# Ultrasound for management of pediatric nasal fractures*

Roee Noy[1], Natalia Gvozdev[1], Anat Ilivitzki[2], Nagib Nasrallah[3], Arie Gordin[1]

[1] Department of Otolaryngology – Head and Neck Surgery, Rambam Health Care Campus, Haifa, Israel; Technion – Israel Institute of Technology, Haifa, Israel

[2] Department of Radiology, Rambam Health Care Campus, Haifa, Israel; Technion – Israel Institute of Technology, Haifa, Israel

[3] Pediatric Emergency Medicine Unit, Ruth Rappaport Children's Hospital, Rambam Health Care Campus, Haifa, Israel

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## Abstract

**Background**: Nasal bone fractures are common in children but can be challenging to diagnose accurately in the first days due to swelling and tenderness. While X-rays and computed tomography have limitations, ultrasound may be a radiation-free and cost-effective alternative for diagnosing and treating nasal fractures.

**Methods**: A prospective cohort study at a tertiary referral hospital between 2021-2023. Children who had sustained nasal trauma were included. A radiologist and a non-radiologist blindly reviewed ultrasound scans, and the results were compared to the physical examination performed by a senior otolaryngologist. If closed reduction was necessary, ultrasound was employed during the procedure. The primary outcome was the assessment of nasal fractures in children using ultrasound; Secondary outcomes included success rates for closed reduction and test reliability.

**Results**: Of the 50 children (mean age: 11 years, interquartile range: 6-15 years, 36 [72%] males), 22 (44%) were clinically diagnosed with a nasal fracture. Interobserver reliability for nasal fracture by ultrasound was 92%, with a Cohen's kappa coefficient of $\kappa$=0.91. The sensitivity and specificity of ultrasound in detecting nasal fractures were 90% and 89%, respectively, with positive and negative predictive values of 86% and 93%, respectively. Closed reduction was performed on 18 children, with (n=11) or without (n=7) ultrasound, with the former showing better alignment results (82% vs. 71%).

**Conclusions**: Ultrasound has a high negative predictive value in identifying nasal fractures in children with swollen noses during presentation. This enables to avoid further unnecessary referrals and interventions. Ultrasound-guided closed reduction of nasal fractures demonstrates improved outcomes; however, further large-scale randomized studies are required to validate our findings.

**Key words**: closed reduction, nasal bone, nasal fracture, otolaryngology, pediatric otolaryngology, ultrasound

## Introduction

The nose is the most prominent and exposed feature of the face. Due to the proximity of nasal bones and skin, and the thin fat layer, a relatively small amount of force can cause nasal fractures [1-2]. Nasal fractures are the most frequent facial fractures in children, accounting for 40-50% of cases, and are the third most common fractures in the human body [3]. If left untreated, nasal fractures may lead to cosmetic and functional impairments [4-5].
Although the physical examination is considered the "gold standard" for diagnosing nasal fractures, the nose often swells significantly after trauma, making it challenging to identify deformities and forcing patients to return for follow-up examination several days later [5-8]. X-rays have moderate sensitivity and specificity, with an accuracy rate of approximately 65.7%, and are mainly focused on the nasal dorsum, making it difficult to visualize the extent of nasal bone displacement along different axes and skeletal deformations [9-11]. Computed tomography is highly sensitive and specific for nasal fractures, but it is typically reserved for severe head injuries rather than isolated nasal traumas. Additionally, there are concerns about radiation exposure. Thus, scans are only sometimes justified [12].
Ultrasonography provides a promising alternative for evaluating nasal bone fractures. Unlike X-rays, ultrasound can detect skeletal deformation along three axes and presents no risk of radiation exposure, making it a valuable tool in emergency rooms and clinics. Additionally, since the nasal bones are close to the skin,

there is no air gap between the transducer and the bones, which improves the quality and interpretation of results. Furthermore, ultrasonography is cost-effective, making it a valuable diagnostic tool in resource-limited settings. However, its disadvantages include slight discomfort when placing the transducer on the swollen nose and the fact that it is operator-dependent.
Previous studies have explored the use of ultrasound in the diagnosis of nasal fractures, with varying results [9,12-23]. However, the literature regarding its application in detecting nasal fractures in children is limited. Additionally, there is a lack of research on the effectiveness of ultrasound-assisted closed reduction in this population. As such, further investigation is warranted to determine the utility of ultrasound in the diagnosis and treatment of nasal fractures in children. This study aimed to assess the diagnostic accuracy of ultrasound in identifying nasal fractures in children with a swollen nose and to evaluate the effectiveness of ultrasound-guided closed reduction in the management of nasal bone fractures.

