Accuracy of Orbital Volume Measurement by Computed Tomography

Shaimaa Mostafa*[1]*, Waleed E Reda*[1]*, Hamed M Kadry*[1]*, Amr A Zaky*[1]*,
***Mohamed A Hussein*[1]*, Karim M Mousa*[2]**
[1]Department of Plastic & Reconstructive Surgery, Faculty of Medicine, Cairo University
[2]Department of Radiology, Faculty of Medicine, Cairo University

ABSTRACT

Purpose: *To detect the accuracy and feasibility of computed tomography in orbital volume and fracture assessment, using it as an evaluating tool, its clinical implication and whether it is affected by specific approach either subciliary or transconjuctival approach.* ***Methods:*** *This study included 28 orbits presenting to Kasar Al-Ainy hospital from July 2014 to July 2016 by unilateral orbital floor fracture, who were all assessed by doing pre-and post-operative orbital volumetery which was assessed for being an aiding tool for operative decision and diagnosing the different causes of enophthalmos.* ***Conclusion:*** *Consistent volume measurements can be obtained using different 3-D image analysis programs. Measuring pre, postoperative volume changes and postoperative reductions in volume can ensure a good surgical result and thereby decrease the incidence of enophthalmos in addition identifying the cause of enophthalmus whether due to bony or soft tissue element.*

Key Words: *Computed tomography, orbital volume try, measurement, orbital volume., enophthalmos, orbital fracture*

INTRODUCTION

Orbital fracture remains one of the most difficult fractures to manage as it has great functional and aesthetic implication. The main imaging method used is computed tomography (CT) with multiplanar axial and coronal cuts as well as 3D reconstruction, which is an important tool in orbital fracture assessment. [(1)]

One of the important point in orbital blow out fracture repair is restoring normal orbital volume. This is why accurate preoperative measurements affects the operative decision in addition it could avoid postoperative complication as enopthalmus.[(2)]

Furthermore, orbital volume measurement is important for the treatment plan by providing an accurate estimation of orbital implant volume, and the cause of enophthalmus whether soft tissue or bony element which is necessary for optimal reconstruction of enophthalmos. [(3)]

PATIENTS AND METHODS

This study included 28 orbits who were presented to Kasr Al-Ainy hospital from July 2014 to July 2016, by orbital floor fracture. All the 14 patients were subjected to CT volumetery to evaluate it as a tool for diagnosis and avoiding postoperative complication especially enophtalmus.

All patients were subjected to proper history taking, regarding the mode of trauma and associated co morbidities. General examination was done first following ATLS protocol followed by local examination

Inspection was done to detect facial edema (per orbital edema)., ecchymosis and sub conjunctival hemorrhage, any degree of ocular movement limitation, enophthalmos, exophthalmos, change in the level of the orbital contents, or increased inter-canthal distance and skin or soft tissue injury.

Palpation must be done gently, without causing much distress to the patient. It is carried out simultaneously, bilaterally, starting from the supraorbital ridges, proceeding in the following order; the lateral orbital rim, the medial orbital rim, the infraorbital rim, the bridge of the nose and lateral nasal walls, the paranasal regions, the zygomatic bone and the arch contour any step deformity, abnormal mobility of fragments, tenderness.

Patients who fulfilled the inclusion criteria were included in this study.

- Inclusion criteria:
  - Patients with unilateral orbital floor fracture.
  - Patient with intact Globe.
- Exclusion criteria:
  - Bilateral cases.
  - Extreme of ages.
  - Cases associated with major morbidities.

Radiological imaging (CT face), and CT volumetery were done through which the site and shape of the fracture could be assessed , associated other facial fractures, and measuring of the orbital volume. All patients were photographed pre and postoperatively.

Technique:

The orbital volumetry was done pre-and post-operative to detect the degree of orbital volume changes by comparing both the affected and the normal eye and whether this change in orbital volume is due to bony elements caused by the fracture

Our study was performed on a 16 slice multislice CT scanner (Siemens Emotion 16, Erlangen, Germany). The patients were placed supine on the CT scanner. Helical multislice scanning was performed with the axial images reconstructed at 0.5 mm slice thickness. The images were then transferred to the workstation where multiplanar reconstruction of 2 mm slice thickness axial and coronal images was performed in high resolution bone window.

The bony orbit volume on each scan was calculated by manually tracing the orbital wall on each cut of the coronal reconstructed images. On the coronal CT cuts, the anterior orbital boundary was defined when both the medial and the lateral orbital rims appears on the same level. On the coronal CT cuts, the anterior border was determined as the CT slice in which 50% of the inferior orbital rim was visible (This is what was done according to REF JAEHWAN KWON), with the posterior limit being the orbital apex. The regions lacking a bony boundary (i.e., superior orbital fissure, inferior orbital fissure, lacrimal fossa, and optic canal) were traced with a straight line.

