ADVANCED ENDOUROLOGY
**CURRENT CLINICAL UROLOGY**

Eric A. Klein, MD, SERIES EDITOR


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Dedication

To our spouses, Deanna and Jack, who remind us that there is more to life than endourology.
Endourology is one of the most important subspecialties in the field of urology because of the widespread use of endoscopy for the diagnosis and treatment of a variety of upper genitourinary tract pathologies. Although most clinical urologists incorporate some basic endourology into their practices, complex upper tract pathology and anatomy require more advanced endoscopic skills and instrumentation.

*Advanced Endourology: The Complete Clinical Guide* is intended as a resource guide for all aspects of clinical endourology, particularly the more advanced procedures. This volume encompasses endourological applications for upper urinary tract calculi, strictures, and urothelial cancer. It will also serve as a comprehensive overview of available endoscopes and instrumentation.

*Advanced Endourology: The Complete Clinical Guide* is unique in that most of its individual chapters include videos that clearly illustrate critical portions of the techniques and provide tips and tricks from the experts. Every practicing urologist should have this book in his or her library, with the accompanying DVD kept near a DVD player, for quick access to detailed procedural instruction and immediate review of the videos.

*Stephen Y. Nakada, MD*

*Margaret S. Pearle, MD, PhD*
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Companion DVD

The companion DVD to this volume contains video segments in support of the book, organized in sections corresponding to the book. The DVD can be played in any DVD player attached to a NTSC television set. The DVD may also be viewed using any computer with a DVD drive and DVD-compatible playback software, such as Apple DVD Player, Windows Media Player 8 or higher (Win XP), PowerDVD, or WinDVD.
I

DIAGNOSIS AND INSTRUMENTATION
SUMMARY

With the advancement of materials science and optics, endoscopes have undergone major refinements since Bozzini’s lichtleither, leading to the development of the modern endoscopes. This chapter presents the basic physics and characteristics of both rigid and flexible endoscopy. Included is a discussion on video systems and the integrated operating rooms. The future of cystoscopes, ureteroscopes, and nephroscopes for both rigid and flexible devices is presented. In addition to presenting the present-day endoscopes and delineating their features, this chapter includes discussions of the limiting factors of some of these fragile instruments and future trends to look forward to. It is important for the urologist to have a clear understanding of the characteristics of these highly technical instruments in order to make appropriate choices when purchasing these devices, and in understanding the nuances of handling them in their clinical practice. In addition, discussion of care and sterilization has been presented with recent research data reported to help in the decision-making process of acquiring these endoscopes and using them clinically. With the availability of a wide range of rigid, semi-rigid, flexible endoscopes, and specifically designed working instruments, most of the upper urinary tract lesions encountered in urology can be effectively diagnosed and treated in a minimally invasive approach. Continued refinements may potentially improve the optics, durability, and efficacy of these instruments as technological advances are incorporated into the design of endoscopes and accessory instruments.

Key Words: Endoscope; optics; light source; ureteroscopes; video imaging system; integrated operating room; cystoscopes; nephroscopes; rigid; flexible; semi-rigid; working channel; irrigation channel; deflection; sterilization.
INTRODUCTION

The goal of endoscopy is to access and treat organs, through natural or artificial orifices in the body, with a telescope. The gradual evolution toward the modern endoscopes began with Philipp Bozzini’s construction of the “lichtleiter” in 1806 for direct inspection and treatment of the uterus and bladder (1). These early endoscopes were cumbersome and impractical, made of hollow examining tubes with illumination by candle light directed by a mirror. With the advancement of material science and optics, endoscopes have undergone major refinements since Bozzini’s lichtleither, leading to the development of the modern endoscopes.

Optics

The first major improvement in optics was made by Nitze in 1877 by using a series of precisely aligned thin lenses within a tube (1). The optical image is relayed from the distal end of the scope to the ocular lens where it can be viewed. The next breakthrough in optics did not occur until 1960 when Harold Hopkins developed the rod–lens system (Fig. 1) (2). A more durable and smaller diameter scope was made possible by replacing the conventional thin lenses with long, contoured glass rods. The rods now served as the transmission medium and the thin pockets interspersed between the glass rods acted as lenses. The light reflecting off an object is detected by the objective lens at the distal tip and the image is transmitted via the rod–lens system back to the ocular lens where it is viewed by the surgeon’s eye or captured by a camera. The rod–lens system offers better light transmission, reduced image distortion, wider viewing angle, and improved image brightness by nine fold. The size, or the degree of magnification, of the image is dependent on the diameter of the lenses, therefore a smaller caliber telescope, such as a ureteroscope, would have a smaller image than a larger caliber cystoscope. Although the Hopkins lens system provides excellent visualization and clarity when the shaft is straight, in straight cystoscopy and nephroscopy, significant deterioration can occur when torque is placed on the scope, as during passage through the ureter. The lenses and air spacers may come out of alignment, and up to half of the image may disappear, leading to a crescent field defect, or a “half-moon” appearance. Further stress on the shaft may lead to permanent lens damage or misalignment. Therefore, as demands for ureteroscopes increased, semirigid ureteroscopes or miniscopes...

