Use of Intraoperative Computed Tomography During Repair of Orbitozygomatic Fractures

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**Objective:** To assess the practicality and potential benefits of intraoperative computed tomography using a mobile scanner in the operating room during repair of orbitozygomatic fractures.

**Setting:** Level I trauma center.

**Design:** Twenty-five patients undergoing open reduction of a unilateral displaced fracture of the zygoma and/or repair of a blow-out fracture of the orbit with cranial bone grafts were placed into a radiolucent head holder and interfaced with the mobile scanner. Spatial vectors were drawn on scans displayed on a computer monitor to allow intraoperative side-to-side comparison of the position of the malar prominences and orbital walls. Corrections of fracture reduction or bone graft position were made as indicated by the comparisons.

**Results:** All scans were accomplished without apparent contamination of the surgical field. Major revisions were performed, based on the scans, in 2 patients whose displaced, comminuted zygoma fractures had been initially reduced with wide exposure of all fracture sites.Minor revisions were performed in 3 patients with displaced but less severely comminuted fractures that had been reduced without exposure of all fracture sites. Bone grafts were repositioned within the orbit in 2 patients with large 2-wall blow-out fractures.

**Conclusions:** Intraoperative computed tomographic evaluation of the adequacy of repair of orbitozygomatic fractures is feasible with the mobile computed tomographic scanner. The scanner allows correction of discrepancies in position of the malar prominences and orbital walls at the time of acute repair, rather than during costly, more difficult delayed revisions. It may eliminate the need for direct visualization of all fracture sites to ensure adequate reduction in selected cases with displaced, comminuted fractures, thus decreasing operating room time and expense. Further study is required to fully document the cost-effectiveness of this approach to facial fracture management.

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**The Measure of Success**

The measure of success in the treatment of orbitozygomatic fractures is symmetry of facial form and function. Ocular alignment requires restoration of the orbital walls so that the globe and its supporting soft tissues are returned to an untethered position within an orbit that has normal shape and volume. Optimal repair of a large blow-out fracture that involves 2 or more walls of the internal orbit is obtained with (1) a posterior orbital dissection; (2) bone grafts to redefine the postbulbar constriction of the orbital volume; and (3) metallic implants to minimize postoperative bone graft displacement. Symmetry of cheek projection requires restoration of the correct articulation of the zygoma through its multiple projections with the surrounding craniofacial skeleton. Optimal repair of a comminuted, displaced fracture of the zygoma is obtained with (1) wide fracture segment exposure; (2) reduction with visualization of all fracture sites, including the zygomatic arch; and (3) rigid miniplate fixation in at least 2 fracture sites.

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The operative techniques now advocated for optimizing management of complex orbitozygomatic fractures have increased the expense of surgery, mainly because of increased length of surgery and implant costs. The accepted justification for this increased expense is the decreased need for take-back surgical procedures for major revisions of the skeletal architecture. However, even with “optimal” management, results are still...
PATIENTS AND METHODS

Twenty-five patients with orbitozygomatic fractures of varying patterns and severity underwent intraoperative CT scans. To allow the patient to fit into the scanner aperture, a narrow wooden backboard of the type used by emergency medicine personnel for patient transport was cantilevered from a standard operating room table with multiple Velcro straps and then covered with the table padding. The patient was positioned with the head suspended and immobilized off the end of the backboard in a radiolucent graphite head holder attached to the operating table (Figure 1). The Frankfurt plane was aligned perpendicular to the floor. This position was chosen because the height of contour of the malar prominence, with the patient in an upright position, is just at or slightly inferior to the Frankfurt plane. An intraoperative axial scan taken at a level approximating the glenoid fossae would thus be in the plane of this height of contour. Once the patient and CT gantry were correctly interfaced, the position of the wheeled carriage of the scanner was marked on the operating room floor. The scanner was repositioned to these marks during subsequent scans when the surgical field was totally covered with a drape to maintain sterility.

