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THREE-DIMENSIONAL CT VOLUME RENDERING TECHNIQUE - ORTHOPEDIST'S "SECOND IMAGINATION"

Bone fractures in children's traumas are enormous problem not only from psychological point of view but in these cases the diagnostic issue is much more relevant. The correct diagnosis leads to proper treatment and reduces the risk of adverse effects. For this reason, plain radiography is not the only step in diagnostic procedure and is often combined with Computed Tomography (CT) and sometimes with Magnetic Resonance (MR). The aim of the study was to assess a contribution of three dimensional volume rendering (3D VRT) images on the diagnosis and the possible qualification to the surgical treatment. The study was performed on 21 patients (12 boys, 9 girls) hospitalized at Pediatric Surgery Department in Sosnowiec from January 2007 to April 2008. All of the patients underwent plain radiography as the first diagnostic step and had CT as an additional imaging procedure. A total number of fractures were 28 vs. 32, respectively diagnosed on X-ray and CT scans. The necessity of surgical reposition was present in 8 patients. Spiral CT and its postprocessing technique 3D VRT play major role in musculoskeletal trauma. They bring particular importance in fracture detailed estimating and any multiorgan injuries. However, the need of performing CT should be limited to uncertain cases and before operation planning because of higher radiation dose.

1. BACKGROUND

Childhood is a period of common and multiple injuries – contusions, dislocations and bone fractures. All of them are caused by children's increased activity combined with lack of imagination and caution. Trauma is the most common cause of mortality and morbidity in the US pediatric population. Each year, approximately 20,000 children and teenagers die as a result of injury. An estimated 50,000 children acquire permanent disabilities each year. Death from unintentional injury accounts for 65% of all injury deaths in children younger than 19 years. Approximately 30-45% of children with trauma have multiple injuries and at least 1 skeletal fracture [4]. The equivalent data in Polish pediatric population are not complete and underestimated. Every year, approximately 1,500 children and teenagers younger than 19 years die as a result of injury what accounts for almost 30% of all deaths in that age group [6]. The imaging of these injuries typically begins with plain radiography and in some cases further diagnostic evaluation is needed. The methods of second choice include multidetector-row computed tomography (MDCT) and Magnetic Resonance (MR). The advantages of MDCT include performing 2-dimensional (2D) and 3-dimensional (3D) reconstructions in traditional and nontraditional views, rapid scanning and precise images reduce the need of performing additional examinations, thereby decreasing patient radiation exposure [2]. MR allows for excellent evaluation of cartilage, bone marrow, ligaments, tendons and surrounding soft tissues [5]. The correct diagnosis leads to proper treatment and reduces the risk of adverse effects. Therefore, that adequate radiological imaging should be performed according to clinical indications and contraindications.

2. MATERIALS AND METHODS

The study was performed on patients hospitalized as a result of injury at Pediatric Surgery Department in Sosnowiec from January 2007 to April 2008. The entry criteria to the study group (age of patient 0-18 years, performed double diagnostic imaging: plain radiography of injured bones and then CT) met 21 patients (12 boys, 9 girls). A mean age was 11,7 years (4-18). On the basis of plain radiography and CT (especially 3D VRT reconstruction) the place (distribution), morphology (type, displacement) of fractures and soft tissue changes were evaluated. The study was performed in the Radiology Department at the Pediatrics Centre in Sosnowiec. X-ray studies were taken using Siemens Axiom Iconos MD and CT scans using 16-slices Siemens Somatom Emotion 6 scanner with 1 mm collimation and pitch 0,85 (for upper and lower extremities) and 2 mm collimation and pitch 1,5 (for the pelvis). The examinations were processed on Siemens Sienet Sky (for the X-ray studies) and Siemens Leonardo (for the CT scans) workstations. Each X-ray study was assessed on anteroposterior and lateral views and CT images were assessed on transverse, sagittal, coronal and postprocessed reconstructed (multiplanar reconstruction – MPR and 3D VRT) scans.

A fracture was defined as a break in anatomical continuity of a bone (Fig.1) and on that basis a comparison between plain radiography (Fig.1 A, B) and 3D VRT CT (Fig.1 C) was evaluated. Simplifying, all the pathological changes visible on imaging studies were divided into two groups: changes diagnosed on X-ray studies (group A) and on CT examinations (group B).

