

Value of high-definition imaging in neuroendoscopy

Henry W. S. Schroeder · Matthias Nehlsen

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Abstract To compare the image quality of a standard definition (SD) three-chip camera with a new high-definition (HD) three-chip camera. In five neurosurgical interventions, an SD three-chip camera and an HD three-chip camera were used with the same endoscopic equipment. Both cameras were used while performing one endoscopic third ventriculostomy, one endoscope-assisted microvascular decompression, one endoscope-assisted removal of a vestibular schwannoma, and two endonasal pituitary surgeries. To provide comparable conditions, the outputs of both cameras were displayed on the same flat screen and were recorded on hard disk with an appropriate workstation using a visually lossless codec. Both cameras were used with full light intensity and maximal zoom. The cameras were connected to the same rod-lens endoscopes (2.7- and 1.7-mm lens) one after the other. The image quality of the HD camera was far superior in all applications. Especially in pituitary surgery, the difference was striking when the tumor had to be differentiated from the normal pituitary tissue. Improved resolution and color information explained the better images in HD imaging. Additionally, because of the 16:9 aspect ratio, the viewing field of the HD camera was larger than with the 4:3 aspect ratio of the SD camera. The progressive image processing of the HD camera provided a much clearer image than the interlaced image processing of the SD camera, especially with a modern flat panel screen. HD imaging provides a much better image quality compared to SD imaging.

Therefore, we recommend use of HD cameras in neuroendoscopic procedures.

Keywords High-definition imaging · HDTV · Neuroendoscopy · Third ventriculostomy · Endoscope-assisted skull-base surgery · Endonasal pituitary surgery

Endoscopic techniques in neurosurgery have developed rapidly since the beginning of the 1990s and are now well established at many institutions. Initially, neuroendoscopy was most frequently applied in hydrocephalus. However, nowadays endoscopes are additionally used in many other intracranial interventions such as in endoscope-assisted microsurgical procedures and in endoscopic endonasal skull base surgeries. When operating with the endoscope, the surgeon usually looks at a video monitor screen to control the surgery. Depending on the video camera and monitor, the image has a more or less good image quality. With the development of three-chip charge-coupled devices, the image quality improved markedly. However, the image was still far from ideal. The flickering of the monitor and the limited resolution provided an image that was far inferior to the image obtained when looking through the microscope or directly through the eyepiece of an endoscope. To overcome these limitations, camera technology has been further improved. Recently, the first high-definition (HD) cameras designed for endoscopic surgery have been developed. They provide the HD Television (HDTV) image format. For the very first time, we compared a standard three-chip camera with a high-definition three-chip camera in neuroendoscopic interventions.

H. W. S. Schroeder (✉)
Department of Neurosurgery, Ernst Moritz Arndt University,
Sauerbruchstr,
D-17475 Greifswald, Germany
e-mail: henry.schroeder@uni-greifswald.de

M. Nehlsen
Department of Neurosurgery, Ernst Moritz Arndt University,
Greifswald, Germany

Material and methods

The image quality of an Image 1 SD three-chip camera (KARL STORZ GmbH & Co. KG, Tuttlingen, Germany),

Table 1 Rating of resolution, color information, field of view, and tissue differentiation for HD and SD camera

