RESEARCH

Comparison of ultrasonography with computed tomography in the diagnosis of nasal bone fractures

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Objectives: The aim of this study is to compare ultrasonography with CT in the diagnosis of nasal bone fractures.

Methods: 40 patients (9 female and 31 male) with mid-facial fractures, which were suspected nasal bone fractures, were included. All of the patients had mid-facial CT images. Ultrasonography with a 7.5 MHz transducer (Aloka 3500, Tokyo, Japan) was used to evaluate the nasal bone fractures. All of the sonograms were compared with CT findings for sensitivity, specificity and predictive values. A χ^2 test was applied to the data to assess statistical significance.

Results: CT diagnosed nasal bone fractures in 24 of the 40 patients (9 unilateral fractures and 15 bilateral fractures) while ultrasonography diagnosed the fractured bones in 23 patients (9 unilateral fractures and 14 bilateral fractures). Ultrasonography missed one fractured bone in a bilateral fractured case and a unilateral fracture was also missed (two false-negative results). The sensitivity and specificity of ultrasonography in assessing nasal bone fracture in comparison with CT were 94.9% and 100%, respectively. The positive predictive value (PPV) and the negative predictive value (NPV) of ultrasonographic evaluation of the nasal bone fractures were 100% and 95.3%, respectively. The χ^2 test did not show any significant difference between CT and ultrasonography in diagnosis of nasal bone fractures ($P = 0.819$).

Conclusion: Ultrasonography can be used as a first line of diagnostic imaging for evaluating nasal bone fractures, especially in children and pregnant women.

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Introduction

The nose is the most prominent facial structure and the nasal pyramid is reportedly the most commonly fractured facial bone.¹ The nasal pyramid is a complex structure consisting of the two nasal bones and the two frontal processes of the maxillary bone. A nasal fracture can involve any part of the nasal pyramid but the lateral nasal walls, the nasal dorsum and the nasal septum generally require the most attention when assessing a nasal pyramid fracture.²

Although clinical examinations are considered standard procedure in the diagnosis of nasal fractures, haematoma and oedema of adjacent tissues make it difficult to diagnose them. Imaging procedures in mid-face traumas are also needed for forensic reasons.³ Although a routine radiographic examination is the main diagnostic tool for traumas to the nose, it is not very accurate and it is difficult to determine which side is fractured on conventional radiographs.^{4,5} CT has been considered as a gold standard and it is the procedure of choice for diagnosing complex facial fractures, especially mid-facial fractures.^{6–8} However, CT techniques are expensive, are not readily available and provide a high patient exposure dose. Owing to the proximity of the eyes and the thyroid gland, there is an increased risk for cataract and thyroid carcinoma from

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X-ray exposure. Furthermore, CT techniques cannot be freely used for pregnant women and coronal CT sections cannot be provided for patients with traumas to cervical vertebrae and for non-co-operative patients.^{9,10} These considerations make it necessary to find an alternative and appropriate technique to CT imaging.

Ultrasonography is a non-invasive, inexpensive technique that has been shown to reveal fractures of different areas of the face, such as the nasal bone,^{2,3,6} orbital floor,^{7,11} anterior wall of the frontal sinus⁶ and zygomatic fractures.^{8,12} Previous studies have evaluated the use of ultrasonography in detecting nasal bone fractures in cases where a fracture had already been diagnosed.^{2,3} However, the sensitivity and specificity of ultrasonography has not been tested in the diagnosis of nasal bone fractures. The aim of this study was to evaluate the diagnostic value of ultrasonography in detecting nasal bone fractures compared with CT as the reference method in a single-blind study.

Materials and methods

In this cross-sectional study, 40 patients (9 female and 31 male) with mid-facial fractures, which were suspected nasal bone fractures, were included. All of the patients had mid-facial CT images and were referred to the Department of Oral and Maxillofacial Surgery, Imam Reza Hospital, Tabriz University of Medical Sciences, Tabriz, Iran, between April 2009 and March 2010. Patients with a severe abrasion, which prevents the proper use of an ultrasonographic probe, were excluded from the study.

Coronal and axial CT sections of all patients were obtained with a single slice spiral scanner (Somatom Balance, Siemens Medical Solutions, Forchheim, Germany). All participants underwent nasal ultrasonography using a small linear 7.5 MHz transducer (Aloka 3500, Tokyo, Japan) which was placed parallel to the nasal bone without a stand-off pad³ by a radiologist who has 10 years clinical experience and is an expert in soft-tissue and musculoskeletal imaging. The radiologist was blind to the CT findings. Patients were

examined in the supine position to achieve the views required to evaluate the right and left side of the nose (Figure 1). Any interruption in the continuity and displacement of the nasal bone was diagnosed as a nasal fracture. The study process was explained to the patients and written informed consent was taken. There was an interval of no more than 15 days between the incidence of trauma and the ultrasound procedure, and the ultrasound examination lasted less than 5 min.