A grid with spatial vectors was created on the scans, as displayed on the computer monitor, to locate the position of the normal malar prominence and zygomatic arch in relation to a central point on the skull base. The vectors were then transposed to the side of the injury to allow comparison of the desired to actual position of these structures following reduction of the fractures and application of partial fixation. Reduction was corrected if indicated by the comparison and final fixation applied. In patients undergoing reconstruction of orbital walls with bone grafts, axial scans of 2-mm thickness were obtained through the entire orbit. Coronal re-formations were then generated, and the orientation of each bone graft was compared with the corresponding wall of the uninjured orbit. In the case of 2-wall injuries, the angle between the bone grafts was measured and compared with the normal transition from the floor to the medial wall. Again, adjustments of position were performed based on the comparisons.

Feasibility of intraoperative scanning was judged by the quality of the scans, the added time and thus the increased operating room expense required to obtain and interpret the scans, and the difficulties encountered while moving the scanner in and out of the same interface with the patient’s head without disrupting the sterile field. The scans were judged to have an effect on management of the injuries if adjustments in fracture reduction or graft placement were performed based on the side-to-side comparisons or if CT confirmation of the adequacy of repair eliminated the need for extended access exposure of all fracture sites.

RESULTS

Scan quality was sufficient to allow a detailed evaluation of fracture patterns in all patients. In some cases, fragment displacement was more accurately documented on the intraoperative CT than on the preoperative CT scan obtained in a fixed scanner. This improved imaging was attributable to a more symmetrical positioning of the head in the mobile unit. The time needed to correctly interface the CT gantry with the patient’s head at the start of the case for the first 10 patients in the series ranged from 40 to 65 minutes. Multiple trial-and-error adjustments of the scanner position were required to obtain symmetrical alignment in relation to the glenoid fossae. The time and number of axial scans required to position the scanner gradually improved over the next 10 patients so that 15 to 20 minutes and only 1 or 2 scans were required to confirm accurate interfacing in the final 5 patients. This improvement was achieved by positioning the scanner with pendulums temporarily suspended in the aperture to mark symmetrical points on the face and with a string placed
at the diameter of the aperture, tracing a symmetrical path across the face. The time required to reposition the scanner and to obtain and interpret postreduction scans ranged from 35 to 45 minutes in the first group of patients and similarly improved to 15 to 20 minutes in the final group. No instances of contamination of the covered sterile surgical field were noted by the operating room personnel.

Major adjustments of the initial attempt at repair of the orbitozygomatic injuries were made based on the intraoperative CT findings in only 4 patients. Two of these were for inadequate reduction of the zygoma and 2 for poor alignment of bone grafts placed into the orbit. Both of the inadequate reductions of the zygoma occurred in patients with severe comminution of the inferior orbital rim and lateral antral wall, as well as comminution of the zygomatic arch and lateral orbital wall, including the zygomaticosphenoid suture line (Figure 2). Initial reduction of these fractures had been performed with extended access exposure of all fracture sites, and the malposition of the malar prominence resulted from overreduction of the fragmented inferior orbital rim. This overreduction produced a medial rotation of the malar prominence with flattening of the cheek. Successful revision was accomplished with rotation of the zygoma laterally and insertion of a split calvarial bone graft to restore the inferior orbital rim. Both patients with poor alignment of bone grafts placed into the orbit had large 2-wall blow-out fractures (Figure 3). The floor and medial wall grafts had been placed at a 90° angle to each other to produce a square orbit with increased volume. Correction of the position of both grafts re-created the normal obtuse angle between the floor and the medial wall.