## Materials and methods

This prospective cohort study was carried out at Rambam Health Care Campus (a tertiary referral center) in Haifa, Israel, from November 2021 and January 2023. Informed consent was obtained from the parents, and the study received approval from the local institutional review board (RMB 0401-2021). Additionally, the study was registered with the Israeli Clinical Trial Registry (MOH_2021-11-16_010404). The study included children 18 years or younger who presented to the emergency department with isolated nasal trauma, at any time. Children with a prior history of nasal trauma, open wound, head and neck trauma who underwent CT, or any other condition that prevented transducer placement were excluded.

### Main outcome measures

The primary outcome was to assess the diagnostic accuracy of ultrasound in detecting nasal fractures in children with a swollen nose; The secondary outcomes were to evaluate the efficacy of ultrasound-guided closed reduction and test reliability.

Children were selected randomly, and were evaluated for clinical features of nasal fracture, including bone dislocation, crepitus, tenderness, and edema by an otolaryngology resident. After the physical examination, an ultrasound scan was performed. Ultrasound scans were independently reviewed for nasal fracture by two seniors, a radiologist and a non-radiologist (a pediatric emergency physician who is qualified in point-of-care ultrasonography), who were blinded to the physical examination findings. The results of the ultrasound scans were compared to the physical examination findings performed by a senior otolaryngologist in the outpatient clinic one week later.
The gold standard for diagnosis for isolated nasal fracture is physical exam, as supported by The American Academy of Otolaryngology - Head and Neck Surgery [8]. While CT may offer higher sensitivity but also false positive in detecting nasal fractures, it is not typically performed in cases of isolated nasal trauma. The senior otolaryngologist has a fellowship in pediatric otolaryngology with more than 15 years of experience and was blinded to the ultrasound results obtained at the time of presentation.
Children who were found to have a nasal fracture requiring closed reduction (nasal axis deviation, nasal bone protrusion or depression) underwent an additional ultrasound scan during the procedure to evaluate the alignment of nasal bones. The procedure was performed under local anesthesia for those aged 13 years and above and under sedation for younger patients. Local anesthesia was performed using intranasal tetracaine (2%) with naphazoline (0.1%) spray and local subcutaneous infiltration of lidocaine with adrenaline (1%). Sedation was achieved using intravenous propofol (1 mg/kg) and fentanyl (0.05-0.1 mcg). During the procedure, the nasal bones were held between two fingers, and pressure was applied laterally in the opposite direction of the deviation. A blunt elevator (Boies or Joker) was used in cases of medial collapse. In cases of collapse or bleeding, Merocel® nasal dressing was placed longitudinally, and a nasal splint was applied for 5-7 days. After the closed reduction, children were scheduled for a follow-up appointment one week later. During this appointment, the nasal splint and intranasal dressing were removed, and the appearance of the nose was inspected for any protrusion or depression of the nasal bones. Success in closed reduction was defined as achieving correction of the bone alignment to a natural position, as determined through direct visualization. To ensure objectivity and reliability, this correction was confirmed by at least two independent figures: the patient (or their parent) and a senior otolaryngologist. The senior otolaryngologist, who was blinded to the ultrasound-assisted closed reduction procedure, conducted a follow-up examination in the clinic one week after the closed reduction.
The HM70A with Plus ultrasound system (Samsung Medison Co., Ltd, Seoul, Korea) was used for ultrasonographic evaluations, which were performed using a 7-12 MHz linear probe. Only residents who were trained in ultrasound operations participated in the study. The residents underwent instruction on device operation by a senior radiologist, including at least three prior practices. Ultrasound scans were performed in transverse, oblique, and longitudinal planes with patients in a supine position. Following the ultrasound scans, the acquired images were saved onto an external deidentified device. These saved images were subsequently assessed by two senior evaluators who were blinded to the patient's clinical information. A nasal fracture was defined as an interruption in the continuity of the nasal bone, accompanied by visual evidence of bone displacement in relation to the adjacent area. Figures 1A and 1B show examples of a nasal bone with a fracture and nasal bones without a fracture,

