Quantification of increased exposure resulting from orbital rim and orbitozygomatic osteotomy via the frontotemporal transsylvian approach

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Object. Use of orbital rim and orbitozygomatic osteotomy has been extensively reported to increase exposure in neurosurgical procedures. However, there have been few attempts to quantify the extent of additional exposure gained by these maneuvers. Using a novel laboratory technique, the authors have attempted to measure the increase in the “area of exposure” that is gained by removal of the orbital rim and zygomatic arch via the frontotemporal transsylvian approach.

Methods. The authors dissected five cadavers bilaterally. The area of exposure provided by the frontotemporal transsylvian approach was determined by using a frameless stereotactic device. With the tip of a microdissector placed on targets deep within the exposure, the position of the end of the microdissector handle was measured in three-dimensional space as the microdissector was rotated around the periphery of the operative field. This maneuver was performed via the frontotemporal approach alone as well as with orbital rim and orbitozygomatic osteotomy approaches. After data manipulation, the areas of exposure corresponding to the polygons used to define these handle positions were calculated and directly compared. On average, the area of exposure provided by the frontotemporal transsylvian approach was increased 26 to 39% (p < 0.05) by adding orbital rim osteotomy and an additional 13 to 22% (not significant) with removal of the zygomatic arch.

Conclusions. Significant and consistent increases in surgical exposure were obtained by using orbital osteotomy, whereas zygomatic arch removal produced less consistent gains. Both maneuvers may be expected to improve surgical access. However, because larger and more consistent gains were afforded by orbital rim removal, the threshold for removal of this portion of the orbitozygomatic complex should be lower.

KEY WORDS • orbital osteotomy • orbitozygomatic approach • quantitative anatomical study • skull base surgery • zygomatic osteotomy

Much attention in the neurosurgical literature has been focused on the use of orbitozygomatic osteotomy to facilitate exposure along the base of the brain. Although the traditional techniques of frontal, temporal, and periorbital craniotomy are adequate for reaching many lesions located in the regions of the interpeduncular fossa, clivus, and cavernous sinus, newer methods involving disarticulation of the orbital rim and zygomatic arch have increasingly been used.

The goal of these surgical adjuncts has been to improve exposure areas and to minimize retraction of neural structures.

The range and location of pathological entities that have been treated via orbitozygomatic osteotomy are quite extensive. Considerable literature exists extolling the advantages of the transorbital and transzygomatic approaches for augmenting exposure via several routes, including the frontotemporal and transsylvian. Despite these reports, other surgeons have been more circumspect about the advantages of these procedures. Some have asserted that the incidences of morbidity and the lengths of operative time resulting from these approaches outweigh the need for any additional exposure in all or most cases; others continue to doubt whether additional exposure is gained at all.

Because little attention has been paid to quantifying the additional exposure that can be gained by orbit and/or zygoma removal, the decision whether to perform these techniques remains one of personal operative style. Quantifying this type of exposure is a relatively complicated issue. Because the area that must be measured is located close to the surgeon’s hands rather than within the depths of exposure, simply placing a ruler within the wound would not be sufficient. Rather, it is the area within which surgical instruments can be inserted—the “surgical window”—that must be quantified.

To achieve a more accurate understanding of the benefits afforded by additional removal of bone, we developed a novel laboratory method for measuring surgical exposures obtained via traditional frontotemporal craniotomy, transsylvian craniotomy, and transzygomatic craniotomy. We used a frameless stereotactic device (Stealth Station Treatment Guidance Platform; Sofamor-Danek, Mem-
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Fig. 1. Drawing showing the extent of bone resection for the frontotemporal approach alone (A) and the frontotemporal approach with orbital rim osteotomy (A + B) and additional orbitozygomatic osteotomy (A + B + C). Note that, before any measurements, bone removal was maximized along the floor of the anterior fossa (small arrow) and the subtemporal area (large arrow). Orbital decompression and anterior clinoidectomy were conducted as well.

