The Lacrimal Keyhole, Orbital Door Jamb, and Basin of the Inferior Orbital Fissure

Three Areas of Deep Bone in the Lateral Orbit

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Objectives: To calculate the volume of bone in 3 areas of the deep lateral orbit that are available for removal in decompression surgery and to demonstrate these 3 areas within a three-dimensional computed tomographic reconstruction of the orbit.

Design: The 3 areas of bone in the deep lateral orbit were designated the lacrimal keyhole, the sphenoid door jamb, and the basin of the inferior orbital fissure. By means of digitized computed tomographic scans, these 3 areas of bone were analyzed by measuring preoperative and postoperative orbital volumes and predicted bony expansion volumes in 9 patients (17 orbits) who underwent deep lateral orbital decompression surgery. We also calculated the volume of bone that could be removed from 11 normal orbits. A three-dimensional computer reconstruction of an orbital computed tomographic scan was created, and the 3 areas of potential bone were delineated within it.

Results: The average volumes of the basin of the inferior orbital fissure, the sphenoid door jamb, the lacrimal keyhole, and the total of the 3 regions were 1.2, 2.9, 1.5, and 5.6 cm³, respectively. The 3 areas of bone contributed variably to the total, with the door jamb contributing the most volume of the 3, nearly twice the value of the other 2. There was, however, a significant amount of interpatient variability, especially for the door jamb region.

Conclusion: Orbital decompression surgery of the deep lateral wall can provide adequate volume expansion because of the amount and location of potential space that exists in the 3 areas of deep bone.


Orbital decompression surgery is indicated in Graves orbitopathy for optic nerve compression, corneal exposure, disfiguring proptosis, and compressive orbitopathy. Traditional lateral orbital decompression involves removal of the anterior portion of the lateral orbital wall and is limited in the degree of orbital expansion that can be achieved. There is, however, considerable room for orbital expansion in the lateral part of the orbit if the thicker, deep areas of lateral wall are removed. These are the surfaces that were removed in the historic neurosurgical approaches; they can be successfully removed through an orbital approach with adequate anatomical knowledge. The deep lateral wall can be accessed through a coronal, lateral cutaneous (for example, eyelid crease), or lateral transconjunctival (subcanthal) approach.

We have found it helpful to conceptualize the 3 separate areas of thick bone in the lateral orbit that are amenable to removal in deep lateral orbital decompression surgery. These areas are conceptual rather than anatomical structures, and we find them helpful in surgical planning. The 3 areas of thick bone are designated the lacrimal keyhole, sphenoid door jamb, and the basin of the inferior orbital fissure. By means of digitized computed tomography (CT), these 3 areas of bone were analyzed by measuring preoperative and postoperative orbital volumes and predicted bony expansion volumes in 9 patients (17 orbits) who underwent deep lateral orbital decompression surgery. We also calculated the volume of bone that could potentially be removed from 11 normal orbits. A three-dimensional computer reconstruction of an orbital CT scan was created, and the 3 areas of potential bone were delineated within the three-dimensional orbital image.

RESULTS

Eleven normal orbits were sampled to estimate the amount of potential bone available in the deep lateral orbit. The total amount of potential bone available in the 3

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MATERIALS AND METHODS

CT SCANNING

Volume measurements of orbital bone and soft tissue structures were obtained by importing axial orbital CT scans (1.5-mm or 3-mm thickness, contiguous slice) into the NIH Image computer program (National Institutes of Health, Bethesda, Md). With the use of NIH Image, consecutive CT scan slices were displayed on a computer monitor and a “draw” function was used to outline the perimeters of the structures, either bone or soft tissue, from which computer-generated area measurements were obtained (Figure 1). The volume of each structure was calculated by multiplying the area of the outlined structure by the thickness of each scan slice; the sum of volumes from the scan slices were added to compute the volume occupied by the measured structure. The scans were measured by 3 independent observers (R.A.G., A.J.K., and K.M.K.); a high level of interobserver consistency was found, with agreement within 2%.

