Evaluation of the 3-Dimensional Endoscope in Transsphenoidal Surgery

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BACKGROUND: Three-dimensional (3-D) endoscopy is a recent addition to augment the transsphenoidal surgical approach for anterior skull-base and parasellar lesions. We describe our experience implementing this technology into regular surgical practice.

OBJECTIVE: Retrospective review of clinical factors and outcomes.

METHODS: All patients were analyzed who had endoscopic endonasal parasellar operations since the introduction of the 3-D endoscope to our practice. Over an 18-month period, 160 operations were performed using solely endoscopic techniques. Sixty-five of these were with the Visionsense VSII 3-D endoscope and 95 utilized 2-dimensional (2-D) high-definition (HD) Storz endoscopes. Intraoperative and postoperative findings were analyzed in a retrospective fashion.

RESULTS: Comparing both groups, there was no significant difference in total or surgical operating room times comparing the 2-D HD and 3-D endoscopes (239 minutes vs 229 minutes, $P = .47$). Within disease-specific comparison, pituitary adenoma resection was significantly shorter utilizing the 3-D endoscope (surgical time 174 minutes vs 147 minutes, $P = .03$). These findings were independent of resident or fellow experience. There was no significant difference in the rate of complication, reoperation, tumor resection, or intraoperative cerebrospinal fluid leaks. Subjectively, the 3-D endoscope offered increased agility with 3-D techniques such as exposing the sphenoid rostrum, drilling sphenoidal septations, and identifying bony landmarks and suprasellar structures.

CONCLUSION: The 3-D endoscope is a useful alternative to the 2-D HD endoscope for transnasal anterior skull-base surgery. Preliminary results suggest it is more efficient surgically and has a shorter learning curve. As 3-D technology and resolution improve, it should serve to be an invaluable tool for neuroendoscopy.

KEY WORDS: Learning curve, Neuroendoscopy, Surgical time, Three-dimensional endoscopy, Transsphenoidal surgery

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WHAT IS THIS BOX?
A QR Code is a matrix barcode readable by QR scanners, mobile phones with cameras, and smartphones. **The QR Code above links to Supplemental Digital Content from this article.**

The first successful transsphenoidal surgery for a pituitary lesion was performed by Schloffer in 1907.[1] Harvey Cushing in Baltimore and 2 surgeons in Chicago, Allen Kanavel and Albert Halstead, each reported their results between 1909 and 1910.[2-4] During the 1960s, improvements were introduced, such as the operative microscope and video fluoroscopy. Gerard Guiot and Jules Hardy reintroduced and revitalized the transsphenoidal approach for pituitary lesions.[5,6] Surgical techniques continued to develop, and transsphenoidal neuroendoscopy became part of the armamentarium.[7-9] A major limiting factor for the endoscopic surgeon is to work in a 3-dimensional (3-D) field while viewing a 2-dimensional video image.[10,11] The introduction of 3-D neuroendoscopy has begun to address this issue. As experience with these devices increases and the technology matures, the advantages and disadvantages of 3-D neuroendoscopy can be further delineated.[9,12] This report describes our experience with implementing this technology into regular surgical practice at the Brigham and Women's Hospital.

ABBREVIATION: HD, high definition

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PATIENTS AND METHODS

Surgical Approach

The patient is positioned recumbent in a beach-chair fashion, with the head placed in 3-point fixation tilted slightly away from the surgeon. Intraoperative neuronavigation is used routinely. The initial exposure is performed with a short (18-20 cm) endoscope by 1 surgeon (2 hands). After the sella is exposed, the operation is continued via a bi-nostril 2-surgeon (3 or 4 hands) technique. The endoscope is always held by the assistant surgeon (resident or fellow), and the endoscope holder is not used. This allows for the assistant to remain engaged in the operation—a notable aspect in a teaching institution. Additionally, the ability to magnify on a specific area of interest is much quicker than if an endoscope holder was used. Angled endoscopes can be introduced after initial debulking of the tumor. A pedicled, nasoseptal flap is used for closure for extended transsphenoidal approaches. Fat grafts are placed only in the setting of intraoperative cerebrospinal fluid (CSF) leakage. CSF diversion by lumbar drain is used sparingly. Postoperative management includes frequent neurological evaluation, strict fluid management, and hormone replacement when indicated. Routine evaluation for delayed syndrome of inappropriate secretion of antidiuretic hormone and hypocortisolemia is performed 1 week after the operation.

