Pesquisa Brasileira em Odontopediatria e Clínica Integrada 2019; 19:e4832
DOI: http://doi.org/10.4034/PBOCI.2019.191.133
ISSN 1519-0501

ORIGINAL ARTICLE

Diagnostic Accuracy of Ultrasonography in the Assessment of Facial Fractures

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Academic Editors: Alessandro Leite Cavalcanti and Wilton Wilney Nascimento Padilha

Received: 19 April 2019 / Accepted: 15 August 2019 / Published: 30 August 2019

Abstract

Objective: To assess the diagnostic accuracy of Ultrasonography (USG) in diagnosing superficial facial fractures. **Material and Methods:** Patients visiting our facility with facial trauma and suspected fracture of the facial skeleton, those who had undergone CT scans, and conventional radiographic examinations and those who were conscious and cooperative were included in the study. All conventional radiographs, CT scans and ultrasound examinations were done during 0-20 days after trauma in all the patients. **Results:** A total of 20 patients participated in our study, out of which 18 were male (90%) with a mean age of 34.4 years (range of 19-75 years). Eleven sites of the face were examined bilaterally in each patient, i.e., a total of 440 sites. Of these, 84 sites were found to be fractured according to the CT scan examination whereas conventional radiographs detected 59 and ultrasonography detected 74 fractures (of which 70 were true fractures, while 4 were false-positive results). The sensitivity and specificity of USG in all fracture sites were 83.33% and 98.88% respectively. The positive and negative predictive values were 94.59% and 96.17% respectively. **Conclusion:** Ultrasound examination had a better sensitivity when compared to conventional radiography in detecting superficial facial fractures.

Keywords: Tomography, X-Ray Computed; Facial Injuries; Sensitivity and Specificity.

Introduction

Conventional assessment of facial injury involves a structured approach, including history, inspection, palpation, percussion, and auscultation [1]. Only clinical diagnosis without radiographic examination would be inaccurate, especially in cases with fracture lines distal to the dentition, which require radio-diagnosis [2].

The use of conventional radiographs is the preliminary step in the diagnosis of facial fractures. They help in understanding the type, location, magnitude, and displacement of fractures [3]. However, due to the complexity and superimposition of facial structures, conventional radiographs are steadily being replaced by more specialized imaging modalities such as computed tomography (CT) scans and cone-beam CT (CBCT) scans. Some drawbacks to these techniques were fear of radiation exposure among the patients, compliance in maintaining steady position especially in children, expensive equipment and lack of availability of the equipment and they might prove fatal when there is a delay in extricating the patient from the CT machine [1]. Hence, there is a constant endeavour from the part of clinicians to limit the use of such imaging modalities. One such advent is the use of ultrasonography in the assessment of facial fractures.

Ultrasound imaging or Ultrasonography (USG) in the head and neck region is mainly recommended for the identification of pathological alterations related to soft tissues [2]. Traditionally it has been used in the detection of soft tissue lesions, assessment of salivary glands and orbital and ocular diagnosis, but its role in maxillofacial trauma is less widely recognized and has been reported previously [3].

Previous studies developed with ultrasonography showed 85% accuracy in diagnosing fractures of the zygomatico-orbital complex (ZMC) [1,4]. Other authors have proposed that USG is useful in the visualization of the zygomatic arch and the anterior wall of the frontal sinus [5]. However, due to the inability of ultrasound to penetrate deeper bony structures, its use is currently restricted to the assessment of superficial facial fractures. Diagnosis of midfacial fractures with USG has been reported to be successful in regions like orbit [6,7], zygomatic arch [8,9], and nasal bone [10-12]. It is also very useful for intraoperative examination of the reduction of fractures to attain adequate repositioning of fractured segments [13,14]. A systematic review concluded its usefulness in the diagnosis of fractures concerning nasal bone, orbital walls, anterior maxillary wall and zygomatic complex [15].

The most important advantage of using with USG is that there is no radiation exposure to patients and hence can be used safely in pregnant women and small children. Many times, due to its relatively less expense and ease of availability, USG may be a more feasible option when compared to CT scans in the assessment of superficial facial fractures. Given the above facts, this study aimed to assess the accuracy of USG in the diagnosis of superficial facial fractures when compared to conventional radiographs and CT scans.

