Transnasal Skull Base Reconstruction Using a 3-D Endoscope: Our First Impressions*

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Abstract

Nowadays endoscopic skull base reconstruction is safely and effectively performed by means of two-dimensional (2-D) endoscopic technique. The aim of our study is to compare our 2-D experience with the novel 3-D technology in the field of skull base reconstruction techniques. In this study four patients treated with various kinds of planned duraplasty are included. The new 3-D technology was compared with the high-definition 2-D scopes during the different steps of the procedures. The 3-D endoscopic skull base reconstruction obtained primary closure without complications in all cases. According to the subjective opinion of experienced endosurgeons, this novel technique improved depth perception, distance and size estimation, ability to identify specific anatomic structures, and hand–eye coordination. The main drawbacks detected were inferior sharpness, contrast and lighting that impaired the application of the technique in narrow sinonasal spaces. According to our preliminary impressions, 3-D endoscopic skull base reconstruction is an effective and safe procedure and could represent a significant advantage for accurate managing of the skull base region.

Keywords

- three-dimensional
- stereoscopic
- skull base reconstruction
- endoscopic
- duraplasty

Endoscopic endonasal duraplasty has been demonstrated to be an effective, safe, and reliable approach in most cases of skull base defects, regardless of the size.^{1–6}

One of the primary restrictions of the endoscopic technique, however, in contrast with microscopic procedures, is the lack of binocular vision and consequently of third dimension. In fact current endoscopic technology offers excellent resolution (high-definition [HD] cameras) but creates a two-dimensional (2-D) image that impairs depth perception and hand–eye coordination, and reduces the ability to estimate size.⁷

To gain a depth cue in such a 2-D environment, surgeons seek sensorial and tactile feedback during manipulation of instruments by constantly moving the scopes in and out or from side to side. In this manner, depth perception is based on integration of indirect information from a variety of sources,

including the surgeon's former knowledge of the spatial relationship between anatomical structures.⁸

Recently introduced HD stereoscopes produce a three-dimensional (3-D) image of the surgical field, with natural binocular ability to perceive depth, volume, and distance accurately.⁹ Although in preliminary series, stereoscopic skull base surgery has proved to be a feasible and safe procedure, with outcomes comparable to those achieved with standard 2-D endoscopes.^{10,11} Moreover, earlier task-based simulator studies have shown the benefit of 3-D technology in terms of speed, efficiency, and error rates when compared with the 2-D technique.¹²

Thus, on the basis of these considerations and our large skull base reconstruction experience (more than 400 cases), we have begun to use 3-D endoscope in endonasal endoscopic procedures. Accordingly, in this study we report our preliminary impressions about the application of a novel 3-D endoscopic system in the field of skull base

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surgery. Perceived advantages and limits, possible drawbacks and developing areas are critically analyzed and discussed.

Materials and Methods

The cohort of this study is represented by our first unselected four patients, treated with various kinds of planned skull base reconstruction. All patients underwent a purely endoscopic transnasal approach to the skull base and were operated by experienced surgeons. All procedures were performed by four surgeons using the two-nostril-four-handed technique. Both HD 2-D (Karl Storz, Tuttlingen, Germany) and 3-D (Visionsense, Ltd., Petach Tikva, Israel) endoscopes were contemporaneously used and compared during the different phases of the procedure. The 3-D system used during the study was composed of 0- and 30-degree rigid endoscopes, sized 150 mm in length and 4 mm in diameter at the distal end. The system requires the use of passive glasses, which emulate the binocular perception in combination with a 3-D screen.

In all the cases, an intraoperative magnetic navigation system (Medtronic Navigation, Inc., Louisville, CO) was used to well localize the instrument position in the surgical field and to constantly verify the anatomical landmarks (►Fig. 1).

Two patients underwent an endoscopic transnasal craniectomy (ERTC) for the management of a sinonasal malignancy with intracranial involvement, and subsequent repair of the resulting defect. The extent of the resection was tailored to specific tumor characteristics (histology, site of origin, and proximity to critical areas), according to the

principles of oncological radicality. The other two patients underwent skull base reconstruction for posttraumatic cerebrospinal fluid leaks, located in the ethmoidal roof and in the olfactory cleft, respectively.

Preoperative diagnostic work-up included magnetic resonance imaging with gadolinium enhancement in all cases. A prophylactic antibiotic regimen with third-generation cephalosporin was started intravenously the day before surgery and was continued for at least 5 days.

Patients were transferred directly to the ward after surgery, with no need for intensive care. Nondegradable nasal packs were removed 2 days after surgery and bed rest was maintained for 2 days with trunk and head raised at 25 degrees. A brain computed tomography scan was performed 24 hours after surgery for early detection of any signs of postoperative pneumocephalus or intracranial bleeding.

