When Is Posterolateral Orbitotomy Useful in a Pterional Craniotomy? A Morphometric Study

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ABSTRACT

Adding posterolateral orbitotomy to pterional craniotomy allows greater exposure of the anterolateral skull base. However, there is a paucity of literature quantifying the relative benefit of adding posterolateral orbitotomy for various surgical targets. Our study is a step to address this issue. We performed dissections of five cadaveric heads (10 sides). The anterior communicating artery (A-Com) complex, posterior chiasm (anterior third ventricular region), ipsilateral optic canal, and ipsilateral supraclinoid internal carotid artery (ICA) bifurcation were chosen as targets. A pterional craniotomy was performed and the targets were morphometrically analyzed. Subsequently, posterolateral orbitotomy was done and analysis repeated. The field of view and measurements quantifying the angle of attack were compared. Addition of orbitotomy to pterional craniotomy increased the angle of exposure to ICA bifurcation, anterior third ventricular region, and A-Com complex by average of 15%, 29%, and 50%, respectively. Our study shows the addition of a posterolateral orbitotomy to the pterional craniotomy improves the angle of attack to the anterior third ventricular region and the A-Com complex, thus supporting the use of orbitopterional craniotomy for suprasellar lesions extending into anteroinferior third ventricle and A-Com aneurysms that point superiorly/posteriorly.

KEYWORDS: Pterional craniotomy, posterolateral orbitotomy, Morphometric, study

The pterional craniotomy provides wide, multi-directional access to the anterior and middle cranial fossae as well as many structures of the interpeduncular fossae.^{1,2} Nevertheless, the associated surgical corridor is both long and narrow. To improve exposure without excessive brain retraction, various extensions of the pterional approach have been devised including removing the lateral orbital rim and the zygomatic arch. Obtaining objective data regarding the actual “surgical window” created by these different exposures is of much interest. Of the above extensions, the orbitozygomatic

osteotomy is perhaps the best known and most popularized, validated by various quantitative measurements documenting an increased field-angle view.^{3,4} However, in a study using human cadavers, Schwartz et al have suggested that removal of the lateral orbital rim alone may be sufficient to reach many of these same targets for which the orbitozygomatic craniotomy has been used.⁵ But their study did not address the more important “angle of attack.” Also, their surgical window, defined as being 10 cm from the anatomic structures, did not represent the actual working space under the

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microscope. Subsequent studies by Andaluz et al⁶ and Figueiredo et al,⁷ although demonstrating significant increase in the angles of observation, were focused on the anterior communicating artery (A-Com) region and did not demonstrate a relative benefit over other targets. Alaywan and Sindou³ found a 75% gain in sagittal exposure of the optic nerve and carotid artery after resection of the superolateral orbital rim, which increased the angle of exposure. Gonzalez et al⁸ also found that partial orbital resection improved the angle of attack compared with the pterional approach. However, in both these studies, neither the area of exposure nor the angles of approach to the anterior third-ventricular region (posterior chiasm) were assessed. The present morphometric study supplements these studies by quantifying the relative benefit to often targeted areas.

MATERIALS AND METHODS

Five cadavers were prepared for bilateral dissection, yielding a total of 10 data sets. The heads were fresh and dissected under $\times 3$ and $\times 40$ magnifications. The rationale for using fresh cadavers was to simulate the in vivo environment of brain descent while dissecting and exposing the specific target.

Bilateral pterional craniotomies were performed followed by posterolateral orbitotomies. A standard pterional craniotomy (Fig. 1) was made by joining a burr hole at the root of the zygoma with a burr hole in the frontal bone and with the McCarty keyhole. The bone flap was then elevated and the sphenoid ridge drilled until the middle cranial fossa base was flattened.

Figure 1 Illustration of a standard pterional craniotomy.

The medial cut for the posterolateral orbitotomy (Fig. 2) was made just lateral to the supraorbital neurovascular bundle, the lateral cut was made along the frontozygomatic suture, and the orbital roof was removed up to the superior orbital fissure.

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. Four targets were exposed and identified via the fronto-temporal transsylvian route. The targets specified in our study were: (1) the intracranial opening of the optic canal (OC); (2) the ipsilateral internal carotid artery bifurcation; (3) the midpoint of the posterior chiasm; (4) the midpoint of the A-Com artery.

After the initial dissection was complete, the first set of data could be obtained for each of the four targets. Following removal of the orbital rim, additional data sets were collected. The dissections and the subsequent measurements were done first on the right side and then on the left side. For collection of data, a self-retaining retractor was placed over the frontal lobe. The position of the retractor was not changed throughout the duration of data gathering for either type of craniotomy.

Measurements

The vertical angle of approach for each target was measured between the skull base and the frontal lobe.

Figure 2 Illustration of a posterolateral osteotomy (the shaded area denotes the extent of orbital bone removed).

Figure 3 Mechanical caliper used to measure the angles of approach.