Fig. 2. Drawing demonstrating the technique for measuring microdissector positions in 3D space using a frameless stereotactic device. This also shows the various angles via which a lesion can be approached. As the microdissector was held in positions around the periphery of the exposure, the position of the end of the instrument’s handle was measured in cartesian space (x, y, and z axes).

Materials and Methods

Cadaver Preparation

Five cadavers were prepared for bilateral dissection, yielding a total of 10 data sets. Our preparation technique was based on that described in the USC Skull Base Dissection Manual. After disarticulation, the cerebral arterial and venous systems were flushed with normal saline, then with one bottle of an arterial conditioner, Metalfow (Dodge Chemicals, Cambridge, MA). The heads were soaked in diluted Metalfow solution overnight, after which they were soaked in methanol for 24 hours. The carotid arteries were flushed with 5% buffered formalin and the heads were left to soak in this solution for 1 to 2 days. Prior to injection, the cerebral vessels were flushed with acetone. Pigmented silicone latex compound (Dow–Corning, Midland, MI) was used to inject the cerebral vasculature. This compound was allowed to harden overnight. Small frontal cranietomies were performed bilaterally to monitor brain fixation. Fixation was continued for 1 to 2 weeks by using 5% buffered formalin until the elasticity and consistency of the brains mimicked that of living tissue.

Dissection Technique

A three-point rigid headframe was used to immobilize each specimen for the duration of dissection and data gathering. A bicornoral scalp flap was raised, through which craniotomies could be performed bilaterally. On each side, a frontotemporal craniotomy was performed. To maximize the exposure down to the orbitozygomatic complex, an extensive extradural dissection was conducted. The entire greater sphenoid wing was removed along with the superior and lateral walls of the orbit. Following decompression of the superior orbital fissure, removal of the anterior clinoid process was performed using high-power magnification. After opening the dura, the arachnoid of the sylvian fissure was dissected and the sylvian fissure itself was widely opened. Next, we performed a thorough dissection of the basal cisterns and divided all anterior veins that limited mobilization of the temporal lobe. Three targets were exposed and identified via the frontotemporal transsylvian route: the posterior clinoid process, the edge of the tentorium at the entry point of the fourth cranial nerve, and the basal tip.

It should be noted that our goal was to obtain the widest possible exposure and that additional bone was removed, as necessary, to prevent limitation of view by any bone structures other than the orbital rim and the zygoma. For example, wide subtemporal cranietomies were performed and exposure over the orbital rim was maximized by removing bone in this area down to the level of the frontal floor in all specimens (Fig. 1). After the initial dissection was complete, the first set of data could be obtained for each of the three targets. Following removal of the orbital rim and again after resection of the zygomatic arch, additional data sets were collected. For collection of data, self-retaining retractors were placed over the frontal temporal lobes. The positions of these retractors were not changed throughout the duration of data gathering for all three types of craniotomy.

Stereotactic Data Gathering

To quantify the area of exposure, we used the frameless stereotactic device to define a series of points in 3D space. The area of exposure was defined as the planar space through which surgical instruments could be used in approaching an operative target. This was measured by circumferentially placing a microdissector around the field, with its tip touching the target and the position of the end of its handle recorded (Fig. 2). A separate data set was recorded for exposure of each target via each exposure. For the entire experiment, 90 data sets were collected: three targets via each of three exposures bilaterally in five heads.

Each data set consisted of 10 points that were used to describe a roughly conical solid: the apex was the target (Point 1) and the base,
shapes were overlaid for direct comparison of exposures. Point 1 indicates the target; Points 2 through 4 are located along the temporal lobe; Points 4 through 7 are located along the frontal lobe; and Points 7 through 10 are located along the orbital rim or the orbit. The area of each nonagon was calculated and the values represent the areas of exposure computed to be 10%.