Endoscopy

The high-definition (HD) 2-dimensional (2-D) endoscope (Karl Storz Neuroendoscopy) was used for all 2-D cases. The 3-D endoscope (Visionsense VSII) was introduced at the Brigham and Women's Hospital in November 2010. After a trial period of 20 operations, it was reintroduced in November 2011. From November 2010 to May 2012, 160 endoscope-only transsphenoidal operations were performed, of which 65 were with the 3-D endoscope. Subsequent to the initial trial, the 3-D endoscope was preferentially used when available for each operation. During the period that the 3-D endoscope has been available at our institution, the 2-D HD endoscope was only used for intraoperative magnetic resonance imaging (MRI) operations (5 cases), during technological malfunctions of the 3-D endoscope system (3 cases), and when instrument turnover time prohibited timely availability of the 3-D endoscope (5 cases).

Data Analysis

After approval by the institutional review board (IRB # 2011P001284), all sequential transnasally operated patients since the introduction of the 3-D endoscope at the Brigham and Women's Hospital were identified (November 2010 to May 2012). Patient demographics, pituitary function, intraoperative findings, imaging, pathological evaluation, and postoperative outcomes were recorded and analyzed. Operations that included the use of both the endoscope and microscope were excluded. Statistical analysis was performed with SPSS software package v12. Analysis OF variance was performed for continuous variables. χ^2 analysis was performed for nonparametric variables.

RESULTS

During the period of the study, 95 operations were performed with the 2-D endoscope and 65 with the 3-D endoscope. Seven patients had required the use of microscopy and were excluded from the analysis. There was no significant difference in patient age, sex, tumor type, or recurrence (Table 1).

TABLE 1. Demographic and Clinical Information of the Study Patients

	2-D Endoscope	3-D Endoscope
Number	95	65
Age	50.3 ± 17	49.1 ± 15
Sex, % female	56.4	56.3
Macroadenomas, n (%)	49 (51.6)	39 (60)
Microadenomas, n (%)	11 (11.6)	16 (24.6)
Nonadenomatous lesions, n (%)	35 (36.8)	10 (15.4)
Recurrent tumors, n (%)	22 (23)	14 (21.5)

The overall postoperative length of stay was similar between both groups. There was no significant difference in complications in both groups, including those that required a second operation for the complication. The average total operative times and actual surgical times (from surgical start to closure) were approximately 10 and 8 minutes shorter with the 3-D endoscope group, although not statistically significant (Table 2). There was a notable difference in adenoma resection times, approximately 30 minutes faster in both total operative time and surgical time in the 3-D endoscope group (P = .02 and P = .03). This relationship was more pronounced with the microadenoma subgroup, although not statistically significant (Table 3). There were no significant differences in anesthesia time, preparation time, or extubation time. There were too few patients with comparable non-adenomatous lesions for statistically significant analysis.