Fig. 1. Traditional and Hopkins rod–lens designs.
that incorporate flexible fiberoptics within rigid shafts were designed to circumvent optical problems encountered during passage through a tortuous ureter.

**Light Source**

Throughout this period, the light source also underwent considerable modification. Trouve in 1873 moved the light source from the outside to the inner tip of the endoscope using a glowing hot platinum wire (1). This was later replaced by a small incandescent light bulb. A major step toward modern endoscopy was made in the 1960s with the introduction of fiberoptic cable that enabled the transmission of light from an outside source. Fiberoptic cables provided more illumination with a cool light which made cystoscopy safer; it also made smaller profile scopes with larger irrigation and working channels possible. The fiberoptic cable may be built into the design of the scope, or it may be attached via a light post to the scope.

**INSTRUMENTATION**

Early endoscopic procedures were limited by the lack of accessory instruments to treat disease. As the optics of rigid endoscopes underwent continuous refinement, more sophisticated accessory instruments evolved to broaden their therapeutic potentials. The first true endoscopic procedure was performed by Desormeaux in 1853, extracting a papilloma from the urethra through an urethroscope. The usefulness of electrocautery was demonstrated in 1874 when Bottini performed blind electrosurgery of the prostate. A lever was introduced by Albarran in 1897 allowing the ability to control the electrode. This was improved by Freudenberg in 1900 with the addition of an endoscope for visualization. High-frequency current was introduced by Beer in 1910 which revolutionized the field of therapeutic endoscopic procedures. Subsequently, the first resectoscope was constructed in 1926 by Stern. It was modified by McCarthy in 1931, with the addition of a lever to move the cutting loop. This basic design is still used today for modern resectoscopes. Subsequently, surgeons developed different loops, catheters, and wire baskets that could be passed through the endoscopes for the treatment of stone disease. Today, these instruments have become increasingly more powerful, with the development of ultrasonic, pneumatic, electrohydraulic, and laser lithotriptors.

**Ureteroscopes**

In 1912, Hugh Hampton Young performed the first ureteroscopic procedure using a pediatric cystoscope in a 2-month-old child with posterior urethral valve (3). Our modern day concept of endoscopy of the ureter and renal pelvis was made possible first by Marshall in 1960 with the advent of a 3-mm flexible fiberoptic (4). Similarly, in 1968, Takayasus and Aso developed the first flexible pelviureteroscope with an operating channel (5). The first rod–lens ureteroscopy was performed by Lyon to explore the distal ureter with a 11-Fr pediatric cystoscope in 1977 (6). Ureteral orifice dilation was performed cystoscopically with Jewett sounds prior to insertion of the scope. The original ureteroscope was made by Richard Wolf Medical Instruments (Vernon Hills, IL) in 1979, modeled after a pediatric cystoscope, and was available with 13-, 14.5-, and 16-Fr sheaths (7). The first practical ureteroscope was developed in 1980 and 1981 by Enrique Perez-Castro and the Karl Storz Company (Culver City, CA) (8). However, these ureteroscopes utilized the rod–lens optical system and were limited by their size and the lack of adequate instrumentation for stone fragmentation and removal. They were purely instruments for diagnosis and not for therapeutic efficacy.
The application of fiberoptic technology was the next major step in the development of ureteroscopes. This was based on the principle of total internal reflection; light traveling inside of an ultrathin glass fiber surrounded by a cladding with a lower refractory index can be transmitted over a long distance with minimal degradation. A coherent fiberoptic bundle contains thousands of individual fibers with identical orientation at the ends of each bundle so the exact image is transmitted to the eyepiece. Therefore the image obtained by fiberoptic bundles is not a single image but a composite matrix of each fiber within the bundle, giving it a “honeycomb” appearance (Fig. 2A). The early flexible ureteroscopes were limited by the lack of irrigation, active deflection, or instrumentation. Continuous refinements have led to the 7.5-Fr flexible ureteroscopes with high pixel densities today. These ureteroscopes contain two coherent bundles for light transmission and one noncoherent bundle for image transmission, a working/irrigation channel to allow both irrigation and insertion of instruments, and active dual deflection, as well as secondary passive deflection. As demands for reliable rigid ureteroscopes grew, the fiberoptic technology was applied to a new generation of “miniscopes” or semirigid fiberoptic ureteroscopes. The flexibility of the fiberoptic bundles allowed for the metal shaft to be flexed up to 2-in. off the vertical axis without significant image distortion. It also allowed a significant reduction of the outside diameter of the endoscopes, while maintaining larger working channels and greater irrigation flow rate compared to the rod–lens system. Semirigid ureteroscopes with small distal diameters of 4.5 to 8.5 Fr became available, making the inspection of the distal to midureter possible without routine dilation of the intramural ureter. At the same time, a host of new graspers, baskets, biopsy forceps, and laser fibers were also developed specifically for ureteroscopic procedures.

