Ultrasonography Findings in Nasal Bone Fracture; 6-Month Follow-up: Can We Estimate Time of Trauma?

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Abstract  Differentiation of a recent nasal bone fracture from an old one may become of utmost importance, especially in medico-legal issues. The aim of this study was to demonstrate the value of high-resolution ultrasonography (HRUS) in determining the time of nasal bone fracture. A longitudinal, descriptive–analytic study was done on 45 patients with a clinical manifestation of acute unilateral nasal bone fracture. After a thorough rhinologic physical examination, HRUS was performed by an expert consultant who was blinded to the clinical data of the patients. All patients were followed-up for 6 months: in the first 5 days, 3rd, 6th, 12th and 24th weeks after the trauma. In each session, the ultrasonographic findings were recorded. Thirty-six cases (mean age, 27 years) completed the study course successfully. On HRUS, subperiosteal hematoma, with a mean thickness of 1.14 mm (0.79–1.31 mm) was highly sensitive (100 %) for the diagnosis of nasal bone fracture during the first few days after the trauma, but it was present in 13 cases in the 6th week, with a mean thickness of 0.71 mm (0.62–0.80 mm), and disappeared in all patients in the 24th week, with a mean thickness of 0.47 mm (almost equal to the non-traumatic side). According to the changes of subperiosteal reaction on the traumatic side and by means of generalized linear model and generalized estimating equations, we proposed an equation to estimate the time of nasal bone trauma. In conclusion, HRUS is a reliable diagnostic tool for estimating the time of nasal bone fracture.

Keywords  Nasal bone · Fracture · Ultrasonography · Trauma

Introduction

The nasal pyramid is a complex structure composed of the paired nasal bones and the frontal processes of the maxillary bone. Nasal fracture is the most common mid-facial fracture and is twice more common in men than in women [1, 2]. Hematoma and the swelling of surrounding tissues make nasal bone fractures difficult to be diagnosed by routine physical examination. Although conventional radiographic examination is usually performed for legal reasons, it may not demonstrate the precise site of nasal fracture [3]. In a comparative study, high-resolution ultrasonography (HRUS) was superior to conventional radiography (CR) in the evaluation of the lateral nasal wall in patients with nasal bone fracture [4]. Furthermore, Hong et al. [3] showed that HRUS can also be used as a reference
To the best of our knowledge, no study has been performed to investigate the serial ultrasound findings of the nasal fracture to date. Since callus formation may take place in only 15% of patients with nasal fracture, differentiation of recent from chronic fracture lines might become quite difficult by CR [5]. The aim of the current study was to estimate the time of the nasal fracture according to the corresponding imaging findings on HRUS. This issue has potential medico-legal implications in which the prediction of the time of nasal trauma might be of importance.

Materials and methods

Institutional review board approved this prospective study. Written informed consent was obtained, with patients’ confidentiality being maintained during the study. Forty-five patients with a recent unilateral nasal bone fracture were considered for enrollment in the study which was carried out between April 2012 and April 2013. Patients with a history of rhinoplasty, septoplasty, nasal bone manipulation such as closed or open reduction before presenting to our hospital, and also those with a nasal fracture which had occurred more than 5 days before our visit were excluded.

First, a thorough rhinologic physical examination was done on all patients by an expert attending the department of otolaryngology—head and neck surgery, and the clinical manifestations of patients were recorded. In our cases, we considered ‘definite’ clinical findings of nasal bone fracture (i.e. nasal bone mobility and/or crepitus) as the standard of the diagnosis. Then, 2 radiological examinations, including nasal bone CR and HRUS were performed in all patients. Thereafter, in all the patients, the fractured nasal bone was reduced in the operation room, under local anesthesia by closed reduction with an obvious click and reposition. Indeed, case selection and ‘gold standard’ for nasal fracture in our study were both on the basis of clinical examination and intraoperative findings.

Finally, patients were followed-up for 6 months after the injury in the 3rd, 6th, 12th and 24th weeks after the trauma. In each session, HRUS was repeated and the imaging findings of the patients were recorded. HRUS was performed by an expert radiologist using a SonixOP system (Ultrasonix Medical Corporation, Richmond, Canada). The radiologist was blinded to the results of physical examinations and CR. A 14 MHz linear probe was used for sonographic evaluation, while the patients were in the supine position and the transducer applied directly on the skin without using a standoff pad. On HRUS, both bilateral transverse and longitudinal views were obtained, and cortical disruption, lucency, and stepping of the nasal bone were considered as positive findings for nasal bone fracture. Soft tissue swelling and subperiosteal hematoma were also looked for as possible indicators to differentiate an acute from a chronic fracture line. The thickness of periosteal reaction in the affected side was measured and compared with the thickness of nasal bone periosteum on the opposite side.