Fig.1: Shows CT volumetery

In the case of missing bone of the lateral orbital wall (owing to the lateral wall being out of plane) on coronal CT scans, a line was drawn similar to that of the closest slice in which the whole orbital bone was seen and was used to demarcate the extent of the orbital volume

The volume of the fracture was measured as the discrepancy in volume between the fractured and the normal contralateral orbital volumes.

RESULTS

The following table shows the orbital volumetry pre/post-operative and their ratio for the 14 cases (28 orbits).

Table 1: shows the orbital volume measurement of both normal eye and affected side.

Serial	**Affected side (pre) (cm^3)**	**Affected side (post) (cm^3)**	**Affected side (diff.) (cm^3)**	**normal side (pre) (cm^3)**	**Normal side (post) (cm^3)**	**Normal side (diff.) (cm^3)**	**Normal minus affected pre-)**	**Normal minus affected post-)**	***% pre***	***% post***
1	29.1	30.1	1	27.9	26.7	1.2	1.2	3.4	4.1	11.3
2	27.2	31.4	3.2	26.3	27.7	1.4	0.9	3.7	3.91	11.7
5	26.6	28.4	1.8	26.7	27.2	0.5	0.1	1.2	0.37	4.2
3	25.5	25.8	0.3	26.6	26.8	0.2	1.1	1	4.1	3.7
4	24.2	22.9	1.3	23.4	23.2	0.2	0.8	0.3	3.3	1.2
6	26.9	27.1	0.2	23.8	24.2	0.4	3.1	2.9	11.5	10.7
7	25.7	25.5	0.2	25.1	25.4	0.3	0.6	0.1	2.33	0.39
8	29.5	26.2	3.3	22.9	22.3	0.6	6.6	3.9	22.3	14.8
9	22.3	23.1	0.8	23.8	23.1	0.7	0.8	0.0	3.36	0
10	36.6	33.9	2.7	28.8	28.6	0.2	7.8	5.3	21.3	15.6
11	28.4	28.5	0.1	28.1	28.2	0.1	0.3	0.3	1.0	1
12	22.4	19.2	3.2	19.9	19.6	0.3	2.8	0.4	12.5	2.0
13	28.8	24.0	4.8	25.6	25.6	0.0	3.2	1.6	11.11	6.25
14	17.8	20.7	3.1	20.3	20.6	0.3	2.5	0.1	12.3	0.48

orbital volume study

Table key: light shaded columns represent preoperative measurement while deep shaded columns represent the post-operative measurement; grey shaded rows represent 3 cases measurements error till standardization of the technique

The first 3 cases in this study showed inaccurate results, until standardization of technique was reached, as we failed to minimize the difference between the normal and the affected eye. The rest 11 cases showed correction of the orbital volume and showed decrease in the orbital volume difference between the affected and the normal eye.

The preoperative percentage of the volume difference between the affected and normal orbit range between 1 to 22%, while the post-operative percentage range from 0 to 14.8% which still significant range, despite there is clinical improvement and good radiological alignment as shown.

Fig.2: CT 3 D reconstruction shows proper bony alignment

Orbital volume measurements can be considered important for treatment plan by providing an accurate estimation of proper orbital implant positioning, which is necessary for optimal reconstruction of enophthalmos.

Our results demonstrate that it is very difficult to measure the exact bony orbital volume, The ideal measurement method should be available world wide , and be easy to perform on standard radiological scans, have a short learning curve, and be able to be performed in a short amount of time, with low systemic measurement errors.

Orbital volumetery was not affected by the used approach either subciliary or transconjuctival.

Case series:

Case 1:

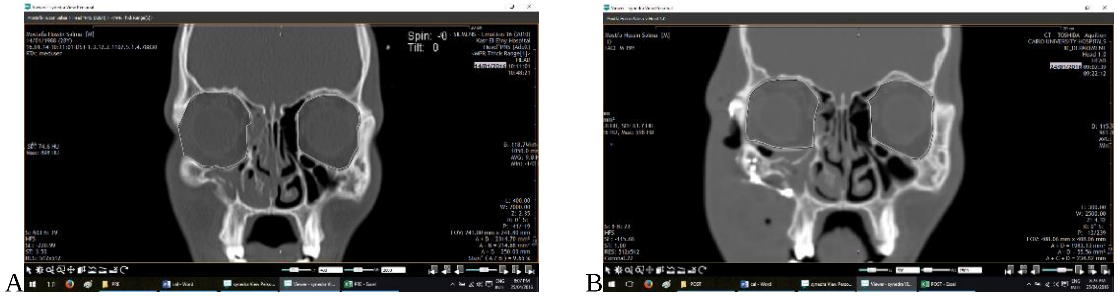

Fig. 3: A) preoperative CT of the patient with increase in the orbital volume of the affected orbit; B) postoperative CT of the same patient after repair with proper bony aligment and approaching the volume of the normal eye

