Instrumentation: Endoscopes and Equipment

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Key words
- Accessories
- Application
- Endoscopy
- Instruments
- Principles
- Scopes
- Sterilization
- Technology

Abbreviations and Acronyms
CCD: Charge-coupled device
CJD: Creutzfeldt-Jakob disease
CNS: Central nervous system
CSF: Cerebrospinal fluid
EFIS: Electronic flight instruments
ETV: Endoscopic third ventriculostomy
HD: High-definition
LED: Light-emitting diode

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OBJECTIVE: **The technology and instrumentation for neuroendoscopy are described: endoscopes (principles, designs, applications), light sources, instruments, accessories, holders, and navigation. Procedures for cleaning, sterilizing, and storing are included.**

METHODS: **The description is based on the author's own technical development and neuroendoscopic experience, published technology and devices, and publications on endoscopic surgery.**

RESULTS: **The main work horses in neuroendoscopy are rigid glass rod endoscopes (Hopkins optics) due to the optical quality, which allows full high-definition video imaging, different angles of view, and autoclavability, which is especially important in neuroendoscopy due to the risk of Creutzfeldt-Jakob disease infection. Applications are endoscopy assistance to microsurgery, stand-alone endoscopy controlled approaches such as transnasal skull base, ventriculoscopy, and cystoscopy in the cranium. Rigid glass rod optics are also applicable in spinal endoscopy and peripheral nerve decompression using special tubes and cannulas. Rigid minifiberoptics with less resolution may be used in less complex procedures (ventriculoscopy, cystoscopy, endoscopy assistance with pen-designs) and have the advantages of smaller diameters and disposable designs. Flexible fiberoptics are usually used in combination with rigid scopes and can be steered, e.g. through the ventricles, in spinal procedures for indications including syringomyelia and multicystic hydrocephalus. Upcoming flexible chip endoscopes ("chip-in-the-tip") may replace flexible fiberoptics in the future, offering higher resolution and cold LED-illumination, and may provide for stereoscopic neuroendoscopy. Various instruments (mechanical, coagulation, laser guides, ultrasonic aspirators) and holders are available. Certified methods for cleaning and sterilization, with special requirements in neuroapplications, are important.**

CONCLUSIONS: **Neuroendoscopic instrumentation is now an established technique in neurosurgical practice and is experiencing rapid development (stereoscopy, integrated operating room).**

INTRODUCTION

Endoscopes were the first optical instruments used in neurosurgery. They were used much earlier than microscopes: Lespinasse performed endoscopic plexus coagulation in 1910 (5, 11), Mixter (17) introduced endoscopic third ventriculostomy (ETV) in 1923, and at the same time Grant and Fay (10) used photographic documentation in ventriculoscopy. All of these surgeons used Nitze-Leiter–type cystoscopes with an array of lenses (**Figure 1A**). This scope was improved for a special ventriculoscope by Scarff in 1936 (23). In 1934, Putnam (19) designed a 7-mm ventriculoscope with a rod of optical glass resulting in wider optical aperture.

Before World War II, the principles of neurosurgical endoscopes were known: an optical system inside a tube with an integrated illumination, channels for instruments and for irrigation to avoid the frequently deadly ventricle collapse with Dandy's simple tube ventriculoscope (4), special coagulation devices (19), and endoscopic photography. The technique of plexus coagulation and ETV proved to be the first effective treatment for hydrocephalus. Although endoscopy showed decreased surgical mortality of $<$ 10% (24, 25), which compared well with hydrocephalus shunt implants, and was associated with much lower secondary failure and complication rates (20, 26), it did not yet become routine in clinical practice. Reasons were surgical discomfort, risk of infection with the eye at the scope, burns by the heat of the lamp in the tip, and less optical quality compared with the stereoscopic microscope. However, with the introduction of more powerful optics, tolerance of glass rod optics to autoclaving, cold light, and mini color

