Technical Note

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Three-dimensional HD endoscopy – first experiences with the Einstein Vision system in neurosurgery

Abstract: Lack of stereoscopy and inferior image resolution prevented endoscopes to become standard in Neurosurgery. The new Einstein Vision® system provides a 3D HD non-distorted image. The objective is to evaluate image quality and suitability for neurosurgery. The Einstein Vision® system was used for nine operations including four meningiomas, two aneurysms, one intraspinal lipoma, one lumbar stenosis, and one neuroma of the sciatic nerve. Image quality and suitability were analyzed in a semi-quantitative manner based on each 10 aspects and compared to an operating microscope. The system was successfully used in eight operations. Two operations could be completed with the new system as the only optical tool. In six operations it could be used only for certain parts, and in one operation the 3D effect was significantly disturbed. Overall, the image quality was rated “equal” to the microscope. Two aspects were found to be superior, four aspects equal, and four aspects inferior. Suitability was rated overall as “inadequate”. No aspect was rated superior, two aspects equal, six aspects inferior and two aspects could not be rated. Presently, image quality was found to be equal to the operating microscope but suitability for minimal invasive neurosurgical operation is inadequate.

Keywords: 3D endoscopy; neuroendoscopy; minimally invasive neurosurgery.

Introduction

Presently, endoscopes are predominantly used in neurosurgery for intraventricular lesions and transsphenoidal skull base surgery [19]. In a few centers worldwide, endoscopes are also used as an adjunct to microneurosurgery for a variety of indications, including transcranial skull base surgery and vascular neurosurgery [5, 8, 10, 14, 18]. Here, endoscopes were found to be particularly helpful in providing a much better overview, illuminating in depth and enabling a look around sensitive structures. This technique, using the endoscope only for specific parts of an otherwise microsurgical operation, was previously described as endoscope-assisted microneurosurgery (EAM) by the first author [9]. In transsphenoidal surgery, the advantages of endoscopes over the operating microscope are so obvious, that the microscope is completely abandoned in most leading centers. In contrast, for transcranial indications, the disadvantages of contemporary endoscopes, i.e., lack of stereoscopy, inferior image resolution, and “fish eye” distortion, prevented the same development.

Therefore, a stereoscopic endoscope with the best possible resolution and a natural non-distorted image has requested for decades by leading neurosurgeons in this field. In recent years, the number of publications about the neurosurgical and transnasal application of three-dimensional (3D) endoscopic techniques have increased (1–4, 12, 13, 15, 17). The only commercially available 3D endoscope for neurosurgery does not fulfill these requirements, since it does not provide HD image resolution and only an electronic 3D effect calculated from one single sensor on the tip of the endoscope (Visionsense Corp., NY, USA). However, this single sensor 3D image still proved to have an advantage over 2D endoscopes in anticipating distances and therefore, leading to an improved task completion in 87.4% in an experimental setting [6]. Besides image quality, suitability for use in neurosurgical operations is another important issue why endoscopes are used reluctantly. Here, a major factor is the holding system and
positioning of the endoscope to not disturb the delicate bimanual dissection of the surgeon. The new Einstein Vision laparoscope system [7, 11, 16, 20] seems to provide many of the requirements needed for neurosurgery. The objective of this study is to evaluate image quality and suitability of this new system for its use in neurosurgery.

**Material and methods**

**Patient groups**

A total of nine patients (seven female, two male) with different neurological diseases were operated on using the new Einstein Vision system. Indications were intracranial, spinal and peripheral nervous system lesions, including four intracranial meningiomas, two intracranial aneurysms, one intraspinal lipoma, one lumbar stenosis, and one neuroma of the sciatic nerve (Table 1). The patients were aged from 36 to 75 years (mean 50 years).

**Equipment**

The Einstein Vision system (Aesculap AG, Tuttlingen, Germany) consists of a 10 mm rigid endoscope, with two separate 2.7 mm optical channels. The camera head harbors two separate full HD sensors, with a resolution of 1920×1080 pixels each. The image is displayed on a 32 inch 3D HD monitor. Three-dimensional vision is enabled by polarized glasses. The system further includes a robotic remote controlled holding arm (Figure 1). In addition to the standard holding arm, a weight-balanced holding arm was used for selected cases. All operations were recorded for further evaluation using a 3D/HD digital recording system (Sony Corp., Tokyo, Japan).

