Surgical fidelity: comparing the microscope and the endoscope

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Abstract

Background: Both the microscope and the endoscope are widely used as visualization tools in neurosurgery; however, surgical dexterity when operating with endoscopic visual control may differ. The aim of this study was to compare the surgical fidelity when using each of these visualization tools.

Methods: Junior residents and expert surgeons performed standardized motor tasks under microscopic and endoscopic visualization. Demerits for inaccuracy and time needed to complete the tasks were used to compare the surgeons' performance with the microscope and the endoscope. The participants also performed a motor task under direct vision using different instruments to evaluate whether the shape of the instrument had any impact on the surgical fidelity.

Results: For the junior residents, the number of demerits accrued was lower with the microscope than with the endoscope, and the time needed to complete the tasks was also lower with the microscope. There was no difference in the number of demerits between the microscopic and the endoscopic experts, but the microscopic expert completed the task in a shorter time. There was no difference in demerits or performance time when comparing a short, straight instrument and a longer, bayoneted one.

Conclusion: For junior residents, surgical fidelity is higher with the microscope than with the endoscope. This difference vanishes with experience, but a slower speed of execution is observed with endoscopic visualization, both in junior and expert surgeons.

Keywords: Microsurgery; endoscopy; surgical fidelity; task performance; learning curve

Introduction

Adequate visualization of anatomic structures is necessary for proper eye–hand coordination of the surgeon. The naked eye provides the best resolution and three-dimensional perception; however, the need for magnification and illumination in small, deep surgical fields often calls for the use of more sophisticated technology. The excellent stereoscopic view and powerful, adjustable magnification of the microscope are familiar to neurosurgeons. Although the use of the endoscope in neurosurgery is also not new, its indications have expanded with improvements in surgical technique and endoscope technology. The endoscope's wide field of view and superior illumination are advantages in many surgical approaches, but the lack of a true three-dimensional view is a major drawback.

Many studies have compared microscopic and endoscopic approaches with respect to various anatomic sites [1,2,7,21] and pathological conditions [5,6,12-14,16,17]. Many of these studies discuss the different characteristics of the microscope and the endoscope in terms of illumination, width of field, and three-dimensional perception, but there has been no systematic attempt at quantifying these differences and their effect on the eye–hand coordination of the surgeon.

It has been our experience that the surgical dexterity by inexperienced surgeons when operating with endoscopic visual control is limited when compared with standard microscopic vision. The reasons for this have not been elucidated, but considerations include the two-dimensional rather than three-dimensional vision, the longer lever arm and reach with most endoscopic instrumentation, and perhaps a distortion from the wide-angle view of the endoscope. The purpose of this study was to examine and quantify the surgical fidelity of the microscope and the endoscope. We define surgical fidelity as the ability of a visualization tool to provide the surgeon with visual input that results in the precise performance of a motor task.

Methods

Four junior neurosurgical residents (naïve to both endoscopic and microscopic surgery) and two surgeons experienced with both microscope and endoscope (professor level) were selected to perform standardized motor tasks under microscopic and endoscopic visualization. The experienced surgeons performed the tasks using a single visualization tool, according to their expertise.

The first motor task consisted of drawing a spiral with a surgical instrument, based on a form printed on a transparent sheet placed on a table whose height could be adjusted for optimal position with respect to the microscope or endoscope. The instrument had a pen tip attached at its end so that the tracings could be evaluated and compared. In addition, the performances were filmed in real time. The same motor task was also performed under direct vision using a straight dissector (Penfield #4) and a longer, bayoneted dissector to determine whether the length and shape of the instrument or the distance from the tip at which it is held when performing endoscopic surgery had any effect on the overall surgical fidelity.

To quantify the performance of the motor task, one demerit was charged every time the spiral drawn by the surgeon crossed over to the dark area. The lowest total number of demerits therefore meant the best performance. In addition, the time needed to draw the spiral was measured.

A second task was designed to measure differences in speed of execution. In this task, the participant was required to touch a series of 10 dots with the instrument, under microscopic and endoscopic visualization. The dots were also printed on transparent sheets placed on adjustable tables. Only the time needed to complete the task was recorded as a measure of performance.

To further characterize the surgical fidelity with the junior residents, we required them to complete a third motor task in which they drew a series of five straight lines with the Penfield #4 dissector under microscopic and endoscopic vision, based on dotted lines printed on transparent sheets and placed on adjustable tables. A demerit was charged for every dot that was not touched by the line drawn by the resident, and the time needed to draw the lines was recorded.