Material and Methods

Study Design and Sample

We conducted this comparative study at the Department of Oral Medicine and Radiology, Manipal College of Dental Sciences, Manipal, in collaboration with the Department of Radio-diagnosis and Imaging, Kasturba Medical College, Manipal.

We estimated the sample size, and it accounted to be a minimum of 277 with expected sensitivity of 90%, precision of 0.05 with a 95% confidence interval using a nomogram. Our study took the fracture site as the computational unit for analysis, and each patient was screened for 11 sites bilaterally (22 sites per patient). This accounts to be 13 patients. However, we have recruited a total of 20 patients to get a broad spectrum of fractures, which accounted for 440 sites.

Data Collection

Patients visiting our facility with facial trauma and suspected fracture of the facial skeleton, those who had undergone CT scans and conventional radiographic examinations, and those who were conscious and cooperative were included in the study. Facial trauma is mostly accompanied by varying degrees of symptoms. In this study, the subjects were chosen for the study during 0-20 days after trauma. This duration was chosen because many patients in our hospital have been referred from other hospitals due to which there was a delay in presentation. Many symptoms related to soft tissues were resolved in many patients who reported late to the hospital. Only subjects where there was no such difficulty in placing the transducer were recruited. Subjects with complex fractures and severe soft tissue lacerations, edema, abrasions, and dressings were not included in this study due to ethical reasons. Although the USG is a non-invasive procedure, the manipulation with transducer would induce pain and discomfort due to which they have not been approached for participation in this study.

The protocol for radiological assessment that is followed for all patients with facial fractures was to subject them to conventional radiographs as well as CT scans, prior to surgical treatment. Patient's demographic details were collected by a single examiner including name, age, gender, occupation, address, and hospital number, along with details of the trauma, such as date and time of trauma, cause of injury and preliminary treatment rendered after trauma. Basic clinical examination was also performed for each patient by the same examiner, and relevant findings of the extraoral and intraoral examinations were recorded in a proforma.

The conventional radiographs were performed by standard techniques using GE Wipro Genius 60 - for Submentovertex and Water's views (Wipro GE Healthcare Pvt. Ltd., Mumbai, India) and Proline Planmeca PM 2002 CC - for panoramic views (Planmeca OY, Helsinki, Finland). Two radiologists interpreted the radiographs and came to a conclusion regarding the diagnosis after discussion. The types of conventional radiographs used were the Submentovertex view, Water's view, and a panoramic view.

The CT scans were performed using a multidetector Brilliance 64 slice CT scanner (Koninklijke Philips N.V., Amsterdam, Netherlands). The scans were interpreted by a single experienced radiologist. The results of the CT scan were considered as the gold standard against which other comparisons were made.

All USG examinations were carried out using a GE- 730 Expert or a Philips IU22 USG machine (Koninklijke Philips N.V., Amsterdam, Netherlands). The type of transducer used was a linear extraoral transducer (hockey stick type) using frequencies between 7-15 MHz. During the examination, the patient was seated in an upright position, facing the sonologist. After the application of a sterile gel, the transducer was placed over the site to be examined. The working definition of fracture was taken as reported previously viz., "any interruption in the continuity of the radiopaque line of the bony contour, including displacement or depression" [3].

All ultrasound examinations were performed and interpreted by a single experienced examiner, who was unaware of the results of the conventional radiographs and CT scans.

Digitized images of all the conventional radiographs, images of the CT scans and ultrasound examinations, including photographs of the ultrasonography procedures, were collected and stored for future reference.

Statistical Analysis

The sensitivity, specificity, positive predictive values, and negative predictive values were calculated for USG and conventional radiographs using a CT scan as a gold standard. The results of the USG were then compared with that of the conventional radiographs for these values.

Ethical Aspects

Permission to conduct the study was obtained from the respective departments, and approval from the Institutional Ethical Committee, Kasturba Hospital, was sought prior to the study. Informed consent was obtained from all individual participants included in the study.

