fiber producing total internal reflection of light. The bottom drawing is without cladding or with impurities in the fiber glass allowing loss of light where it hits the surface of fiber.

is known as “total internal reflection” of light. Each fiber is clad with a substance with a lower refractive index than the core of the fiber to keep light within the individual fibers. The fibers are very small so that they are flexible, and many fibers are assembled to create a flexible fiber bundle. If a fiber is not clad properly, if there is any foreign matter on the fiber, or if the fiber touches adjacent fibers, light will leak at those points, total internal reflection does not occur, and light is lost through the sides of the fiber (Figure 1.5). Total internal reflection of light is not total and in reality, not all light that enters one end of a fiber will exit at the other end. The amount of light lost is dependent on the length of the optical path, which is determined by the length of the fiber and the number of internal reflections. Even with a properly clad fiber, a small amount of light is lost at each internal reflection and with thousands of internal reflections per meter, the amount of light lost may be significant. The smaller the fiber and the greater the length, the more light is lost. Light is also lost at the surfaces of both ends of the fiber and light falling between fibers or on the cladding.

There are two types of fiber bundles: incoherent and coherent. Coherent fiber bundles are arranged so that the individual fibers are at the same location at both ends of the fiber allowing an image to be transmitted from one end of the bundle to the other end (Figure 1.6). Flexible endoscopes use coherent bundles to transmit images from the distal tip of the endoscope to the eyepiece. Each individual glass fiber transmits a small part of the total image and with each fiber at the same position at each end of the bundle, an image is transmitted from the tip of the endoscope to the eyepiece. Fiber bundles of this type are called image guide bundles and are composed of smaller diameter fibers with little cladding to produce an image with



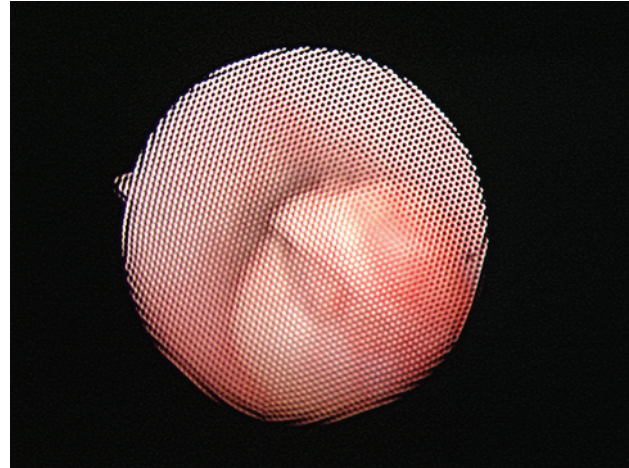
**Figure 1.6** A coherent fiber bundle used for image transmission in flexible fiberoptic endoscopes maintains the exact arrangement of individual fibers at both ends providing transmission of an image.



**Figure 1.7** An image through a coherent fiber bundle of a flexible fiberoptic gastroscope showing a subtle individual glass fiber pattern. This is a high-quality image with small fibers and minimal inter fiber space producing little interference with the image.

better resolution. The fiber pattern is visible in the transmitted image with the quality of the image dependent on the size of the fibers and the thickness of the cladding (Figures 1.7 and 1.8).

The fibers of incoherent fiber bundles are randomly arranged and are used to transmit light from the light source into the patient and are called light guide cables or bundles. They do not transmit an image. The individual fibers in incoherent bundles are thicker than in image or coherent bundles making them more efficient at transmitting light. Flexible endoscopes will have one or two incoherent fiber bundles for the transmission of light from the light source to the distal tip. Rigid endoscopic telescopes use an incoherent flexible fiberoptic light guide cable to transmit light from the large external light source to the light post of the telescope. An incoherent fiber bundle is also present in the telescope to transmit light from the connection with the light guide cable at the light post to the tip of the telescope. This allows a bright powerful light to be transmitted to the end of the endoscope and into the body with a minimum of heat (Figure 1.9).



**Figure 1.8** An image through a coherent fiber bundle of a flexible fiberoptic urethroscope showing a marked individual glass fiber pattern. This is an image of lesser quality due to the size of the fibers and thickness of the inter fiber space producing significant interference with the image.