Three-dimensional HD endoscopy was used either as the only optical tool, or as an adjunct to microsurgery in the manner of endoscope-assisted microsurgery [9].

**Score system**

Image quality and suitability of the new system for its use in neurosurgery were analyzed in a semi-quantitative manner, using a specific score sheet with each 10 aspects, and compared with the high-end operating microscope Pentero (Zeiss, Oberkochen, Germany) as the gold standard. For the image quality recognition of details, color brilliance, illumination, magnification, 3D effect, image distortion, size of field, depth of field, fogging, and fatigue were separately rated; for suitability, the aspects ergonomics, conflict with instruments, positioning, time for preparation, sterility, availability, additional functions, risk profile, initial costs, and maintenance costs were rated. For each aspect, a maximum of four points were awarded by the surgeons in comparison to the image quality and suitability provided by the operating microscope, which was defined as gold standard and awarded three points for each aspect. In case of a slightly inferior performance, only two points were given, in case of a strongly inferior performance, only one point was given. If there was no function at all, or no information available, no points were awarded. In case of a superior performance than the microscope, four points were awarded. Overall, the performance was rated as supe-

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**Table 1** Overview of diseases and use of the Einstein Vision system.

<table>
<thead>
<tr>
<th>Operations</th>
<th>No</th>
<th>Sex</th>
<th>Age</th>
<th>Disease</th>
<th>Location</th>
<th>Use of system</th>
<th>Problem</th>
<th>Placement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>36</td>
<td>Neurinoma</td>
<td>Sciatic nerve</td>
<td>Complete surgery</td>
<td>None</td>
<td>Outside</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>75</td>
<td>Spinal canal stenosis</td>
<td>Lumbar spine</td>
<td>Abortion</td>
<td>3D effect</td>
<td>Outside</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>39</td>
<td>Lipoma</td>
<td>Conus medullaris</td>
<td>Approach, partial dissection</td>
<td>Color brilliance</td>
<td>Outside</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>54</td>
<td>Meningioma</td>
<td>Opticocerebral groove</td>
<td>Complete surgery, inspection</td>
<td>None</td>
<td>Outside/inside</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>F</td>
<td>49</td>
<td>Meningioma</td>
<td>Opticocerebral groove</td>
<td>Approach, inspection</td>
<td>Magnification, conflict with instruments</td>
<td>Outside/inside</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>47</td>
<td>Meningioma</td>
<td>Opticocerebral groove</td>
<td>Approach, inspection</td>
<td>Magnification, conflict with instruments</td>
<td>Outside/inside</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>F</td>
<td>50</td>
<td>Aneurysm, mpl</td>
<td>Opticocerebral groove</td>
<td>Approach, inspection</td>
<td>Magnification, conflict with instruments</td>
<td>Outside/inside</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>M</td>
<td>51</td>
<td>Aneurysm, mpl</td>
<td>Opticocerebral groove</td>
<td>Approach</td>
<td>Magnification, conflict with instruments</td>
<td>Outside/inside</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>F</td>
<td>50</td>
<td>Aneurysm, mpl</td>
<td>Opticocerebral groove</td>
<td>Approach</td>
<td>Magnification, conflict with instruments</td>
<td>Outside/inside</td>
<td></td>
</tr>
</tbody>
</table>

F=female, M=Male, AComA=Anterior communicating artery, conflict=conflict of instruments with endoscope, ICA=Internal carotid artery, MCA=Middle cerebral artery.
terior when it reached \( >33 \) points, equal between 27 and 33 (10% range), inferior between 26 and 20, and inadequate when it reached \(<20\) points.

## Results

The Einstein Vision system was successfully used in eight out of the nine operations. In the case of the lumbar spinal stenosis a dark colored retractor system led to an instable 3D effect, as well as inferior color quality. Therefore, the system was not further used for this particular surgery.

In two operations, the system was used as the only optical tool. This was the complete resection of a neuroma of the sciatic nerve at the level of the knee and a meningioma of the left parietal convexity. In both cases, the tumor could be removed completely, experiencing comparable conditions as with the microscope concerning stereoscopic vision and image quality. In all other operations, the new system was either used for visualization of bimanual dissection only of certain parts of the surgery (five cases), or for a short endoscopic inspection (one case). In the majority of these cases, magnification was not adequate when placing the 3D endoscope outside the situs or conflicts with the instruments when placing it inside (Figure 2). In the case of the spinal lipoma, the colors visualized with the 3D system did not allow safe discrimination between the tumor and the myelon, but the operating microscope did. Complications related to the use of the Einstein Vision system did not occur. One patient with a meningioma experienced a postoperative hemorrhage, which required surgical revision. This complication was thought to be independent from the use of the endoscope system.

