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Application of digital tomosynthesis in diagnosing the fractures or dislocations in irregular bones and regions with complex structures

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ABSTRACT

Objective: The application potential of digital tomosynthesis in diagnosing fractures or dislocations in irregular bones and regions with complex structures was evaluated.
Methods: Digital radiography and tomosynthesis were performed in 121 patients, and the image quality, accuracy, sensitivity, and specificity were compared.
Results: The number of participants with a definite diagnosis of fracture and/or dislocation was 98. The ratio of excellent images, accuracy, sensitivity, and specificity of digital tomosynthesis were higher than that of direct radiography.
Conclusion: Digital tomosynthesis could be applied in the diagnosis of fractures or dislocations in irregular bones and regions with complex structures.

1. Introduction

Digital radiography (DR) is the preferred examination for bone trauma. However, its image often generates superimpositions and artifacts, which may lead to false-negative or false-positive results especially in the fractures or dislocations in irregular bones and regions with complex structures. As a three-dimensional imaging technology, digital tomosynthesis (DTS) makes an improvement in conventional geometric tomography [1,2]. It permits an arbitrary number of in-focus planes to be generated retrospectively from a sequence of projection radiographs, and specific planes may be then reconstructed by shifting and adding these projection radiographs [3,4]. Therefore, it can reduce the residual blur from out-of-plane structures and provide better visualization. Nowadays, DTS is mainly applied in the examination of breast and chest [5,6], and the application is rare in bone wound [7].

We report the results of DTS in 121 patients with suspected fractures or dislocations in irregular bones and regions with complex structures and evaluate the image quality and diagnosis index of DTS by comparing with DR. The aim was to learn more about the application potential of the technology in diagnosing the fractures or dislocations in irregular bones and regions with complex structures.

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2. Materials and methods

2.1. Participants

The study enrolled 121 consecutive patients (68 male and 54 female) with suspected fractures or dislocations in irregular bones and regions with complex structures. The participants included 39 outpatients and 82 emergency patients. Among them, 63 patients suffered falls, 41 patients suffered traffic accidents, and 18 patients suffered strikes. The age range was 13–58 years [mean, 35.5±8.74; (SD), years]. The examination locations included the nasal bone (12 patients), maxilla (6 patients), orbit (4 patients), cervical vertebra (16 patients including 13 cases of atlanto-axial joint), thoracic and lumbar vertebra (9 patients), pelvis and sacrococcygeal vertebra (18 patients), clavicle (4 patients), sternum (2 patients), rib (10 patients), shoulder joint (6 patients), knee joint (9 patients), foot and ankle joint (13 patients), and hand and wrist joint (12 patients).

2.2. Examination methods

DR was performed with Ysio (Siemens, Germany), and DTS was performed with Sonialvision Satire II (Shimadzu, Japan). DR was first performed in all the participants, and DTS was then performed after obtaining the informed consent. The exposure conditions of DR were determined according to different locations and body thickness. DTS was performed using the procedure of TOMOS, the distance was 1100 mm between the X-ray tube and flat panel detector, and the exposure conditions were determined according to the thickness of different

Table 1
Comparison of image quality between DR and DTS

Images of DTS	Images of DR		Total
	Excellent	Acceptable and inadequate	
Excellent	78	36	114
Acceptable and inadequate	0	7	7
Total	78	43	121

locations. The exposure conditions were 70–100 kV and l.25 mAs for the axial and sagittal scanning of the nasal bone; 70–100 kV and l.25 mAs for the coronal scanning of the maxilla and orbit; 70–90 kV and 1.25 mAs for the coronal scanning of the cervical vertebra, and 60–90 kV and 1.25 mAs for the sagittal scanning; 95–130 kV and 1.25 mAs for the coronal scanning of the thoracic vertebra, and 100–130 kV and 1.25 mAs for the sagittal scanning; 90–120 kV and 1.0 mAs for the coronal scanning of the lumbar vertebra, and 100–130 kV and 1.0 mAs for the sagittal scanning; 80–90 kV and 2.50 mAs for the coronal scanning of the pelvis; 90–120 kV and 1.0 mAs for the sagittal scanning of the sacrococcygeal vertebra; 100–120 kV and 0.50 mAs for the coronal scanning of the clavicle and sternum; 100–120 kV and 0.50 mAs for the coronal scanning of the rib; 75–80 kV and 1.25 mAs for the coronal scanning of the shoulder joint; 65–70 kV and 1.25 mAs for the coronal and sagittal scanning of the knee joint; 50–55 kV and 1.25 mAs for the coronal and sagittal scanning of the foot joint; 55–60 kV and 1.25 mAs for the coronal scanning of the ankle joint; 45–50 kV and 1.25 mAs for the coronal scanning of the hand joint; and 45–50 kV and 1.25 mAs for the coronal and sagittal scanning of the wrist joint. The X-ray tube moved in a 40° arc. The slice separation of image reconstruction was 1.0 mm for the nasal bone, 3 mm for the maxilla and orbit, 2 mm for the cervical vertebra, 3 mm for the thoracic vertebra, 2 mm for the lumbar vertebra, 2 mm for the pelvis, 1.5 mm for the sacrococcygeal vertebra, 2 mm for the clavicle and sternum, 5 mm for the rib, 1.5 mm for the shoulder joint, 1.5 mm for the knee joint, 1.0 mm for the foot joint, 1.5 mm for the ankle joint, 1.0 mm for the hand joint, and 1.0 mm for the wrist joint.