A mechanical caliper (Fig. 3) and protractor device were used to measure the angles of approach. The midpoint of each specified target was taken as the vertex for each angle. The caliper's hinge was placed at the target and the arms were adjusted to contact the frontal lobe and skull base (Fig. 4). The angle between the two arms was then measured using a protractor. The frontal lobe retraction was kept constant between the measurements. The protractor had accuracy to one-twelfth of a degree. The measurements were taken to the nearest whole number.

Statistical Analysis

The paired t test was used to determine significant average difference or increase in angle measure-

ment before and after orbitotomy at each target site.

RESULTS

Table 1 elucidates the angle of approaches (in degrees) for each of the four specific targets attained via pterional craniotomy and orbitopterional craniotomy as well as the percent change. The dissections and the subsequent measurements in each cadaver were done first on the right side and then on the left side. Table 2 shows the average angle measurements in degrees before and after orbitotomy for each of the four targets. Also included is the mean change in angle measurement with corresponding p values for each target before and after orbitotomy. These p values test the null hypothesis of no significant change in angle measurement before and after orbitotomy. (Note: The mean change is the average for five heads, and a head measurement is the average of the angle measurements at the right and left sides of the skull.)

The mean percent change in the angle of exposure in the OC, the carotid bifurcation (ICB), the posterior chiasm (anterior third ventricular region), and the A-Com were 8.6%, 15.2%, 28.5%, and 50.7% respectively. Following the addition of the orbitotomy to the pterional craniotomy, there was a statistically significant increase in the angle of exposure to the posterior chiasm area ($p = 0.006$), the A-Com complex ($p = 0.01$), and also to the ICB ($p = 0.02$). We noted that the gains actually result from an increase on the caudal side of the angle of approach, an important factor in avoiding resection of the gyrus rectus while approaching the A-Com complex.

DISCUSSION

Surgical manipulations of the supraorbital rim and orbital roof for approaches to the cranial base were described nearly a century ago by McArthur.⁹ Since then, several refinements have followed.^{3,10-15} The quantitative interpretations of these surgical procedures, which intend to "extend" the exposure of the standard pterional craniotomy, are much in vogue now.^{4,5,13} Schwartz et al⁵ used a frameless stereotactic system to measure the area of exposure associated with removal of the orbital roof compared with the zygomatic arch. They sequentially performed a frontotemporal craniotomy (inclusive of removing the entire greater sphenoid wing), then removed the superior and lateral walls of the orbit, followed by resection of the zygomatic arch. Morphometric data were collected at each step. They found that on the basis of targets located on the posterior clinoid process, tentorial edge, and the basilar tip, exposures significantly increased by 26%, 39%, and 28%, respectively, after resection of the superolateral orbital rim. Inclusion of the zygomatic arch in the

Figure 4 Demonstration of the measurement technique using the mechanical caliper.

Table 1 Angle of Approaches for Specific Anatomic Targets

Target*	Pterional (Degrees)	Orbitopterional (Degrees)	Change (%)
Cadaver 1			
OC	27	39	44.44
OC	34	35	2.94
ICB	27	40	48.15
ICB	32	34	6.25
PC	32	38	18.75
PC	18	34	88.89
AcomA	25	41	64.00
AcomA	21	25	19.05
Cadaver 2			
OC	30	35	16.67
OC	30	34	13.33
ICB	37	38	2.70
ICB	36	35	-2.78
PC	26	34	30.77
PC	20	28	40.00
AcomA	19	34	78.95
AcomA	21	31	47.62
Cadaver 3			
OC	23	25	8.70
OC	30	31	3.33
ICB	25	26	4.00
ICB	30	30	0.00
PC	20	27	35.00
PC	25	31	24.00
AcomA	15	30	100.00
AcomA	26	32	23.08
Cadaver 4			
OC	31	32	3.23
OC	26	28	7.69
ICB	26	28	7.69
ICB	25	26	4.00
PC	22	27	22.73
PC	29	32	10.34
AcomA	19	31	63.16
AcomA	24	34	41.67
Cadaver 5			
OC	22	25	13.64
OC	24	35	45.83
ICB	20	22	10.00
ICB	21	24	14.29
PC	22	25	13.64
PC	24	30	25.00
AcomA	19	29	52.63
AcomA	22	31	40.91

*For each target, the right-sided data are listed first. AcomA, anterior communicating artery; ICB, internal carotid bifurcation; OC, optic canal; PC, posterior chiasm.