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Fig.1 Six years old male patient. A,B- plain radiography shows oval shade (arrow) made of two displaced structures: capitulum of the humerus and lateral humeral epicondylus; C- 3D VRT clearly shows separated fragments of the humeral bone

3. RESULTS

A total number of fractures were 28 vs. 32 (respectively, group A vs. group B) but anatomical determination of fracture was possible in 23 vs.32 cases, respectively X-ray vs. CT. Fractures per patient ratio was estimated at 1,5. The proper localization of fracture on CT scans did not cause serious problems in contrary to X-ray studies where in several cases (n=5) intermediate fragments were only seen with no precise location of injured bone what gives only suspicion of the fracture. So that observed distribution of fractures involving upper extremity were respectively (group A vs. group B): humerus (8 vs. 10), radius (6 vs. 6), ulna (1 vs. 3), carpus (1 vs. 1), metacarpus (0 vs. 1); lower extremity: tibia (1 vs. 1), tarsal bones (1 vs. 2); pelvis (6 vs. 8). The differences and similarities of X-ray and CT in diagnosing fractures distribution are shown in Table 1.

Table 1. Anatomical distribution and number of fractures diagnosed using X-ray and CT

Localization of bone fracture	**X-ray**	**CT**
Upper extremity		
Humerus		
- proximal epiphysis	1	1
- distal epiphysis	1	1
- medial epicondyle	2	4
- lateral epicondyle	3	3
- capitulum	1	1
Radius		
- head	5	5
- proximal epiphysis	1	1
Ulna		
- olecranon	1	1
- coronoideal process	0	2
Carpus		
- hamate bone	1	1
Metacarpus		
- IVth metacarpal bone (basis)	0	1
Lower extremity		
Tibia		
- distal epiphysis	1	1
Tarsus		
- talus	1	1
- navicular bone	0	1
Pelvis		
Pubic bone		
- superior ramus	2	2
- inferior ramus	2	2
- body	0	1
Ischium (body)	2	2
Sacral bone	0	1
Total	**23**	**32**

Table 2 shows morphology (type, displacement) of fractures. As it is demonstrated, fractures with displacement and non-displacement were noticed in 16 and 5 cases, respectively. Intra-articular displacement was diagnosed in 3 patients. Both, CT and X-ray, diagnosed intermediate fragments displacement in the same number of patients. CT and X-ray alike diagnosed intra-articular fractures in 5 patients. The situation was reversed when considered complex fractures. In all 21 patients complex fractures on CT scans were observed in 8 cases whereas X-ray studies showed them in 3 patients. None of soft tissue (ligaments, muscles) changes were found during radiological examination (excluding edema).

The necessity of surgical treatment of bone fracture was present in 8 patients.

Table 2. Morphology and number of fractures diagnosed using X-ray and CT

Fracture morphology	X-ray	CT
Displacement (total)	16	16
- *intra-articular (included)*	3	3
Complex fracture	3	8
Intra-articular fracture	5	5

4. DISCUSSION

Spiral CT has two major roles in pediatric musculoskeletal trauma: firstly to define or exclude an equivocal fracture on plain radiography studies, secondly to select which patient will need internal fixation. On the other hand, CT gives additional information about soft tissue abnormalities especially in anatomically complex areas such as pelvis.

In high amount of cases, the diagnosis of the fracture is based on plain radiography but CT with its VRT reconstruction should be complementary examination in clinical diagnosis difficulties. The indications to perform CT are rather individual and based on plain radiography results but sometimes CT should be a method of choice in multiorgan injuries, especially concerning pelvis, where time is priceless.

On the basis of our study data the CT with VRT was mostly performed to assess displaced intermediate fragments (amount, their position one to another, intra-articular displacement and compression of the vessels). CT also enabled proper pathological assessment in suspicion of intra-articular fractures, especially in inaccessible for plain radiography structures like tarsus and pelvis. Taking into consideration radiological examinations and every patient clinical data in 8 cases orthopedists decided to perform internal fixation of fractures.

The results from CT and X-ray were not statistically compared because of high heterogeneity and small number of cases in respective groups, such as fractures concerning ex. medial epicondyle of humerus or distal epiphysis of tibia.

It seems that CT more precisely diagnosed fractures and anatomical or pathological conditions what is connected with its three-dimensional imaging ability. A total number of fractures were 28 vs. 32 (respectively, group A vs. group B) but anatomical determination of fracture was possible in 23 vs. 32 cases, respectively X-ray vs. CT. Partially it is caused by the fact that during X-ray examination patient often lies in compulsory position making impossible to perform anteroposterior and lateral projections. That leads to false bones overlapping and makes the fracture diagnosis less precise. In contrary, CT can be performed in any comfortable position and acquired data can be reformatted into any plane of choice what makes the diagnosis easier [2]. Fractures per patient ratio was estimated at 1,5.