The data were analyzed using SPSS version 17.0 (SPSS Inc, Chicago, IL, USA). Moreover, sensitivity, specificity, negative predictive value (NPV), positive predictive value (PPV), negative likelihood ratio (LR−), positive likelihood ratio (LR+), and their 95% confidence intervals were calculated and used for determining the diagnostic accuracy of HRUS in nasal bone fracture. Generalized linear model and generalized estimating equation were used to estimate the time of nasal injury based on serial HRUS findings.

Results

Only 36 (22 men and 14 women; mean age, 27 years; range 17–38 years) out of 45 patients completed the course of study successfully; two patients demonstrated no obvious audible click in nasal bone reduction and were excluded from the study and the remaining seven patients failed to complete the long course of study as they did not return for HRUS follow-up sessions because of their lack of compliance.

In physical examination, mobility had the highest sensitivity (80.65%), specificity (100%), NPV (45.45%), and PPV (100%). In comparing the suggestive criteria for nasal bone fracture in physical examination, nasal bone depression had the most sensitivity (61.29%), epistaxis had the highest specificity (80%), and ecchymosis had the highest score of LR+ that was 1.37, and the most PPV that was 89.47%.

On HRUS, the lucency in the lateral nasal bone in the first 5 days after the trauma had the highest sensitivity (90.32%) compared to other follow-up sessions. The sensitivity of nasal bone lucency declined to 64.52% in the fifth follow-up session. The PPV of the lucency of lateral nasal bone was in the range of 84.85–88.00% during the 6-month follow-up ultrasonographic examinations.

In the first sonographic investigation, the sensitivity of nasal bone stepping was 77.42% which declined to 19.35% in all other follow-up sessions, and the PPV of stepping of lateral nasal bone was in the range of 85.71–88.89% during the 6-month follow-up ultrasonographic examinations.

Subperiosteal hematoma was detected in the first sonographic examination of all 36 patients, with a mean thickness of 1.14 mm (range 0.77–1.31 mm); that was present in
only 13 cases in the sixth week with a mean thickness of 0.711 mm (range 0.62–0.80 mm). In the 24th week after the trauma, subperiosteal hematoma disappeared in all patients, and the mean periosteal thickening in the affected side reached to 0.47 mm that was almost equal to that in the normal side (Table 1). In the first session, subperiosteal hematoma had the highest sensitivity (100 %) among all HRUS findings for the diagnosis of nasal bone fracture. On the other hand, the PPV of subperiosteal hematoma was in the range of 80–100 % during the 6-month follow-up ultrasonographic examinations. During the first 3 weeks after nasal trauma, subperiosteal hematoma and lucency in the lateral nasal bone had the a significantly higher diagnostic value compared to other imaging findings (p < 0.0001). The predictive value of lateral nasal bone lucency and subperiosteal hematoma on HRUS for estimating the elapsed time from the nasal trauma was 67.7 and 86.3 %, respectively, which were statistically significant (p values of 0.003 and 0.0001, respectively).

Based on the thickness of periosteal reaction on the traumatic side of nasal bone on HRUS, we proposed the following formula to estimate the elapsed time from the onset of nasal bone trauma using generalized linear models and generalized estimating equations (Fig. 1; Table 2):

\[ t = 127.5 - (81.5 \times d) \]

\[ t = 136.2 - (78.2 \times d_1) + (69.4 \times d_1 \times d_2) - (65.9 \times h) - (18.4 \times s) \]

\( t \) is the elapsed time from the onset of nasal bone trauma (day), \( d_1 \) is the periosteal thickness on the traumatic side of nose (mm), \( d_2 \) is the periosteal thickness on the non-traumatic side of nose (mm), \( h \) is the subperiosteal hematoma (zero or 1), \( S \) is the nasal septum (zero or 1). In the above equation, the values of subperiosteal hematoma (\( h \)) and nasal septum stepping (\( s \)) are 0 or 1 in the absence or presence of each findings, respectively.

**Discussion**

Nasal fracture is usually diagnosed on the basis of taking an accurate history and physical examination; however, assessment of radiological findings can confirm the diagnosis [1]. Soft tissue swelling may obscure a mild to moderate nasal fracture and may get in the way of the physician when performing an immediate closed reduction so the patient must be reassessed 3–4 days after the injury [6, 7]. The sensitivity of conventional radiography for detecting nasal bone fracture is reported to be as 53–63 %

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**Table 1** The thickness of the periosteal reaction of traumatized nasal bone in 6 months follow-up of 36 cases using HRUS

