Comparing Operative Exposures of the Le Fort I Osteotomy and the Expanded Endoscopic Endonasal Approach to the Clivus

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Abstract

Objectives We compare surgical exposures to the clivus by Le Fort I osteotomy (LFO) and the expanded endoscopic endonasal approach (EEEA).

Methods Ten cadaveric specimens were imaged with 1.25-mm computed tomography. After stereotactic navigation, EEEA was performed followed by LFO. Clival measurements included lateral and vertical limits to the midline lower extent of exposure (*t* test).

Results For EEFA and LFO, respectively, maximal lateral exposure in millimeters (mean ± standard deviation) was 24.5 ± 3.7 and 24.5 ± − 3.8 ($p = 0.99$) at the opticocarotid recess (OCR) and 25.1 ± − 4.1 and 24.1 ± − 3.0 ($p = 0.53$) at the foramen lacerum level; lateral reach at the hypoglossal canals was 39.0 ± − 5.88 and 56.1 ± − 5.3 ($p = 0.0004$); and vertical extension was 56.0 ± − 4.1 and 56.3 ± − 3.4 ($p = 0.78$).

Conclusions For clival exposures, LFO and EEEA were similar craniocaudally and laterally at the levels of the OCR and foramen lacerum. LFO achieved greater exposure at the level of the hypoglossal canal.

Keywords
- cadaveric study
- clivus
- chordoma
- expanded endoscopic transsphenoidal approach
- Le fort I osteotomy
- operative exposure

Introduction

Lesions of the clivus are relatively rare but present a surgical challenge with continued controversy related to the optimal approach. Although chordomas seem to occur most often, other clival lesions include neoplasms (e.g., chondrosarcomas, teratomas, metastatic disease) and nonneoplastic processes (e.g., infectious processes, cholesterol granulomas, fibrous dysplasia, cerebrospinal fluid [CSF] fistulas).[1,2] Because most clival lesions are benign with often partial response to chemotherapy and radiation, surgical resection is often the mainstay of treatment.[3,4]

Among various surgical approaches to the clivus, the intradural approaches include the frontotemporal (with or without a zygomatic osteotomy), subtemporal transtentorial, presigmoid petrosal, and retrosigmoid approaches. In general, intradural approaches provide limited exposure of the clivus, particularly for lesions without a significant intradural component that often disrupts the normal anatomy in a way to create a surgical corridor. However, in the absence of an intradural corridor, drilling the clivus can be hazardous; thus extradural approaches are often preferred. Transoral approaches provide excellent exposure to the inferior clivus and upper cervical spine, whereas transmaxillary (Le Fort 1 maxillotomy), transpalatal, or open door maxillotomy provide access to both the clivus and sphenoid sinus.[5]

Of the existing options, the Le Fort I osteotomy (LFO) has proven to achieve maximum exposure of the clivus in

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cadaveric models.[6] Several small clinical series of LFO approaches to clival lesions reported good results with low rates of complications (i.e., CSF leak, meningitis, abducens palsy, oral malocclusion, velopharyngeal insufficiency, wound healing).[7,8] The LFO approach to the clivus has produced satisfactory results. At the same time, less invasive approaches are increasingly popular given the advances in surgery and technology. One option, the expanded endoscopic endonasal approach (EEEA), has been reported in several small clinical series to yield rates of complications comparable with the LFO series.[9,10] Additionally, an EEEA provides a less invasive surgical corridor when compared with open surgical techniques (i.e., transfacial). Although one could argue that the EEFA offers a preferred approach to the clivus because of its equivalent operative exposure and limited facial soft tissue morbidity, the limits of exposure afforded through endoscopy have not been well defined. Therefore, in this cadaveric study, we directly compare the clival exposures achieved by the EEEA and a transfacial/LFO approach.