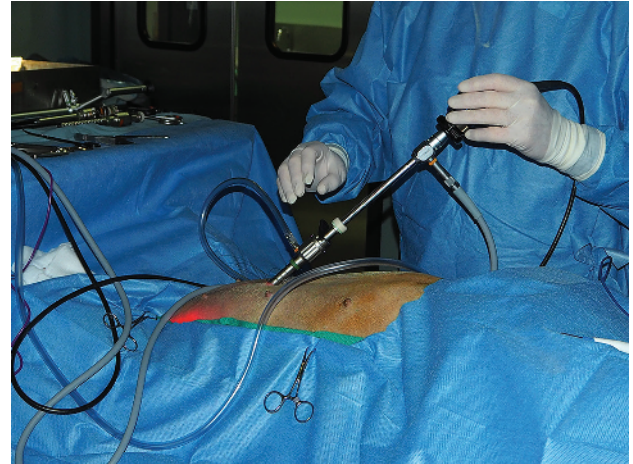


**Figure 1.9** The light transmission system for a rigid endoscopic telescope with the large external remote "cold light source" shown as a box, the flexible fiberoptic light cable seen as a coiled gray cord attached to the light source on one end, attached to the light guide post of a telescope at the other end, and there is a fiberoptic light guide bundle in the rigid telescope continuing from the light post through the telescope shaft to conduct light to the tip of endoscope. This light transmission system is composed of incoherent fiber bundles. The image of rigid telescopes is transmitted through a series of solid glass lenses. (Source: Photo courtesy of Karl Storz; ©Karl Storz SE & Co KG, Germany.)

Another quantum leap forward critical to continuing the advance of endoscopy was the development of video camera systems specifically designed for endoscopy. Small lightweight camera heads (Figure 1.10) made possible placing of the signal processing hardware in a separate



**Figure 1.10** A small lightweight endoscopy video camera head with a separate remote box containing the video signal processing hardware. A Karl Storz Endoscopy IMAGE 1 FULL HD camera control box on the bottom, an Image 1 capture module on the top, and a 3 chip HD camera head on top of the capture module. (Source: Photo courtesy of Karl Storz: ©Karl Storz SE & Co KG, Germany.)



**Figure 1.11** An endoscopy video camera head coupled to a 10 mm diameter laparoscope making a functionally one-piece unit allowing easy examination and surgery with a stable video image of the telescope field of view.

remote box away from the endoscope. The camera head couples securely to either rigid telescopes (Figure 1.11) or flexible endoscopes with a video image displayed on a monitor so that multiple people could see the endoscopic images simultaneously. This allowed all members of a surgical team to participate as assistants during procedures (Figure 1.12). This technology made operative procedures possible and allowed the development of minimally invasive surgery. Initial cameras had a single CCD video chip, this was followed by three chip cameras, and then by high-

definition cameras. Another significant advance in endoscope technology was video endoscopes with a CCD chip at the tip of the endoscope (Figure 1.13). This is most important in flexible endoscopes with elimination of the pixilated fiber pattern to greatly improve image quality (Figure 1.14). For many years, CCD chip size limited the diameter of flexible video endoscope to sizes greater than 10 mm restricting their use to gastrointestinal-sized equipment. This has been overcome and with CMOS technology, flexible video endoscopes as small as 3 mm are currently available.



**Figure 1.12** A surgery team utilizing video for laparoscopic surgery where all members of the team can see the image on the video monitor.



**Figure 1.13** A video gastroscope with a video camera chip at the tip of the endoscope with elimination of the image guide bundle and the eyepiece at the handle of the endoscope. (Source: Photo courtesy of Karl Storz; ©Karl Storz SE & Co KG, Germany.)



**Figure 1.14** An image of the duodenum in an 8-year-old neutered male 10 kg mixed breed dog with IBD illustrating the superior image produced with a video gastroscope.

Three-dimensional video systems have been attempted for many years, but none have become popular or achieved a significant market presence. A recently released computer-enhanced dual image system with significant improvement of image function may change this position for this technology.