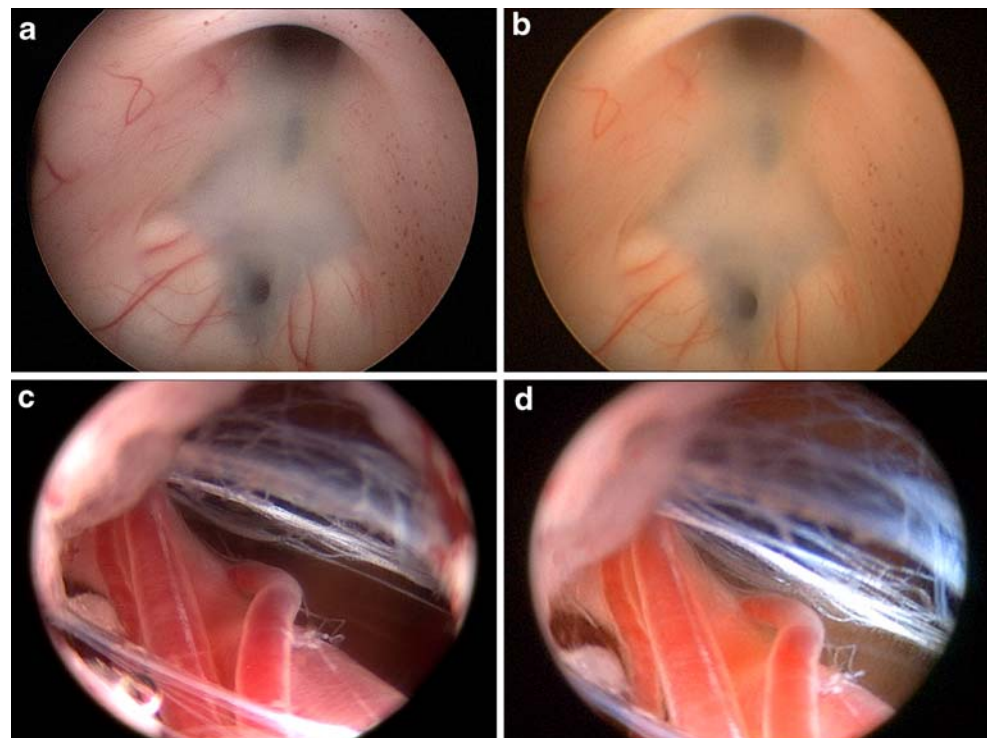
	Resolution		Color information		Field of View		Tissue Differentiation	
	HD	SD	HD	SD	HD	SD	HD	SD
Figure 1	++	+	++	+	++	+	n/a	
Figure 2	+++	+	+++	+	++	+	n/a	
Figure 3	+++	+	+++	+	++	+	+++	+
Figure 4	+++	+	+++	+	++	+	n/a	
Figure 5	+++	+	+++	+	++	+	+++	+

n/a not applicable, (+) good, (++) very good, (+++) excellent

and an Image 1 HD three-chip camera (KARL STORZ GmbH & Co. KG, Tuttlingen, Germany) were compared in five neurosurgical interventions. Resolution, color information, field of view, and in tumor cases, tissue differentiation was evaluated. We used an HD camera model that provides 1080p50 signal [6]. Both cameras were used with the same endoscopic equipment and were attached via an optical adapter to the same rod-lens Hopkins® II endoscopes (2.7- and 1.7-mm lens, 0°, 30°, and 70° viewing angle, KARL STORZ GmbH & Co. KG, Tuttlingen, Germany) one after the other. Xenon light was provided by the cold light fountain Xenon Nova® 300 (KARL STORZ GmbH & Co. KG, Tuttlingen, Germany). Both cameras were used while performing one third ventriculostomy in occlusive hydrocephalus, one endoscope-assisted microvascular decompression in hemifacial spasm, one endoscope-assisted removal of a vestibular schwannoma, and two endonasal pituitary surgeries for nonsecreting adenomas. To provide comparable conditions, the outputs of both cameras were

displayed on the same 23-in. thin-film transistor flat screen (1920×1200, 16:9 aspect ratio) and were recorded on hard disk in their respective formats. For SD, the serial digital interface (SDI) feed [6] from the camera control unit was fed into the workstation. For HD, we had to use the digital visual interface (DVI) output [1] since a high-definition serial digital interface (HD-SDI) out is not available in the camera control unit yet. The DVI out in 1920×1080p50 was converted to HD-SDI 1920×1080p25 [7] using a Doremi Labs XDVI converter box (Doremi Labs, Inc., Burbank, CA, USA), dropping every other frame and, thus, preserving each frame's image quality. The HD-SDI signal was then recorded on hard disk. The workstation was equipped with an AJA Xena LHe HD-SDI Capture Card (AJA Video Systems Inc., Grass Valley, CA, USA), the Adobe CS 3 Production Suite (Adobe Systems Inc., San Jose, CA, USA), and the Cineform Prospect 2K Codec (CineForm Inc., Solana Beach, CA, USA). The Cineform codec is an advanced wavelet-based codec that is supposed to work

