RESEARCH ARTICLE

A comparable study of the diagnostic performance of orbital ultrasonography and CBCT in patients with suspected orbital floor fractures

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Objectives: To compare the diagnostic performance of ultrasonography and CBCT against CT in detecting orbital floor fractures.

Methods: A total of 120 orbits with clinical suspicion of isolated orbital floor fractures underwent multislice CT scanning with coronal reconstruction; orbital ultrasonography using a standard machine equipped with a 7- to 10-MHz linear transducer; and CBCT. Patients with severe head and face injuries were not included. The diagnostic performance of ultrasonography and CBCT was reported assuming conventional CT as the imaging method of choice.

Results: According to CT findings, fractures of the floor were present in 39 orbits. The sensitivity, specificity, positive-predictive value and negative-predictive value of ultrasonography in detecting orbital floor fractures were 87.2%, 100%, 100% and 94.2%, respectively. The corresponding values for CBCT were 97.4%, 97.5%, 95.0%, and 98.8%, respectively. Areas under the receiver operator characteristics curves of orbital floor fracture detection were 0.94 for ultrasonography and 0.98 for CBCT.

Conclusions: When conventional CT cannot be performed in patients with clinically suspected orbital floor fracture and no severe or complex head and face injuries, CBCT could be used in detecting fractures as a reliable surrogate. Because of a lower sensitivity of ultrasonography, however, its use is limited in this regard.

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Introduction

Orbital fractures are very common in patients with craniofacial trauma.¹ Because the orbital floor is very

thin and brittle, it is the most frequently involved part in traumatic orbital fractures.² When orbital floor fractures are clinically suspected, a radiological confirmation is necessary³ because missed or incorrectly managed cases may encounter serious consequences such as enophthalmos, diplopia, limited ocular

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movement and altered sensory function of the infraorbital nerve.^{4,5}

Because of a high accuracy of conventional CT, it is generally accepted as the imaging method of choice in detecting orbital fractures.^{6,7} The maxillofacial CT, however, is accompanied by hazards of radiation exposure, particularly to the lens of the eyes.^{8,9} Image degradations by metal artefacts, such as those emitted by dental fillings, and the need for positioning of a traumatic patient inside imaging machines are other potential drawbacks of CT in orbital imaging.¹⁰

Instead, some investigators have recommended orbital ultrasonography as an alternative to conventional CT. The available reports, however, are not uniform in terms of its accuracy,^{11–17} probably because of imperfect methodologies and using outdated ultrasonography equipment in older series.^{18–20}

Another suggested alternative to conventional CT in detecting orbital fractures is CBCT.²¹ The most prominent advantage of CBCT over conventional CT in maxillofacial imaging is lower patient radiation doses for the former.²² The usefulness of this technique in detecting orbital fractures, however, is still questionable because scarce available data cannot sufficiently support the quality of images.³

Because of the mentioned uncertainties, the present study seeks to examine and compare the diagnostic performance of orbital ultrasonography and CBCT in patients with suspected orbital floor fractures.

Methods and materials

Between March 2014 and June 2015, a total of 120 orbits of patients with clinical suspicion of isolated orbital floor fractures were prospectively studied in a teaching trauma centre. Subjects with extensive head and face injuries/complex fractures, embedded foreign bodies in the orbital area, severe periorbital swelling/oedema, and admissions beyond 1 week from the primary trauma were not included. Informed written consent were obtained from the participants, and the ethics committee of the Tabriz University of Medical Sciences approved this study.

Initially, patients underwent axial multislice spiral CT scanning with coronal reconstruction (Somatom[®] Sensation 16; Siemens, Forchheim, Germany). The employed parameters were as follows: the reconstruction matrix size = 512×512 , kVp = 110, minimum slice thickness = 0.6 mm. Soft-tissue reconstruction was performed using a dedicated software package (Syngo[®] DynaCT, Leonardo; Siemens). An experienced radiologist evaluated findings, and accordingly, the orbits were divided as with ($n = 39$) and without ($n = 81$) orbital floor fractures.

Subsequently, an experienced oral and maxillofacial radiologist performed orbital ultrasonographic examinations using a standard machine (Medison V10; Medison, Republic of Korea) equipped with a 7- to 10-MHz linear probe (Figure 1). This observer was blind to CT findings. A previously described closed-eye

technique^{11,19} was employed. Briefly, after using sterile ultrasound gel to the closed eyelids, the ultrasonography beam was used in the coronal plane and angled caudally to intersect with the orbital floor. To detect fractures involving the most anterior part of the orbital floor, scanning was performed inferiorly from the superior aspect of the orbit while the ultrasound fan beam was applied in the coronal plane. A fracture was defined as a discontinuity in the well-defined bright echoes of the orbital margins. In this technique, the globe and structures within it, the optic nerve and the rectus muscles could also be clearly visualized.