The data obtained from ultrasound examinations were compared with the CT findings for sensitivity, specificity and predictive values. Sensitivity was calculated using the following formula: TP/TP+FN (TP, true-positive results; FN, false-negative results); specificity was calculated using TN/TN+FP (TN, true-negative results; FP, false-positive results); and positive predictive values (PPV) and negative predictive (NPV) values were calculated using TP/TP+FP and TN/FN+TN, respectively. The χ^2 test was applied to the data to assess statistical significance. The SPSS 16 computer software program (SPSS Inc., Chicago, IL) was used for statistical analysis.

Results

40 patients (31 male and 9 female; mean age: 41.5 years) were evaluated in this study.

Based on CT findings, a nasal bone fracture was diagnosed in 24 of the 40 patients (9 unilateral fractures and 15 bilateral fractures). A total of 39 fractured nasal bones were determined. Ultrasonography diagnosed the fractured bones in 23 patients (9 unilateral fractures and 14 bilateral fractures). Figure 2 shows the CT (a) and sonogram (b) of a case with nasal bone fracture, and ultrasonography detected this fracture. However, ultrasonography did not show one fractured bone in a bilateral fractured case and a unilateral fracture was also missed (Figure 3). Therefore, there were two false-negative results. In the non-fractured bones, ultrasound images were always concordant with the CT findings. Figure 4 shows the CT and sonogram of a patient with no fracture of the nasal bones. The findings of the study

Figure 1 (a–c) The positions of the patient and ultrasound probe

Figure 2 A 40-year-old woman with unilateral nasal bone fracture (white arrows). (a) CT view and (b) sonogram which detected the nasal bone fracture

are summarised in Table 1. The sensitivity and specificity of ultrasonography in assessing nasal bone fractures in comparison with CT were 94.9% and 100%, respectively. The PPV and the NPV of ultrasonographic evaluation of the nasal bone fractures were 100% and 95.3%, respectively. The χ^2 test did not show any significant difference between CT and ultrasonography in the diagnosis of nasal bone fractures ($P = 0.819$).

Discussion

In addition to the clinical examination (crepitation, deviation from the midline and dislocated fracture), the

nasal bone fracture is often diagnosed by radiography. Conventional radiographs do not demonstrate the line of fractures of nasal bone well.³ CT has high contrast resolution, is not operator-dependent and shows soft and hard tissues very well.³ However, it has a high cost and may not be available everywhere. CT also delivers a high radiation dose to patients. In recent years, ultrasonography has been introduced as an alternative technique in the evaluation of maxillofacial fractures because it is easy and quick to perform, inexpensive, portable and non-invasive.^{3,6}

Nezafati *et al*⁸ studied 17 patients with suspected zygomatic arch fractures and concluded that ultrasound is an accurate diagnostic tool with sensitivity and

Figure 3 A 25-year-old man with a left nasal bone fracture (white arrow). (a) CT view and (b) sonogram which did not show the left nasal bone fracture

Figure 4 A 28-year-old man without nasal bone fracture. (a) CT view and (b) sonogram view

specificity rates of 88.2% and 100%, respectively. Jank et al¹¹ suggested using ultrasound as an alternative method for the diagnosis of fractures of the orbital floor. In another study by Jank et al⁷ there was no statistically significant difference between ultrasonography and CT in the diagnosis of orbital rim fractures and orbital floor fractures.

Friedrich et al⁶ conducted a study on 81 patients with clinical signs of mid-facial fractures. In that study, the most important disadvantage of the ultrasound technique was related to the diagnosis of non-displaced facial fractures. In addition, it was demonstrated that the ultrasound technique does not exactly reveal the extension of peripheral fracture lines toward the central depressions. The results indicated that the ultrasound signal has a relative function in the nasal cartilage; therefore, there is interference between bone and cartilage by ultrasound. All the displaced fractures were diagnosed by the ultrasound technique.⁶

In the present study, 40 patients with mid-facial fractures, which were suspected nasal fractures, underwent ultrasonography (7.5 MHz) and all the ultrasounds were evaluated by 1 radiologist. In this study, ultrasound technique demonstrated sensitivity and specificity rates of 94.9% and 100%, respectively, in the diagnosis of nasal fractures; PPV and NPV rates were 100% and 95.3%, respectively. The results of this study are in agreement with the findings of Kishibe et al.¹³ In that research, ultrasonography was compared with CT in the diagnosis of nasal bone fractures in 12

patients. They demonstrated that the results of ultrasonography and the CT scan of the nasal bone were the same.