Results

A total of 20 patients participated in our study, out of which 18 were male (90%). The mean age was 34.4 years (range of 19-75 years). In the majority of cases, the cause of injury was road traffic accidents (90%), followed by fall (10%). The average time taken for the USG examination of all sites per patient was approximately 15-20 minutes, with < 1 minute taken for each site. None of the patients reported any pain or discomfort during the USG examination. In the case of conventional radiographs, the time taken for each radiograph was approximately 20 minutes, including the time for processing, and an average of 30-40 minutes was utilized for each CT scan.

Eleven sites of the face were examined bilaterally in each patient, i.e., a total of 440 sites. Of these, 84 sites were found to be fractured according to the CT scan examination, and this was considered as the gold standard. The conventional radiographs detected 59 of the 84 fractures correctly. Similarly, ultrasonography detected 74 fractures in these 440 sites, of which 70 were true fractures, while 4 were false-positive results (Table 1).

Table 1. Distribution of fractures detected by each modality at each site.

Sites Examined	CT Scan Gold standard	Radiographs (TP+FP)	USG (TP+FP)	Sensitivity†	Specificity†
Zygomatic Arch	12	12 (12+0)	12 (12+0)	100%	100%
Fronto-Zygomatic Process	9	0 (0+0)	3 (3+0)	33.33%	100%
Zygomatic Bone	4	1 (1+0)	2 (2+0)	50%	100%
Anterior Wall of Frontal Sinus	4	0 (0+0)	4 (4+0)	100%	100%
Anterior/Lateral Wall of Maxillary Sinus	18	14 (14+0)	16 (16+0)	88.89%	100%
Infraorbital Margin	19	17 (17+0)	19 (19+0)	100%	100%
Supraorbital Margin	2	2 (2+0)	5 (2+3)	100%	92.10%
Orbital Floor	3	0 (0+0)	0 (0+0)	0%	100%
Symphysis/ Parasymphysis	7	7 (7+0)	7 (7+0)	100%	100%
Angle	1	1 (1+0)	2 (1+1)	100%	97.43%
Condyle/Subcondyle	5	5 (5+0)	4 (4+0)	80%	100%

TP- True Positive; FP- False Positive; †Sensitivity and Specificity values for USG

USG was able to detect all the fractures at certain sites viz., the zygomatic arch, the anterior wall of the frontal sinus, infraorbital margin, supraorbital margin, mandibular symphysis/parasymphysis, and mandibular angle. Similarly, conventional radiographs were able to detect all the fractures at the zygomatic arch correctly, supraorbital margin, mandibular symphysis/parasymphysis, mandibular angle, and mandibular condyle/subcondyle. However, neither ultrasonography nor conventional radiography was able to identify any of the fractures on the orbital floor.

The sensitivity and specificity of USG in all fracture sites were 83.33% and 98.88% respectively. The positive and negative predictive values were 94.59% and 96.17% respectively. The sensitivity, specificity, positive and negative predictive values were also calculated for the detection of fractures at all sites using conventional radiography when compared to CT scan, which showed values of 70.24%, 100%, 100% and 93.44% respectively (Table 2).

Table 2. Comparison of CT scan with USG and conventional radiography.

Method		CT Scan (Gold Standard)		Sensitivity	Specificity
		Fracture	No Fracture		
USG	Fracture	70 (TP)	4 (FP)	83.33%	98.88%
	No Fracture	14 (FN)	352 (TN)		
Conventional Radiography	Fracture	59 (TP)	0 (FP)	70.24%	100%
	No Fracture	25 (FN)	356 (TN)		

TP- True Positive, FP- False Positive, TN – True Negative, FN – False Negative

Thus it was found that ultrasound examination had a better sensitivity when compared to conventional radiography in detecting superficial facial fractures. Similarly, the negative predictive value was also slightly better for an ultrasound examination. However, the specificity and the positive predictive value for conventional radiographs were better than for the ultrasound examination.

Discussion

Fractures of the face can occur at multiple sites, and varying patterns may occur alone or in combination with other serious injuries. However, identifying the regions of involvement can result in effective and timely patient management.

