

Basic Endoscopic Equipment

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The modern era of endoscopy began with the development of fiberoptic instruments in the 1960s. For most purposes these are being supplanted by video chip endoscopes in the 1990s. Details of instruments for specific purposes, accessories and precise methods for management are outlined in other chapters. This chapter serves to introduce the true beginner to some principles which are common to all endoscopes and procedures.

Flexible endoscopes are complex (Fig.1.1). Basically, they consist of a control head and a flexible shaft with a manoeuvrable tip. The head is connected to a light source via an 'umbilical' cord, through which pass other tubes transmitting air, water and suction, etc. The suction channel is used for the passage of diagnostic tools (e.g. biopsy forceps) and therapeutic devices.

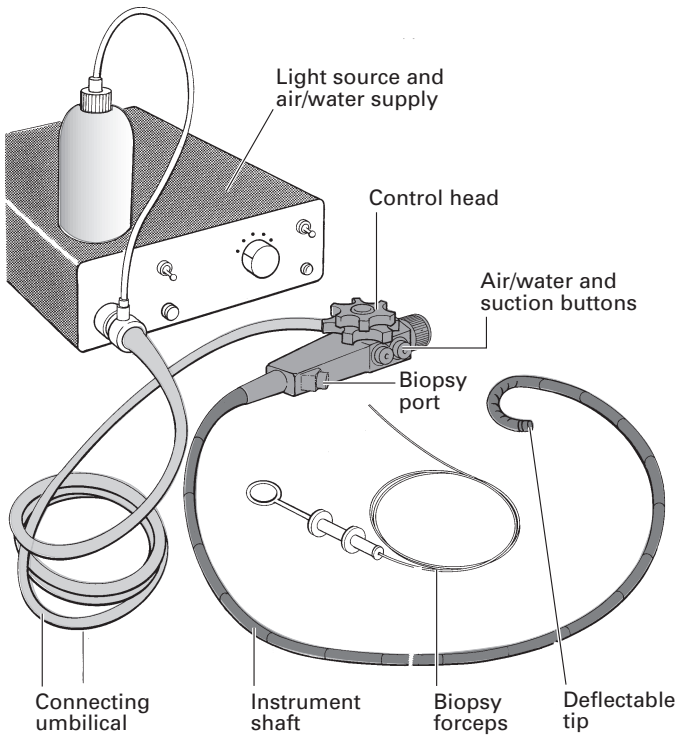


Fig. 1.1 Fiberoptic endoscope system.

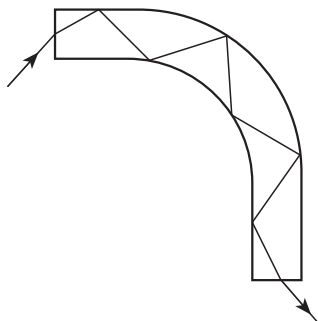


Fig. 1.2 Total internal reflection of light down a glass fibre.

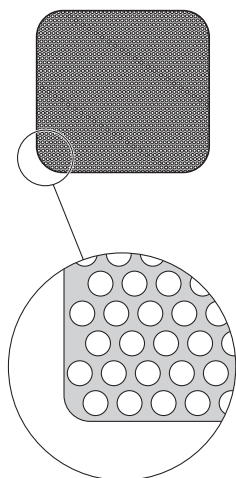


Fig. 1.3 Fibre bundle showing the 'packing fraction' or dead space between fibres.

Fibreoptic instruments and video-endoscopes

Fibreoptic instruments

These are based on optical viewing bundles, well described as a 'highly flexible piece of illuminated spaghetti'. The viewing bundle of a standard fibre-endoscope is 2–3 mm in diameter and contains 20 000–40 000 fine glass fibres, each close to 10 μm in diameter. Light focused onto the face of each fibre is transmitted by repeated internal reflections (Fig. 1.2). Faithful transmission of an image depends upon the spatial orientation of the individual fibres being the same at both ends of the bundle (a 'coherent' bundle). Each individual glass fibre is coated with glass of a lower optical density to prevent leakage of light from within the fibre, since the coating does not transmit light. This coating and the space between the fibres causes a dark 'packing fraction', which is responsible for the fine mesh frequently apparent in the fibreoptic image (Fig. 1.3). For this reason, the image quality of a fibreoptic bundle, though excellent, can never equal that of a rigid lens system. However, fibreoptic bundles are extremely flexible, and an image can be transmitted even when tied in a knot. In most modern instruments the distal lens which focuses the image onto the bundle is fixed, and a pin-hole aperture gives a depth of focus from 10–15 cm down to about 3 mm. The image reconstructed at the top of the bundle is transmitted to the eye via a focusing lens, adjustable to compensate for individual differences in refraction.