Fig. 1 Endoscopic third ventriculostomy. **a** HD image of the floor of the third ventricle. **b** SD image of the floor of the third ventricle. **c** HD image of the perforators below the floor of the third ventricle. **d** SD image of the perforators below the floor of the third ventricle



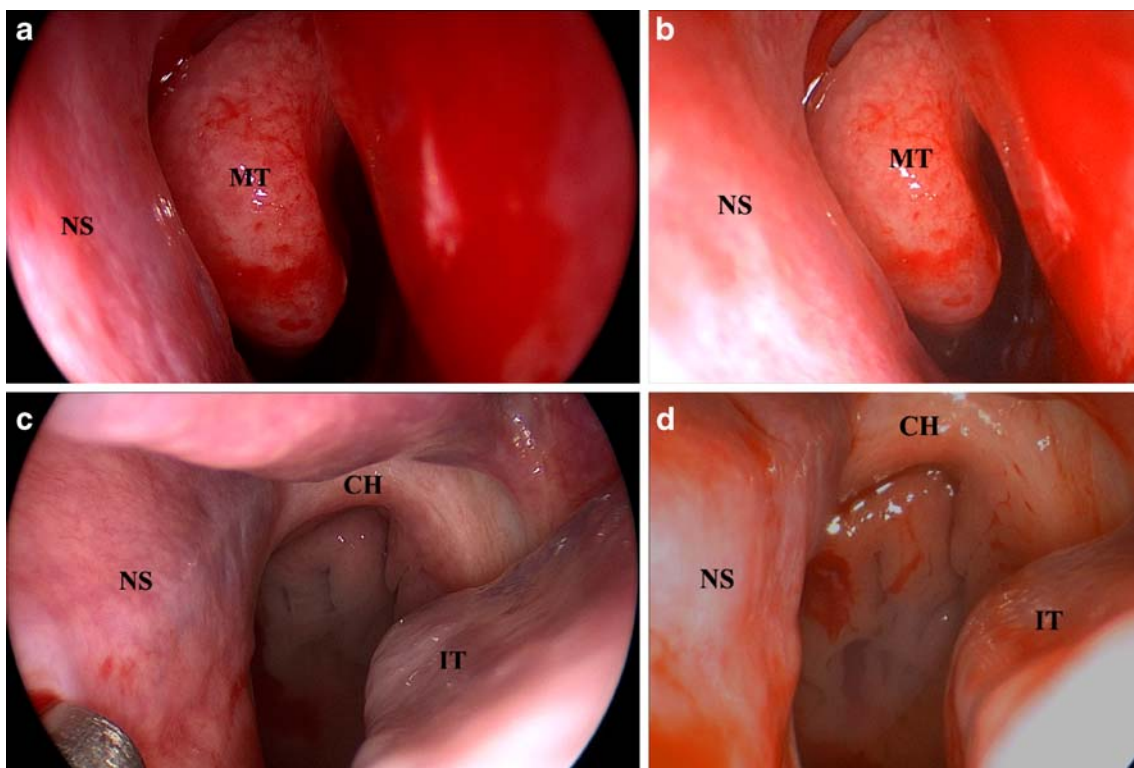


Fig. 2 Pituitary adenoma surgery. **a** HD image of the middle turbinate (MT) and nasal septum (NS). **b** SD image of the middle turbinate (MT) and nasal septum (NS). **c** HD image of the choana (CH) with

nasal septum (NS) and inferior turbinate (IT). **d** SD image of the choana (CH) with nasal septum (NS) and inferior turbinate (IT)