Several motor tasks were designed to assess the surgical fidelity in three dimensions. In the first, two rows of five dots, spaced 2 cm from each other, were printed on the inside of a hollow truncated cone measuring 11 cm in height, and 9.5 cm and 5.2 cm in upper and base diameter, respectively. The junior residents had to touch each of the dots with a Penfield #4 dissector, starting from the nearest dot and proceeding to the deepest dot in the cone. The time needed to complete the task under microscopic and endoscopic visualization was recorded.

Two final motor tasks were designed to assess depth perception of all participants when performing complex motor tasks. The first task (3D cup) was set up with a styrofoam cup with thumb tags placed within the cavity. Each participant had to touch the tags in sequential order with a Penfield #4 surgical instrument starting with the deepest to the most superficial using either microscopic or endoscopic vision. In the second task, the participants had to move 4 objects from one cup to another using Adson pick ups under microscopic or endoscopic vision. The time needed to complete these tasks was recorded.

To minimize training effect, each trial session was scheduled at least one week after the previous session so that the skills acquired during the previous trial session would not persist. In addition, the visualization tool to be used first alternated between microscope and endoscope on successive sessions. In each individual session, the residents performed the task no more than two times with each visualization tool.

The data were analyzed with Student t-tests when comparing the effect of device between two individuals and two-way ANOVA tests when comparing more than two individuals. The significance was set at $p<0.05$.

Results

An illustrative case of spirals drawn for the first task by a junior resident is shown in Figure 1, and representative tracings of the expert surgeons are shown in Figure 2. The accompanying video shows the tracings in real time (Video 1).

For all the motor tasks, the number of demerits accrued by the residents was significantly lower using microscopic visualization than endoscopic visualization. The time needed to accomplish these tasks was also lower under microscopic visualization (Tables 1 and 2). For the expert surgeons, there was no difference in the number of demerits, but the endoscopic surgeon took more time to complete the task (Table 3).

Table 4 shows the results for the spiral tracings using a short, straight instrument and a longer, bayoneted one. There were no significant differences between the two instruments with respect to the number of demerits accrued by the residents or the time needed to complete the task. Each of the expert surgeons only completed this task one time so the results were not analyzed statistically but are presented for comparison.

Discussion

Surgical fidelity offers the ability to complete precise tasks with great accuracy using the surgical microscope and endoscope. For junior residents naïve to either technique, the surgical fidelity was better with microscopic visualization than with endoscopic visualization. This gap in surgical fidelity essentially disappeared when surgeons experienced with either technique were compared; however, the expert microscopic surgeon performed the selected tasks faster than the endoscopic expert.

Performance of even such a seemingly simple motor task relies on multiple factors. Among them, three-dimensional perception is a crucial component of the feedback loop to correct deviations from the planned trajectory as they are identified.[3,4,8,9,11,15,18-20,22,23]. In the case of our first simple motor task, the drawing of a spiral on a two-dimensional surface becomes a three-dimensional task because the incidence of the surgeon's sight is not exactly orthogonal to the surface. The last experiments were designed to simulate a three-dimensional field and complex motor tasks, and the difference in surgical fidelity was also observed for these tasks with junior residents. Through the microscope, the surgeon has an excellent perception of depth and can therefore directly see the actual trajectory of the instrument and make the necessary adjustments. A surgeon using the endoscope, however, has to rely on indirect clues such as motion parallax, relative size of visualized structures, and in-and-out movements of the endoscope to substitute for depth perception. The ability to use these clues improves with experience, which explains why no difference in surgical fidelity was observed with the expert surgeons.

The coordination of gaze with hand movements is another important part of overall eye-hand coordination [10]. The microscope is essentially immobile, whereas the hand-held endoscope is subject to voluntary and involuntary movements for which the eye and brain of the surgeon have to compensate. We observed that during the performance of the tasks the experienced endoscopic surgeon tended to follow the instrument with the endoscope, making a deliberate attempt to keep the tip of the instrument in the center of the field of the endoscope. This technique contributes to a better performance with increased experience of the surgeon.

The endoscope also induces distortion of the image caused by a differential magnification that is maximal at the center and minimal at the periphery of the field (fish-eye effect) [5]. Whereas the beginner in endoscopic surgery has to compensate for this distortion, introducing a supplementary departure from the true shape of the structures that are visualized and increasing the difficulty of the task, the expert endoscopic surgeon integrates it and uses it to an advantage as an additional mechanism to infer the relative depth of the structures that are visualized, an effect called pseudo-three-dimensional impression [16].

The better surgical fidelity with the microscope was only observed with junior residents. With experience, endoscopic surgeons learn to perform motor tasks reliably with the instrument. Nevertheless, completion of the defined task took longer with endoscopic visualization than with the microscope. Making deliberately slower movements to execute the motor task correctly is probably one of the mechanisms that the expert develops to improve performance.