Video-endoscopes

These are mechanically similar to fibre-endoscopes, with a charged couple device (CCD) 'chip' and supporting electronics mounted at the tip, to and fro wiring replacing the optical bundle and further electronics and switches occupying the site of the ocular lens on the upper part of the control head. Removing any need to hold the instrument close to the endoscopist's eye has hygienic advantages (avoidance of splash contamination) and also gives the opportunity for radical changes of instrument design and handling techniques in the future.

The subtleties of different CCD systems in design and performance are beyond the scope of this book. However, in essence, a CCD chip is an array of 33 000–100 000 individual photo cells (known as picture elements or pixels) receiving photons reflected back from the mucosal surface and producing electrons in proportion to the light received. In common with all other television systems the individual receptors of the CCD respond only to degrees of light and dark, and not to colour. 'Colour' CCDs have extra pixels to allow for an overlay of multiple primary colour filter stripes, making the pixels under a particu-

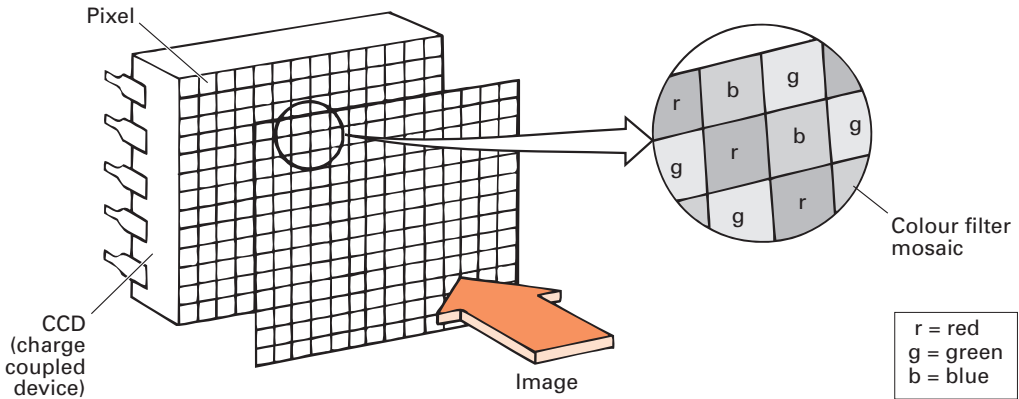


Fig. 1.4 Static red, green and blue filters in the 'colour' chip.

lar stripe respond only to light of that particular colour (Fig. 1.4). 'Black and white' (or, more correctly, sequential system) CCDs can be made smaller, or potentially of higher resolution, by the expedient of illuminating *all* the pixels with intermittent primary colour strobe-effect lighting produced by rotating a colour filter wheel within the light source (Fig. 1.5). The sequential primary colour images (in the gut mostly red, some green and little blue) are stored transiently in banks of memory chips in the processor and fed out sequentially to the red/blue/green electron guns of the TV monitor. The large numbers of chips and sophisticated computer 'image-processing' technology used to optimize the underlying single CCD output account for the excellence of the image produced by sequential CCD systems (and the high price involved), as well as the relatively large processor.

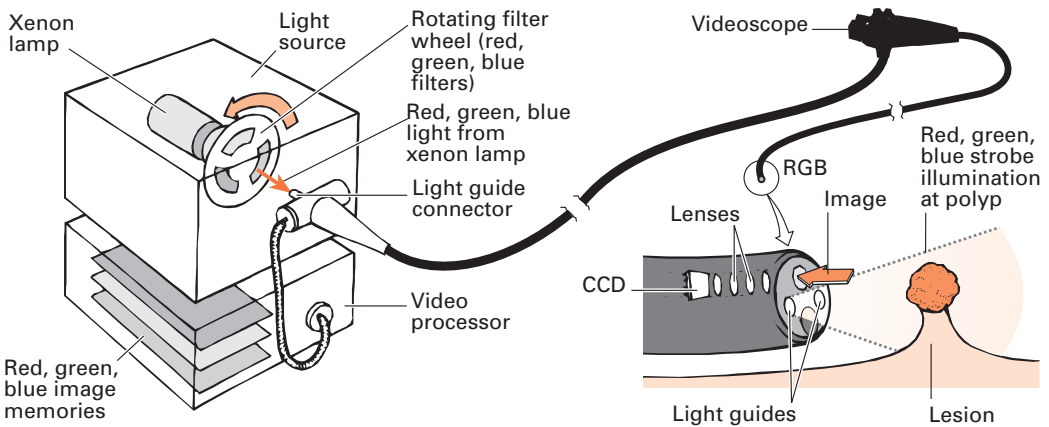


Fig. 1.5 Sequential colour illumination.