Computer-enhanced image technology has also entered the market with image manipulation to increase the visibility of normal and abnormal tissues. Photodynamic analysis systems are available that use fluorescing dyes combined with specific wavelength light sources, filters, and cameras facilitating the identification of tumors used to improve early diagnosis.

### 1.3 Clinical Application in Veterinary Medicine

Use of endoscopy in animals was listed in the early history of endoscopy in human medicine but it was not a clinical application and is not relevant to our history. At the time I graduated from Veterinary School in 1969, endoscopy was not a part of our clinical discussions. Endoscopy in small animal veterinary medicine first appeared in the early 1970s. Endoscopic evaluation of the lower respiratory tract in dogs and cats was first reported in 1970 (O'Brien 1970). The first use of laparoscopy for the evaluation of liver and pancreatic disease was reported in 1972 (Dalton and Hill 1972; Lettow 1972). The first reported use of gastrointestinal endoscopy in practice was in 1976 (Johnson et al. 1976). Gastrointestinal endoscopy developed widespread clinical application before any other techniques and has been the most frequently used endoscopic procedure in small animal medicine. Bronchoscopy also gained wide acceptance during this time period.

Other techniques were slow to develop but have recently expanded to become a major portion of small animal diagnostic and operative procedures. Arthroscopy of the shoulder and stifle joints was reported in the late 1970s and during the 1980s (Siemering 1978, Kivumbi and Bennett 1981; Person 1987; Person 1989) but was very slow to gain acceptance because of its difficulty and the long, steep, frustrating learning curve.

Cystoscopy in male and female dogs was first reported as a research technique in 1930 (Vermooten 1930) but did not appear in clinical use until the 1980s. A technique conceived from the concept of cystocentesis and adapted from human medicine was used in early 1983 for access to the bladder using a prepubic percutaneous approach (McCarthy and McDermaid 1986). This technique initiated endoscopic evaluation of the urinary tract in clinical practice. This publication also initiated identification and study of feline lower urinary tract disease as it relates to interstitial cystitis (Buffington 1994). As an accidental incident, while performing vaginoscopy with the 2.7 mm multipurpose rigid telescope (MPRT), the urethral orifice was identified followed by passage of the telescope through the urethra and into the bladder. From this, transurethral cystoscopy emerged as an easy and effective diagnostic procedure in the 1980s (Biewenga and van Ostrum 1985; Senior and Sundstrom 1988; McCarthy and McDermaid 1990; McCarthy 1996). Availability of small flexible urethroscopes made transurethral cystoscopy in male dogs and cats possible.

Invasion of other natural orifices continued to progress with rhinoscopy, otoscopy, and vaginoscopy being added to

the list of procedures available. Invasion of body cavities expanded to include thoracoscopy. All these procedures started as diagnostic techniques allowing examination of the area of interest with ability to collect diagnostic samples.

Expansion of these procedures to include treatment allowing us to correct the pathology that we found provided strong incentive for continued growth of endoscopy in small animal practice. Introduction of minimally invasive surgery in human medicine in the 1980s exploded as the procedure of choice for many abdominal surgeries. This translated rapidly into small animal practice with veterinary involvement including design, development, and testing of instrumentation for minimally invasive surgery plus training human surgeons.

Laparoscopic ovariectomies in small animals first performed as research procedures, identified the possibility of Minimally Invasive Surgery (MIS) in small animals, and was used for technique development. The list of

MIS procedures performed in small animal practice has grown to include many of the surgical procedures traditionally done as open surgery. Interventional endoscopy, application of therapeutic corrective procedures with cystoscopy, was developed for correction of ectopic ureters, stone removal, and tumor removal. Laparoscopic-assisted techniques have also promoted expansion of MIS by applying laparoscopy for access to visualize and exteriorize organs with the use of open surgical technique to perform the actual procedure. This approach allows a minimally invasive approach but without the need for special skills and instrumentation needed for a totally intra-corporeal procedure. NOTES, natural orifice transluminal endoscopic surgery, is the newest addition to our armamentarium of minimally invasive approaches where surgery is performed with special flexible endoscopes through oral, vaginal, or rectal approaches with no skin incisions.

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