For each data set, raw data collection resulted in 10 sets of x, y, and z coordinates that could be used to describe a roughly conical solid with a nonagonal base (Fig. 4). Each data set was entered in a computer software spreadsheet (Microsoft Excel; Microsoft Corp., Redmond, WA). First, the data set was translated to place the vertex (target) point at the origin. Next, the arithmetic mean of the nine points at the base of the “cone” was calculated to give a point at the geometric center of the base of the cone. The cone was then rotated so that this calculated center point was located at an x of zero and a y of zero, following which the entire cone was scaled so that the calculated center point was at a z of 10 cm. The nine surrounding points were also adjusted along their trajectories toward the vertex point to the plane at a z of 10 cm. The area of the nonagon in this x–y plane at a z of 10 cm was calculated using a spreadsheet macro. These calculations were confirmed by using both the sum-of-triangles and sum-of-trapezoids methods, with the plots of the data inspected manually as well (Fig. 5). Statistical comparisons among the various measurements were performed using repeated-measures analysis of variance (ANOVA). The Bonferroni–Dunn post hoc procedure was used to extract significance in individual comparisons.

Results

Table 1 demonstrates the average target exposures attained via frontotemporal craniectomy, frontotemporal craniectomy with orbital rim osteotomy, and frontotemporal craniectomy with orbitozygomatic osteotomy. Each value represents the areas of exposure computed to be 10 cm away from the target along the periphery of the space in which the microdissector can be used. For the posterior clinoid target, exposure increased from 2915 mm² via the frontotemporal approach to 3702 mm² with removal of the orbital rim and to 4170 mm² with additional removal of the zygomatic arch. For the target at the edge of the tentorium at the entry point of the trochlear nerve, these values were, respectively, 2521 mm², 3536 mm², and 4249 mm², and for the basilar tip target they were 1639 mm², 2020 mm², and 2400 mm². Also shown are the confidence intervals, which range from ± 244 mm² to ± 1186 mm². It should be noted that confidence intervals were relatively greater when zygomatic arch removal was used, especially for more superficial targets.

To present the data in a manner more amenable to comparison, the area-of-exposure values were translated into percentages (Table 2). For the posterior clinoid target, exposure was increased 26% by removal of the orbital rim and only an additional 13% by subsequent removal of the zygomatic arch. For the edge-of-tentorium target, exposures increased 39% and 17%, and, for the basilar tip target, increases were 28% and 22%, respectively. Using ANOVA with Bonferroni–Dunn post hoc analysis, all increases obtained via orbital rim osteotomy reached statistical significance, whereas the additional gains seen with zygomatic arch osteotomy were not statistically significant.

Discussion

Although the advantages of using orbital and zygomatic osteotomy for increased operative exposure have been described numerous times in the neurosurgical literature, little attention has been focused on actually measuring these benefits. The decision whether to remove additional bone along the orbital rim or zygomatic arch remains one of personal operative style, based on the surgeon’s judgment and experience but with little actual data to support any particular view. Because orbitozygomatic osteotomy carries with it not only the burden of additional operative time but also the risk of additional morbidity, data regarding its beneficial effects on exposure may be very useful. Possible complications include cosmetic and functional problems, orbital injury, and more severe difficulties in cases of bone flap infection. This study was designed to quantify the increase in operative exposure afforded by these more extensive methods. To do this, it was necessary to measure the area at the base of a conical structure, the apex of which lies at the operative target. This concept is similar to the “cone d’approche” described by Emery, et al.,10 and the “window of access” of Honeybul and colleagues.14 We chose to measure the area of exposure via the frontotemporal approach with wide exposure at the temporal tip. This approach and its variants have been used extensively for vascular lesions in the anterior or posterior circulation and are useful for treating tumors in similar locations. The frontotemporal approach is one of several approaches that theoretically can be augmented by orbital or zygomatic osteotomy. To complete this task, we made use of a frameless stereotactic system to define points in cartesian space. Using this device, we were able to construct a 3D shape corresponding to the operative exposure. This object is actually a roughly conical solid with a nonagonal base rep-
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Fig. 4. Schematic diagram representing mathematical manipulation of the data. A: The conical solid with its base representing the area of exposure is translated so that its apex (target) is at the origin. B: The solid is rotated so that the arithmetic mean of its base is at an x of zero and a y of zero. C: The solid is scaled so that its base is along the plane at a z of 10 cm. D: The area of this polygonal base can then be calculated.