Qualitative intraoperative differences between these devices are difficult to quantify. In particular, residents who were naïve to endoscopy were quicker to learn how to manipulate the 3-D

TABLE 2. Select Clinical Outcomes Comparing 2-D and 3-D Endoscopy[a]

	2-D Endoscope	3-D Endoscope	*P*
Length of stay, days	3.0 ± 0.79	2.87 ± 1.17	.59
Total operating room time, min	239.1 ± 81.1	229.7 ± 56.0	.47
Surgical time, min	157.6 ± 71.3	149.4 ± 45.8	.47
Complications, n (%)	18 (18.9)	9 (13.8)	.66
Reoperation for complication, n (%)	5 (5.3)	4 (6.2)	.85
Epistaxis, n (%)	4 (4.3)	2 (3.1)	
CSF leak, n (%)	4 (4.3)	1 (1.6)	
Delayed SIADH, n (%)	3 (3.2)	1 (1.6)	
Permanent DI, n (%)	2 (2.1)	1 (1.6)	
Sinusitis, n (%)	1 (1.1)	2 (3.1)	
Mucocele, n (%)	2 (2.1)	0 (0)	
Vision loss, n (%)	0 (0)	1 (1.6)	
Pulmonary embolism, n (%)	1 (1.1)	0 (0)	

[a]SIADH, syndrome of inappropriate antidiuretic hormone secretion; DI, diabetes insipidus.

TABLE 3. Pituitary Adenoma Operative Times With Comparison of Microadenomas and Macroadenomas

	2-D Endoscope	3-D Endoscope	*P*
Adenoma resection			
Total operating room time, min	259.5 ± 81.2	227.1 ± 43.8	.02
Surgical time, min	174.4 ± 70.4	147.5 ± 41.7	.03
Macroadenomas			
Total operating room time. min	257.7 ± 74.5	232.1 ± 32.2	.09
Surgical time, min	172.4 ± 67.1	154.1 ± 44.1	.19
Microadenomas			
Total operating room time, min	269.3 ± 121.1	212.3 ± 32.2	.14
Surgical time, min	185.7 ± 93.7	128.3 ± 26.4	.06

endoscope. An advantage was seen with drilling of complex sphenoid septations with multiple compartments (see 3-D Video 1, available at: http://www.youtube.com/watch?v=631YRCxuXZM&feature=html5_3d). There was less "air drilling" and more direct application of rongeurs and Kerrison punches. Although there did not appear to be a notable difference in tumor manipulation at the face of the sella, there was an advantage for tumors with complex intrasellar architecture. Microsurgical technique was enhanced when working in the supradiaphragmatic/suprachiasmal region, in particular, during dissection of the lesion from the optic apparatus, the ventricular components, and the surrounding vasculature (see 3-D Video 2, available at: http://www.youtube.com/watch?v=sJBhr8VpGkQ&feature=youtu.be). Additionally, the 3-D endoscope is lighter in weight than the 2-D HD system and only requires 1 cable, because the light source is in the camera itself. The system autofocuses itself with no need to white-balance the image.

Drawbacks of the 3-D endoscope include lower-resolution imaging with red-color saturation variations (Figure). The slightest amount of blood on the camera lens completely distorts the color and clarity of the image. A component of disequilibrium and vertigo has been noted among users and observers, with some requiring the use of scopolamine patches. This problem is ameliorated by the use of an assistant's monitor with 2-D projection. The use of an endoscope holder could also ameliorate this aspect, but this was not used at our institution, as previously described.

A potential drawback to implementing the 3-D endoscope in routine practice is the cost of the device. Traditional 2-D endoscope systems share hardware resources with other endoscopic operations such as laparoscopy, cystoscopy and arthroscopy. Many operating suites are equipped with ceiling-mounted fixtures for these 2-D imaging devices. Hence, the introduction of the stand-alone 3-D system can add further capital cost to the hospital and surgeon's practice. At our institution, the equipment is leased from the manufacturer with a service contract. This allows for continuing technological updates and can accommodate for the lifespan of the endoscopes.