Materials and Methods

Ten embalmed adult cadaveric heads were prepared for serial dissection, yielding 10 data sets for each procedure. Bilateral internal carotid arteries (ICAs), vertebral arteries, and internal jugular veins were cannulated, flushed, and injected with colored silicone rubber (Dow Corning, Midland, MI, USA). Specimens were imaged before surgical dissection using computed tomography with 1.25-mm cuts. After fixation in a Mayfield headholder, specimens were registered to stereotactic navigation (Brainlab Curve, Felkrchen, Germany) using surface registration. Zero-degree 1288 high-definition Stryker (Kalamazoo, MI, USA) endoscopes were used for visualization.

Surgical Approach

Once accurate registration was achieved with the stereotactic navigation system, an EEEA was performed and measurements were taken. After data collection, an LFO was performed and measurements made as follows:

EEEA: Specimens were oriented supine with the head tilted 10 degrees to the right. The middle turbinates were lateralized bilaterally and the endoscope was advanced until visualization of the sphenoid ostia. No turbinates were resected. Bilateral sphenoid osteotomies were completed in addition to a posterior septectomy. Visualization was achieved from the planum sphenoidale to the roof of the palate.

LFO: Specimens were oriented supine. After a sublabial mucogingival incision was completed along the length of the maxilla, the muscles and mucosa were elevated superiorly until the infraorbital nerve was identified. The piriform aperture was identified, and the mucosa was elevated from the floor. The maxilla was then fractured from the inferolateral margin of the piriform aperture laterally to the pterygomaxillary fissure. Osteotomes were then used to fracture the pterygoid plates and disarticulate the nasal septum base. The maxilla was then down fractured and retractors were inserted.

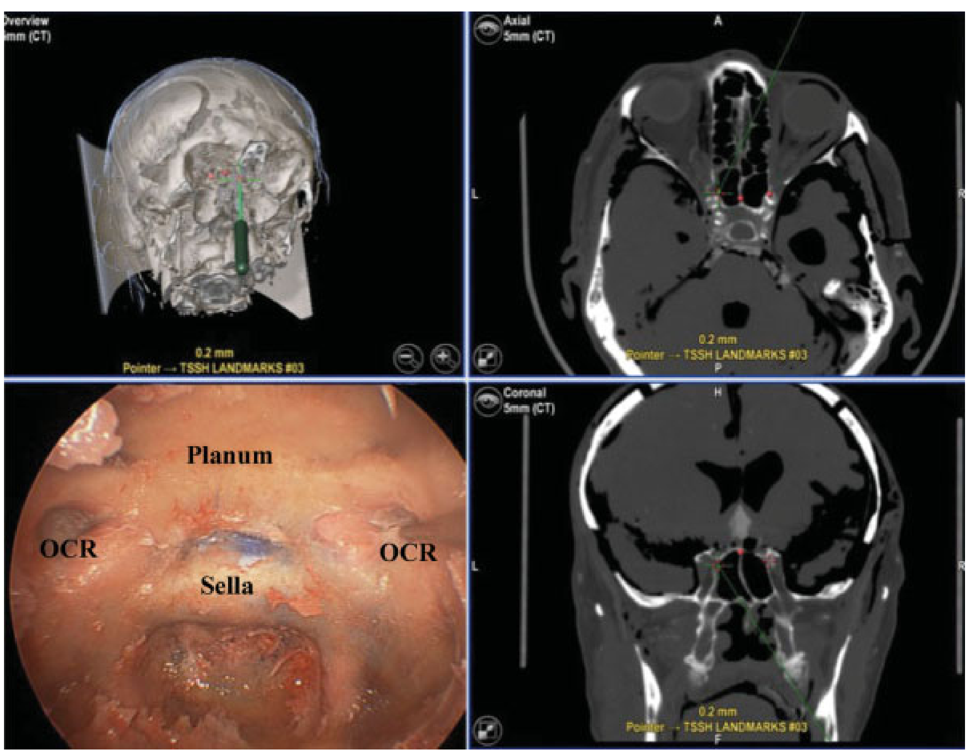

Fig. 1 Data collection for real-time placement of the probe in a three-dimensional reconstruction (top left) and simultaneous position of the probe on the endoscope located in the left opticocarotid recess (OCR) (bottom left). Axial (top right) and coronal (bottom right) views during point placement.