A number of studies have compared ultrasonography with conventional radiography in the diagnosis of nasal fractures.^{2,3,14–16}

Thiede et al² compared ultrasound and radiography techniques in the diagnosis of nasal fractures in 63 patients with suspected nasal bone fractures. Ultrasonography demonstrated greater accuracy rates in the evaluation of the lateral nasal wall compared with the radiography technique, which was statistically significant ($P = 0.04$). However, the radiography technique demonstrated higher accuracy rates compared with ultrasonography in the evaluation of the nasal dorsum, which was statistically significant. While all the ultrasound images were evaluated by two radiologists, which might have resulted in interexaminer discrepancies, the results did not demonstrate a significant difference between the two readers. However, the authors emphasized that results of an ultrasound examination are better when the procedure is performed by the same person reading the results.²

Gurkov et al¹⁴ have shown that accuracy of ultrasonography in the diagnosis of nasal fractures is higher than radiography. In addition, some previous studies have reported that all fractures of the nose could be detected correctly using ultrasound.^{15,16}

In a study of 26 children with nasal traumas,³ routine radiographs revealed 14 fractures out of 26 compared

Table 1 Comparison of ultrasonography with CT in diagnosis of nasal bone fracture

	Technique			
	CT		Ultrasonography	
Number of patients with fracture	24	Bilateral: 15 Unilateral: 9	23	Bilateral: 14 Unilateral: 9
Number of patients with no fracture	16		17	
Total number of fractured nasal bone	39		37	
Total number of non-fractured nasal bone	41		43	

with ultrasonography, which revealed all the fractured cases. CT was also used in the study which failed to diagnose a fracture in the septal cartilage. Finally, Hong et al³ introduced ultrasonography as a primary technique for the diagnosis of nasal fractures. The study did not include healthy individuals without nasal fractures, though the ability of a procedure to diagnose healthy individuals is of utmost importance.

In the present study, ultrasonography was also used to evaluate healthy nasal bone; all the cases were diagnosed correctly without any false-positive results as determined by CT (the gold standard). Ultrasonography has also been introduced as a gold standard, where it revealed all the fractured cases.³ Furthermore, ultrasound was evaluated because previous studies have not been conclusive regarding the diagnostic value of ultrasound in nasal bone fractures.

According to our results, two fracture lines in two nasal bones were not diagnosed by the ultrasound technique, probably because there was minimal bone displacement, which is consistent with the results of previous studies.^{6,8}

It has been reported that high-frequency probes reveal subtleties of bone structure and high-resolution scanners reveal minor bone displacements up to 0.1 mm, although operator expertise should also be taken into account.⁸ A 7.5 MHz linear probe was used in the present study and the results were consistent with the results of studies carried out by Mohammadi¹⁷ and Thiede² in which a 10 MHz linear probe was used. Furthermore, our results are consistent with the results of Danter,¹⁸ in which a 20 MHz probe was used to evaluate nasal bone fractures. It seems that a 7.5 MHz ultrasound head can detect nasal fractures just as well as 10 MHz and 20 MHz ultrasound probes.^{2,18}

The major limitation of ultrasound is that it is operator dependent, based on training and experience,

and interoperator variability also plays a role.¹⁹ Some studies have been performed by two or three examiners or readers of sonograms.^{2,20,21} Jank et al²⁰ investigated interrater reliability of sonographic examination in the diagnosis of orbital fractures. There was good agreement among ultrasound examiners regarding the infra-orbital margins; this was not the case for the orbital floors.

In addition, another study carried out by Jank et al²¹ about the intrarater reliability in the ultrasound diagnosis of orbital walls demonstrated good to excellent intrarater reliability. Also, in a study by Thied et al,² no significant difference was found between the results of two examiners in the evaluation of nasal bone fractures. However, the reliability of sonographic examination in the evaluation of nasal bone fractures should be investigated in further studies.

Conclusion

The use of ultrasonography in the evaluation of fractures has increased. Considering the advantages of ultrasound, such as the absence of ionizing radiation and ease of use, and given the results of the present study, it is concluded that ultrasound can be an alternative primary technique in the diagnosis of nasal bone fractures, especially in pregnant women and children. In addition, intraoperative evaluation of repositioning of the nasal bone can only be performed using ultrasonography.^{13,22} In cases of suspected complex facial bone trauma, a CT examination should be performed.³ However, to provide acceptable results using ultrasonography, further studies are needed to investigate the reliability of this technique in the evaluation of the nasal bone fractures.

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