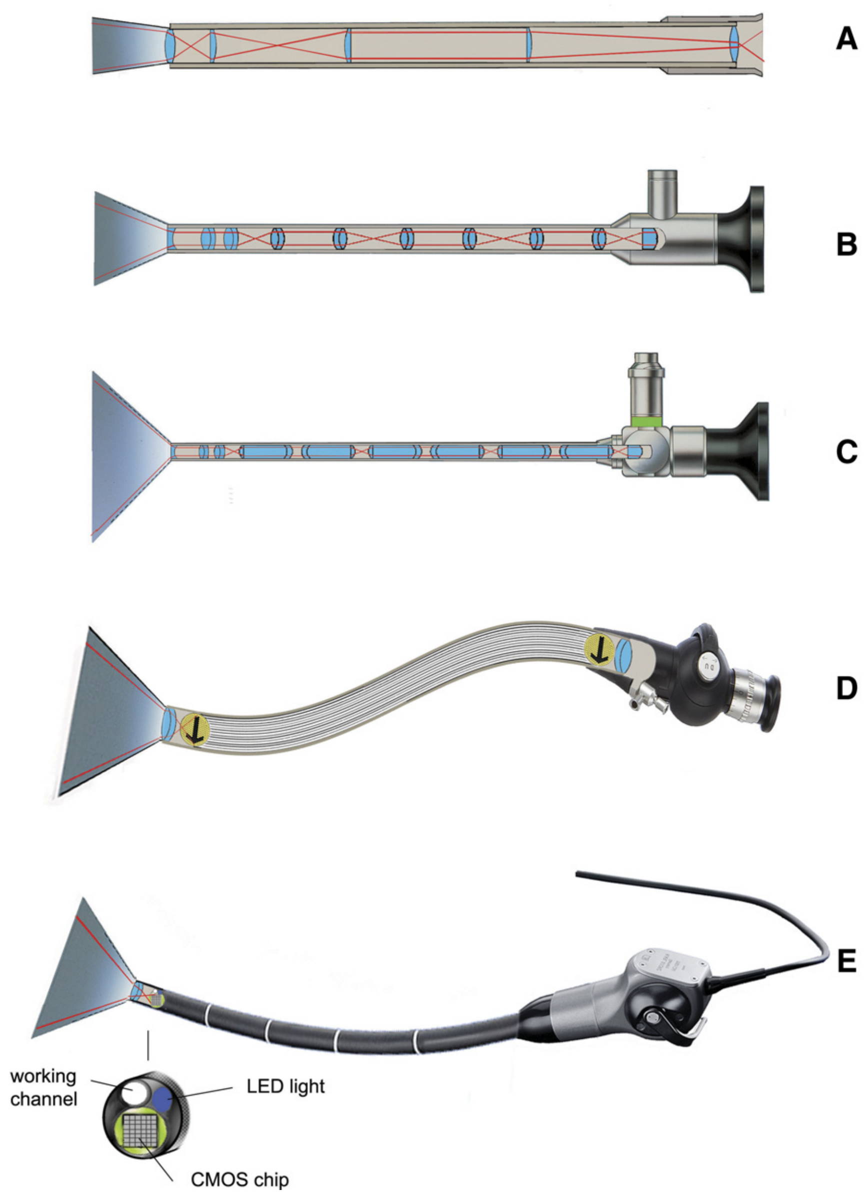

Figure 1. Types of endoscopes. (**A**) Initial lens scope with external illumination (Nitze & Bénèche, 1877). (**B**) Traditional lens scope. (**C**) Hopkins rod lens endoscope. (**D**) SELFOC lens (Nippon Sheet Glass, Tokyo, Japan) rigid endoscope ("needle scope" based on gradient fiber). (**E**) Flexible fiberscope. (Endoscopes depicted in **B–E** are used with external cold light and fiberglass light cable.) (**F**) Video-endoscope ("chip-in-the-tip"), with integrated LED light.

video cameras in the late 20th century, endoscopy has become an essential part of neurosurgery with dynamic development.

ENDOSCOPES

The endoscopes used in neurosurgery today are classified as rigid lens endoscopes, "semi-rigid" mini-fiberscopes, flexible fiberscopes, and video-endoscopes ("distal chip") (**Figure 1A–F**); upcoming innovations are stereoscopic endoscopes, either with conventional scopes (glass rods) using dual charge-coupled device (CCD) cameras/rapidly alternating views with dual "chips on the tip," or with a microscopic array of lenses in front of a single video chip on the tip ("bee eyes technology") (21). Features, advantages, and disadvantages of these scope technologies are summarized in **Table 1**. Endoscopes, instruments, and accessories used for different indications are shown in **Table 2**.

Rigid Lens Endoscopes

The area of vision of rigid endoscopes with glass lenses can be increased by using more lenses (**Figure 1B**). However, these endoscopes have limited image quality and low light transmittance; the small lenses (relay and field lenses) inside the endoscopes require supporting rings, which obscure the train of lenses; are difficult to assemble with the required precision; and are rapidly damaged in clinical use. After initial success with a glass rod instead of lenses by Putnam (19), the breakthrough to today's superb quality of rod-lens endoscopes was achieved by Hopkins' patents (British Patent No. 954629; U.S. Patent No. 3247906; both obtained in 1959) on using several glass rods to fill the former air spaces between the lenses. The glass rods as relay lenses are much longer compared with the diameter of traditional lenses (**Figure 1C**); the optically shaped ends produce an image in the center between two glass rods, and the final image is viewed through the ocular. These rods of optical glass fit exactly to the endoscope tube and are self-aligning without the need of other support, and different glass types of the rods correct for image distortions that occur in every optical system. Karl Storz, who bought Hopkins' patents, introduced this technique into clinical practice in the 1960 (1).

Hopkins' rod lens optics, now Hopkins II with a still wider angle of vision, are the present gold standard in optical quality, area of vision, light transmission, and color fidelity. In deep-seated lesions, these optics "move the eye of the surgeon in front of the lesion," with a large focus range and with the complete amount of xenon light available in the depth, in contrast to microscopes, which have only a small focus range at higher magnification and lose most light on the surface.

A perfect optical quality achieving full high-definition (HD) video resolution requires an outer diameter of the rod lens scopes of $>$ 3 mm (with integrated light fibers), which are recommended for initial anatomic information. Multirod lens scopes with smaller diameters of $<$ 2 mm still provide a good optical quality with much more brightness and resolution than fiberscopes and are used in small ap-