For 9 patients who underwent bilateral decompression of the lateral wall only, preoperative and postoperative CT scans were analyzed. First, preoperative CT scans were examined and the volume was calculated for each of the 3 areas of deep bone to be removed. These measurements served as predictions of the volume available for potential orbital expansion. Measurements of orbital soft tissue volume were then calculated on each preoperative scan. The postoperative orbital soft tissue volumes were also calculated. The postoperative scans were also examined to determine the extent of soft tissue expansion into the newly created orbital spaces.

Axial CT scans of 11 orbits with normal bony anatomy were also examined. The scans were from 7 women and 4 men, ranging in age from 30 to 84 years. The perimeters of each of the 3 areas of deep bone that could potentially be removed for deep lateral orbital decompression were outlined, and the volumes of the bony areas were calculated. Including the 17 preoperative orbits from our 8 surgical patients, a total of 28 orbits were sampled.

A 3-dimensional reconstruction of a normal orbit highlighting the 3 bony areas available for deep lateral orbital decompression was obtained by downloading an axial CT scan (1.5-mm thickness, contiguous slices) into a 3-dimensional graphic computer workstation. The lacrimal keyhole, sphenoid door jamb, and basin of the inferior orbital fissure were then highlighted, allowing for visualization from different angles.

SURGICAL ANATOMY

The frontal bone, part of the lesser wing of the sphenoid, and a small portion of the greater wing form the lacrimal keyhole (Figure 2). It is a wedge-shaped section of bone in the superior orbit that begins with a full-thickness notch in the superolateral rim. It extends into the entire fossa of the lacrimal gland. It is limited externally by the temporalis muscle, medially by the point at which the orbital roof thins as the thin frontal bone, and posteriorly by the frontal cranial fossa and the posterior thick border of the lesser wing of the sphenoid; inferiorly it blends into the thick trigone of the greater wing of the sphenoid (the door jamb) (Figure 3). The lacrimal keyhole forms a potential space in which the lacrimal gland and the associated fibro adipose structures can prolapse laterally and superiorly; the lacrimal gland can actually prolapse outside of the orbital boundary, providing substantial volume expansion. The thick posterior portion of the lesser wing of sphenoid in the region that separates the frontal and middle cranial fossae is a rich area of thick bone that is responsible for much of the decompression achieved by the transcranial approach; it can be removed from the orbital side, providing substantial orbital volume expansion.

The door jamb is formed of the greater wing of the sphenoid. The thick trigone of the greater wing is a large marrow-filled bone that laterally borders the inferotemporal fossa (temporalis muscle) and posteriorly borders the middle cranial fossa (Figure 4). Not only is this the most voluminous bony area of the 3 deep regions of bone, but also this bone lies almost directly posterior to the globe. In the case of a “woody” orbit, removal of the door jamb can allow posterior displacement of the globe in an orbit that has little ability to expand its lateral shape. Therefore, in these fibrotic orbits, the door jamb area may be the only area of bone that can effectively reduce proptosis. Inferiorly, the door jamb consists of the thick part of the greater wing of the sphenoid that borders the inferior orbital fissure on its superolateral edge. In a maximal deep lateral orbital decompression, the inferior orbital fissure is completely deskeletonized.

The basin of the inferior orbital fissure consists primarily of zygomatic bone and part of the lateral maxilla (Figure 5). The body of the zygoma can be sculpted until there is only a thin rim of bone along the lateral orbital rim and face of the zygoma, allowing a large segment of space for inferolateral prolapse of orbital adipose tissue. Medially, the basin of the inferior orbital fissure can be removed all the way to the zygomatic-maxillary suture. The lateral portion of the maxillary sinus roof can also be removed, and the sinus can be entered for some additional prolapse of tissue. Near the inferior orbital fissure the zygoma thins, and removal of bone in this region typically exposes the buccal fat; the buccal fat can be cauterized both to reduce its volume, allowing outward prolapse of orbital tissues, and also to keep the buccal fat from flowing into the surgical field and obstructing further drilling.

regions ranged from a low of 4.3 cm³ to a high of 6.8 cm³, with an average of 5.6 cm³. The average volumes of the bone of the inferior orbital fissure, the sphenoid door jamb, and the lacrimal keyhole were 1.2, 2.9, and 1.5 cm³, respectively. The 3 areas of bone contributed variably to the total, with the door jamb contributing the most volume of the 3, nearly twice the value of the other 2. There was, however, a considerable amount of interpatient variability, especially for the door jamb region. The individual measurements are shown in the scatterplot (Figure 6). These are idealized measurements; for practical purposes, it would be difficult to remove all of this bone.