senting the “base of exposure” and an apex at the surgical target. The points defining this structure were obtained using a microdissector placed along the periphery of the surgical exposure with its tip at the target and its handle along the temporal lobe, frontal lobe, or orbit. After gathering data sets for each target via each approach in multiple specimens, we were able mathematically to rotate and superimpose the areas of exposure for each. Direct comparisons of shapes and areas could thus be made.

Our data indicate notable increases in exposure with addition of orbital or orbitozygomatic osteotomy. For the three targets—the posterior clinoid, edge of tentorium, and basilar tip—the area of exposure increased on average 26, 39, and 28% when orbital rim removal was added to the frontotemporal approach and an additional 13, 17, and 22% when zygomatic osteotomy was added. On average, 43, 64, and 51% was gained with removal of the entire orbitozygomatic complex. These increases have definite implications regarding the choice of approach for many neurosurgical procedures. A statistically significant increase was obtained with orbital rim removal, but not with additional zygomatic arch removal. From this we infer a definite role for orbital rim removal as part of the frontotemporal transsylvian approach in many cases. However, because a measure of additional exposure was also gained with zygomatic arch removal, this operative technique cannot be discounted in cases in which the pathological condition is more complicated.

As stated earlier, only removal of the orbital rim produced a statistically significant increase in the area of exposure. Zygomatic arch osteotomy led to an additional average gain of 13 to 22%; however, this was not a statistically significant gain over orbital rim removal. The lack of statistical significance was due not only to the quantity of the increase but also to the variability of the increase. The variability of gain was found to be much higher with

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zygomatic arch removal, as shown in Table 1. Our impression was that brain atrophy and relaxation were especially important for obtaining maximum exposure gains with removal of the zygomatic arch. Of course, we were using cadaveric material and brain relaxation was limited by the fixation technique. In specimens in which the brain was very relaxed or atrophic, the advantages of zygoma removal appeared to be greatest. We infer from this that brain relaxation must play an especially critical role, via hyperventilation, diuresis, cerebrospinal fluid drainage, or other measures, if zygomatic osteotomy is to be used in conjunction with the frontotemporal transsylvian approach.

It is noteworthy that our dissections were performed with very aggressive bone removal, including subtemporal craniectomy, removal of supraorbital bone down to the floor of the anterior fossa, sphenoid wing removal, and anterior clinoidectomy. Also, our measurements correspond only to the area exposed via the frontotemporal approach, with a widely opened sylvian fissure. Although this exposure includes subfrontal access and access along the temporal tip, no attempt was made to approach targets subtemporally. Zygomatic arch removal especially might be expected to affect subtemporal exposure to an even greater degree.

To standardize our measurements, we chose to determine areas of exposure at a constant distance of 10 cm from the operative targets. By controlling this distance, it was possible to make a direct comparison between the extents of exposure allowed for each of the targets. For example, the area of exposure of the posterior clinoid was found to be almost twice that of the basilar tip, as would be expected. However, our construction of the problem does not account for measurements of actual operative distance. There are actually two beneficial effects of orbital or zygomatic osteotomy. The first is an increase in the angle of approach, which directly correlates with the area of exposure that we measured. The second is that by removing these portions of bone, it is possible to operate closer to the target. The distance to the target may be decreased by up to 2.5 cm, as has been previously remarked.