The direct comparison of the image quality resulted in 27 points for the Einstein Vision system compared to the 30 points for the high-end operating microscope as the defined gold standard (Table 2). The Einstein Vision system was rated worse for color brilliance, illumination, and fogging with each two of three points, and for magnification with one of three points. In operations longer than 1 h, it became obvious that color brilliance got worse with increasing time and the amount of blood within the operating field. Suboptimal grades for illumination were caused by automatic down regulation of the light intensity by the system and not by inferior light capacity. In contrast, the size and depth of field were rated better those of the operating microscope, with each four points. Even when the 3D HD endoscope was placed outside the operating field, the size of the visualized field was much larger (Figure 3). Concerning the depth of field, we measured a distance of at least 5 cm where the structures were perfectly in focus using the Einstein Vision system (Figure 4).

Concerning the suitability for use in neurosurgery, the 3D HD endoscopy system reached a final score of only 14 points compared with the defined 30 points for the operating microscope (Table 3). Inferior ratings were given for risk profile and initial costs with each two points, as well as for ergonomics, conflict with instruments, positioning, and availability with each one point. Additional tools, like fluorescence based imaging (i.e., ICG angiography, 5-ALA

Figure 1  Einstein Vision laparoscope system including the 10 mm endoscope connected to the 3D HD camera head and fixed to a holding arm, which can be connected to the operating table. Tower including the 32 inch full HD 3D monitor, light source, video controller, and recording device.

Figure 2  Einstein Vision system positioned inside the operating field, demonstrating the conflict between the endoscope and the instruments through right-sided retrosigmoid keyhole approach.
imaging), were not available for the Einstein Vision system and therefore rated with zero points as for maintenance cost, since reliable information on that issue is still pending.

### Table 2  Results for the individual aspects concerning the image quality of the Einstein Vision 3D HD endoscopy system in comparison to the operating microscope.

<table>
<thead>
<tr>
<th>Einstein Vision evaluation</th>
<th>Microscope</th>
<th>Endoscope</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recognition of details</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Color brilliance</td>
<td>3</td>
<td>2</td>
<td>Worse with advanced time/blood</td>
</tr>
<tr>
<td>Illumination</td>
<td>3</td>
<td>2</td>
<td>Automatic downregulation by system</td>
</tr>
<tr>
<td>Magnification</td>
<td>3</td>
<td>1</td>
<td>No zoom function available</td>
</tr>
<tr>
<td>3D effect</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Image distortion</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Size of field</td>
<td>3</td>
<td>4</td>
<td>Superior even when positioned outside</td>
</tr>
<tr>
<td>Depth of field</td>
<td>3</td>
<td>4</td>
<td>Up to 5 cm</td>
</tr>
<tr>
<td>Fogging</td>
<td>3</td>
<td>2</td>
<td>When used inside the field</td>
</tr>
<tr>
<td>Fatigue</td>
<td>3</td>
<td>3</td>
<td>Up to 2 h</td>
</tr>
<tr>
<td>Result</td>
<td>30</td>
<td>27</td>
<td></td>
</tr>
</tbody>
</table>

**Discussion**

The Einstein Vision 3D HD laparoscopy system was tested for its potential use for neurosurgical operations. It was used for nine different operations involving the peripheral nervous system (neuroma of sciatic nerve), the spine (lipoma of the medullary conus, lumbar stenosis), and the brain (meningiomas, aneurysms). Image quality and suitability for neurosurgery were evaluated in comparison to a high-end operating microscope.

Overall, the image quality of the 3D laparoscope was rated as “equal” to the microscope with 27 and 30 points, respectively. Two of the 10 separately rated aspects were found to be superior to the microscope, four aspects equal, and four aspects inferior. The two superior aspects were the size and the depth of the field. The size of the field was more than five times larger, even when the endoscope was
placed outside the operating field. This is explained by the wide viewing angle of the lens in addition to the closer location of the scope with around 3 cm (Figure 5) compared with around 25 cm of the microscope. The extraordinary depth of field with up to 5 cm, compared to only a few millimeters by the microscope, is a major advantage of the new endoscope system and allows safe and convenient dissection in different regions of the operating field without moving the endoscope.