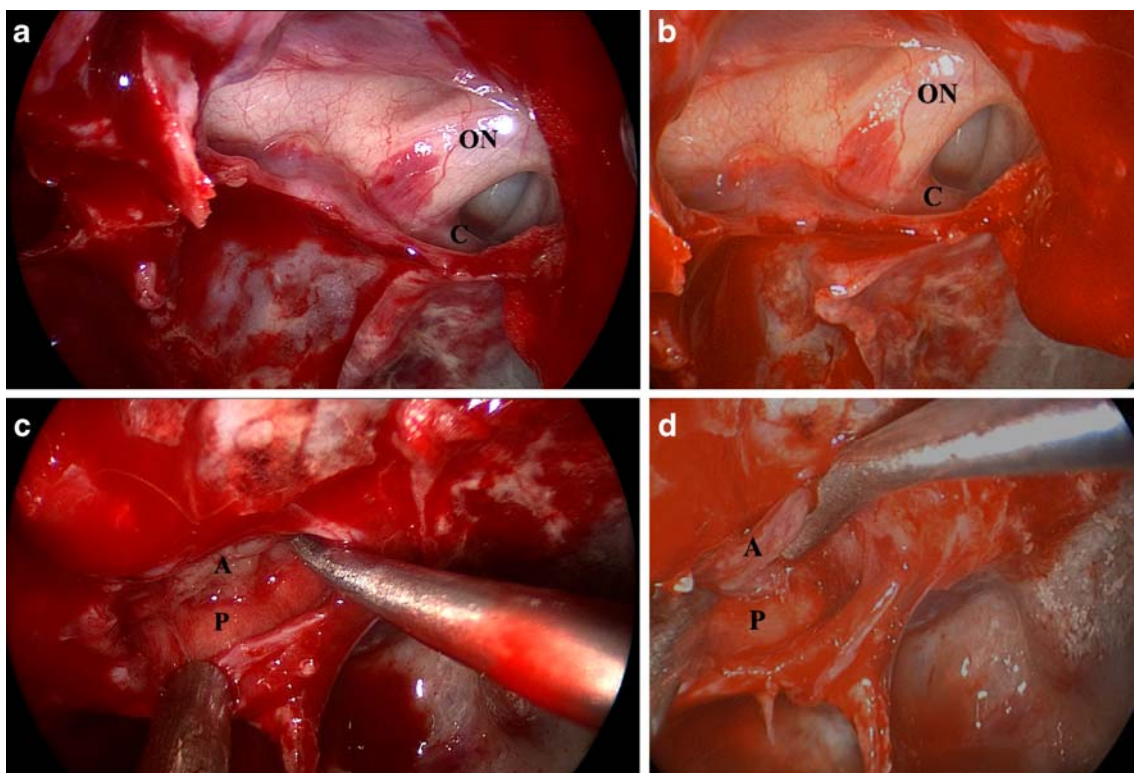


Fig. 3 Pituitary adenoma surgery. **a** HD image of the opticocarotid recess with optic nerve (ON) and carotid artery (C). **b** SD image of the opticocarotid recess with optic nerve (ON) and carotid artery (C). **c**

HD image of adenoma (A) and pituitary gland (P). **d** SD image of adenoma (A) and pituitary gland (P)

visually lossless. The compression factor was approximately 1:10. We did not see any artifacts introduced through recording. Both cameras were used with full light intensity and maximal zoom. For the reviewer of this paper, the images have been reduced in size by 50% (960×540) to minimize the size of the files.

Results

In all procedures, the image quality of the HD camera was superior to the image of the SD camera (Table 1). Improved spatial resolution and a perceivably better color fidelity explained the better images in HD imaging. The HD camera provided a five times higher resolution in comparison to the SD cameras: $1,920 \times 1,080 = 2,073,600$ versus $720 \times 576 = 414,720$ pixels. Because of the 16:9 aspect ratios, the viewing field of the HD camera was larger than with the 4:3 aspect ratios of the SD camera. The progressive image processing of the HD camera provided a much clearer image than the interlaced image processing of the SD camera. The frame rate was 50 full frames per second with the HD camera and 50 interlaced fields and thus 25 frames per second with the SD camera.