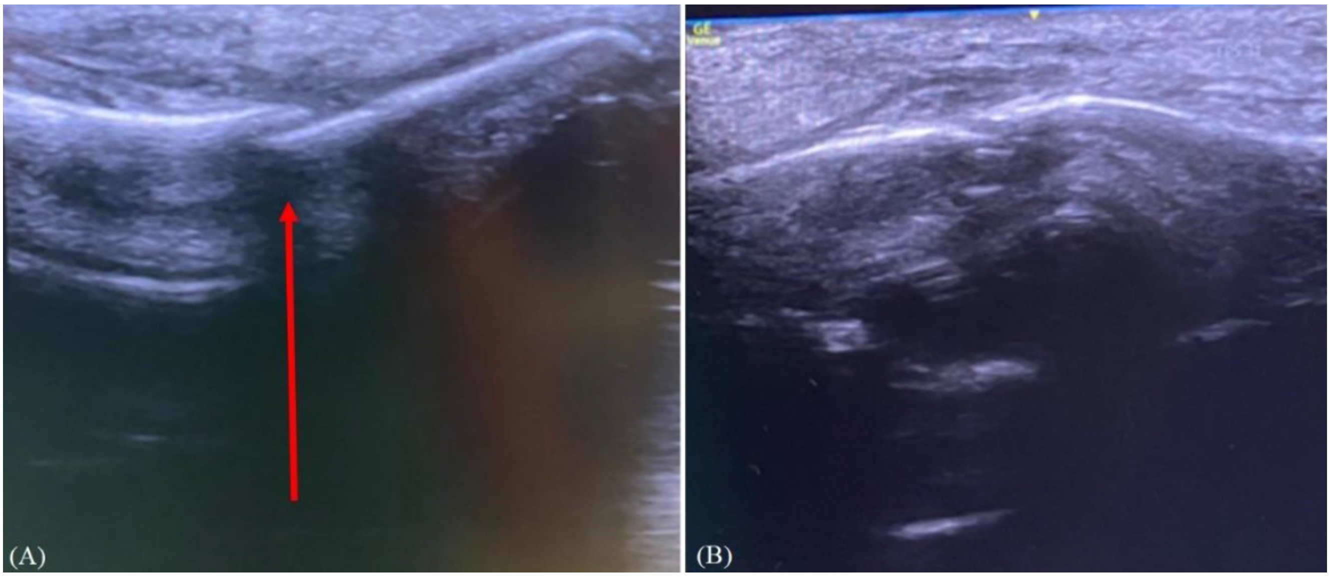


Figure 1. (A) Ultrasound scan showing nasal bone fracture (red line) (transverse plane). (B) Ultrasound scan showing nasal bone without a fracture (transverse plane).

respectively.

To ensure sufficient power to archive a clinically meaningful difference in the utility of ultrasound for the detection of nasal fractures, with a power of 80% and a type 1 error rate of 5%, the calculated sample size required was 47 patients.

### Statistical analysis

Continuous variables were described as mean (standard deviation, interquartile range [IQR]), and categorical variables were described as prevalence (percentage). The differences between patients will be examined using the Chi-square test for categorical variables, the Student's t-test for normally distributed values, or the Mann-Whitney U test for non-normally distributed values. The diagnostic test performance measures, including sensitivity, specificity, positive and negative predictive value, and accuracy, were calculated and presented as percentages. We calculated the overall probability of correct classification using the accuracy formula: Sensitivity × Prevalence + Specificity × (1 − Prevalence), with the assumption of a pretest probability of 50%. The Cohen's kappa coefficient (κ) was used to measure the reliability between radiology and non-radiology reviewers. All data were presented as two-sided with a 95% confidence interval. A p-value $< 0.05$ was considered statistically significant. There was no missing data. All analyses were performed using the Statistical Package for the Social Sciences, version 26.0 (IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY: IBM Corp).