**Video System**

The images transmitted by the endoscopes may be viewed directly from the eyepiece or indirectly on a television monitor using a video system. A video system offers a large viewable area for binocular vision that can be viewed by multiple persons simultaneously, and with greater surgeon comfort and ergonomics. Specially designed cameras may contain “beamsplitters” (Fig. 3) to accommodate urologists who are more comfortable using direct visualization through the endoscope eyepiece while projecting the same image on a television monitor for viewing by the operating assistant. A video system may include a camera and control device, television monitor, printer, and a video capture device. At the heart of modern digital imaging is the charge-coupled device (CCD), an integrated circuit designed to respond to light. A digital image is composed of millions of tiny dots of information or pixels. Each pixel corresponds to a charge generated by the CCD proportional to the intensity of the light striking it. Although single CCD chip cameras are still common, newer cameras for endoscopic procedures contain a prism-based 3 chip (multisensor) system to create a high-resolution image. Light from the image is split by a prism into the three primary colors: red, blue, and green to generate three CCD arrays. The information from each of the CCD is then merged by a computer into a single color pixel. The information is converted into a signal that is processed and refreshed up to 60 times per second and transmitted to a television monitor to form a complete image. New digital filters can be built into the camera system to eliminate the “honeycomb” appearance of the endoscope image at the expense of resolution (Fig. 2B). Continuous refinements in the video system are ongoing with the advancements in digital technology.
As the equipment for endourology has become more sophisticated, the trend is now toward integration of all operating room functions and equipment controls into one central control unit which may even have touch screen or voice control capabilities, such as the OR 1™ system by Karl Storz or the Endoalpha™ Centralized OR system by Olympus (Melville, NY). Thus, the management of multiple complex systems can be simplified. Recent studies on surgeon fatigue and discomfort during minimally invasive surgeries has brought attention to the ergonomics of endoscopic procedures (9). The surgeon’s comfort, hand–eye coordination, and visualization can be greatly improved by using flat-screen, liquid crystal display monitors mounted on booms placed in close range to the surgeon’s direct line of vision, the surgeon’s hands, and endoscope. The integrated operating room provides an efficient and ergonomic work environment for the entire surgical team. This also provides a multidisciplinary, minimally invasive surgical suite. Single flat-screen monitors accommodate laparoscopic surgery, whereas the triple flat-screen monitors, on a single boom, provide simultaneous endoscopic and fluoroscopic visualization during endoscopy (Fig. 4).

**Integrated Operating Rooms**

As the equipment for endourology has become more sophisticated, the trend is now toward integration of all operating room functions and equipment controls into one central control unit which may even have touch screen or voice control capabilities, such as the OR 1™ system by Karl Storz or the Endoalpha™ Centralized OR system by Olympus (Melville, NY). Thus, the management of multiple complex systems can be simplified. Recent studies on surgeon fatigue and discomfort during minimally invasive surgeries has brought attention to the ergonomics of endoscopic procedures (9). The surgeon’s comfort, hand–eye coordination, and visualization can be greatly improved by using flat-screen, liquid crystal display monitors mounted on booms placed in close range to the surgeon’s direct line of vision, the surgeon’s hands, and endoscope. The integrated operating room provides an efficient and ergonomic work environment for the entire surgical team. This also provides a multidisciplinary, minimally invasive surgical suite. Single flat-screen monitors accommodate laparoscopic surgery, whereas the triple flat-screen monitors, on a single boom, provide simultaneous endoscopic and fluoroscopic visualization during endoscopy (Fig. 4).
Future Trends

New development in video technology has allowed the cameras to become increasingly miniaturized with high resolution image output. Despite the advancements in traditional optical systems, they may eventually be replaced by digital and electronic imaging without a viewing lens. A small CCD chip can be mounted at the distal tip of the scope to transmit digitized information via a single fiber to a processor that can reconstruct the image on a television monitor. This will allow for a smaller scope profile with larger working channels while producing a superior image. Three-dimensional imaging may become possible if two CCD chips are used to create a stereoscopic vision. Finally, although still in its infancy, noninvasive virtual endoscopy from emerging computed tomography techniques may be used for surveillance of the entire urinary tract in the future (10–12).

Rigid Cystoscopes

A rigid or flexible cystourethroscope may be used for direct visual inspection of the bladder. The rigid scopes offer a better image quality, larger working channels, and greater control, whereas the flexible scopes offer better access to visualizing all areas of the bladder and greater patient comfort. Basic components of the modern rigid cystoscope include the sheath, bridge, obturator, and telescope. The size of the sheath is expressed in French (Fr), which is a measure of the outer circumference of the scope in millimeters (1 mm = 3 Fr). Available sizes range from 8 to 12 Fr for pediatric endoscopes and up to 16 to 25 Fr for adult endoscopes. The bridge attaches to the sheath and allows for the attachment of irrigation tubing and the passage of the telescope and instruments. A deflecting Alberans
bridge may be used to control deflection of flexible instruments as they pass through the
distal portion of the instrument. The obturator may be inserted into the sheath to create a
smooth tip for insertion. Viewing obturators allow the zero degree telescope to be inserted
to enable direct visualization for passage of the instrument into and through the urethra.
The standard telescopes available are 0 (direct), 12 (operative), 25 or 30 (forward-
oblique), 70 (right angle), and 110 to 120° (retrospective). The telescopes contain the
rod–lens system for image transmission and provide illumination via fiberoptic fibers.