Video-endoscope or fibre-endoscope?

The screen-image quality of present video-endoscopes equals that of present fibrescopes in both colour and resolution. Video-endoscopy scores greatly by the fact that everyone can view the image simultaneously, with a clarity previously restricted to the endoscopist alone (teaching side-arms and add-on television cameras introduce optical interference and reduce quality). Whereas optical fibre technology is near its maximum theoretical performance (since below the 6–8 μm fibre diameter approached in modern bundles there is massive loss of light transmission), there is no reason why the 10 μm pixel size of present CCDs should not be reduced to around 1 μm . This means that future CCDs can be smaller, but also that the greatly increased numbers of pixels will increase resolution and allow the use of high-definition TV monitors. The objection that video-endoscopes introduce 'artificial colour' values is untenable since: (i) they can be shown in technical studies to give a remarkably faithful rendering of test charts; (ii) the visual assessment of lesions depends little on absolute colour values; and (iii) there is the inescapable fact that individual perception of colour varies significantly — the extreme example being colour blindness. In terms of hard-copy imaging there is also a clear advantage in employing only the ocular lens system at the instrument tip without the degrading effects of transmission down an optical bundle and through a secondary lens system. Of crucial importance is the fact that the digital signal simplifies image recording and manipulation, and opens the way for new methods of image enhancement, transmission and analysis.

For the fibre-endoscopist, the mechanical transition to handling video-endoscopes whilst viewing the TV monitor is mastered in a few minutes. Thereafter, most endoscopists tend to work this way instinctively, even with fibre-endoscopes if a video camera attachment is available. The ease of stance, brighter view and the natural visual field (combining a macular view of the image and peripheral view of the patient and the endoscopy room) make video-endoscopes extremely relaxing to use, and facilitates communication with patients and assistants. The mechanical manipulation of endoscope controls and subtle management of its shaft, including de-looping or rotatory movements, are also significantly easier with video-endoscopes, since the manipulating left hand can move freely without relationship to the endoscopist's eye. Although in individual practice no user of fibre-endoscopes need feel disadvantaged, the bonus for larger institutions or teaching hospitals of the shared view, including the ability for experienced endoscopists to see precisely the same image as obtained by an apprentice, scores highly in favour of using video-endoscopes.

For these many reasons, video-endoscopes have taken over a majority position in gastrointestinal (GI) endoscopic units.

Fibreoptic instruments will retain some role, by virtue of their simplicity and small-diameter capability, for instances where portability is relevant, as well as in other special circumstances.

Illumination

This is provided from an external high-intensity source through one or more light-carrying bundles. Since these light bundles do not transmit a spatial image, the fibres within them need not be 'coherent' and are randomly arranged. Because light intensity is reduced at any optical interface, light bundles run uninterruptedly from the tip of the instrument through its connecting 'umbilical' cord directly to the point of focus of the lamp. These may be xenon arc (300 W) or halogen-filled tungsten filament lamps (150 W). Light is focused by a parabolic mirror onto the face of the bundle, and the transmitted intensity is controlled by filters and/or a mechanical diaphragm. The light sources made by different companies are not always interchangeable; adapters may be provided, but involve a further optical interface and some loss of light. Small sources are mobile and relatively cheap and provide sufficient illumination for simple observation and standard photography. Large light sources are necessary for optimal photography and television application when using fibrescopes or video-endoscopes.