**Figure 2.** A, Initial intraoperative axial computed tomographic scan of patient with comminuted left orbitozygomatic fracture. Level of scan approximates height of contour of right malar prominence. B, Vectors that establish position of uninjured right malar prominence (1 and 2) and zygomatic arch (3 and 4). Transposition of vectors to injured left side shows amount of displacement of fragments. Numbers associated with each vector indicate distance from central skull base point/angle of vector from horizontal plane through that point. C, Measurements after first attempt at reduction show persistent displacement. D, Measurements after adjustment of reduction show improved symmetry of position of malar prominences. E, Patient at 9-month follow-up visit. Natural prominence of cheeks emphasizes the importance of the accurate reconstruction of the patient’s left orbitozygomatic fracture.
Minor adjustments of the position of the zygoma were made based on the intraoperative CT findings in 3 patients with a displaced zygoma and comminution of the inferior orbital rim, lateral antral wall, zygomatic arch, and zygomaticosphenoid suture area (Figure 4). More importantly, initial reduction and fixation of the displaced zygoma in each case had been achieved through small lateral brow and upper buccal sulcus incisions with limited exposure and visualization of the fracture lines. Confirmation of postreduction symmetry of the malar prominences in these patients eliminated the need for extended access, in particular the coronal incision that is required for exposure of the zygomatic arch. No adjustments of the position of bone grafts placed into 1-wall blow-out fractures were performed based on intraoperative CT findings. However, the surgeon was reassured by the scans in several cases that bone grafts, placed into large floor defects with no stable posterior ledge and an indistinct transition to a nondisplaced but unstable medial wall, were not overconstricting the volume of the postbulbar orbit to possibly compromise the optic nerve.

COMMENT

This preliminary investigation suggests that it is feasible to use a mobile CT scanner in the operating room during repair of orbitozygomatic fractures and that the scans can be used for intraoperative evaluation of the adequacy of fracture reduction and bone graft placement. Admittedly, perfectly symmetrical axial scans could not be achieved with the prototype equipment that was available for the study, owing to inexact positioning techniques. However, even with errors introduced into the measurement of malar prominence location and orbital bone graft alignment by these positioning difficulties, the measurements provided compelling evidence in several patients with high-

Figure 3. A, Admission computed tomographic scan of patient with retrobulbar hemorrhage and no light perception in the left eye after blunt trauma. Visual acuity returned to 20/20 following canthotomy with cantholysis, and repair of large combined floor and medial wall blow-out was performed 8 days later. B, Top. Intraoperative axial scan shows poorly aligned medial wall graft (large arrow). Posterior edge of floor graft (small arrow) extends to junction of inferior and superior orbital fissures. B, Bottom. Axial view of repositioned medial wall graft. C, Coronal re-formation of correct graft positions. Measurement shows distance from horizontal line to level of floor in middle third of orbit. D, Coronal re-formation in plane of retrobulbar constriction of orbit. Measurement is angle (right, 123.8°; left, 121.6°) between medial wall and floor. E, Patient at 11-month follow-up visit. Traumatic mydriasis persists, but visual acuity is stable at 20/20.
velocity-type injuries that repair was suboptimal. The evidence permitted an immediate revision and eliminated the possible need to return the patient to the operating room if facial asymmetry became apparent postoperatively. Conversely, these measurements confirmed that an accurate reduction had been obtained in several patients with similar fractures treated with limited exposure that did not allow visual confirmation of the alignment of each fracture line. The length of surgery was therefore reduced in these cases.

Future work will include the design of a new holder based on the cephalostat, the head holder used to obtain cephalometric radiographs. The CT gantry will then be interfaced directly with the head holder at the time of the initial scan to ensure symmetrical axial alignment of the scanner at the level of the Frankfurt plane. This alignment will increase the reliability of the measurements used for the postrepair side-to-side comparisons. The precision of these comparisons as drawn on the computer monitor may exceed the surgeon's
capability with present operative techniques to align fractures and position bone grafts to match the specifications dictated by the measurements. This divergence may actually be accentuated if intraoperative CT is used during repair of more extensive injuries, such as panfacial fractures. Therefore, further investigation is required to fully define the role of intraoperative CT in the management of craniomaxillofacial injuries. Consistent results and reduced operating room expenses must be documented to justify the costs of acquisition and operation of a mobile CT scanner.

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REFERENCES


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