Flexible Cystoscopes

The flexible cystourethroscope can also be used as a percutaneous nephroscope. The
basic components include fiberoptic bundles, within a flexible shaft, to provide illumina-
tion and image transmission to the eyepiece, and a large, 6.4 to 7.5 Fr, channel to accom-
modate irrigation and ancillary instruments. The tip of the scope can be deflected in either
direction from 180 to 220° with a thumb control. There are a wide variety of long, flexible
instruments that can be passed through the working channel including grasping forceps,
biopsy forceps, lithotripsy and electrocautery probes, and basket entrapping devices. A new
digital cystonephroscope (Fig. 5) made by American Cytoscope Makers, Inc. (ACMI;
Southborough, MA) has recently become available and is the first scope to address some
of the unique demands of flexible nephroscopy. Besides the improvements in image qual-
ity, the digital cystonephroscope is capable of additional flexion perpendicular to the tradi-
tional up and down axis of deflection of the flexible cystoscopes. This may facilitate easier
access of the calyceal system from the percutaneous nephrostomy tract sheath.

Semirigid Ureteroscopes

The newer generation of semirigid ureteroscopes contain fiberoptic bundles larger than
those in a flexible ureteroscope. Therefore the image is comparable to those derived from
a rod–lens system, and the “honeycomb” effect is further reduced by new fiber-packing
techniques and an advanced camera system. A straight working channel for passage of a
rigid instrument is possible in scopes that take advantage of the flexibility of fiberoptics
and have an offset eyepiece. Most of the available semirigid ureteroscopes have round or
oval tip designs, but scopes with smooth, triangular tips have recently become available,
designed to ease insertion into the ureteral orifice. The shafts of these scopes are tapered
such that they gradually enlarge from 5 to 8.5 Fr at the distal tip to 7.8 to 14.5 Fr at the
proximal shaft. This design increases the proximal strength of the scope while providing
a gradual dilation of the ureter as the instrument is advanced. The distal and lower middle
ureter in men and the renal pelvis in women may be accessed using a 31-cm ureteroscope,
whereas a 40-cm ureteroscope may be needed to reach the renal pelvis in male patients.
The scopes may be designed with one large channel for both instrumentation and irriga-
tion, or with two channels to separate instrumentation and irrigation. A single, straight,
large working channel is possible in ureteroscopes with an offset eyepiece. In contrast,
two channel scopes allow passage of a working instrument without diminution in the flow
of the irrigant fluid. They usually have a 3.4-Fr working channel that can accommodate a
standard 3-Fr instrument and a 2.1- to 2.4-Fr irrigation channel. Some of the currently
available semirigid ureteroscopes and their features are listed in Table 1.

Flexible Ureteroscopes

Several state-of-the-art flexible ureteroscopes are available with a small distal diame-
ter ranging from 4.9 to 11 Fr, and a relatively large working channel up to 3.6 Fr. These
scopes all contain imaging and light transmission fiberoptic bundles, a working channel, and a deflecting mechanism. However, each may have variations in dimensions, image transmission, working channel size, degrees of active deflection, the deflection mechanism, and tip design depending on the manufacturer. The newer scopes have working lengths between 54 and 70 cm. As in the semirigid scopes, they have tapered shaft designs with the proximal shaft size between 5.8 and 11 Fr. The smaller tip design has greatly reduced the need for ureteral dilation and decreased the ureteral complication rate. Some of the currently available flexible ureteroscopes and their specifications are listed in Table 2.

**Optics**

Each scope contains a coherent fiberoptic bundle for image transmission and one or two larger noncoherent light transmitting fiberoptic bundles. In general, two sets of light transmission bundles provide a more even illumination and decreased shadowing. The light cord which carries light from the lightsource to the ureteroscope may be incorporated into the design of the scope, or it may be attached onto a connecting post on the scope. The former uses a continuous bundle from the lightsource to the tip of the scope to provide a better illumination and relatively better visibility, whereas the latter offers the ability to replace the light cord separately if it should become damaged. In vitro evaluation of select, available ureteroscopes was undertaken at University of California-Irvine to compare the resolution and distortion of the ureteroscopes using test targets lined with dots of varying diameters at preset distances. The images of the test target, viewed through the ureterscopes, were analyzed. Resolution was defined as the imaging system’s ability to distinguish object detail, measured in line pairs per millimeter. Distortion was defined as an optical error (aberration) in the lens that causes a difference in magnification of the object at different points in the image. It is calculated as

\[
\frac{(Actual\ distance-Predicted\ distance)}{Predicted\ distance} \times 100
\]