There are some inherent disadvantages of CT scan, such as the patient's exposure to a high dose of radiation and the potential risk of developing cataracts limit its use in many patients, such as pregnant women and children [3]. It is also too expensive and time-consuming to use in isolated simple fractures [3]. This has led to the search for newer or better imaging techniques which may replace, or at least reduce the use of, such as ionizing imaging modalities.

In contrast, there are several advantages to using USG, such as "no radiation exposure, inexpensive, non-invasive, portable, readily available and fast, but has to be performed by experienced investigators". Considering the advantages, USG can be a potential alternative to conventional radiography [5]. Although not a common modality in trauma imaging, its ability to non-invasively diagnose the facial fractures has been previously reported and is increasingly being well recognized. Moreover, it can be used repeatedly and even has considerable bedside potential. Ultrasonography can also demonstrate the various phases of fracture healing and hence is vital for diagnosis and follow up.

Ultrasound, however, cannot penetrate deeper bony structures, and hence, its use is currently restricted to the evaluation of superficial facial structures. Although the resolution can be increased with high-frequency applicators, principle limitations still exist [5].

Of the total 440 sites examined, 84 sites were found to be fractured according to the gold standard CT scan examination. When compared to CT scan, USG evaluation of all fracture sites together showed a sensitivity of 83.33% and a specificity of 98.88% in our study. The positive and negative predictive values were 94.59% and 96.17% respectively. Although no exact similar study was found which evaluated all such fracture sites simultaneously, these values were similar to other studies that utilized ultrasonography in the detection of facial fractures. An earlier study reported that ultrasound could be used with 85% accuracy, but the sensitivity, the specificity, and the positive predictive value vary at different sites [1]. When taking each site into account separately, we found that the sensitivity and specificity of ultrasonography, when compared to CT scan, were 100% for the zygomatic arch, anterior wall of the frontal sinus, infraorbital margin and the mandibular symphysis/parasymphysis regions in the present study. This indicated that there were no false positive or false negative values at these sites. But, it has been shown that ultrasound was most reliable at the lateral wall of the maxillary sinus, where sensitivity was 94%, and specificity was 100% [1]. In our study, the anterior/lateral wall of the maxillary sinus showed a sensitivity of 88.89% and a specificity of 100%.

Some authors have been able to correctly diagnose fractures of the orbito-zygomatic complex, zygomatic arch, medial orbital wall, nasal bone, frontal sinus, and complex Le-Fort-fractures using ultrasonography [5]. However, isolated fractures of the orbital floor could not be identified and concluded that ultrasound in midfacial fractures was most useful for visualization of the zygomatic arch and the anterior wall of the frontal sinus [3]. But the most important deficiency of ultrasound was the difficulty in the detection of non-dislocated fractures. In our study, we were able to detect both dislocated and non-dislocated fractures using ultrasound. However, of the 14 fractures that were not detected in our study, 7 (50%) were non-dislocated fractures.

Of the 84 sites of fracture detected on the CT images, ultrasonography gave 14 false-negative results in our study. The majority of these were at the fronto-zygomatic process (6 of 14, 42.86%), followed by the orbital floor and the anterior/lateral wall of the maxillary sinus (2 of 14 in each; 14.26%). Hence, the sensitivity of ultrasonography at the fronto-zygomatic suture was only 33.33%. The reason for the inability of ultrasound to accurately detect a fracture of the fronto-zygomatic process has not been discussed in previous studies. One possibility could be the assumption that a minute undisplaced fracture of the fronto-zygomatic process was the fronto-zygomatic suture and hence not considered as a fracture line.

Ultrasonography gave four false-positive results; three of these were at the supraorbital margin (75%), thus giving a specificity of 92.10% at this site. Again, the supraorbital margin alone has not been evaluated using ultrasound in other studies, and no specific reason was found for the false-positive values given by ultrasonography at this particular site.