Surgical patients’ preoperative orbital volumes, predicted bony expansion volumes, postoperative orbital volumes, and degree of proptosis reduction are displayed in the Table. As one would expect, more volume expansion was achieved through the coronal approach, which provides the widest access to all 3 areas of thick bone.
bone. Preoperative and postoperative CT scans demonstrate adequate expansion of soft tissue into the newly created orbital spaces (Figure 7).

A 3-dimensional reconstruction of a normal orbit was obtained by downloading an axial CT scan of a normal orbit into a 3-dimensional graphic computer. The 3 areas of bone—lacrimal keyhole, orbital door jamb, and inferior orbital fissure—were then highlighted in different colors, allowing visualization from different angles (Figure 8 and Figure 9). The highlighted portions of bone within the 3-dimensional reconstruction provide a graphic representation of the 3 areas of thick bone and their relationships to surrounding structures.

Consecutive or worsened strabismus after orbital decompression is the most frequent risk of surgery, and our interest in the lateral part of the orbit is precipitated by a continual search for techniques that minimize the risk of new-onset or worsened double vision. In large series, inferomedial orbital decompression into the maxillary and ethmoid sinuses has resulted in consecutive strabismus at least one third of the time. Balanced techniques and strut creation may decrease the risk but still have a notable incidence of new or worsened diplopia. Because the inferomedial shift of the muscle cone is lessened, isolated lateral orbital decompression should further reduce the risk of new or worsened strabismus.

Lateral orbital decompression has been described with the use of several techniques. Traditional ophthalmic techniques primarily involved removal of anterior portions of the lateral orbital wall. Studies designed to calculate increases in orbital volume or the degree of reduction of proptosis after lateral decompressions resulted in the belief that lateral wall decompression does not achieve adequate volume expansion. However, recent reports describe lateral wall decompression techniques that involve removal of thick areas of bone from the posterior lateral wall, specifically from the area that we designate the door jamb and the deep lacrimal keyhole. The removal of this trigone posteriorly as far as the inner table of the cortical bone can achieve substantial expansion and reduction of proptosis as well as relief of optic nerve compression. The posterior location of the door jamb allows posterior displacement of the orbit, even in fibrotic orbits that cannot expand medially or laterally.

Our surgical cases demonstrated that deep lateral wall decompression can achieve successful volume expansion and reduction of proptosis (up to 8 mm in 1 case with orbital rim advancement), with the absence of complications such as hypoglobus or dystopia. Analysis of...
Figure 3. The lacrimal keyhole. Preoperative axial (A) and coronal (B) computed tomographic scans show the lacrimal keyhole outlined in yellow. C and D, Postoperative computed tomographic scans demonstrating bony removal. Copyright 1997, Regents of the University of California, reprinted with permission.

Figure 4. The orbital door jamb. Preoperative axial (A) and coronal (B) computed tomographic scans show the orbital door jamb (red) and basin of the inferior orbital fissure (green). C and D, Postoperative computed tomographic scans demonstrating bony removal. Copyright 1997, Regents of the University of California, reprinted with permission.
orbital volume changes in postoperative scans not only demonstrated the ability to effectively remove a sufficient amount of bone from the deep lateral wall for adequate volume expansion, but also demonstrated the ability of the soft tissue to expand into the newly created spaces.