We used simple dot touching, and spiral and line drawings in this study to standardize the tasks to be performed, but this choice comes with several limitations. It can be argued that these do not represent the complex movements performed during surgery, but we believe they are still a good elementary measures of the eye–hand coordination. The absence of a deep surgical field limits the possibility to use indirect clues, such as motion parallax, to improve three-dimensional perception with the endoscope, and it obviates the advantage of having a better illumination with the endoscope than with the microscope. Conversely, it also minimizes the interference of the endoscope shaft with the instruments that is often problematic as surgeons begin to familiarize themselves with endoscopic surgery.

Conclusion

For junior residents naïve to microsurgical techniques, the surgical fidelity using the microscope is superior to that obtained with an endoscope. This difference vanishes as a surgeon gains experience, but a slower speed of execution under the endoscope seems necessary to perform at a high level. The ability to use indirect clues to compensate for the lack of true three-dimensional perception and other mechanisms to improve the execution of the motor task explain this observation, but these additional visuomotor skills that are required of the endoscopic surgeon generally result in a longer learning curve. Advances in technology such as the development of the three-dimensional endoscope may overcome some of the disadvantages seen with the current devices, and further evaluation will be necessary to quantify the effect of these improvements.

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Conflict of Interest: None

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Figure Legends

Figure 1. Spirals drawn by junior resident #4 under microscopic (left) and endoscopic (right) visualization.

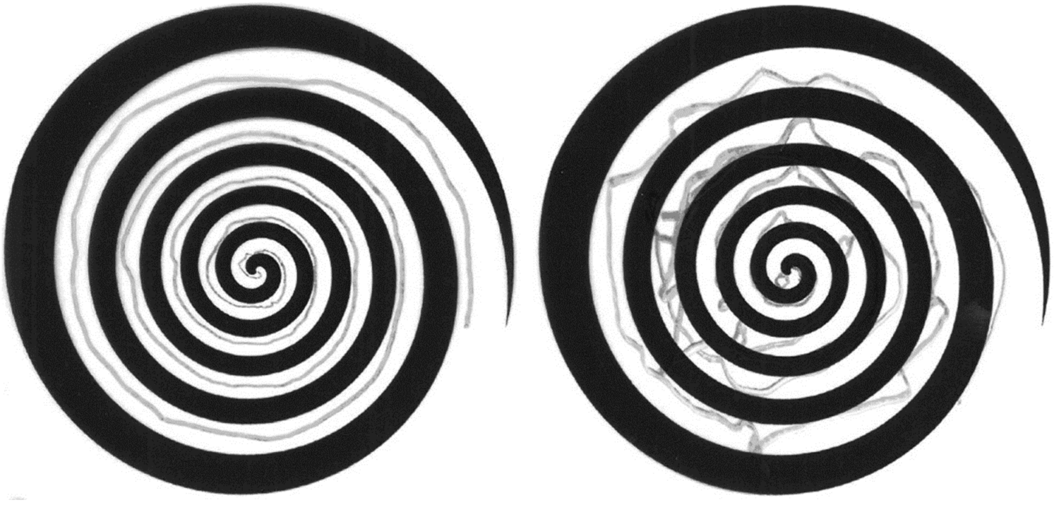


Figure 2. Spirals drawn by experts in microscopic (left) and endoscopic (right) surgery.