Quantifying Exposures

After each procedure, we measured the degree of operative exposure from points marked in the stereotactic navigation dataset using straight instruments (►**Fig. 1**). Horizontal exposure was recorded by the most lateral point obtainable (bilaterally) at the following levels: the opticocarotid recess (OCR), sphenoid rostrum at the level of the foramen lacerum, and level of the hypoglossal canals. Vertical exposure was recorded in the midline between the most superior and most inferior points of exposed clivus possible.

Using the Brainlab v.3.0 software suite (Brainlab Curve), we calculated distances at the previously mentioned vertical and horizontal exposures for each specimen. Distances represent maximal working freedom from right to left for horizontal measurements and superior to inferior for vertical measurements. Mean and standard deviation were compared by *t* test.

Results

Measurements for both approaches showed no significant difference in horizontal operative exposure at the level of the OCR, specifically 25.5 mm for the EEEA and 24.5 mm for the LFO ($p = 0.99$) (►**Table 1**). Both procedures provided a full lateral exposure to the lamina papyracea. Likewise, operative exposure at the level of the foramen lacerum was 24.4 mm for the LFO and 25.1 mm for the EEEA ($p = 0.525$), with each procedure providing access to the lateral wall of the sphenoid sinus, medial pterygoid buttress, and medial wall of the maxillary sinus. At the level of the hypoglossal canal, operative exposure was significantly greater at 56.1 mm for the LFO than the 39.0 mm for the EEEA ($p = 0.0004$). As shown in ►**Fig. 2**, the EEEA provided exposure in almost all specimens to the lateral portion of the hypoglossal canal. The LFO increased exposure allowed access to the distal extracranial ICA and internal jugular vein but not without mobilization of the eustachian tube.

Vertical exposure provided by each approach was similar with 56.3 mm of freedom for the LFO and 56.0 mm for the EEEA ($p = 0.77$). Both procedures allowed exposure from the planum sphenoidale superiorly to the tip of the dens inferiorly. In some specimens, inferior exposure extended to the anterior arch of C1.

Discussion

Although radiotherapy and chemotherapy regimens have been shown to be effective adjutants in the treatment of clival lesions such as chordoma and chondrosarcoma, surgical resection remains the mainstay of treatment, and gross total resection is associated with greater overall survival.[9–17] Our anatomical studies attempted to address some of the challenges of surgical access to the clivus by quantifying the exposures achieved by the LFO, the traditional approach, compared with the less invasive EEEA. Both procedures were nearly equivalent in the vertical and horizontal planes, and they achieved complete exposure of the superior and middle clivus. Only in lateral exposure of the inferior clivus was the traditional open approach superior.

Surgical Approaches to the Clivus

Lesions of the clivus are traditionally accessed through transfacial and transoral approaches. The LFO, originally described by von Langenbeck in 1859 and popularized in Europe in the 1960s, became a favored approach to the clivus.[3,8,18] The LFO avoids the visible incisions created by transfacial approaches, and when compared with transoral approaches, it can provide comparable comprehensive access to the clivus.[6] Despite its success, the LFO was not without complications. Therefore, development of less invasive techniques, like the anterior maxillary resection in a sublabial transsphenoidal approach, followed even before the introduction of purely endoscopic approaches.[19]

Use of the endoscope during the last decade has expanded the choice for transsphenoidal surgery beyond sellar lesions.[20] Reports of successful endoscopic treatment of clival lesions confirmed the viability of EEEAs as a minimally invasive alternative to traditional approaches including the LFO.[2,9,21–23] In fact, in a 2011 meta-analysis of 766 patients in 37 studies comparing open surgical and endoscopic endonasal surgery, Komotar et al noted greater tumor resection,

Table 1 Comparison of horizontal and vertical degrees of exposure in expanded endoscopic endonasal approach and Le Fort I osteotomy[a]

Measurement	EEEA		Le Fort I osteotomy		*p* value
	Mean	Standard deviation	Mean	Standard deviation	
Horizontal					
Widest lateral distance OCR	24.54	3.67	24.5	3.8	0.990
Widest lateral distance lacerum	25.10	4.10	4.4	3.0	0.526
Widest lateral distance hypoglossal	38.95	5.88	56.1	5.3	**< 0.001**
Vertical					
Dens to tubercular exposure	55.99	4.14	56.3	3.4	0.777

EEEA, expanded endoscopic endonasal approach; OCR, opticocarotid recess.
[a]Distances denote maximum right to left or superior to inferior freedom using 0-degree endoscopes with straight instruments. Significant values are shown in boldface.