osteotomies did not improve the surgical exposure. Alaywan and Sindou³ found a 75% gain in sagittal exposure of the optic nerve and carotid artery after resection of the superolateral orbital rim, which increased the angle of exposure. Gonzalez et al⁸ found that disarticulation of a portion of the orbit improved the angle of attack compared with the pterional approach. However, unlike the present study, the main morphometric focus of both these studies was on the orbitozygomatic approach. Andaluz et al⁶ advocated an orbitopterional approach for the treatment of A-Com aneurysms. Using frameless stereotaxy, the angles of exposure and surgical field provided via the pterional and orbitopterional approaches were quantified. The angles of observation were increased 46% in the axial plane (orbitopterional, 72.92 ± 6.57 degrees; pterional, 49.75 ± 2.27 degrees; $p = 0.01$) and 137.5% in the projection plane (orbitopterional, 8 ± 2.19 degrees; pterional, 19 ± 1.78 degrees; $p = 0.01$). These results are similar (albeit quantitatively greater) to the present study (mean percent increase: 29%). In another study, Figueiredo et al⁷ also showed a significant increase in the vertical angle of approach to the A-COM complex following orbitopterional approach (18.4 ± 5.7 degrees) as compared with a pterional approach (11.5 ± 3.7 degrees) without gyrus rectus resection. As in our study, it was concluded that the orbitopterional approach increases the angle of approach compared with the pterional approach and might avoid resection of the gyrus rectus. Similar to the results of Andaluz et al,⁶ we found that the gains result from an increase on the caudal side of the angle of approach. This allows the A-Com complex to be viewed from a progressively more basal approach. As a result, less retraction is needed for dissection of the A2 segments and visualization of the aneurysm neck. This basal approach is particularly important when exposure is limited by an edematous friable brain, such as occurs after subarachnoid hemorrhage, or when the A-Com complex projects upward into the interhemispheric fissure. The cranial side of this angle is limited by frontal lobe retraction; this explains the finding that the vertical angle of approach remained significantly greater for the orbitopterional approach even when the pterional approach was combined with resection of the gyrus rectus.

An increase in the horizontal angle of approach ensures better coronal visualization of the A-Com complex as well as the aneurysm neck and improves exposure of the A1 segments, providing better proximal control should temporary clipping be needed. An increase in the horizontal angle also increases the angle of approach available for clip application to the aneurysm neck. Although in our study the horizontal angle was not measured, literature⁷ supports that it is significantly greater for the orbitopterional versus pterional and orbitozygomatic versus pterional approaches but not

Table 2 Mean Angle Measurements (Degrees) at Four Targets of the Brain before and after Orbitotomy

Target Site	Before	After	Increase (Mean $\pm$ SEM)	p Value*
ICB	27.7 $\pm$ 5.0	31.9 $\pm$ 5.1	4.2 $\pm$ 1.2	0.02 [†]
OC	27.9 $\pm$ 4.0	30.3 $\pm$ 3.9	2.4 $\pm$ 1.3	0.15 [‡]
PC	23.8 $\pm$ 5.2	30.6 $\pm$ 5.2	6.8 $\pm$ 1.3 10.7 $\pm$ 0.5	0.006 [§]
AcomA	21.1 $\pm$ 5.8	31.8 $\pm$ 5.0	10.7 $\pm$ 0.5	< 0.01 [§]

*For testing null hypothesis of no change in angle measurement.

[†]Significant at 5% level ($0.01 < p \text{ value} < 0.05$).

[‡]Not significant at 5% level.

[§]Significant at 1% level ($p \text{ value} < 0.01$).

AcomA, anterior communicating artery; ICB, internal carotid bifurcation; OC, optic canal; PC, posterior chiasm; SEM, standard error of the mean.

between the orbitopterional and orbitozygomatic approaches. The horizontal angle of approach is limited primarily by the anterolateral orbital rim. Because the orbital rim is removed in the orbitozygomatic and orbitopterional approaches, there is no anatomic reason for the horizontal angle to be different for these two approaches.

Advantages of Our Study

Our data complement previously reported studies on the potential benefits of removing the orbital roof and lateral wall of the orbit with regard to angle of attack. As a first, the present study quantifies the comparative gain achieved in exposing the important suprasellar anatomic targets simultaneously, which is more analogous to a real-time transsylvian pterional approach. Specifically, the most benefit is achieved for targets near the A-Com complex and anterior third ventricle and to a lesser degree, the ICB. The benefit seems to dwindle for targets closer to the skull base such as the OC.

A wider angle of attack provides superior anatomic detail, enabling the surgeon to operate more accurately and with lesser brain retraction. This modified angle of observation, supplemented with the anterior translation of the axial angle, shifts the surgical vector relative to the pterional approach, relocating the cone of view medial to the gyrus rectus, thus rendering resection of the gyrus rectus quite unnecessary and dissection essentially extra-axial. The resultant more basal exposure of both A1 segments when temporary clipping is required is also advantageous. We believe that this vector of approach is particularly helpful for patients with large or superiorly pointing aneurysms or other lesions extending toward the third ventricle.

Limitations of Our Study

Cadaveric tissues differ from those in vivo primarily in terms of stiffness and resistance to retraction. Thus, our data may not correlate exactly to those seen in vivo. Additionally, the limited number of observations may have prevented the detection of significant differences in some measurements. Finally, although we made every

effort to minimize variations in setup, such as the extent of retraction, day-to-day and specimen-to-specimen differences may have influenced outcomes. Nonetheless, such anatomic quantitative studies have become increasingly relevant to support surgical approaches and indications as the sophistication of technology and complexity of surgery increase.

CONCLUSION

Adjunctive resection of just the superior and lateral walls of the orbit is morphometrically evident to provide larger working space and statistically significant greater angles of attack to the A-Com complex, anterior third ventricular region, and supraclinoid internal carotid artery bifurcation. Our data indicate the relative benefit in visualization increases as the surgical target moves from the OC superiorly toward the A-Com complex.

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