This was expressed in terms of a percentage. These studies have demonstrated the
Table 1
Specifications of Rigid and Semirigid Ureteroscope

<table>
<thead>
<tr>
<th>Model</th>
<th>Eyepiece design</th>
<th>Working length (cm)</th>
<th>Tip shape</th>
<th>Tip size (Fr)</th>
<th>Mid segment size (Fr)</th>
<th>Proximal size (Fr)</th>
<th>No. channels</th>
<th>Channel size (Fr)</th>
<th>Angle of view (degrees)</th>
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<tr>
<td>ACMI</td>
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<td></td>
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<tr>
<td>MR-6/ MR-6L</td>
<td>Straight</td>
<td>33/41</td>
<td>Beveled/triangle</td>
<td>6.9</td>
<td>8.3</td>
<td>10.2</td>
<td>2</td>
<td>3.4, 2.3</td>
<td>5</td>
</tr>
<tr>
<td>MRO-633/ MRO-642</td>
<td>Offset</td>
<td>33/42</td>
<td>Beveled/triangle</td>
<td>6.9</td>
<td>8.3</td>
<td>10.2</td>
<td>2</td>
<td>3.4, 2.3</td>
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<td>Beveled/triangle</td>
<td>7.7</td>
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<td>34/43</td>
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<tr>
<td>Model</td>
<td>Working length</td>
<td>Tip diameter</td>
<td>Midshaft diameter</td>
<td>Proximal diameter</td>
<td>Tip design</td>
<td>Active primary deflection (degrees)</td>
<td>Active secondary deflection (degrees)</td>
<td>Deflecting mechanism</td>
<td>Working channel size (Fr)</td>
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<td>—</td>
<td>Both</td>
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<td>10.1</td>
<td>Beveled</td>
<td>170/180</td>
<td>0/130</td>
<td>Both</td>
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<td>170/180</td>
<td>—</td>
<td>Both</td>
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<td>URF-P3</td>
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<td>6.9</td>
<td>---</td>
<td>8.4</td>
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<td>180/180</td>
<td>—</td>
<td>Counter-intuitive</td>
<td>3.6</td>
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<td>8.9</td>
<td>Round</td>
<td>120/170</td>
<td>—</td>
<td>Intuitive</td>
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<td>—</td>
<td>Counter-intuitive</td>
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<td>—</td>
<td>Intuitive</td>
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<td>170/120</td>
<td>—</td>
<td>Counter-intuitive</td>
<td>3.6</td>
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<td>Round</td>
<td>270/270</td>
<td>—</td>
<td>Counter-intuitive</td>
<td>3.6</td>
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<tr>
<td>11278AU</td>
<td>65</td>
<td>6.7</td>
<td>7.5</td>
<td>8.4</td>
<td>Round</td>
<td>270/270</td>
<td>—</td>
<td>Intuitive</td>
<td>3.6</td>
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<tr>
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<td></td>
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<tr>
<td>7325.172/125.152/125.122</td>
<td>70/45/20</td>
<td>7.5</td>
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<td>Tapered</td>
<td>130/160</td>
<td>—</td>
<td>Intuitive</td>
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</tr>
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<td>7.4</td>
<td>9</td>
<td>9</td>
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<td>130/160</td>
<td>—</td>
<td>Intuitive</td>
<td>4.5</td>
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<tr>
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<td>9</td>
<td>9</td>
<td>Tapered</td>
<td>130/160</td>
<td>—</td>
<td>Intuitive</td>
<td>3.6</td>
</tr>
</tbody>
</table>
Wolf flexible ureteroscopes to have the best resolution with the least amount of distortion compared to the other commercially available flexible ureteroscopes (Table 3).

### Table 3
Resolution and Distortion of Flexible Ureteroscopes

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Distortion (%):</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wolf 7325.172:</td>
<td>25.39 lines/mm (BEST)</td>
</tr>
<tr>
<td>Wolf 7330.072:</td>
<td>22.62 lines/mm</td>
</tr>
<tr>
<td>Olympus URF-P3:</td>
<td>12.70 lines/mm</td>
</tr>
<tr>
<td>ACMI Dur-8:</td>
<td>14.30 lines/mm</td>
</tr>
<tr>
<td>ACMI DUR-8E:</td>
<td>11.30 lines/mm</td>
</tr>
<tr>
<td>Storz Flex X:</td>
<td>9.54 lines/mm (WORST)</td>
</tr>
</tbody>
</table>

Distortion (%): \[(Actual Distance – Predicted Distance)/Predicted Distance\] × 100.

In general, most of these ureteroscopes have a 0° angle of visualization. However, some have a 9° angle for the visualization of instruments as they are advanced out of the working/irrigation channel. The majority of the flexible ureteroscopes have flush tips, however, some of the flexible scopes have a beveled, triangular tip which in theory may facilitate insertion into the ureteral orifice and decrease ureteral trauma. These beveled tip endoscopes also allow the manufactures to claim a smaller tip diameter, which rapidly enlarges to the distal shaft size, whereas the scopes with flush tips maintain the small distal diameter for several millimeters (Fig. 6).