DISCUSSION

Use of the endoscope in pituitary surgery is widespread, safe, and well-established.[13]

Two-dimensional endoscopes improve peripheral visualization of the sella and surrounding structures within the sphenoid sinus and nasal passages, but lack depth perception and stereoscopic vision, image distortion, and ability to estimate size.[8,14] They are also associated with a steep learning curve.[9,15]

The 3-D endoscope is new technology that was first described in the 1990s by Becker et al[16] The authors pointed out that the 3-D view allows better recognition of the relationships of anatomic structures and makes precise differentiation of tissue layers possible.[16] The earlier generations of 3-D endoscopes used dual-channel video, dual chip-on-the-tip and shutter mechanisms.[16,17] They had a large outer diameter, poor resolution, and lacked angled view endoscopes.[9,12]

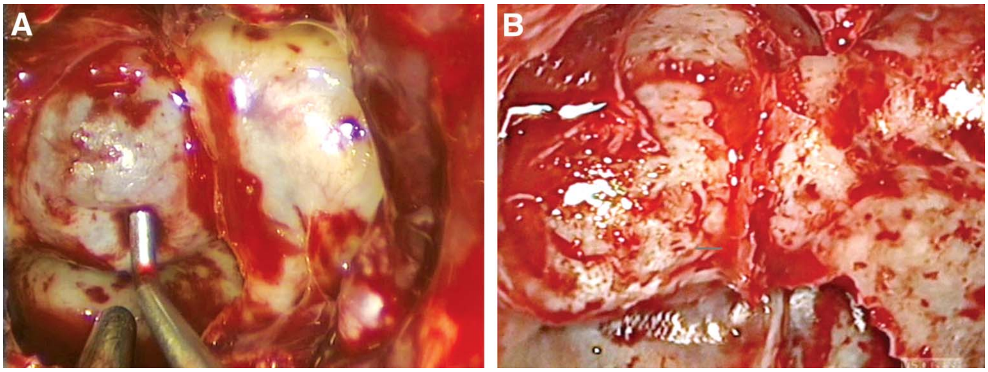

FIGURE. *Intraoperative images taken from 2-D HD (**A**) and 3-D (**B**) endoscope video stills. The resolution of the 3-D endoscope is half of the actual image because both eyes' views cannot be depicted accurately in 2 dimensions. HD, high definition.*

TABLE 4. Comparative Studies of 2-D and 3-D Transsphenoidal Surgery

	Tabaee et al 2009		Kari et al 2012		Present Study	
	2-D	3-D	2-D	3-D	2-D	3-D
Number	13	13	32	26	95	65
Female, %	61.5	30.8	62.5	73.1	56.4	56.3
Male, %	38.5	69.2	37.5	26.9	43.6	43.7
Mean age, y	57.3	55.5	50.1	48.6	50.3	49.1
Tumor volume, cm^3	–	–	3.65	3.94	–	–
Maximal tumor diameter, cm	2.6	2.2	–	–	–	–
Operative time, min	143.5	142.6	162.6	146.4	157.6	149.4
CSF leak intraoperative, n (%)	–	–	9 (28)	6 (23)	51 (54)	39 (60)
Length of hospital stay, days	3	4	5.53	5.46	3	2.87
Hospital readmission, n	–	–	8	6	5	4

Most of the literature comparing 2-D and 3-D endoscopy is related to laparoscopy with "old" 3-D technology. In these studies, the number of surgeons and operations or laboratory tasks were few, and the results were controversial.[16,18-25] The first report of 3-D endoscopy in neurosurgery was to assist in microscopic craniotomy tumor resections.[26] Currently, there are only 2 published reports comparing both 2-D and 3-D neuroendoscopy for transsphenoidal surgery (Table 4).[9,12] Both studies conclude that there are no significant differences in outcomes between the 2-D and 3-D endoscopic techniques.[9,12]

The number and accuracy of required movements are affected by the clarity of the visual feedback and the experience of the surgeon.[9] With 2-D endoscopy, the surgeon will often move the endoscope in various directions to gain motion parallax depth cues for 3-D perception. These movements can sometimes impact the operative time. In both studies, the operative time was longer, but not statistically significant with 2-D endoscope.[9,12] In contrast, several studies have shown benefits in speed, efficiency, and shorter learning curves with the 3-D endoscope.[10,11,18,19,24] In some studies, 3-D endoscopes offer significant differences for novice users.[10,11,20,23]