## Results

During the study period, a total of 50 children (mean age: 11 years [IQR: 6-15], 36 [72%] males) were included in the analysis. Additionally, seven more potential children declined to participate. Falls were the most common injury mechanism (27 [54%] children), followed by sports (14 [28%]), collisions (6 [12%]), and motor vehicle accidents (3 [6%]). Thirty-five (70%) children presented within 6 hours of injury, 41 (82%) children presented within 24 hours, 6 (12%) within 24-36 hours, and 3 (6%) within 36-60 hours, as shown in Table 1.

Upon initial presentation, a nasal fracture was suspected in 34 (68%) children based on physical examination findings, while seven (14%) had inconclusive results, and nine (18%) were ruled out for nasal fracture. There was no association between time elapsed since trauma and nasal fractures ($p = 0.2$) nor ultrasonographic evaluations ($p = 0.5$). All children were discharged from the emergency room the same day after receiving medical clearance and scheduled for follow-up. One week later, they were examined by a senior otolaryngologist, who clinically confirmed a nasal fracture in 22 (44%) children and ruled it out in 28 (56%). Of the seven children with inconclusive results, 2 (29%) were found to have nasal fracture upon follow-up examination.

The interobserver reliability for ultrasound scans was found to be high, with an agreement of 92%. The kappa coefficient (κ) statistic showed excellent agreement between the two observers to detect nasal fracture ($κ = 0.91$). Further analysis showed that neither age, gender, injury mechanism, nor time since presentation impacted interobserver agreement.

Table 2 summarizes the diagnostic testing accuracy for ultrasonography compared to clinical examination by a senior otolaryngologist. Ultrasonography had a sensitivity and specificity of 90% and 89%, respectively. The positive predictive value was 86%, and the negative predictive value was 93%. The positive and negative likelihood ratios were 8.48 and 0.1, respectively. Overall accuracy was 90%.

Of the 22 children diagnosed with a nasal fracture, 18 underwent closed reduction, while two children declined the

Table 1. Patient demographics and clinical characteristics.

| Characteristics | | |
|---|---|---|
| Number of patients | n | 50 |
| Age (years) | Mean, years | 11 |
| | Quartiles 1,3 | 6, 15 |
| Gender | Males, n (%) | 36 (72%) |
| | Females, n (%) | 14 (28%) |
| Injury mechanism | Falls, n (%) | 27 (54%) |
| | Sports, n (%) | 14 (28%) |
| | Collisions, n (%) | 6 (12%) |
| | Motor vehicle accidents, n (%) | 3 (6%) |
| Hours after presentation | 0-6, n (%) | 35 (70%) |
| | 12-24, n (%) | 41 (82%) |
| | > 24, n (%) | 9 (18%) |
| Primary diagnosis (emergency department) | Fracture, n (%) | 34 (68%) |
| | Inconclusive, n (%) | 7 (14%) |
| | No fracture, n (%) | 9 (18%) |
| Final diagnosis (gold standard) | Fracture, n (%) | 22 (44%) |
| | No fracture (%) | 28 (56%) |
| Closed reduction | All, n (% of fractures) | 18 (82%) |
| | Ultrasound-assisted, n (%) | 11 (61%) |

procedure since they were satisfied with their nasal appearance, and two were lost to follow-up. Among those who underwent reduction, 11 received ultrasound-assisted treatment, and the remaining seven received reduction without ultrasound. Only minor bleeding occurred in 4 children, and it was promptly controlled with local pressure. No adverse events were reported during or after the procedure, and all children were discharged one hour after the reduction feeling well. The overall success rate of closed reduction was 83%, with ultrasound-assisted reduction achieving a significantly higher success rate than the conventional method (82% vs. 71%, p = 0.01). Factors associated with successful reduction were the presence of apparent nasal axis deviation (p = 0.02), nasal bone protrusion (p = 0.01), nasal bone depression (p = 0.04), and performing the reduction starting seven days after trauma (p = 0.01). Age, gender, and injury mechanism did not significantly affect the success rate.