All procedures were performed by four surgeons with wide experience in 2-D transnasal endoscopic skull base reconstruction. At the end of each surgical procedure, the “endosurgeons” were asked to qualitatively define the 3-D system, comparing different parameters with the conventional 2-D endoscopic system. Items were scored as follows: score 3, high advantage; score 2, advantage; score 1, low benefit; score 0, no significant difference; score -1, partial drawback; score -2 drawback; score -3, serious drawback (►Table 1).

Surgical Technique

The criterion that guides the skull base repair procedure is “integration of the borders.” The preparatory stage of duraplasty must include appropriate exposure of the defect,

Figure 1 (A) Intraoperative setting showing two endosurgeons working with the 3-D endoscope (monitor located on the left) and the neuronavigation system (monitor located on the right). (B) The surgical procedures were performed by two-nostril-four-handed technique.

Table 1 Subjective Qualitative Evaluation of 3-D Endoscopic System in Comparison with 2-D

Surgeon	Color Perception	Lighting	Sharpness and Contrast	Depth Perception	Distance and Size Estimation	Hand-Eye Coordination	Identification of Skull Base Structures	Speed of the Procedures	Dizziness and Personal Discomfort
No. 1	-1	-2	-3	2	2	1	1	0	0
No. 2	0	-3	-3	2	1	0	2	0	-2
No. 3	1	-1	-1	3	3	3	3	0	0
No. 4	0	-2	-2	3	2	2	2	0	-1

Score 3, high advantage; score 2, advantage; score 1, low benefit; score 0, no significant difference; score -1, partial drawback; score -2 drawback; score -3, serious drawback.

undermining of the dural margins, and smoothing of the defect edges to get a tensioactive effect for the graft or flap. In two patients who underwent ERTC, skull base reconstruction was performed with a multilayer technique, to repair a large defect extending from orbit to orbit and from the frontal recess to the sphenoethmoidal planum. Resection time included dural resection until margins free from tumor were obtained. Iliotibial tract or fascia lata were the materials employed for all the reconstruction layers (intradural layer; intracranial-extradural layer; extracranial-endonasal layer).

In two cases of posttraumatic skull base defect, an overlay or multilayer reconstruction technique was performed, depending on the site of the defect with different autologous materials.

In all the cases, the reconstruction was covered with strips of Surgicel (Ethicon Inc., Johnson and Johnson, Somerville, NJ) and fibrin glue was placed along the graft margins.

Results

The clinical findings of the patients, specific localization of the skull base defect, and surgical details are summarized in ►Table 2.

No intra- or postoperative complications were observed in the patients enrolled in the study. In comparison with our 2-D experience there was no significant difference in the operative time when using the 3-D endoscopic system. The 3-D endoscopic skull base reconstruction obtained primary closure in all the cases without need of lumbar drainage or duraplasty surgical revision.

According to the subjective opinions of the users, collected after each surgical procedure and arranged in a qualitative assessment (►Table 1), the 3-D endoscopic technique improved depth perception (mean score, +2.5), distance and size estimation (mean score, +2), ability to identify specific anatomic structures (mean score, +2), and hand-eye coordination (mean score, +1.5). The main drawbacks detected were the inferior sharpness and contrast (mean score, -2.25) and lighting (mean score, -2) of the 3-D system compared with the 2-D scopes.

There was no color distortion (mean score, 0) or difference in the speed of the procedure (mean score, 0). The users did not complain of significant subjective discomfort attributed to the stereoscopic visualization and to the wearing of polarized glasses (mean score, -0.75).

Discussion

The ability to manage skull base defects with endonasal endoscopic approaches has represented a milestone in otorhinolaryngology and neurosurgical field. Over time, experienced "skull base teams" have proposed different techniques to repair dural defects, focusing on the use of free or pedicle flaps in a single or multilayer fashion.^{2,3,13} Above all, regardless of the technique used, 2-D endoscopes nowadays allow to treat transnasally most of the defects localized in the anterior, middle, and posterior

Table 2 Clinical and Pathological Findings of the Patients

Case	Pathology	Age	Sex	Comorbidity	Previous Treatment	Hospitalization Time (Days)	Site of Skull Base Defect	Skull Base Reconstruction Technique	Material	Complication (Early and Late)
1	Right ethmoidal ITAC with dural involvement (T4bN0M0)	56	M	Ischemic cardiopathy	–	11	Anterior skull base resection	Multilayer	ITT	–
2	Left sinonasal poorly differentiated neuroendocrine carcinoma (T4aN0M0)	54	M	–	I-CHT	9	Anterior skull base resection	Multilayer	ITT	–
3	Posttraumatic CSF leak	39	M	–	–	4	Posterior wall of left frontal sinus	Multilayer	TF, B, MP	–
4	Posttraumatic CSF leak	79	M	Multiple bone fractures (clavicle, hip)	–	6	Posterior portion of left olfactory fissure	Overlay	MP	–