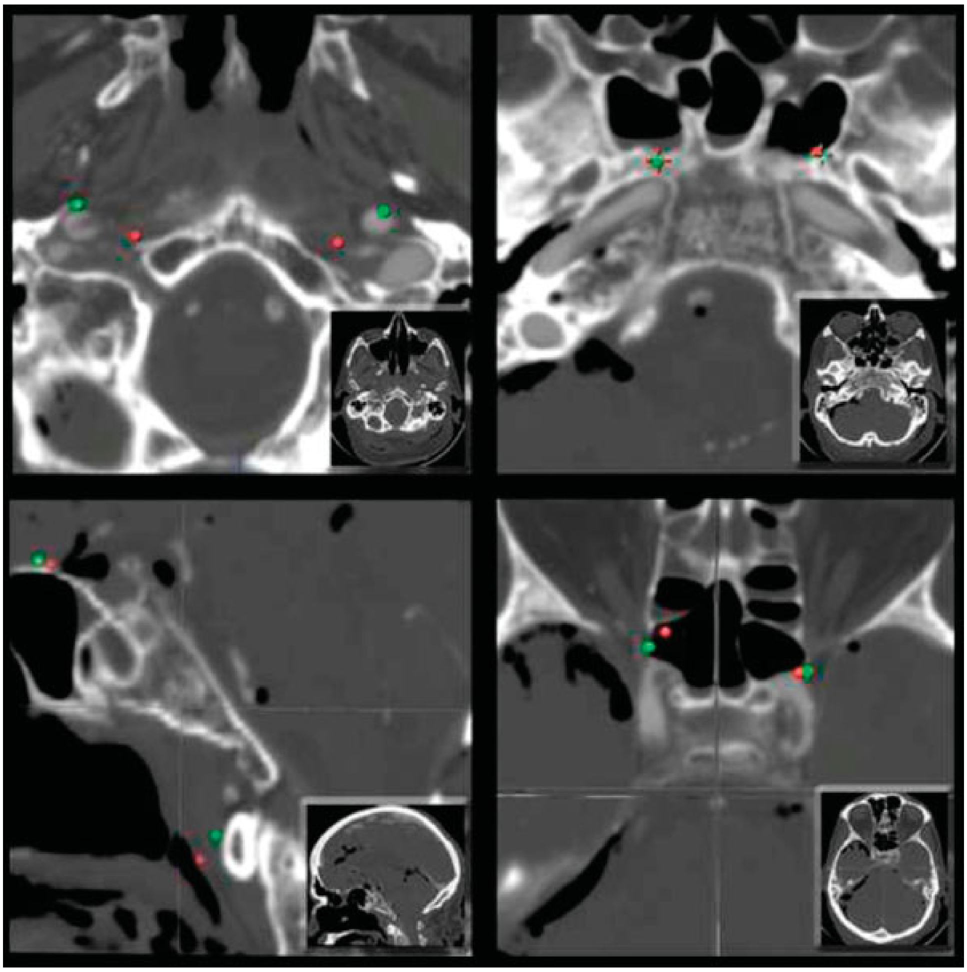

Fig. 2 Computed tomography scans comparing the extent of exposure by the expanded endoscopic endonasal approach (red dot) and Le Fort I osteotomy (green dot) approaches; each inset shows level of cut. Upper left, axial scan showing horizontal exposure at the level of hypoglossal canal. Upper right, axial scan showing horizontal exposure at the level of foramen lacerum. Lower left, midsagittal scan showing vertical extension. Lower right, axial view showing horizontal exposure at the level of the opticocarotid recess.

fewer complications, and fewer recurrences in the endoscopic group.[11] However, one should not interpret these findings as proof of an EEEA's superiority. As the authors suggested, comparisons between subgroups in meta-analyses are inherently inaccurate; many cases in the endoscopic series were carefully selected with results that may not be easily generalizable.