### Tip Design

Working/Irrigation Channels

Most of the modern flexible ureteroscopes have a single 3.6-Fr working channel with the exception of the Wolf 9-Fr ureteroscope that has a 4.5-Fr working channel. The larger caliber allows for a higher flow rate and insertion of larger instruments. Because the single channel is used for both passage of instruments and irrigation, an instrument in the channel will reduce the irrigant flow rate. The loss of flow may be compensated by pressurizing the irrigant fluid and the use of smaller, less than 1.9-Fr caliber instruments. It appears that the 200-μ laser fiber has the least deleterious effects on the flow rate, whereas the 3.0-Fr basket causes the greatest reduction in the flow rate (Table 4).

### Scope Deflection

The active deflection of the tip of the flexible ureteroscope is manually controlled via a lever mechanism on the handle. Depending on the model, the tip may deflect from 130 to 270 degrees in either direction in the same plane. The scope may be designed with intuitive or counterintuitive deflection directions. In the more common intuitive deflection
scopes, the tip deflects in the same direction as the movement of the thumb lever, as opposed to counterintuitive deflection where the tip deflects in the opposite direction to the movement of the thumb lever. Whereas most of the scopes can be deflected 120 to 180° in either direction, the recently introduced “Flex-X” flexible ureteroscope (Karl Storz America Inc, Culver City, CA) can be deflected 270° in either direction (Fig. 7A). Another new ureteroscope, the “DUR-8 Elite” (ACMI Corp, Southborough, MA) incorporates a more proximal secondary 130° one way deflection in addition to the primary 170/180° up and down deflection (Fig. 7B). Besides the active deflection, flexible ureteroscopes also contain a passive deflecting segment; it is a more flexible segment of the scope that is placed several centimeters proximal to the active deflectable segment. This

Table 4

<table>
<thead>
<tr>
<th>Irrigation Flow Rate (cc/min) at 100 mmHg and Percent Reduction With Various Instruments</th>
<th>ACMI Dur 8 Elite</th>
<th>Storz Flex-X</th>
<th>Olympus URF-P3</th>
<th>Wolf 7325.172</th>
<th>Wolf 7330.072</th>
</tr>
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<tr>
<td>Empty</td>
<td>60</td>
<td>56</td>
<td>65.5</td>
<td>70.5</td>
<td>153</td>
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<tr>
<td>200-μ laser</td>
<td>33.3 (44.5%)</td>
<td>28.5 (49%)</td>
<td>36 (45%)</td>
<td>37 (47.5%)</td>
<td>110 (28%)</td>
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<tr>
<td>400-μ laser</td>
<td>12 (80%)</td>
<td>8.5 (84%)</td>
<td>11 (83%)</td>
<td>11 (84%)</td>
<td>63 (58%)</td>
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<tr>
<td>1.9-Fr EHL (ACMI)</td>
<td>17.5 (71%)</td>
<td>13.7 (75%)</td>
<td>18.5 (71.8%)</td>
<td>19 (73%)</td>
<td>81 (47%)</td>
</tr>
<tr>
<td>2.2-Fr basket</td>
<td>15.1 (75%)</td>
<td>11.5 (79.5%)</td>
<td>11 (83%)</td>
<td>14 (80.1%)</td>
<td>79 (48.4%)</td>
</tr>
<tr>
<td>3.0-Fr basket</td>
<td>3.7 (94%)</td>
<td>2.7 (95.1%)</td>
<td>5 (92.3%)</td>
<td>4 (94.3%)</td>
<td>45 (70.5%)</td>
</tr>
<tr>
<td>2.6-Fr grasping forceps (microvasive)</td>
<td>4.5 (92.5%)</td>
<td>3.1 (94.5%)</td>
<td>5.5 (85.7%)</td>
<td>5 (93%)</td>
<td>53 (65.4%)</td>
</tr>
</tbody>
</table>

ACMI, Advanced Cytoscope Makers, Inc.; EHL, electrohydraulic lithotripsy.
passive deflecting segment, when used in consort with the active deflection, allows the scope to curl upon itself when the tip of the scope is reflected off the medial aspect of the renal pelvis for maneuvers into the lower pole infundibulum. Just as the flow rate is negatively impacted, the angle of active and passive deflection can also become severely restricted by the presence of instruments in the working channel. This effect on the angle of deflection can also be lessened with newer, smaller, and more malleable instruments. Various techniques have been described to limit the impact of instruments in the working channel, including the use of an unsheathed (bare naked) nitinol basket to reduce its diameter (13,14). The degree of loss of deflection caused by the presence of various instruments were studied at University of California-Irvine Medical Center; measurements of deflection were made by photocopying the ureteroscopes when completely deflected. In general, the angle of deflection was most impaired by the 365-μ laser fiber, and the least impaired by the 2.2-Fr nitinol basket. The results are shown on Table 5.