The complications of lateral orbital decompression have been discussed in previous articles. The bone is drilled in the region of the frontal and middle cranial fossa, and small exposures of dura are common in aggressive bony removals.Leaks of cerebrospinal fluid can occur if small dural perforations are created. These can be patched intraoperatively, and even if slight leakage is present at the end of surgery, it is generally self-limited. Intracranial bleeding associated with dural laceration could be life threatening; although this should be a rare complication with careful technique, neurosurgical backup should be available. Numbness in the distribution of the zygomaticotemporal and zygomaticofacial nerves is common, and patients should be warned of this. We had 1 patient who developed oscillopsia with chewing; we now avoid complete exposure of the temporalis muscle and, rather, leave a thin shell of bone over as much of the muscle as possible. Double vision can still occur, even in isolated decompression of the lateral wall only. Interestingly, although one might have hoped that stretching the lateral rectus muscle would induce some exodeviation to counterbalance the esotropia that characterizes Graves strabismus, we have noted several cases of consecutive strabismus after lateral-wall-only decompression in which lateral rectus weakness worsened the esotropia, and we have had no cases of postoperative exotropia. None of our patients have sustained orbital trauma after lateral decompression; the lateral orbital buttresses are certainly thinned after aggressive lateral decompression, and we presume that the orbit may be more susceptible to traumatic lateral fractures.

Deep lateral wall decompression surgery can provide adequate volume expansion because of the amount and location of the potential space that exists in the 3 areas of bone. The small sample of patients and normal subjects in this study was not stratified for skull size, sex, or age, and a large study would provide a more accurate estimate. However, these measurements do
provide a useful and reasonably representative estimate of potential bony volume. The average total potential volume for the 3 areas of bone was 5.6 cm³, with the door jamb contributing nearly twice the volume of the other 2 areas. For surgical purposes, we tend to think of the lacrimal keyhole and basin of the inferior orbital fissure as each contributing about one quarter of the total. In our experience, every 1 cm³ of bone removed results in approximately 0.8 mm of proptosis reduction. This type of analysis is helpful for grading the amount of decompression: in any individual case, 1, 2, or 3 areas can be used in part or in full. We remove orbital fat in most of our cases. This is readily accomplished through the lateral orbital approach. Removal of intraconal fat augments the proptosis reduction in orbital decompression.\textsuperscript{17,18} Inferomedial decompression can be added, if necessary, for additional volume expansion.

We hope that the anatomical descriptions and 3-dimensional images can provide a better understanding of the substantial amount of potential space that exists in the deep lateral orbit and facilitate more extensive use of deep lateral orbital decompression.

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\textsuperscript{17,18} Intermedial decompression can be added, if necessary, for additional volume expansion.

Results of Surgery in 17 Eyes

Figure 7. A, Preoperative computed tomographic scan demonstrating significant proptosis. B, Postoperative computed tomographic scan demonstrating soft tissue expansion into the newly created spaces. Copyright 1997, Regents of the University of California, reprinted with permission.

Figure 8. Frontal view of 3-dimensional computed tomographic reconstruction of the orbit highlighting the 3 areas of bone: lacrimal keyhole (yellow), door jamb (red), and basin of inferior orbital fissure (green). Copyright 1997, Regents of the University of California, reprinted with permission.
REFERENCES


Figure 9. Sagittal cut through the orbit demonstrates the volume available posteriorly in the basin of the inferior orbital fissure and the sphenoid door jamb. Yellow indicates the lacrimal keyhole; red, door jamb; and green, basin of inferior orbital fissure. Copyright 1997, Regents of the University of California, reprinted with permission.

Notes From Our Ophthalmic Heritage

A look at the past . . .

Graiae

Literally, “the old women.” Also called Phorcydes. They first appear in Hesiod (Theog.) and are by him declared to be daughters of the sea-god, Phoreys, by his sister, Ceto, and sisters of the three Gorgons. They are beautiful, well-dressed, and white of hair from birth. In Aeschylus (Prom. Vinc.) they are described as monsters, swan-shaped, and possessing in common but one eye and one tooth, which neither the sun nor the moon had ever shone upon, and which they borrowed from one another as occasion demanded. Some of the poets make them guardians of the Gorgons. Their names are: Pephredo, Enyo, and Dino. The Graiae have been thought to symbolize the clouds, the transferable eye and tooth representing the flash of the lightning and its rapid interchange from one cloud to another. For the connection of the Phorcydes, or Graiae, with the Perseus myth, see Gorgon.