In the first patient with occlusive hydrocephalus related to intraventricular hemorrhage, the cerebrospinal fluid was bloody. Nevertheless, with the HD imaging, the orientation was good and the foramen of Monro was easily identified. The vascularization at the floor of the third ventricle as well as the arachnoid fibers around the basilar perforators seen below the floor after performing the fenestration were more clearly displayed (Fig. 1). In the pituitary surgeries, the details of the mucosa were better seen with the HD camera (Fig. 2). Furthermore, the 16:9 aspect ratio of the HD camera provided more information for the surgeon (Fig. 3). The difference between the two cameras was especially striking when the adenoma had to be differentiated from the normal pituitary tissue. With HD imaging, tumor and adenoma could be easily distinguished (Fig. 3c, d). In the microvascular decompression surgery, the endoscopic view with the HD camera provided a more detailed image of the vasculature of the brainstem compared to the SD camera (Fig. 4). The HD images obtained during the vestibular schwannoma removal demonstrated in detail the small vessels of the tumor and the nerves in the jugular foramen (Fig. 5).

No adverse events caused by the use of the endoscopes occurred. There was no procedure-related permanent morbidity or mortality.

Disadvantages of the HD camera are clearly the larger size and the higher weight (280 g) compared to the SD camera (175 g). This was especially cumbersome in pituitary surgery in which a close insertion of the surgical

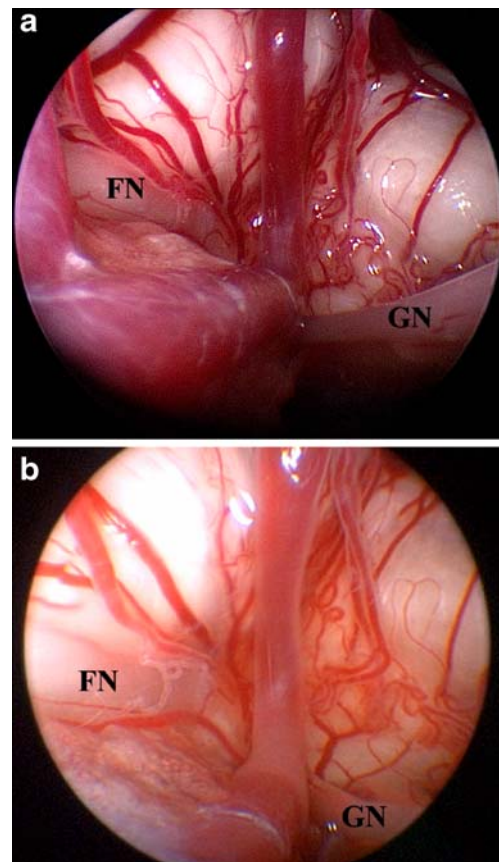


Fig. 4 Microvascular decompression of the facial nerve **a** HD image showing the PICA between facial (FN) and glossopharyngeal nerve (GN) compressing the nerve exit zone of the facial nerve. **b** SD image showing the PICA between facial (FN) and glossopharyngeal nerve (GN) compressing the nerve exit zone of the facial nerve

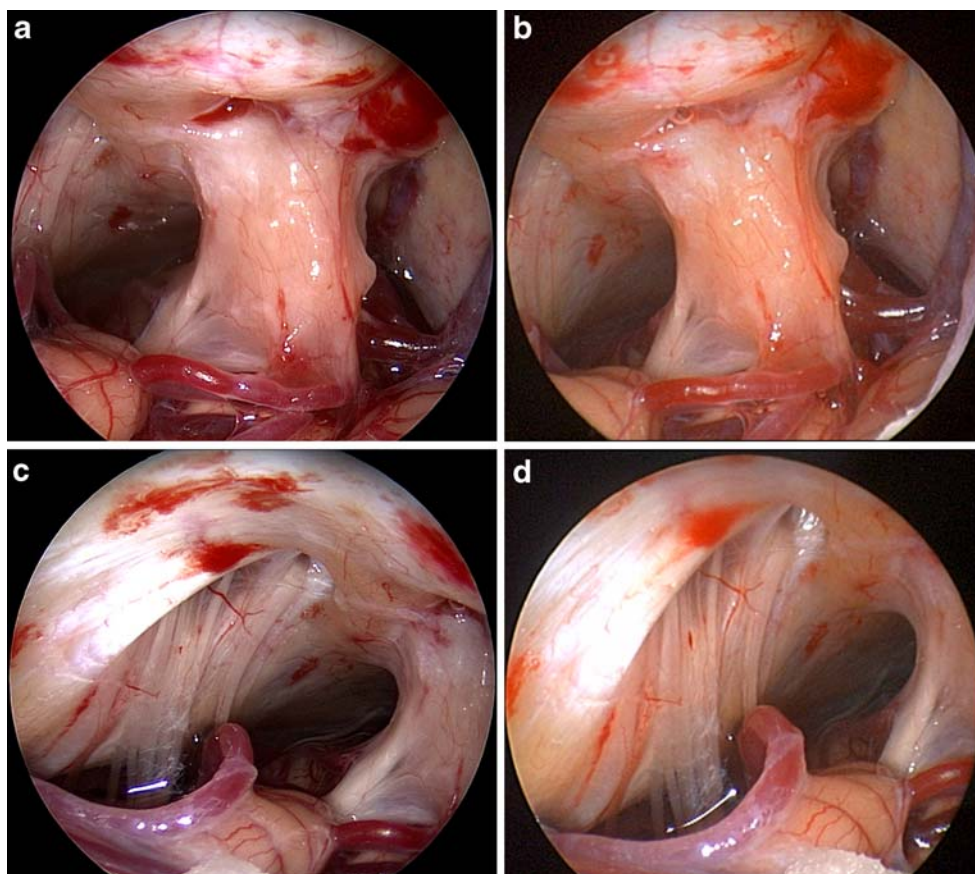
instruments is required. The heat generation of both cameras was equal (about 37°C).