Instrument tip

Control of the instrument tip depends upon pull wires attached at the tip just beneath its outer protective shaft, and passing back through the length of the instrument shaft to the angling controls

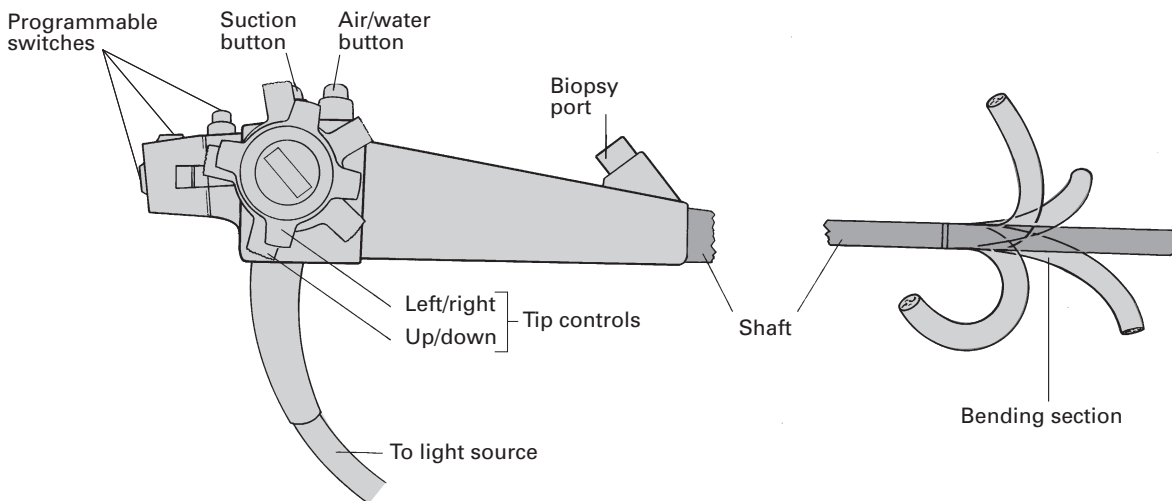


Fig. 1.6 Basic design—control head and bending section.

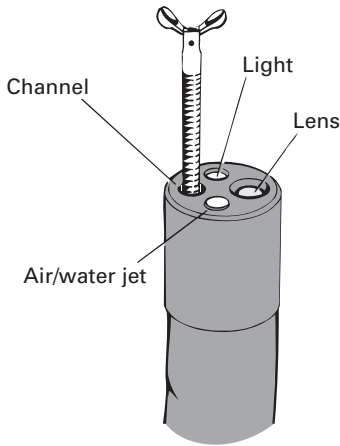


Fig. 1.7 The tip of a forward-viewing endoscope.

in the control head (Fig. 1.6). The two angling wheels/knobs (for up/down and right/left movement) incorporate a friction braking system, so that the tip can be fixed temporarily in any desired position; angling with the brakes on causes no damage. The instrument shaft is torque stable so that rotatory ‘corkscrewing’ movements applied to the head are transmitted to the tip—if the shaft is relatively straight at the time.

Instrument channels

An ‘operating’ channel (usually 2–4 mm in diameter) allows the passage of fine flexible accessories (e.g. biopsy forceps, cytology brushes, sclerotherapy needles, diathermy snares) from a port on the endoscope control head (see Fig. 1.6) through the shaft and into the field of view (Fig. 1.7). In some instruments (especially those with lateral-viewing optics), the tip of the channel incorporates a small deflectable elevator or bridge, which permits some directional control of the forceps and other accessories independent of the instrument tip (Fig. 1.8); this elevator or bridge is controlled by a further thumb lever. The operating channel is also used for aspiration in single-channel instruments; an external suction pump is connected to the ‘umbilical’ cord of the instrument near the light source and suction is diverted into the instrument channel by pressing the suction valve.

The channel size varies with the instrument purpose. ‘Therapeutic’ endoscopes with large channels allow better suction and larger accessories. Twin-channel endoscopes exist for specialized applications. An ancillary small channel transmits air to distend the organ being examined; the air is supplied from a pump in the light source and is controlled by another valve (see Fig. 1.6). The air system also pressurizes the water bottle so that a jet of water can be squirted across the distal lens to clean it. In colonoscopes there is a separate proximal opening for the water channel, to allow high-pressure flushing with a syringe.

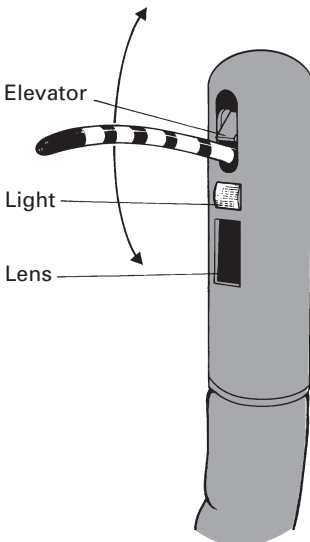


Fig. 1.8 A side-viewer with cannula protruding from the elevator.