Recognition of details, the 3D effect, image distortion, and fatigue were rated equal to the microscope. Even though the absolute resolution of the two HD cameras is less than the image provided by direct visualization through the operating microscope, recognition of details was not found to be impaired. This may be due to the ability to position the Einstein Vision system much closer to the structures of interest. The same is true for the 3D effect; the distance between the two optical channels is less in the endoscope system and therefore presumably inferior. However, the stereoscopic impression was absolutely equal. In one case of a skull base meningioma, the estimation of the distance between the optic nerve and the diaphragm was even closer...
to the actual measurement than under the microscope. The unique construction of the Einstein Vision system as a "real" stereoscopic imaging system with two completely separate optical channels, seems to contribute, to a great extent, to the amazing 3D effect. Image distortion was not a problem with this particular endoscope. A frequent disadvantage of 3D systems is the need of active glasses and rapid fatigue, nausea and headaches of the user. This was not the case using the passive polarized glasses and according monitor of the Einstein Vision system up to more than 2 h, which was the longest continuous use so far of this system by the authors in neurosurgery.

The four inferiorly rated aspects were color brilliance, illumination, magnification, and fogging. Colors and light intensity are automatically regulated by the system and presently adjusted to the needs for laparoscopy. Therefore, improvements of these aspects should be possible by minor changes of the system. The same holds true for magnification and fogging when adding a zoom function and continuous suction as already realized in other systems, such as the transsphenoidal endoscope system MINOP TREND® (Aesculap AG). Thus, the potential image quality of the Einstein Vision system seems to be overall superior to the operating microscope after the above-mentioned minor changes.

As expected, the suitability of the Einstein Vision system for its use in neurosurgery was rated overall as "inadequate", with only 14 points. No aspect was rated superior, two aspects equal, six aspects inferior and two aspects could not be rated at all. The latter two were additional tools and maintenance costs. Reliable information on the maintenance costs is not yet available. However, it may be assumed that in addition to the costs for draping and substitution of wear parts, which would be equal to those of the microscope, costs for sterilization will also accumulate. Additional tools, such as ICG angiography and 5-ALA aided surgical technique, are obviously not incorporated in the laparoscope system at the moment, but this seems to be possible in the future.

The risk profile and initial costs were rated only slightly inferior. Even though we did not experience any endoscope related complications, the risk for the nervous system is at least potentially higher when the endoscope is placed close or next to sensitive structures as it is explicitly intended. The initial costs based on the German market are about one third higher than a high-end operating microscope. Ergonomics and positioning of the system were rated strongly inferior to the microscope. This was due to the inadequate length of the telescope and the large diameter of the camera head. In addition, the system was fixed only in a semi stable manner based on the requirements for laparoscopic operations and not absolutely stable, as is necessary for neurosurgical operations. Therefore, an additional rubber ring had to be used to further stabilize the scope (Figures 2 and 5). The outer diameter of 10 mm led to relevant conflicts between the endoscope and instruments when positioned inside the operating field. This may be related to the use of keyhole craniotomies with an average diameter of 1.5×2 cm in size. However, even if the system would be used with standard or large skull base approaches 10 mm will still be inadequate based on anatomical conditions. A further aspect rated inferior to the microscope was the availability of the systems. This is because the telescope had to be sterilized each time before use. This presets the need for multiple telescopes, or enough time between two operations if more than one surgery is planned on the same day.

Time for preparation and sterility were rated equal to the microscope. Time for preparation included draping of the holding arm and camera head, connection of the telescope to the camera, connection of the light cable, white balance, and basic focusing. All of these did not take longer than the same steps for the preparation of the operating microscope. With adequate preparation and an experienced team in endoscopic procedures, sterility did not become an issue.

**Conclusion**

The new Einstein Vision 3D HD laparoscope system has a great potential for further use in neurosurgery. Presently, the image quality was already found to be equal to that of the operating microscope, but suitability for minimal invasive neurosurgical operations is inadequate. However, changes seem to be possible to adapt the system to neurosurgical needs.

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References


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