Discussion

To the best of our knowledge, to date, the application of HD imaging in neuroendoscopy has not been reported in the literature. We found only one paper that described the recording of microneurosurgical interventions with an HDTV system [4]. The brightness and resolution were stated to be of outstanding quality. However, limitations were the weight of the camera (6 kg) and the price (\$100,000) of the system. Other authors described HD imaging in general surgery and urology [2, 3, 8–10]. Most of them state that video image quality is a crucial factor in the success of endoscopic interventions and that HDTV is a major improvement in image resolution.

The HD camera we used is a full HDTV system with 1,080 lines progressive scanning. Each scan includes every line for a complete picture. In interlaced scanning, which

Fig. 5 Removal of vestibular schwannoma. **a** HD image of the tumor in front of the internal auditory canal. **b** SD image of the tumor in front of the internal auditory canal. **c** HD image of the jugular foramen. **d** SD image of the jugular foramen



was common before HD, each scan included alternating lines, forming half pictures, the so-called fields. As a result of progressive scanning, the image is less noisy and flickering which reduces fatigue while looking at the monitor screen. Furthermore, HD imaging provides improved color fidelity and enhanced image resolution because each frame consists of more than two million pixels, which is around five times as many as in SD cameras. Standard three-chip cameras generate images with up to 576 lines and about 400,000 pixels. The 16:9 aspect ratio offers more information than the 4:3 aspect ratio of the SD camera and resembles the human visual field more closely.

In theory, the DVI output of the camera allows for a 4:4:4 color sampling without color subsampling and, thus, a better color resolution. In 4:4:4 color sampling, the resolution is the same in all red, green, blue (RGB) channels. Color subsampling is usually done in video to save bandwidth since the human eye is more sensitive to luma than to chroma resolution [5]. The perception of luminance is mainly influenced by the green channel; therefore, the luma component of HD video is constructed from 72% green, 22% red, and 7% blue. We had to convert to a 4:2:2 chroma subsampled version to be able to record the video onto a readily available workstation. In practice, we did not see a quality difference between monitoring the DVI output directly on the monitor compared to the

subsampled HD-SDI version. The downside of using DVI compared to HD-SDI is that DVI only offers 8-bit grayscale resolution per RGB channel compared to 10-bit per YCbCr channel in HD-SDI (Y is the luma component, Cb and Cr are color difference channels). HD-SDI, therefore, offers a more subtle grayscale gradation, which becomes apparent in later editing and especially color grading. Ten-bit resolution helps to avoid banding artifacts.