Finally, all the orbits underwent CBCT scanning by a NewTom VGi scanner (Quantitative Radiology, Verona, Italy) using cone X-ray beam, flat-panel detector with pixel size of 0.150 mm, rotation: 360°, scan time: 18 s, kVp = 110, current: 1–20 mA and minimum slice thickness = 1 mm. Image reconstruction and interpretation was carried out using NNT Viewer v. 2.17 (Quantitative Radiology). A second experienced oral and maxillofacial radiologist without knowledge of CT and ultrasonography findings evaluated the images and reported the presence or absence of an orbital floor fracture.

Statistical analysis

Sensitivity, specificity, positive-predictive value and negative-predictive value were determined with the aid of a Microsoft Excel[®]-based spreadsheet (DAG-Stat; Biostats, Australia). Receiver operator characteristic curves were plotted separately for ultrasonography and CBCT, and the area under the curve was used in comparing the diagnostic accuracy of each method. The employed software was the SPSS[®] software for Windows v. 16.0 (IBM Corp., New York, NY; formerly SPSS Inc., Chicago, IL). p -values ≤ 0.05 were considered statistically significant.

Results

Patients were 44 males (73.3%) and 16 females (26.7%) with the mean age of 41.21 ± 12.01 years (28–66 years).

Figure 1 The method used for ultrasonographic examination of the orbit.

According to the findings of conventional CT, 39 orbits had fractures in the floor and 81 orbits were intact.

None of the patients reported discomfort during ultrasonography examinations. Ultrasonography detected 34 out of 39 orbits with fractures (Figure 2a,c) (true-positive rate: 28.3%) and missed 5 cases (false-negative rate: 4.2%). All 81 intact orbits were reported correctly by ultrasonography (true-negative rate: 67.5%).

Based on CBCT findings, fractures in the floor were present in 40 orbits (Figure 2a,b), correctly in 38 cases (true-positive rate: 31.7%) and wrongly in 2 cases (false-positive rate: 1.7%). Intact floors were reported in 80 orbits, correctly in 79 cases (true-negative rate: 65.8%) and wrongly in 1 case (false-negative rate: 0.8%).

Indicators of ultrasonography and CBCT diagnostic performance are set out in Table 1. The related receiver operator characteristic curves are shown in Figure 3. The area under the curve was 0.94 (95% confidence interval: 0.87–0.99; $p < 0.001$) for ultrasonography and 0.98 (95% confidence interval: 0.94–1.00; $p < 0.001$) for CBCT.

Discussion

An orbital fracture could be a challenging condition for diagnosis because the clinical presentation is usually variable and the anatomy of the region could be complex.^{2,23–25} Although the capability of conventional non-contrast CT in providing multiplanar thin slices with good spatial resolution and three-dimensional images in orbital fractures^{21,26,27} has nominated it as the imaging method of choice, a significant concern as to the hazard of radiation exists.^{28–33} To obviate this concern, some investigators have suggested orbital ultrasonography as an alternative, with a sensitivity, specificity, positive-predictive value and negative-predictive value ranging from 85% to 95%, 57% to 100%, 57% to 100% and 60% to 91%, respectively.^{10–12,15,16,18,19}

In the present study, the corresponding values were 87.2%, 100%, 100% and 94.2%, respectively; suggesting a high diagnostic accuracy of ultrasonography in detecting orbital floor fractures. Using a recent cutting-edge ultrasonography equipment, larger sample size and

Figure 2 Three examples with orbital floor fractures diagnosed correctly by both ultrasonography and CBCT (a); by CBCT but not ultrasonography (b); and by ultrasonography but not CBCT (c).

Table 1 Parameters representing diagnostic accuracy of orbital ultrasonography and CBCT in detecting orbital floor fractures

Parameters (%)	Ultrasonography	CBCT
Sensitivity	87.2 (72.6–95.7)	97.4 (86.5–99.9)
Specificity	100	97.5 (91.4–99.7)
Positive-predictive value	100	95.0 (83.1–99.4)
Negative-predictive value	94.2 (87.0–98.1)	98.8 (93.2–99.9)

Data in brackets represent 95% confidence interval.

CT-confirmed diagnoses for all patients are major advantages of the present study over the mentioned reports. In addition, unlike some previous studies that did not pay attention to the site of fractures, only cases with fractures in the orbital floor were included in the present work. This is important because the diagnostic performance of ultrasonography in detecting orbital fractures varies with the site of involvement.^{10,19,20} For example, lateral orbital wall fractures are usually so severe that almost all victims need a CT examination. Fractures with or without medial orbital wall involvements, on the other hand, are very common and, at the same time, usually hard to detect on the basis of clinical findings only. Likewise, it has been found that conventional CT and ultrasonography are equally accurate in detecting fractures in the floor and medial wall of the orbit.^{34,35} According to these facts, we decided to include cases with fractures in the orbital floor only.

Some authors relate inaccuracy of ultrasonography in detecting orbital floor fractures to the poor fitting of a linear transducer to curved orbital margins. This justification has been backed by better results using curved array transducers.^{13–16} By contrast, we found high accuracy of ultrasonography despite using conventional linear probes. This controversy needs to be tested in further studies, noting that all data supporting curved array transducers come from a single group of investigators.