Different instruments

The basic design principles apply to most endoscopes, but specific instruments differ in length, size, stiffness, sophistication and distal lens orientation. Most GI endoscopy is performed with instruments providing *direct forward vision* (Fig. 1.7), via a 90–130° wide-angle lens (the angle being measured across the diagonal of square image endoscopes). However, there are circumstances in which it is preferable to view *laterally* (Fig. 1.8) — particularly for endoscopic retrograde cholangiopancreatography (see Chapter 6). Oblique and even movable lens instruments have been developed, but are no longer popular. The overall diameter of an endoscope is a compromise between engineering

ideals and patient tolerance. The shaft must contain and protect many bundles, wires and tubes, all of which are stronger and more efficient when larger. A colonoscope can reasonably approach 15 mm in diameter to provide resilience and torque stability, but this size is acceptable in the upper gut only for specialized therapeutic instruments. Most routine upper GI endoscopes are between 8 and 11 mm in diameter. Smaller endoscopes are available; they are better tolerated by all patients and have specific application in children. However, smaller instruments inevitably involve some compromise in durability, image quality and biopsy size. All modern endoscopes can be completely immersed for cleaning and disinfection; non-immersible instruments are obsolete.

Several companies now produce a full range of endoscopes at comparable prices. However, since light sources and other accessories produced by different companies are not always interchangeable, most endoscopy units concentrate for convenience on equipment from only one manufacturer. Endoscopes are delicate and some breakages are inevitable. Only close communication, repair and back-up arrangements with an efficient company and its agents can maintain an endoscopy service. The quality of this support varies with different companies (and countries), and is often the critical factor affecting the choice of manufacturer.

Accessories

Tissue-sampling devices

Tissue sampling is a crucial part of endoscopy. Forceps consist of a pair of sharpened cups (Fig. 1.9), a spiral metal cable and a control handle (Fig. 1.10). The maximum diameter is limited by the size of the operating channel, and the length of the cups by the radius of curvature through which they must pass in the instrument tip. This may be acute in side-viewing instruments with forceps elevators. When it is necessary to take biopsy specimens from a lesion which can only be approached tangentially (e.g. the wall of the oesophagus), forceps with a central spike may be helpful; however, these present a significant puncture hazard, and should probably not be used to avoid accidental infectious inoculation of endoscopy staff. Cytology brushes have a covering plastic sleeve to protect the specimen during withdrawal (Fig. 1.11). Other diagnostic and therapeutic devices will be described in the relevant chapters.

Suction traps

Suction traps, such as those used for collecting samples of sputum during bronchial aspiration, are equally useful for

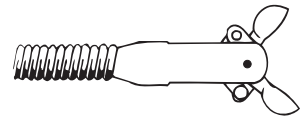


Fig. 1.9 Biopsy cups open.

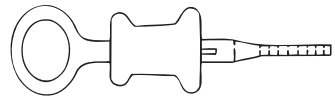


Fig. 1.10 Control handle for forceps.



Fig. 1.11 Cytology brush with outer sleeve.

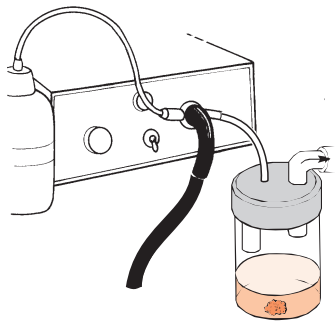


Fig. 1.12 A suction trap to collect fluid specimens.

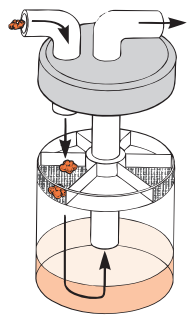


Fig. 1.13 A filtered suction trap is better for tissue specimens.