B, bone; CSF, cerebrospinal fluid; I-CHT, induction chemotherapy; ITAC, intestinal-type adenocarcinoma; ITT, iliotibial tract; M, male; MP, mucoperiosteum; TF, temporal fascia.

cranial fossa, with low morbidity and high success rate.¹⁴

On the basis of our large series of multilayer duraplasty,^{2–4,15–17} we tested the recently introduced stereoscopes to evaluate whether they were able to overcome some limits we observed with 2-D endoscopes. In fact one of the major criticisms of traditional endoscopes is the lack of depth perception in comparison with the open or microscopic surgical field. Skilled endosurgeons well compensate this lack by continuous in-out and side-to-side movements of the scope and by integrating tactile information with previous spatial knowledge. This compensatory perception can sometimes be misleading in 2-D environments. In fact it has been well demonstrated that the primary cause of error in laparoscopic surgery is due to a visual perceptive illusion.¹⁸

From a technological viewpoint, the 3-D system represents one of the most fascinating innovations in the last decade; this technique has been reported to improve the surgeon's ability in recognizing anatomical landmarks and their spatial relationship.^{8–10} Moreover, in the laparoscopic field, significant decreases in “visual endoscopic handicap,” performance time and error rates have been demonstrated with the use of the 3-D scope compared with the 2-D scope; this is true for both experienced and less experienced surgeons⁷ using the 2-D scope.

With the evolution of technology, stereoscopic rigid endoscopes have recently reduced their dimensions (from 6.5 to 4.0 mm) and angled 30-degree scopes have been introduced. This has permitted easier maneuverability inside sinonasal spaces and better visualization around the corner with complete exposure of the anterior skull base.

In recent years, the 3-D system has been applied in the management of skull base and orbital lesions with encouraging results^{8–11} and also our preliminary experience in 3-D skull base surgery seems to confirm the good impressions of other authors in terms of improved hand–eye coordination, better tissue understanding,^{9,10} and a “more natural feeling” during surgery.¹⁰ Furthermore, also the ability to identify anatomical landmarks seems to be improved by this technology.¹¹

In this respect, we maintain that this technology can be really useful when surgery is performed in extremely delicate spaces where neural and vascular structures are often separated by millimeters. Personally, we found that 3-D visualization was really helpful during the intracranial phase in detaching the dura mater from the ethmoidal roof during ERTC because the epidural space was precisely defined, thus making movements better controlled and reducing the risk of dura damage. Once the dura was cut and opened, the relationship between arachnoid, brain, and vascular structures were clearly evident, permitting a safer intradural dissection, thus reducing the risk of vascular and nervous injuries. In multilayer reconstruction, insertion of the first two layers (intradural and extradural-intracranial) was faster and more accurate because of the constant depth perception. Posterior borders of the duraplasty were inserted in a safer manner because of a clear vision of anatomical structures such as optic

chiasm, opticocarotic recess, and parasellar portion of the internal carotid artery.

Furthermore, also in the case of posttraumatic cribriform plate defects, in which the surgical field is smaller, 3-D visualization allowed a better definition of the surgical details, thus making the surgeon more comfortable with drilling the bone and placing the flap. On the whole, surgeons felt at ease and well oriented with the surgical procedures.

With reference to the current drawbacks of this technology, we underline the inferior sharpness, lighting and contrast compared with new HD 2-D systems.¹¹ The short range of focus and restricted viewing angle still make surgery in narrow spaces more difficult.¹¹ Also our experience confirms that 3-D systems currently show some flaws in terms of visual discomfort and distortion, mainly when working in narrow spaces. To date, in the early phases of the transnasal skull base approaches, the HD 2-D system remains the most efficacious and accurate technique. Notwithstanding this, we maintain that 3-D technological evolution will overcome these limits.

Furthermore, new clear-vision systems are needed, given the fact that a 3-D image is more susceptible to poor visualization when soiled⁹ and the resulting image is deeply disturbing.

Despite this fact, although clinical experience is in the early phases and the current limits are well known, we maintain that with further development 3-D endoscopes could represent a really remarkable opportunity for the endosurgeons and the patients of tomorrow.

Conclusion

Although 2-D techniques are able to offer skilled surgeons a valid tool for skull base procedures, we maintain that the 3-D system could represent a significant advantage for managing these complex regions. This is particularly relevant in terms of efficacy and safety of the procedure. Future controlled trials will be necessary to validate this new technology.

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