Although the available clinical data demonstrate the effectiveness of the endoscopic approach for smaller, more contained lesions, concerns remain regarding its limited exposure when compared with open approaches. By quantifying the exposures achieved by the traditional preferred approach, the LFO, and the less invasive EEEA, our results confirmed that both procedures provided nearly equivalent exposure in the vertical and horizontal planes. Both the superior and middle clivus were completely exposed in each technique, and the respective limiting factor for lateral exposure was the lamina papyracea and the pterygoid buttress.

Similarly, vertical exposure did not differ statistically between the two approaches, with both reaching from the rostral planum sphenoidale to the caudal dens. Because the hard palate limits inferior exposure in EEEA approaches, one could easily assume greater inferior clival access by using the LFO. However, the vertical length of the piriform aperture was similar to the vertical length of the corridor created by the down-fractured maxilla and the more superior entry point (piriform aperture). The subsequent downward angle of view of the EEEA allowed equivalent visualization inferiorly when compared with the LFO.

Lateral exposure was notably limited at the level of the inferior clivus for the EEEA when compared with the LFO; specifically, the EEEA was limited at the level of the hypoglossal canal because of the lateral limit of the pterygoid plates. In the LFO, the disarticulation of the inferior pterygoid plates allows increased exposure toward the posterior parapharyngeal space. However, lateral visualization at this level was limited even with the LFO; access to these contents required mobilization of the eustachian tube and would be associated with a resultant morbidity owing to that surgical maneuver.

A qualitative but important difference between these approaches was the visual angle. With an upward angulation to the basisphenoid and a downward angulation to the lower clivus, the visual approach of EEEA was centered on the middle clivus. In contrast, the visual approach of the LFO was centered on the low-middle and lower clivus, having an upward angulation to the middle clivus and basisphenoid. To be clear, we used only 0-degree endoscopes and straight instruments to acquire the endoscopic exposure. However, angled endoscopes and instruments can significantly expand the exposure in any direction at any level of the clivus.

Study Limitations

An obvious limitation of this study is the use of fixed cadavers, specifically the compromised realistic range of motion restricted by the fixed nature of cadaveric tissue. However, both procedures were similarly affected. For example, the limited mobility of the down-fractured maxilla in the LFO and the restricted range of motion of the external nares in the EEEA likely resulted in similar conservative degrees of freedom. An argument could be made for a transpterygoid expansion of the EEEA, allowing increased lateral extension potentially superior to the LFO. Descriptions of this modification are not unique to endoscopic approaches but have also been described in the LFO literature.[24–26] Our study aimed not to define extreme degrees of surgical freedom, but to aid operative decision making by comparing two well-described procedures in their basic form. A final limitation is our inability to quantify the ease of use of instrumentation for each approach. A LFO likely provides a larger operative corridor superficially than the EEEFA because it is not limited by the size of the nares bilaterally. Therefore, a wider range of instruments may be available for use in the LFO including bipolar coagulation and ultrasonic aspirators. Current transsphenoidal instrumentation continues to improve, and the extent of limitation presently remains somewhat questionable.

Conclusions

This cadaveric study demonstrates that clival exposure is nearly equivalent using either an open or endoscopic approach. When comparing the EEEA and LFO, both craniocaudal and lateral exposures for the superior and middle clivus were similar, whereas the EEEFA provided a more direct visualization of the upper clivus. For lesions of the lower clivus, especially those that extend beyond the hypoglossal canal, the LFO provides greater lateral exposure and potentially greater visualization. However, lesions of the jugular foramen region remain difficult to manage from an anterior approach regardless of approach, given their frequent vascular nature and close relationship with the lower cranial nerves; alternative approaches (anterolateral and posterolateral) may be superior in exposure and safety. Concluding that most clival lesions are accessible through an endoscopic approach with the potential advantages afforded by the less invasive corridor, we are working to define clinical validation of our findings.

Note

The authors have no disclosures or potential financial conflict of interests to report related to this article.

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