Overall, although according to high sensitivity and specificity of ultrasonography in detecting isolated orbital floor fractures and considering some advantages of ultrasonography over CT such as lacking hazardous radiation exposure, lower cost and simplicity to use,¹⁵ it still bears some limitations. Severe injuries, gross swelling and oedema in the orbital area, and a “ring down” effect originating from the presence of air in the tissues causing multiple echo areas may compromise the accuracy of ultrasonography in scanning of bony outlines.^{10,36} Ultrasonography is also inaccurate in delineating fractures and differentiating soft tissues of the contents of a traumatized globe; it is operator dependent and contraindicated when a ruptured globe is suspected.^{15,26,37–39}

Another rather novel imaging modality that has been suggested in cases with orbital fractures is CBCT. The major advantage of this modality over conventional CT is the reduced X-ray exposure to the eyes.^{40–43} This benefit is important in the eye because the lens lacks a natural repairing capability of a radiation-induced cellular damage, which is normally seen in other tissues.^{21,44,45}

In CBCT, a pyramidal or cone-shaped X-ray beam and a charge-coupled device or flat-panel detector that

covers all the maxillofacial skeleton in a single rotation are used.⁴⁰ Brisco *et al*²¹ compared the image quality and radiation dose to the lens of the eyes in 10 patients with suspected orbital fractures who underwent CBCT or conventional multislice CT. The mean radiation dose to the lens (by 42%) and the effective dose were significantly lower with CBCT in this study. Accordingly, they suggested further studies for determining the accuracy of CBCT in detecting orbital fractures.

The sensitivity, specificity, positive-predictive value and negative-predictive value of CBCT in diagnosing orbital floor fractures were 97.4%, 97.5%, 95% and 98.8%, respectively, in the current study. In conformity, Drage and Sivarajasingam³ also showed that CBCT could accurately detect isolated fractures of the orbital floor using a lower dose of radiation than conventional CT.

Despite this high accuracy and similarity to orbital ultrasonography, it has been argued that CBCT is not suitable for patients with multiple injuries because conventional multislice CT still provides more extensive details that exceed the orbital region and should be considered the mainstay of imaging in such cases.²¹ But it should be noted that available modern CBCT devices have a field of view sufficiently large to cover the whole midfacial area. For example, the NewTom VGi device used in this study has a field of view of 15-cm height and 15-cm diameter; a spatial resolution comparable or better than conventional CT; and only an inferior contrast value when a conventional CT scanner is used for comparison. This may have important clinical implications, particularly in triage of patients from a surgeon's point of view because the detection of an

Figure 3 Receiver operator characteristic curves of orbital ultrasonography and CBCT in detecting orbital floor fractures.

orbital floor fracture may have only limited therapeutic consequences. For example, to determine if a surgery is urgent, or necessary at all, a surgeon needs to know whether there is a prolapse of orbital contents into the maxillary sinus, or if there is dislocation of bone fragments cranially.

According to previously established criteria, major indications of surgery, including a significant enophthalmos, the absence of an entrapped muscle or tissue, a fracture <50% of the floor, a lack of marked hypophthalmus and a lack of diplopia,³⁸ could be determined clinically or by the use of CBCT. Accordingly, and on the basis of our findings, in patients with clinical suspicion of isolated orbital floor fractures, conventional CT could be replaced with CBCT. Because of a lower sensitivity of ultrasonography than CBCT, however, its utility should be confined to situations in which neither conventional CT nor CBCT is available in dealing with patients with clinically suspected isolated orbital floor fractures. In patients with severe or extensive injuries, and in those with previously mentioned alarming findings, however, conventional CT is still the imaging method of choice.^{8,46}

This study bears some limitations. To perform this study in a blinded manner, observers were unaware of the findings of the other two imaging techniques. However, since concealing clinical signs of a traumatic event such as hyposphagma or haematoma is impossible, an initial real-time orbital ultrasonography could not be truly blinded.⁸

Since findings of the three imaging techniques were evaluated independently by three different observers,

the assessment of an interobserver variability was impossible. Despite this shortcoming, it should be noted that previously good-to-excellent interrater reliability values have been reported in this regard.¹⁷ In addition, the three observers in the present study were selected among highly skilled and well-experienced radiologists.

We employed a commonly used conventional CT protocol, and no direct comparison was implemented between CT and CBCT in terms of X-ray radiation exposure. It is not clear whether there will be still significant differences between the two imaging methods if a radiologist decides to use a low radiation protocol with conventional CT machine and what will be the diagnostic accuracy with this new setting. This needs to be examined in future studies.

Finally, on the basis of a routinely used institutional setting, reconstructions with the NewTom VGi device were performed with a minimum slice thickness of 1 mm, which results in anisotropic voxels. Actual clinical effects of this anisotropy could be an interesting topic for future investigations.

Conclusion

Both orbital ultrasonography using a linear array transducer and CBCT are highly accurate in detecting clinically suspected fractures of the orbital floor in patients without severe or complex head and face injuries. When performing conventional CT is impossible in such cases, CBCT but not ultrasonography could be used as an option.

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