In a previous study using USG for the detection of the orbital floor fracture, the authors reported an overall accuracy of 86% and a sensitivity of 85% [7]. However, in the present study, ultrasonography was unable to detect any of the orbital floor fractures. Previous studies have used a 7.5 MHz curvilinear array endocavity ultrasound probe [7] and 7.5 MHz curved-array scanner [6]. They reported its ease of examination of the orbital floor [7] and as a more helpful diagnostic tool [6]. Hence, it was possible that the difference in the type of probe used may have caused the discrepancy in the results.

In the case of mandibular fractures, ultrasonography was able to correctly detect fractures at the mandibular symphysis/parasymphysis with a sensitivity and specificity of 100%. There was one false-positive observation at the mandibular angle, thus giving a specificity of 97.43% at this site and one false-negative at the mandibular condyle region, thus giving a sensitivity of 80% at the site. The false-negative value at the mandibular condyle was an undisplaced fracture of the condylar neck, which was possibly the reason why ultrasonography could not detect the fracture line. Previous study reported that USG diagnosis of fractures of the mandibular ramus and condyle with a sensitivity of 66% and specificity of 52% and concluded that the main disadvantage of ultrasonography was its inability to identify non-dislocated fractures of the mandible, as was seen in our study [2].

The literature shows that conventional radiographs missed several fractures that were detected only during operation [1]. In our study also, conventional radiographs were found to have a sensitivity of only 70.24% when compared to CT scan, with a false negative value of 25 out of 84. Of these 25 sites, 9 (36%) were again at the fronto-zygomatic process, followed by the anterior wall of the frontal sinus (4, 16%) and the anterior/lateral wall of the maxillary sinus (4, 16%). The conventional radiographs, however, did not give any false-positive values in our study, thus giving a specificity of 100%.

Hence from our study, we could infer that ultrasound examination had a better sensitivity when compared to conventional radiography in detecting superficial facial fractures. Similarly, the negative predictive value was also slightly better for an ultrasound examination. We found that overall, ultrasound examination had similar efficacy in detecting fractures of the midface and mandible, except for undisplaced mandibular condyle/subcondyle fractures. It was particularly beneficial at certain sites such as the zygomatic arch, anterior wall of the frontal sinus, infraorbital margin, supraorbital margin, mandibular symphysis/parasymphysis and mandibular angle where all the fractures at these sites were correctly detected. Unfortunately, neither ultrasonography nor conventional radiographs were able to detect any of the orbital floor fractures, suggesting that CT scan may be needed to confirm a fracture at this particular site.

USG can be a useful tool in the management of zygomatic complex fracture [13] and in evaluating fracture healing [16]. Hence, future studies should assess the applicability of USG in intra-operative assistance in the closed reduction of facial fractures along with monitoring remodeling and healing of fractures. Further studies utilizing ultrasonography to measure the approximate space between fractured segments in particular for non-dislocated fractures, and the space between sutures of the facial skeleton, such as the fronto-zygomatic suture, so as to standardize these values and may help in fine-tuning the ultrasound examination of facial fractures, thus making it more reliable and valid in the accurate diagnosis of facial fractures.

Conventional radiographs and imaging modalities would help in treatment planning. Since this study aimed at the diagnostic accuracy of USG with other imaging modalities, we could not evaluate aspects of treatment planning. Also, in our study, we have included those patients who do not have complex fractures and soft tissue injuries. The examiner who performed USG examinations was able to interpret the fracture patterns and communicate with the surgeon. This was a preliminary study of the USG ability to diagnose superficial facial fractures. Newer software applications might develop in the future for the applicability of USG in treatment planning.

Conclusion

Ultrasonography can be a useful, diagnostic, adjunctive, non-invasive and economical tool in the detection of superficial facial fractures and has better sensitivity when compared to conventional radiography.

Authors' Contributions: AR and KMP, conceived the idea, designed the study, and initial draft of the manuscript. ARKS, SG, RK and ATK performed data acquisition, data interpretation, literature review and final draft of the manuscript. KCP performed the study design, data analysis, interpretation and final draft of the manuscript. All authors declare that they contributed to the critical review of intellectual content and approval of the final version to be published.

Financial Support: None.

Conflict of Interest: The authors declare no conflicts of interest.

Acknowledgements: We thank all the participants for their co-operation during the study.

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