The 3-D Visionsense system uses an "insect eye" technology that incorporates a microarray of lenses similar to the compound eye of an insect in a single video chip at the end of the endoscope. This in turn generates multiple small images that are processed and divided into simultaneous left and right images. The images are overlaid on a stereoscopic flat screen monitor. Fraser et al conducted a task simulator study with this system and demonstrated significantly higher efficiency than subjects using 2-D.[27] Compared with the 2-D endoscope, the 3-D endoscope has a narrower visual field, a slightly larger endoscope diameter, and produces images with occasionally distorted colors (red hues).[9,12,28] Newer iterations of the 3-D technology have improved these parameters. The surgeon is positioned orthogonally to the monitor, which is at least twice the size of conventional displays. About 2% of the healthy population have no stereoscopic vision and would not be expected to benefit from the 3-D image.[24] Some minor degree of stereo deficiency is present in a further 15%, and 3-D may have limited benefit for those surgeons.[24]

In the present study, there were no significant differences in surgical outcomes. There was, however, a notable difference in surgical times for pituitary adenoma resection. The likely advantage of the 3-D endoscope is due to nonquantifiable aspects of neuroendoscopy training. These include manipulation of the endoscope, 3-D perception and spatial awareness, accurate placement of surgical instruments, and precise microdissection of sensitive structures. These differences were seen with various residents and fellows at different stages in their surgical training. Ideally, one would expect a shortened learning curve with the use of the 3-D endoscope. Given the structure of our institutional training program and the retrospective nature of this study, it was not possible to definitively quantitate changes in the learning curve for specific residents or fellows.

All the stages in the present study were done with the 3-D endoscope: approach, tumor resection, and closure. Kari et al[12] emphasize that the approach phase with the 2-D endoscope could be advantageous because of the wider field of view. In contrast, the same author affirms that the tumor resection phase is better with the 3-D endoscope in visualizing multiple tissue layers and neurovascular relationships.[12] Brown et al[17] noted improvement in recognizing the carotid and optic protuberances in the lateral sphenoid sinus with 3-D endoscopes. Similar to Kari et al, we did not need to switch from the 3-D system to the 2-D system, and most surgeons did not complain of nausea, headache, ocular fatigue, or dizziness intraoperatively or postoperatively, as opposed to other reports.[9,12,21,22] One surgeon did require a scopolamine patch to alleviate his symptoms. This effect is diminished as the surgeons decrease the excessive movements while driving the endoscope.

The current iteration of the Visionsense II 3-D endoscope still has a notable, but improved problem of excessive red-color saturation. This is particularly problematic during the nasal phase of the operation, because there is a tighter working corridor with multiple bleeding points. Surgical technique can help alleviate this aspect, but we affirm that the device requires further technological improvements to parallel the color display of traditional 2-D endoscopes.

CONCLUSION

To date, this is the largest study comparing 2-D HD and 3-D endoscopy for transsphenoidal surgery. The 3-D endoscope is a useful surgical tool with advantages for resident and fellow training in transsphenoidal surgery. Currently, the slightly lower-resolution image and imperfect color resolution is offset by the 3-D stereoscopic display. As the technology improves, its role in transsphenoidal neuroendoscopy will become increasingly evident.