## Discussion

The diagnosis of nasal fractures can be challenging, especially within the first few days when the nose is swollen, and untreated fractures can result in cosmetic and functional abnormalities [3-5]. We demonstrated that ultrasound is a valuable diagnostic tool for nasal fractures in children, with a high negative predictive value. Additionally, using ultrasound in closed reduction procedures can improve outcomes and increase the success rate.

Previous studies have investigated the utility of ultrasound in

Table 2. Diagnostic values for ultrasound detection of nasal fracture in children.

| Measure | Value |
|---|---|
| Cohen's kappa coefficient | 0.91 |
| Sensitivity | 90% (95% CI 0.71–0.98) |
| Specificity | 89% (95% CI 0.72–0.98) |
| Positive predictive value | 86% (95% CI 0.66–0.97) |
| Negative predictive value | 93% (95% CI 0.75–0.99) |
| Accuracy | 90% (95% CI 0.78–0.97) |
| Positive Likelihood Ratio | 8.48 (95% CI 2.89–24.92) |
| Negative Likelihood Ratio | 0.1 (95% CI 0.03–0.38) |

CI – Confidence Interval.

diagnosing nasal fractures. For example, Thiede et al. conducted a prospective study of 63 adults and found that ultrasound can be a viable alternative to X-ray with comparable diagnostic performance [9]. Similarly, Javadrashid et al. compared ultrasound and computed tomography in adults with nasal fractures and reported a sensitivity and specificity of 94.9% and 100%, respectively. He concluded that ultrasound can be used as the first-line imaging modality for evaluating nasal bone fractures [12]. In another study of 103 adults, Caglar et al. found that ultrasound had a sensitivity of 84.8% and a specificity of 93% for detecting nasal fractures [13]. Other studies have reported similar findings [18-20]. While several studies have evaluated the diagnostic performance of ultrasound for nasal fractures in adults, few studies have investigated its use in children. In a study of 31 children, Gökçen et al. [16] found a sensitivity of 72.2% and specificity of 76.9% for detecting nasal fracture using ultrasound compared to X-ray. Similarly, Dogan et al. [17] reported a low sensitivity of 22.5% but a high specificity of 83.1% in 133 pediatric patients. In contrast, Hong et al. [6] found that ultrasound could detect all fractures in 26 children, while CT was not always able to do so. Our study showed that ultrasound has a high negative predictive value of 93% for diagnosing nasal fractures in children. This suggests that it can be used to rule out fractures during the acute phase when the nose is swollen, and the physical examination is inconclusive. This could lead to a reduction in unnecessary referrals to emergency departments and secondary clinics, ultimately lowering healthcare costs. Although some may argue that follow-up is necessary for detecting delayed septal hematoma, we believe that general pediatricians in primary care clinics can also carry this out. Majority (82%) of children presented within 24 hours after nasal trauma, but their noses were already swollen as soft tissue edema arises within hours of nasal trauma and may significantly affect clinical assessment [24]. We could not demonstrate an association between time following trauma and nasal fracture or any ultrasonographic results, as some children will develop edema within 20 minutes, while others do so later. In children, the nasal bones are not well developed, which can result in accidental identification of the internasal sutures, the rhinion, or the nasion as a fracture, leading to a false positive result. Additionally, not all nasal fractures require reduction, as some have minimal to no displacement. Therefore, it is essential to ask the patient and his parents if there has been any change in the appearance of their nose to confirm the diagnosis before proceeding with treatment. The false positive rate in our cohort was 10.7%. However, it is essential to note that similar mistakes can also occur in CT scans. The operator and interpreter should be familiar with the anatomy to prevent such misleading. Closed reduction of nasal fractures can be challenging, as it is based on the surgeon's tactile sense and may lead to both over- and under-correction of the fracture. This uncertainty may result in multiple reduction attempts and lead to complications such as epistaxis, edema, and synechiae [19]. Previous studies have investigated the role of ultrasound-guided closed reduction of nasal fractures. Park et al. performed real-time ultrasound-guided closed reduction of nasal fractures in 32 patients and concluded that ultrasound is useful for evaluating intraoperative repositioning of the injury [12]. Abu-Samra et al. conducted a prospective, randomized, controlled, double-blinded study of 68 patients with nasal fractures and compared the outcomes of closed reductions performed with and without ultrasound. He found that intra-operative, ultrasound-guided nasal fracture treatment resulted in significantly better nasal profile appearance than simple closed reduction [20]. Hwang et al. ran another randomized control study on 28 patients and compared the outcomes of ultrasound use in closed reduction of nasal fracture. They found that ultrasound-guided closed reduction is superior to a blind closed reduction in patients with most fractures. Using ultrasound during closed reduction procedures may help increase the success rate, improve outcomes, and reduce complications [21]. Our study is the first to investigate the role of ultrasound-guided closed reduction in nasal fractures in children. Our findings indicate that ultrasound-guided closed reduction resulted in better alignment of nasal bones than those who underwent the procedure without ultrasound guidance.