**Care and Sterilization**

Although these modern flexible ureteroscopes are capable of accessing the most difficult areas in the upper urinary tract, they are fragile and require major repair after an average of 6 to 15 uses (15). Common reasons for repair are broken fiberoptic fibers, damaged working channel, and poor, or loss of, deflection. Currently, the durability and cost of maintenance is the main limiting factor against incorporation of these delicate instruments in most general urology practices (16,17).

Rigid and semirigid ureteroscopes are considerably more durable than their flexible counterparts because of their outer metal casing. However, proper handling by holding these scopes near their eyepieces at the base while supporting the shaft should be emphasized. Cleansing with warm water and a nonabrasive detergent, as well as irrigation of the working channels, following each use is important. The rigid and semirigid ureteroscopes can be sterilized by gas (ethylene oxide) or by soaking; some may be autoclaved. Similarly, the more fragile flexible ureteroscopes should also be cleaned initially by rinsing and irrigating with warm water and a nonabrasive detergent, and then sterilized by gas or soaking. These delicate scopes are prone to damages from bending or

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**Fig. 7.** Comparison between the Flex-X and DUR-8 Elite tip deflection mechanism. (A) Flex-X (Karl Storz Inc). (B) Dur-8 Elite, (ACMI).
<table>
<thead>
<tr>
<th>Instrument</th>
<th>ACMI DUR 8 Elite</th>
<th>Storz FLEX-X</th>
<th>Olympus URF-P3</th>
<th>Wolf 7325.172</th>
<th>Wolf 7330.027</th>
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<tbody>
<tr>
<td></td>
<td>Down</td>
<td>Up</td>
<td>Active secondary</td>
<td>Active I+2</td>
<td>Down</td>
</tr>
<tr>
<td>200-μ laser fiber</td>
<td>18.3%</td>
<td>21.1%</td>
<td>22.7%</td>
<td>7.1%</td>
<td>9.3%</td>
</tr>
<tr>
<td>365-μ laser fiber</td>
<td>46.3%</td>
<td>39.5%</td>
<td>28%</td>
<td>25.9%</td>
<td>26.8%</td>
</tr>
<tr>
<td>1.9-Fr EHL</td>
<td>9.1%</td>
<td>11.2%</td>
<td>18.9%</td>
<td>6.8%</td>
<td>8.5%</td>
</tr>
<tr>
<td>2.2-Fr basket</td>
<td>4.9%</td>
<td>14.5%</td>
<td>16.7%</td>
<td>6%</td>
<td>2.4%</td>
</tr>
<tr>
<td>3-Fr basket</td>
<td>12.2%</td>
<td>17.1%</td>
<td>18.2%</td>
<td>7.9%</td>
<td>10.6%</td>
</tr>
<tr>
<td>2.6-Fr grasper</td>
<td>22%</td>
<td>20.4%</td>
<td>25.8%</td>
<td>14.3%</td>
<td>15.9%</td>
</tr>
</tbody>
</table>

EHL, electrohydraulic lithotripsy.
trauma to the distal tip or the eyepiece. Therefore, every effort should be made to main-
tain them in a straight orientation during cleansing and use. In addition, the flexible 
ureteroscopes require venting during gas sterilization, either by manually opening a 
vent near the irrigation port near the light post, or some may have an automatic, 
patented, *Autoseal* system. Liquid sterilization may be accomplished by soaking in 2.4%
glutaraldehyde (i.e., Cidex, Advanced Sterilization Products, Irvine, CA) or 35% peroxy-
acetic acid (i.e., Steris, Mentor, OH). Peroxyacetic acid is harsh on flexible endoscopes 
and has been demonstrated to be associated with higher flexible cystoscope repair costs 
(18). However, the durability of the flexible ureteroscopes may also be effected by the 
technique and number of personnel involved in the cleaning and maintenance rather 
than the technical demands of the procedure and the endoscopists’ technique (19). The 
routine use of newer ureteroscopic accessories such as ureteral access sheaths, nitinol 
devices, and 200-μ holmium laser fibers can decrease the strain on the flexible uretero-
scopes and significantly increase the longevity (17).

**Rigid and Flexible Nephroscopes**

The rigid nephroscopes have undergone little change since the advent of percuta-
neous nephrostolithotomy. In general, they provide excellent visualization with a 
rod–lens system and an offset eyepiece to allow passage of large, straight instruments 
for stone fragmentation, such as the ultrasonic lithotripter or the lithoclast. Various 
lengths are available, ranging from 17.5 to 30 cm, to accommodate a variety of patient 
body habitus. Sheaths range from 15 to 27 Fr in size; “mini-nephroscopes” with a 
smaller, 11-Fr diameter which can be used as a compact cystoscope are also available. 
A flexible cystoscope may be used as a nephroscope when needed. A new digital cy-
sitonephroscope by ACMI has been developed and offers additional flexion to the tradi-
tional up/down plane to meet the demands of percutaneous nephrostolithotomy (Fig. 5).