Disclosure

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

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COMMENTS

The authors provide a nice technical review of their clinical experience with 3-D endoscopes, pointing out its primary advantages for accelerating resident and fellow training, as well as potentially facilitating intracranial dissections. They indicate the several disadvantages of the present-day systems, including large scope size, the marked loss of visual clarity with even small amounts of blood, and the vertiginous feeling that some users experience. It is important for potential users to understand the cost of the 3-D endoscope system compared with a standard 2-D system. It is disposable after about 70 cases, and it requires a special monitor. In contrast, the 2-D endoscope system requires standard endoscopy stacks and cameras that can be used for other laparoscopic and general surgical procedures in the hospital. These may be nontrivial considerations to most centers in our present cost-cutting era. Ironically, based on the authors' conclusions that a primary advantage of the 3-D scope is that it facilitates the learning cure for residents and fellows, the 3-D endoscope would appear to be of more practical value to surgeons that do a low volume of pituitary surgery, yet these are the least likely centers to invest in this technology. In general, 3-D endoscopy for all surgical fields has been found to facilitate initial surgeon learning, but to have relatively little value for experienced endoscopists, and the authors' present findings mirror these observations. We use a high-quality endoscope holder (Mitaka UniArm) for the sellar phase of the operation and find that this technique facilitates 2-handed surgery with no loss of mobility or visualization, and improved surgeon comfort. One might think that an endoscope holder would be ideal for the 3-D endoscope to avoid ongoing movement of the endoscope when manually held, which can increase surgeon's sense of disequilibrium and reduce stereopsis. I would be curious to hear the experiences of surgeons who have used the 3-D endoscope with a scope holder compared with those who have used the 3-D endoscope without a scope holder. Overall, I remain fairly underwhelmed by the present-day technology but suspect this field will continue to evolve and may ultimately become the standard of care. I congratulate the authors for their detailed and clear review.

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The authors compare their experience using the 3-D endoscope to that of using the 2-D endoscope. In this retrospective review, twenty 3-D cases were performed during an initial trial period, followed by a period in which 2-D cases were exclusively performed, which was then followed by another period in which 3-D cases were performed preferentially. No significant differences were found regarding outcomes except that pituitary adenoma surgeries were shorter when a 3-D endoscope was used. The subjective benefits of the 3-D endoscope were felt to be most pronounced for residents and fellows than for the senior author. Problems with 3-D endoscopy included poor image quality, particularly during the approach, and vertiginous symptoms experienced by a few residents/fellows. Three-dimensional endoscopy provides comparable results to 2-D endoscopy when performed by an experienced transsphenoidal surgeon in an academic setting. Its benefits appear to be most pronounced for residents and fellows.

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This paper is dealing with a topic of special interest for the neurosurgical community such as the impact of the development of 3-D visualization techniques in transnasal skull-base surgery. The classic dispute between supporters of the microscope and supporters of the endoscope is going to be overcome by the creation of miniaturized microscopes able to provide perfect stereoscopic vision along the main trajectory of approach and "behind the corner" also. The authors' experience is of paramount importance because it shows that 3-D endoscopes are improving and are already an interesting alternative to full HD 2-D endoscopes. In the years to come we will discover if the sunset of the classic microscopes that we are used to seeing in all neurosurgical operating theatres has begun in favor of miniaturized scopes able to provide a wonderful view from both outside and inside the craniotomy.

So far, little data exist comparing surgical outcomes with 2-D vs 3-D endoscopic systems and the authors should be complimented for their effort in this direction. This study examines perioperative and postoperative factors in 160 patients undergoing transnasal surgery for sellar and parasellar lesions with the use of 2-D vs 3-D endoscopes. No differences were found in terms of outcome, complications, length of stay, reoperations and readmission rates and this supports the idea that 3-D endoscopes can be safely used as an alternative visualization tool during transnasal procedures. Unfortunately, the authors were unable to measure parameters that might provide stronger evidence of the fact that 3-D visualization can make the difference in the learning curve of transnasal procedures. In addition, the authors' series and case analysis do not provide data strong enough to demonstrate that better recognition of anatomy and easier surgical dissection should lead to a reduction of the complication rate and to an increased rate of tumor removal. Despite that the authors data are preliminary, and further studies are required to analyze the above-mentioned issues, I share the authors opinion that "as this technology improves, its role in transsphenoidal neuroendoscopy will become increasingly evident."

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