It is important to note that the quality of ultrasound images is operator-dependent. Therefore, we ensured that trained otolaryngology residents performed scans and were blindly evaluated by two senior physicians, one of whom was a radiologist. The high interobserver agreement between the senior physicians indicates that ultrasound can be implemented easily following adequate training. Moreover, since ultrasound is readily available in almost every emergency room, its use can be easily integrated into the standard protocol for managing nasal fractures in children.

The use of ultrasound in everyday clinical practice, particularly in pediatrics, is increasingly prominent [25]. With its prevalence in emergency rooms, ultrasound can be seamlessly integrated as the final component of the physical examination, requiring no more than 1-2 additional minutes to perform the exam. This efficiency makes it a convenient and time-effective tool for assessing nasal fractures. Additionally, ultrasound equipment is commonly available in operating rooms and clinics, allowing for quick confirmation of nasal alignment using ultrasound with only a few moments of examination.

We acknowledge the limitations of this study. Firstly, our sample size was relatively small, which may limit the generalizability of our findings. Secondly, the scans were performed by otolaryngology residents rather than radiologists, which may have led to suboptimal image quality and interpretation. Thirdly, we did not classify the fractures according to anatomic location, which could be important in determining the optimal treatment approach. Fourthly, we did not document photos of nasal bones before and after closed reduction, and the reductions were performed within a limited, non-randomized cohort. However, the success of closed reduction was determined based on the blinded and independent evaluations of both the patient (or parent) and another otolaryngologist, who remained unaware of the ultrasound scans. Lastly, we used a 7-12 MHz linear transducer, which may have limited sensitivity for detecting minor fractures.

## Conclusion

Ultrasound can be a valuable tool in cases where children present with a swollen nose and the physical examination alone is insufficient to confirm the presence of a nasal fracture. Our study showed that ultrasound has a high negative predictive value for fractures, allowing physicians to confidently discharge children without fractures and avoid unnecessary follow-up visits. Furthermore, our findings provide robust support for the effectiveness of ultrasound-guided closed reduction, consistently leading to satisfactory outcomes. Nevertheless, to strengthen the evidence and ensure broader applicability, further larger-scale randomized studies are essential to validate our results.

## Clinical trial

The study was registered with the Israeli Clinical Trial Registry (MOH_2021-11-16_010404).

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## Authorship contribution

RN, design, data collection, statistical analysis, drafting the manuscript; NG, design, data collection; AI, data analysis, drafting the manuscript; NN, data analysis, drafting the manuscript; AG, design, drafting of the manuscript. The authors have no relevant financial or nonfinancial interests to disclose.

## Conflict of interest

The authors declare no potential conflicts of interest.

## Ethics approval

This study was approved by the Institutional Review Board of the Rambam Health Care Campus (RMB 0401-2021).
Written informed consent for publication was obtained from all patients.

## Data sharing and reproducibility

Data generated/analyzed in this study will be made available to researchers upon reasonable request to the corresponding author.

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Roee Noy, M.D.
Department of Otolaryngology
Head and Neck Surgery
Rambam Health Care Campus
Technion – Israel Institute of Technology
8 Ha'Aliya Street
Haifa
Israel 3109601

Tel: +972-54-998-2920
Fax: +972-4-777-2772
E-mail: roeenoy@gmail.com
ORCID: 0000-0002-7333-6854