There are several issues that may affect the differences seen among our targets. First is the preferential increase in exposure for targets located high in the operative field. For instance, the posterior clinoid target was located relatively inferior, directly along, or below, a tangent from the sphenoid wing. Because of this, the advantage of orbit and zygoma removal was somewhat less than that for the tentorial target. It could be expected that removal of these structures would be especially beneficial for accessing targets well above this tangent line, such as the anterior communicating artery or the terminal plate (Fig. 6A). Another issue is the depth of the operative target. For deeper targets, relatively more surgical hindrance is due to neural structures rather than to bone or muscular structures and the effects of osteotomy on brain position are relatively small (Fig. 6B).

This experiment was performed using cadavers and thus the three exposures could be directly compared within the same individuals, who could also serve as controls for themselves. Although great care was taken to prepare specimens so that the consistency and elasticity of the neural structures mimicked those of living patients, nevertheless there may be some differences in the manner in which area calculations. Axes are given in millimeters.

**TABLE 1**

Quantification of exposure for selected targets via frontotemporal craniectomy with or without orbital rim osteotomy and/or orbitozygomatic osteotomy.*

<table>
<thead>
<tr>
<th>Surgical Approach</th>
<th>Posterior Clinoid</th>
<th>Edge of Tentorium</th>
<th>Basilar Tip</th>
</tr>
</thead>
<tbody>
<tr>
<td>FTC alone</td>
<td>2915 ± 585</td>
<td>2521 ± 301</td>
<td>1639 ± 244</td>
</tr>
<tr>
<td>FTC &amp; ORO</td>
<td>3702 ± 943</td>
<td>3556 ± 539</td>
<td>2020 ± 350</td>
</tr>
<tr>
<td>FTC &amp; OZO</td>
<td>4170 ± 1053</td>
<td>4249 ± 1186</td>
<td>2400 ± 386</td>
</tr>
</tbody>
</table>

* Mean values are expressed in square millimeters with rim of exposure 10 cm from target. Confidence intervals are shown at a probability value of 0.05. Abbreviations: FTC = frontotemporal craniectomy; ORO = orbital rim osteotomy; OZO = orbitozygomatic osteotomy.
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which brain tissue or other structures can be handled. We used retractor s on the frontal and temporal lobes in a manner typical of surgery. More important than this, in terms of operative planning, is the fact that these specimens had normal anatomy. In actual operations, the positions of normal structures may be altered so that the geometric relationships assumed in this study do not apply. For instance, in many cases of sphenoid wing meningioma, the lesion may actually push the brain away from the skull base, creating a larger corridor of access and eliminating much of the benefit of orbitozygomatic osteotomy.

Essentially, we have shown increases in operative exposure afforded by orbital and zygomatic osteotomy via the frontotemporal transsylvian route to several targets along the base of the brain. However, these increases are finite. Removal of the orbital rim and zygomatic arch carries the risk of some additional morbidity, especially in terms of cosmesis and postoperative discomfort. It also requires additional operative time. The advantages of removing these structures must be weighed against the potential for morbidity in each individual patient. Although the additional exposure may be warranted for a difficult lesion, this may not always be the case. In the end, the surgeon’s experience and judgment, perhaps influenced by the quantitative data presented here, must remain the most important determinants of the approach chosen.

Conclusions

In our study of cadavers, the areas of exposure for the posterior clinoid, edge of tentorium, and basilar tip targets, when approached via the frontotemporal transsylvian route, on average were increased 26 to 39% with orbital rim osteotomy and an additional 13 to 22% with removal of the zygomatic arch. The gains achieved with orbital rim removal were statistically significant and more consistent, whereas zygomatic arch removal produced less consistent gains. The amounts of additional exposure that were gained depended on the locations of targets and varied considerably from one cadaver to the next. The data presented in this paper should be used to inform individual surgeons regarding the potential advantages of orbital or orbitozygomatic osteotomy; however, the decision to use these techniques should still be made on a case-by-case basis, depending on the pathological condition to be treated.

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References


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