Ethical permission was obtained from the ethical committee of the hospital, and informed consent was conducted in all the participants.

2.3. Reading and evaluating image

Two associate chief physicians, engaging in the imaging diagnosis of fractures and dislocations for more than 10 years, were asked to simultaneously read the images of DR and DTS. Image quality was evaluated, and diagnostic result (fracture or dislocation) was decided. The two radiologists should be in agreement after discussion if they had different opinions on image quality and diagnostic result. An excellent image should include complete anatomic structure, good contrast, and clear bone trabeculae and cortical bone in the target location; an acceptable image should include acceptable contrast of anatomic structure and acceptable visualization of bone trabecular and cortical bone in the target location; and an inadequate image should include incomplete anatomic structure and/or poor contrast and resolution, or extracorporeal artifacts in the target location.

2.4. Gold standard for definitive diagnosis

The fractures or dislocations in irregular bones and regions with complex structures could not be completely determined only by DR and/or DTS. Therefore, a definitive diagnosis still required to refer to the results of clinical follow-up and review.

2.5. Statistical analysis

The image quality, accuracy, sensitivity, and specificity between DR and DTS were compared with chi-square test. The statistical analysis was performed with the Statistical Product and Service Solutions (SPSS) version 17.0. Significance was set at $P<.05$.

3. Results

3.1. Image quality of DR and DTS

The ratio of excellent images was 94.2% for DTS, and the ratio of excellent images was 64.5% for DR (shown in Table 1), and the difference was significant ($\chi^2=32.670$, $P=.000$).

3.2. Diagnostic results

After clinical follow-up, the number of participants with a definite diagnosis of fracture and/or dislocation was 98 (including 11 cases of dislocation) among 121 participants. The locations included the odontoid process (in 5 participants, shown in Fig. 1), atlanto-axial joint (in 9 participants with dislocation), nasal bone (in 9 participants), maxilla (in 7 participants), clavicle (in 4 participants), sternum (in 2

A.1 A.2

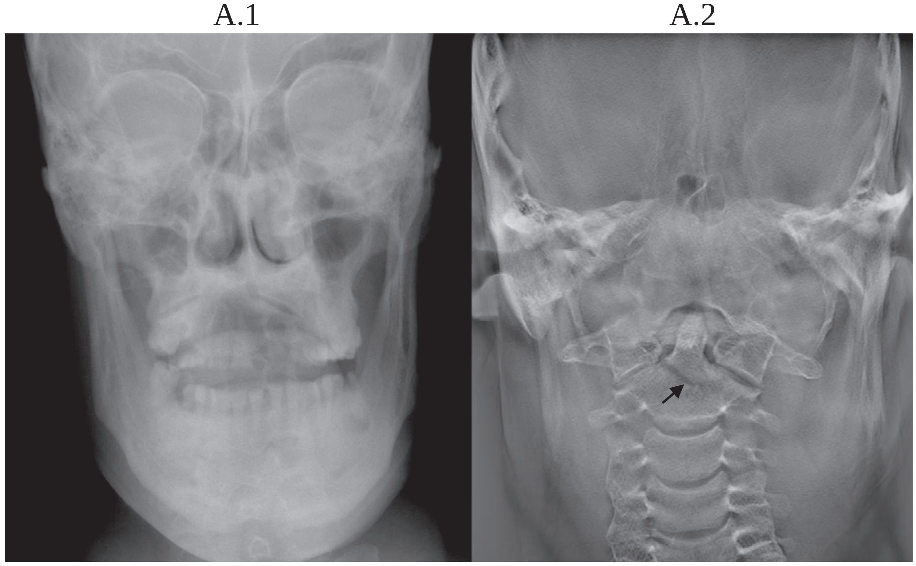

Fig. 1. A 37-year-old man with the axis fractures and complicated with atlanto-axial subluxation. (A.1) DR image: the patient could not open the mouth, and the result was negative; (A.2) DTS image: the fracture line could be seen in the basilar part of the atlanto-axial joint, and the gap of the atlanto-axial joint was wider in the right side than in the left side (as indicated by the arrow).