<table>
<thead>
<tr>
<th>Time of visit after trauma</th>
<th>5 days</th>
<th>3 weeks</th>
<th>6 weeks</th>
<th>12 weeks</th>
<th>24 weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (mm)</td>
<td>1.1361</td>
<td>.8889</td>
<td>.7111</td>
<td>.5583</td>
<td>.4750</td>
</tr>
<tr>
<td>95% confidence interval for mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower bound</td>
<td>0.7867</td>
<td>0.7687</td>
<td>0.6222</td>
<td>0.4934</td>
<td>0.4187</td>
</tr>
<tr>
<td>Upper bound</td>
<td>1.3101</td>
<td>1.0091</td>
<td>0.8000</td>
<td>0.6232</td>
<td>0.5313</td>
</tr>
<tr>
<td>5% Trimmed mean</td>
<td>1.1062</td>
<td>0.8642</td>
<td>0.6975</td>
<td>0.5506</td>
<td>0.4660</td>
</tr>
<tr>
<td>Median</td>
<td>1.0500</td>
<td>0.8000</td>
<td>0.7000</td>
<td>0.5000</td>
<td>0.5000</td>
</tr>
<tr>
<td>SD</td>
<td>.48116</td>
<td>.35519</td>
<td>.26271</td>
<td>.19180</td>
<td>.16626</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.50</td>
<td>0.30</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
</tr>
<tr>
<td>Maximum</td>
<td>2.40</td>
<td>2.10</td>
<td>1.60</td>
<td>1.10</td>
<td>1.00</td>
</tr>
<tr>
<td>Range</td>
<td>1.90</td>
<td>1.80</td>
<td>1.40</td>
<td>0.90</td>
<td>0.80</td>
</tr>
</tbody>
</table>

**Table 2** Regression coefficients of predictive agents in sonographic investigations

<table>
<thead>
<tr>
<th>Model</th>
<th>B</th>
<th>Std. error</th>
<th>Sig.</th>
<th>Lower bound</th>
<th>Upper bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>127.493</td>
<td>8.193</td>
<td>.000</td>
<td>111.324</td>
<td>143.662</td>
</tr>
<tr>
<td>Periost_Trauma</td>
<td>-81.494</td>
<td>9.654</td>
<td>.000</td>
<td>-100.545</td>
<td>-62.443</td>
</tr>
</tbody>
</table>

**Fig. 1** The predictive value of periosteal thickness in estimating the time of nasal trauma
[8]. Midline nasal suture, nasomaxillary suture, developmental defects or thinning of the nasal wall and short radiolucent lines reaching the anterior aspect of the nasal bone may erroneously be reported as fracture lines [9]. To date, only a few studies have been conducted to assess the diagnostic value of ultrasonography in nasal bone fracture. In one study, the sensitivity and specificity of HRUS in the diagnosis of nasal bone fracture were reported as 97 and 100%, respectively [10]. Also, a sensitivity of 83% and a specificity of 50% were reported by Danter et al. [11] using a 20 MHz transducer compared to physical examination; the authors also showed a sensitivity of 94% and a specificity of 83% for HRUS compared to CR. Zagolski et al. [12] found that the diagnosis of nasal bone fracture can be made exclusively on the basis of the HRUS. One report showed that even a 0.1 mm disruption in nasal bones can be detected in ultrasonography [4].

A 14 MHz linear probe was used in the present study, and our results were in agreement with those of the studies carried out by Mohammadi et al. [10] and Thiede et al. [2]. Furthermore, our results corroborated with those of Danter et al. [11] in which a 20 MHz probe was used to evaluate nasal bone fractures. It seems that a 14 MHz transducer can detect nasal fractures just as well as 20 MHz ultrasound probe. In this study, by measuring the subperiosteal hematoma, we were able to differentiate acute from chronic fracture lines which is usually impossible in CR. Our study showed that ultrasonography can detect the trauma of cartilaginous part of the nose more precisely than plain radiography [3]. In our observations, by measuring periosteal thickness of the traumatic side of the nose on HRUS, we were also able to estimate the time of nasal trauma which can be useful in forensic medicine; to the best of our knowledge, no study has been performed so far to investigate the serial ultrasound findings of the nasal fracture and to estimate elapsed time from the nasal fracture according to the corresponding HRUS findings.

The projected external shape of the nose is a limitation for performing ultrasonography in this site; to overcome this problem, we used a hockey stick probe with a 14 MHz linear array transducer keeping contact between the probe and the nose. In our study, we showed that during nasal trauma, lucency or stepping in the nasal septum can be detected in ultrasonographic investigations which are usually missed in CR studies. At the same time, we showed that the sensitivity and specificity of ultrasonographic evaluation is not only the same, but also even higher than CR in detecting lucency or stepping in the lateral nasal bone, and this was compatible with previous studies [3].

Nowadays, 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 suggested that ultrasound can be a valuable primary technique in the diagnosis of nasal bone fractures and a reliable diagnostic tool for estimating the time of nasal bone fracture especially in forensic medicine cases, in which it is of importance to show if the fracture is a new or an old one. Finally, further investigation in a larger group of patients with shorter intervals between the sonographic follow-up sessions seems necessary to generalize the results of the present study.

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Conflict of interest The authors declare that they have no conflict of interest.

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