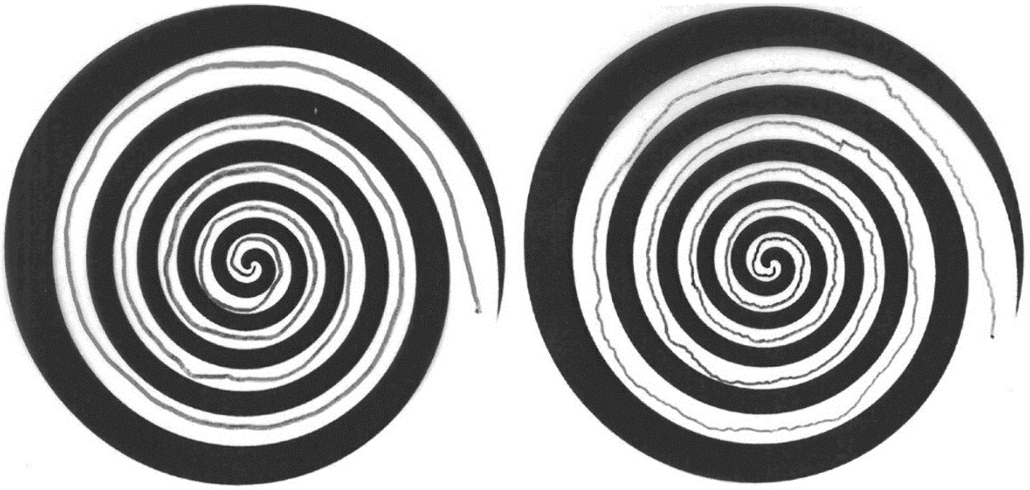
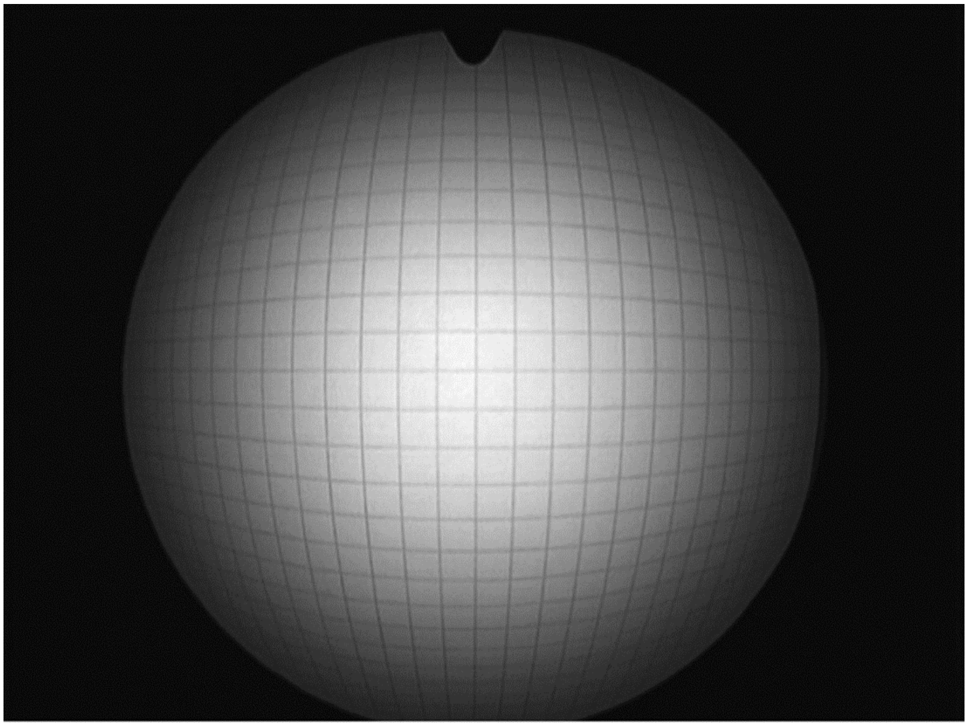


Figure 3. A grid seen through an endoscope.



Video. Video demonstrates how the tests of surgical fidelity were completed and illustrates these completions in real time.

This video can be accessed under the supplemental material tab at the following link : http://link.springer.com/article/10.1007%2Fs00701-013-1889-4

Table 1. Mean number of demerits and timing of motor tasks for residents using microscopic and endoscopic visualization

Motor task		Mean (standard deviation)		p-value
		Microscope	Endoscope	
Spiral drawing	Demerits	3.2 (2.5)	9.8 (4.6)	< 0.0001
	Time (s)	37.6 (9.0)	43.8 (5.7)	0.016
Touch 10 dots	Time (s)	8.3 (3.1)	12.9 (3.9)	0.0001
Dotted-line drawing	Demerits	46.1 (30.1)	94.1 (34.4)	0.0001
	Time (s)	32.1 (13.9)	50.2 (16.8)	0.0018
Touch 10 dots in 3D	Time (s)	15.5 (4.9)	26.1 (6.0)	0.0001

Table 2. Mean time required to complete complex motor tasks using microscopic or endoscopic visualization

Complex three-dimensional tasks		Mean		p-value
		Microscopic vision	Endoscopic vision	
3D cup	Time (s)	11.7	25.4	0.0031
Object transfer	Time (s)	11.6	31.8	0.0022

Table 3. Mean number of demerits and timing of motor tasks for expert surgeons using microscopic or endoscopic visualization

Motor task		Mean		p-value
		Microscope expert	Endoscope expert	
Spiral drawing	Demerits	0.67	0.75	0.89
	Time (s)	29.0	51.5	0.0078
Touch 10 dots (1 trial)	Time (s)	9	15	

Table 4. Mean number of demerits and timing for spiral drawing under direct vision using a short, straight instrument and a longer, bayoneted instrument

Group	Result	Mean (standard deviation)		p-value
		Short, straight instrument	Long, bayoneted instrument	
Residents	Demerits	4.0 (5.8)	4.8 (7.4)	0.057
	Time (s)	35.9 (15.1)	35.6 (13.8)	0.80
Expert surgeons (1 trial)	Demerits	4	2	
	Time (s)	20	29	