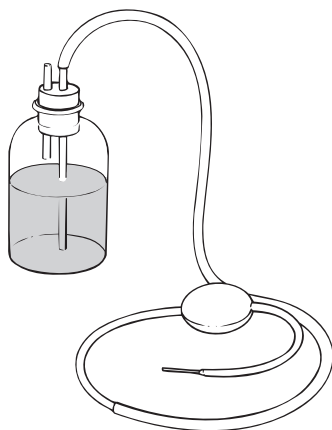


Fig. 1.14 A rubber bulb for flushing through the instrumentation channel.

taking samples of intestinal secretions and bile. When fitted temporarily into the suction line (Fig. 1.12) they allow the collection of samples for microbiology, chemistry and 'salvage' cytology. Solid or snare-loop specimens can also be retrieved in an ingenious filtered suction trap available commercially (Fig. 1.13).

Fluid-flushing devices

Flushing fluids through the channel may be necessary to provide optimal views of lesions, particularly in the presence of food residue or acute bleeding. With standard endoscopes, this can be done with a syringe, manual bulb (Fig. 1.14) or a pulsatile electric pump, with a suitable nozzle through the biopsy port. Some therapeutic instruments have an in-built forward-facing flushing channel at the tip. For more precise aiming, a simple Teflon tube can be passed down the instrument channel to clear mucus or blood from areas of interest with a jet of water, or to highlight mucosal detail by 'dye spraying' (using a nozzle-tipped catheter).

Overtubes (sleeves)

These are flexible hoses (24–45 cm long, depending on the indication) designed to fit over the endoscope shaft (Fig. 1.15). Sophisticated low-friction versions are produced but suitable alternatives can be made from plastic hose; the internal diameter needs to be tailored to the size of the endoscope. The wall should be as thin as possible (to minimize patient discomfort) but should have sufficient strength not to kink and to maintain its shape when the endoscope is removed. The top end of the tube should have a flange which abuts against the mouthguard, or some device which can be gripped by the assistant (to prevent it from disappearing into the mouth or anus). Overtubes are mainly used when repeated intubation is anticipated, e.g. for change of endoscopes, removal of multiple polyps, variceal banding or use of muzzle-loaded forceps and biopsy capsules. The endoscope is passed in the usual way, with the overtube at the top of the shaft. Once the endoscope is in position, the overtube is lubricated and slid over the shaft. It is then simple to remove and to replace the endoscope without significant patient

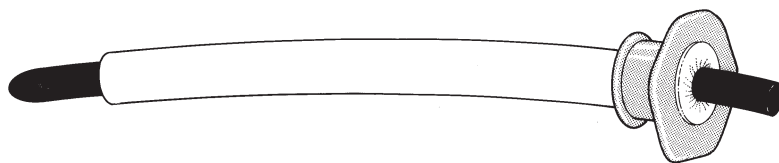


Fig. 1.15 An overtube with toothguard over a rubber lavage tube.

discomfort. Alternatively, the upper GI overtube can be passed first, sitting snugly on a large dilator (or lavage tube) (Fig. 1.15). The dilator is then withdrawn, leaving the overtube in place; this protects the airway and allows the passage of endoscopes without additional patient discomfort.

Longer and larger overtubes are used for the removal of sharp foreign bodies from the stomach and, by some practitioners, windowed overtubes have been found useful during variceal injection sclerotherapy, especially during active bleeding. They can be used also as stiffening devices during colonoscopy and enteroscopy. The use of colonic (split) overtubes is described in Chapter 9.

Electrosurgery equipment

Details are given in Chapter 10.

Teaching attachments

Sharing an image from a fibrescope requires a 'clip-on' side-arm teaching attachment, or a 'video converter', essentially a small CCD chip camera which is applied to the eyepiece of the fibrescope, and transmits the image to a TV monitor (for both the primary operator and assistants).

Use and maintenance

Handling, storage and security

Endoscopes are expensive and complex tools. They should be stored safely, hanging vertically in cupboards through which air can circulate. Care must be taken whilst carrying instruments, since the rigid optics are easily damaged if left to dangle or knocked against a hard surface. The head, tip and umbilical connector should all be held (Fig. 1.16).

Instrument checking

Instruments must be checked before use. The nurse assistant will normally set up the system with the water bottle and other accessories suitably cleaned and disinfected. However, the endoscopist must check that the equipment is ready and safe for use, that the controls are all functional (including tip deflection and air/water/suction channel) and that the image is clear, before starting the procedure.