**CONCLUSION**

Since the initial concept of inspecting a body cavity using a light and image trans-
mittinf system, significant development and advancements have been made in the field 
of urologic endoscopy. With the availability of a wide range of rigid, semirigid, flexi-
ble endoscopes, and specifically designed working instruments, most upper urinary 
tract lesions can be effectively diagnosed and treated in a minimally invasive approach. 
Continued refinements to these instruments may potentially improve the optics, dura-
bility and efficacy of the treatment as technological advances are incorporated into the 
design of the endoscopes and accessory instruments.

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Access, Stents, and Urinary Drainage

Ben H. Chew, MSc, MD, FRCSC
and John D. Denstedt, MD, FRCSC

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THE ROLE OF NEW BIOMATERIALS AND COATINGS
TIPS AND TRICKS
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SUMMARY
Ureteral access is necessary in many endourological procedures including ureteroscopy and ureteral stenting. Technologies such as ureteral access sheaths, balloon dilators, and coaxial dilators may be helpful in facilitating ureteral access in difficult cases. This chapter describes a stenting technique that relies on fluoroscopic guidance once the initial guidewire is placed and the cystoscope is removed.

Key Words: Ureter; stent; calculi; ureteroscopy; nephrostomy tube; shockwave lithotripsy.

INTRODUCTION
Ureteral stents are a mainstay in the urological armamentarium and are utilized in the treatment of urolithiasis including post-ureteroscopy, pre-shockwave lithotripsy, and to relieve symptomatic renal colic. Routine stenting post-ureteroscopy and intracorporeal lithotripsy, once the standard of care, have been shown to be unnecessary following uncomplicated ureteroscopy and stone manipulation. Advances such as laser lithotripsy and smaller ureteroscopes have minimized the potential morbidity of ureteroscopy to the point that the indwelling stent has become the most morbid part of the procedure. Ureteral stents may cause considerable side effects ranging from dysuria, urgency and frequency to hematuria.
and suprapubic pain. There is an emerging body of literature that routine stenting post-
tureteroscopy is not necessary and that the need for stenting should be determined on a case
by case basis.

Stents are also used to provide urinary drainage in nongenitourinary causes of
ureteral obstruction, such as pregnancy and malignant ureteral obstruction. An alterna-
tive and effective method of urinary drainage is the percutaneous nephrostomy tube
which is easily placed in patients with significant hydronephrosis and may be even
more successful than retrograde ureteral stenting when urinary drainage is required as a
result of obstruction of the distal ureter. Incompressible stents incorporating metal into
the stent material have been used to provide urinary drainage to patients with malignant
ureteral obstruction. Conversely, biodegradable stents have been developed to provide
ureteral drainage temporarily following an endourological procedure before degrading
and being excreted in the urine, thus obviating the need for cystoscopic stent removal.
Other stent advancements will see coatings, new materials, and drugs loaded directly
into the stent material or coated on the stent surface to improve comfort and reduce
biofilm formation, infection, and encrustation.

Access to the ureter is required any time closed endoscopic ureteral procedures are to
be carried out including during ureteral stenting and in association with diagnostic and
therapeutic ureteroscopy for urolithiasis. More detail will be provided in other chapters
regarding procedure specific aspects of ureteroscopy and percutaneous procedures; this
chapter will focus on initially gaining retrograde access to the ureter, aspects related
to ureteral stenting and a comparative analysis of alternative methods of urinary drainage.
A brief summary of new stent technologies and biomaterials will also be presented.

**Indications to Access the Ureter**

Achievement of ureteral access is necessary for performing retrograde endoscopic
procedures such as ureteroscopy, or for placing a ureteral stent. Table 1 lists common
indications for ureteral stent placement.

**Stones**

Urolithiasis represents one of the more common reasons to insert a ureteral stent.
Clinical indications for stenting include patients with intractable pain, those with
infected pyonephrosis, or patients with impaired renal function from obstruction. In
addition, ureteral stenting is often employed as an adjunct to shockwave lithotripsy or
endoscopic procedures in patients requiring surgical stone management.

**Ureteral Stones: Retrograde Ureteral Stenting
ds Nephrostomy Tube Drainage**

Pyonephrosis with an obstructing stone requires urgent decompression using either ret-
rograde ureteral stent placement or antegrade percutaneous nephrostomy tube drainage
(1). Whether urinary drainage to bypass the obstruction is best accomplished via a ureteral
stent or a nephrostomy tube is a subject of debate. The first randomized clinical trial to
compare these two methods in obstructed, infected patients was performed by Pearle et al.
(2) in 42 patients with obstructing urolithiasis and pyonephrosis. The time to deferves-
cence, length of stay in hospital, pain symptoms, and normalization of leukocytosis did
not differ between these two groups suggesting that urinary decompression by either ret-
rograde ureteral stenting or antegrade percutaneous nephrostomy tube insertion are both
equally effective in treating obstructed pyonephrosis. However, patients had significantly
less fluoroscopy exposure (2.6 minutes less) when they were stented in a retrograde fashion.