Although a high image quality is desirable in any surgery, HD imaging has proven to be most beneficial in the endonasal pituitary interventions. Prior to using the HD camera, the first author preferred an endoscope-assisted microsurgical technique in pituitary surgery because the image quality of the SD camera was clearly inferior to the image quality obtained when looking through the microscope. In some interventions, it was hard to differentiate between tumor and normal pituitary gland. Since using the HD equipment, that has no longer been a matter of concern. Thus, HD imaging brings us one step closer to the replacement of the microscope, although the perceived resolution of the microscope is still superior so far. Nevertheless, we have no doubt that HD imaging will become the standard used in the endoscopic operating room in the near future. The price of the HD camera system (camera unit and monitor) is currently only one third higher than the price of the SD camera system. That price

difference is justified by the remarkable difference in image quality. Furthermore, as with any new technical equipment that price will drop in the future.

Conclusion

HD imaging provides a much better image quality compared to SD imaging. Therefore, we recommend use of HD cameras in neuroendoscopic procedures. Further clinical studies will show whether HD imaging has an impact on clinical results.

Disclosure The first author (HWSS) is consultant to Karl Storz GmbH & Co. KG, Tuttlingen, Germany.

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Comments

Nikolai Hopf, Stuttgart, Germany

Schroeder et al compared in this well-written paper the new high definition (HD) video technology with the standard definition (SD)

technology. Image quality was analyzed during different neuroendoscopic procedures using the exact same equipment with exception of the two camera systems. Quality was estimated by rating different aspects of the image, such as color information, tissue differentiation, resolution, and viewing field. The HD system was found to be superior in all aspects. Even though this is not a big surprise, Schroeder et al. demonstrated for the first time this difference using a scientific approach. It is still very important to recognize that the better the surgeon sees, the better he is able to perform the operation. This is especially true for endoscopic operations, where blood and humidity may impair the vision. This paper is an excellent example how small technological improvements support minimally invasive neurosurgery in a great deal. I completely agree with the conclusion of the authors that HD systems should be used for all neuroendoscopic procedures.

Robert Reisch, Zurich, Switzerland

Endoscopic techniques offer several advantages in transcranial and transsphenoidal surgery. Advantages in visualization are the increased light intensity in the deep-seated surgical field and the clear representation of patho-anatomical details. In addition, the extended viewing angle of endoscopes enables surgeons to observe hidden parts of the surgical field.

However, image quality of conventional one- or three-chip camera units is clearly restricted compared with the excellence of a direct view into the surgical microscope. In the past, this inferior imaging has limited the application of endoscopes in cranial neurosurgery.

Recently, the intraoperative use of high definition (HD) image quality offers a new area in endoscopic neurosurgery with enlarged range of indications in transcranial and transsphenoidal surgery.

In this paper, Schroeder and Nehlsen describe their experiences with HD imaging in comparison with standard three-chip charge-coupled devices (3CCD) in typical conditions: during ETV, MVD, EAM, and transsphenoidal surgery. The HD and 3CCD camera units were used with the same endoscopic equipment; the authors describe the high definition technique and present the video documentation accurately.

Not surprisingly, the image quality of the HD camera was superior to the image of a standard three-chip camera in all procedures, according to a five-times-higher optical resolution. This superior quality was especially important in delicate conditions: by blurry vision in case of bloody CSF by ETV or by differentiation on adenoma from normal pituitary tissue by transsphenoidal surgery.

I agree with the authors in recommendation of HD cameras in neuroendoscopic procedures.

Veit Rohde, Göttingen, Germany

In three truly endoscopic and two endoscope-assisted operations, the authors used both a standard definition and a high definition three-chip camera for the endoscope and compared the image quality. Not surprisingly, the image quality with the high definition camera was superior, as it is proven by impressive intraoperative photographs.

Neurosurgery has witnessed tremendous technical advancements in the last two decades. During the same period of time, the intervals in which the industry had provided the neurosurgeon with a new or improved technology dropped substantially. These aspects lead to the major question which rises when reading papers comparing “not so new” with “new” technology: is it necessary to have again and again the latest technology in the operating room to perform state-of-the-art neurosurgery? My personal answer is no because operative results are much more influenced by the experience and skills of the neurosurgeon than by technology. Thus, the recommendation of the authors to use high-definition instead of standard-definition cameras routinely in neuroendoscopic procedures has to be questioned.