Channel blockage

Blockage of the air/water (or suction) channel is one of the most

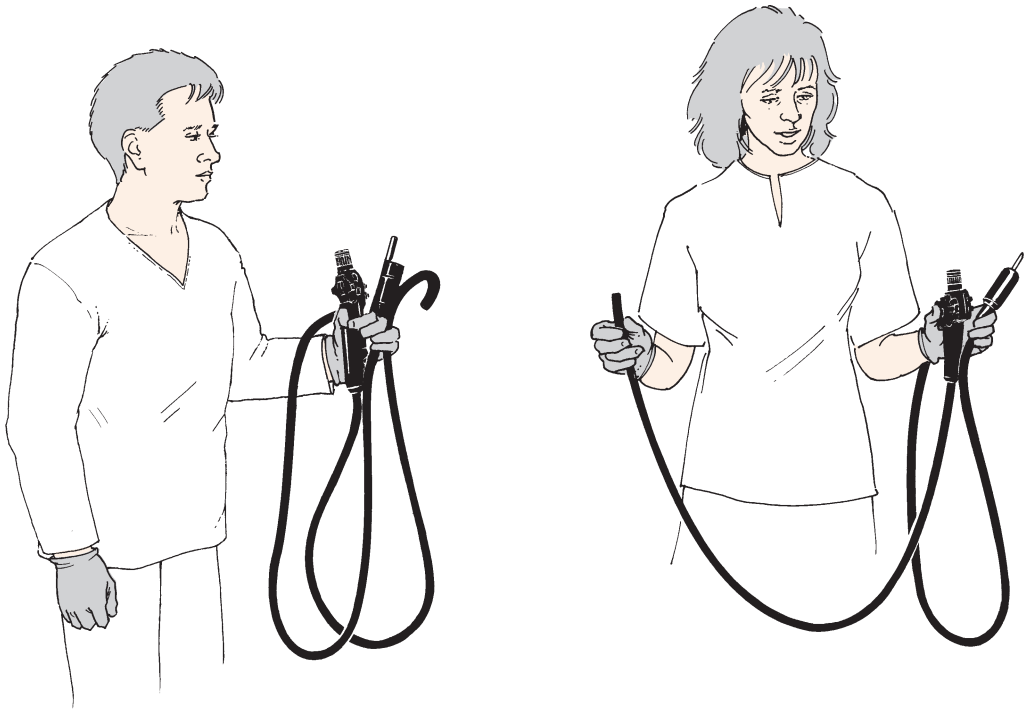


Fig. 1.16 Carry endoscopes carefully to avoid knocks to the optics in the control head and tip.

common endoscope problems. When blockage occurs, the various systems and connections (instrument umbilical, water bottle cap or tube, etc.) must be checked, including the tightness and the presence of rubber O-rings where relevant. It is usually possible to clear the different channels by flushing with a syringe and a suitable soft plastic introducer or micropipette tip. Water can be injected down any channel and, since water is not compressed, more force can be applied than with air. Remember that a small syringe (1–5 ml) generates more pressure than a large one, whereas a large one (50 ml) generates more suction. The air or suction connections at the umbilical, or the water tube within the water bottle can be syringed until water emerges from the instrument tip. Care should be taken to cover or depress the relevant control valves while syringing. Another method for unclogging the suction channel is to remove the valve, and apply suction directly at the port.

Irreversible air-channel blockages are invariably due to coagulated residue inside or just above the small-angled tube inserted at the instrument tip and held in place by a small grub screw covered with soft mastic. If irrigation with a small syringe and fine needle is ineffective, as a last resort this angled tube can

be removed with a very small screwdriver and cleaned with a fine wire. The best way to avoid such blockages is to insist on scrupulous cleaning regimens (see Chapter 3).

Maintenance

The life of an endoscope is almost completely determined by the quality of maintenance. Details of cleaning and disinfection are given in Chapter 3. Close collaboration with hospital bioengineering departments and servicing engineers is essential, but most of the important work is done in the unit by the GI staff—for example regular ‘leakage testing’ of immersible endoscopes. It is important to maintain complex accessories (e.g. electrosurgical equipment) in a safe condition, properly calibrated and adjusted. Repairs and maintenance must be properly documented. A case can be made for returning some instruments to the manufacturers for detailed inspection and ‘tightening up’ from time to time. Some large endoscopy units may find it cost-effective to employ their own biomedical technician.

Further reading

- Sivak M. *Gastroenterologic Endoscopy*. Philadelphia: WB Saunders, 1987.
- Zuccaro G. Video endoscopy and the charge-coupled device. In Sivak M, ed. *Gastrointestinal Endoscopy Clinics of North America*, Vol. 2(2). Philadelphia: WB Saunders, 1992.