Case (2):

Fig. 4: Female patient with motor car accident despite of proper bony alignment seen in CT but there is still enophthalmus detected clinically which is caused due to soft tissue atrophy. A) Preoperative; B) postoperative; C and D): Showed patient C.T

DISCUSSION

The development and routine use of computed tomography (CT) in patients with facial trauma has led to improved delineation of craniomaxillofacial injuries and orbital fractures. Three-dimensional (3D) reconstruction of CT data and measurement of orbital volume may become useful in the assessment of orbital floor fractures. Numerous articles have highlighted the importance of orbital volume measurement of blowout fractures. [(1)] However; few studies have examined the changes in orbital volume before and after surgery in patients with blowout fractures. [(4)]

Proper and accurate preoperative measurement of orbital volume is invaluable in predicting the need for surgery and, if it leads to operative intervention, preventing post injury enophthalmos, which is a common complication.[(2)]

Furthermore, orbital volume measurements can be considered important for treatment planning by providing an accurate estimation of orbital implant positioning, which is necessary for optimal reconstruction of enophthalmos. However, several problems can arise when CT scans are used to measure the orbital volume with standard computer based programs. Difficulties in measuring the exact orbital volume include [(3)]
(1) bony orbital cavities, which are roughly the shape of a quadrilateral pyramid with its base directed forward and laterally, not exactly located horizontally or perpendicularly to the axial or coronal plane; (2) bony defects, which in some locations can introduce errors in measurement (e.g., orbital apex, inferior orbital fissure, superior orbital fissure, lacrimal sac, and orbital base, with errors caused by including the missing anterior wall of the orbit); (3) Interoperator or Intraoperator variability; and (4) Errors caused by the use of different measurement techniques and software programs.

This study shows that bony orbit volume is increased in patients with enophthalmos following orbital trauma also, total soft tissue volume and fat volume were not significantly different in the enophthalmic eye. The region growing computer program cannot distinguish among these elements because of their similar radio densities (neuromuscular, fat…etc.).

This study fails to support the hypothesis that enophthalmos following trauma is caused by atrophy of periorbital fat or loss of orbital soft tissue.

Rather, the results suggest that the cause is a discrepancy between the soft tissue volume and bony orbital volume.

This study supports the view that in most cases it is necessary to decrease the bony orbital volume in order to correct surgically post-traumatic enophthalmos. This may be done by osteotomy, grafting, alloplastic materials, or combination of both.

Patients without increased bony orbital volume on the enophthalmic side are unlikely to be corrected by the techniques described above. The enophthalmos is caused by cicatricial contracture of the retro bulbar tissues or extra ocular muscles tethering. Investigating enophthalmos was done by measuring the: total bony orbital volume,., total soft tissue volume,. Orbital fat volume, .and neuromuscular tissue volume.

We hope that studies such as ours will lead to the development of a computer software program that is specifically designed to measure the volume on CT scans more accurately and reproducibly.

In conclusion, consistent volume measurements can be obtained using different 3-D image analysis programs. Reaching to proper measurements of pre-postoperative volume changes and postoperative reductions in volume can ensure a good surgical result and there by decrease the incidence of enophthalmos.

REFERENCES

1. Ahn HB, Ryu WY ,YooK W (2008):prediction of enopthalmus by computer based volume measurement of orbital fractures in a Korean population. Ophthal Plast Reconstr Surg;24(1):36-39
2. Cooper WC (1985): a method for volume determination of orbit and its contents by high resolution axial tomography and quantitative digital image analysis .Trans Am Ophtalmol Soc 83:546-609

3. Ploder O, Klug C, Backfrieder W ,Voracek M, Czerny C, Tschabitscher M,(2002)2D-based measurements of orbital floor fractures from CT scans .J Cranio maxilla fac. Surg.30(3):153-159.
4. Ye J, Kook KH, Lee SY (2006): Evaluation of computer -based volume measurement and porous polyethylene channel implant in reconstruction of large orbital wall fractures .invest ophtalmol vis Sci.47(2):509-513.