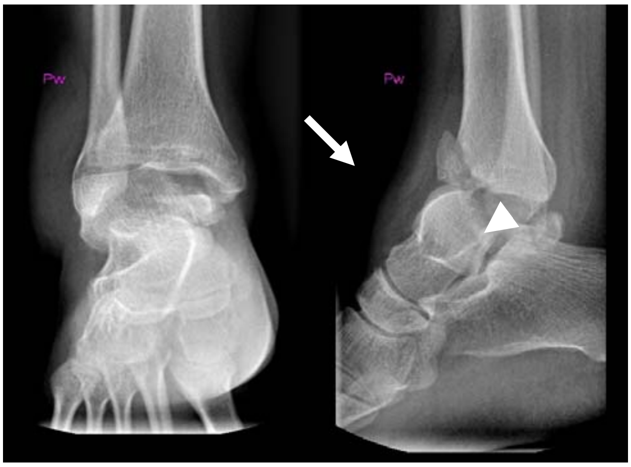

Fig.2 Sixteen years old female patient. Plain radiography (anteroposterior and lateral views) - on the lateral view two intermediate fragments probably separated from tibia (arrow) and talus (arrowhead).

Fig.3 The same patient as on Fig.2. Postprocessed CT scans (sagittal, coronal and 3D VRT) – referring to Fig.2 notice higher number of fissures and intermediate fragments concerning tibia and talus

This study results and results of other authors' studies [1,8] are not comparable due to differences in patient prequalification (ex. age, trauma mechanism) and complex nature of bone fractures. However the most common fracture diagnosed in our study was supracondylar fracture of the humerus – 30% of all cases (n=7) and Alburger et al. also reports that type of fracture to be most common [1].

When considering the displacement of intermediate fragments X-ray seems to have the same high diagnostic sensitivity as CT (16 vs. 16 cases). However, it can be only illusory statement because of heterogeneity of groups and in some cases plain radiography is not enough to make correct therapeutic decision. X-ray studies allow only 2-dimensional imaging with no chance of reformatting them and CT with its ability to follow slice by slice reformatted scans shows real pathologic conditions (Fig.2, Fig.3). Routine fractures of the ankle do not require CT. However, in complex intra-articular fractures of the distal tibia and tarsus (as in the case above), the added information provided by spiral CT and volume-rendered imaging may assist the clinician in triaging the patient to immediate surgery (Fig.4) or later, definitive arthroplasty [7,10].

Both CT and X-rays estimated correctly intra-articular fractures, what is probably connected with patient prequalification or lack of randomness and to verify this observation a study of more numerous group would be needed.

In detecting complex fractures CT is the method of choice. Plain radiography diagnosed only 3 cases of complex fractures whereas CT showed them in 8 patients. Obviously, it is related to the injured place because visualization of long bones such as humerus is similar in both examinations and anatomically complex regions such as pelvis or tarsus are inaccessible for plain radiography. Complex fractures can be better demonstrated with multiplanar and volume-rendered images, and complicated spatial information about the relative positions of fracture fragments (displacement, rotation) can be easily demonstrated to the orthopedic surgeons [9]. CT and its postprocessing techniques are often performed before surgical treatment planning. 3D VRT technique can demonstrate to the surgeon the proper direction of intermediate fragments and plan the way of fixation before surgery. In our study internal fixation of the fracture was present in 8 patients. The indications to the surgery are individual and based on overall clinical conditions.

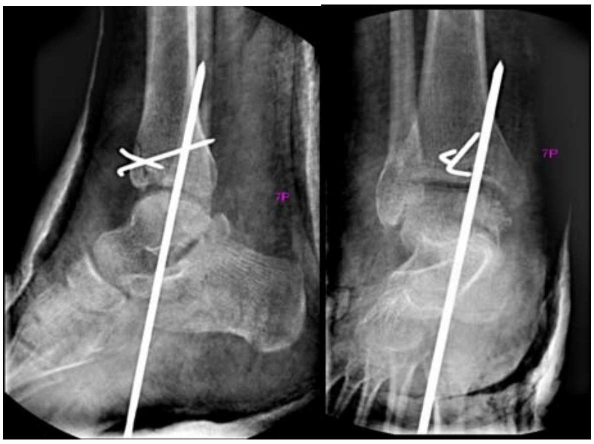

Fig.4 Sixteen years old female patient in a plaster of Paris after internal fixation of injured bones (compare with Fig.2 and Fig.3)

CT is a valuable diagnostic tool, however inappropriate use and unnecessary radiation dose may have a significant risk of cancer, especially in young children so it is important to limit radiation by following the ALARA (as low as reasonably achievable) principle. This strategy relates to performing only necessary examinations, limiting the region of coverage and adjusting individual CT settings based on indication, region imaged and size of a child [3]. Performing CT the need for sedation is nearly eliminated because most of the examinations take less than 10 seconds in contrary to MR where cooperation is required and sedation is more often. None of our patients needed sedation.

5. CONCLUSIONS

3D VRT imaging is a fast, non-invasive and accurate technique for diagnosis of musculoskeletal injuries. In trauma cases, subtle and complex fractures are better seen on VRT and MPR images and complicated spatial information about the relative positions of fracture fragments can be easily demonstrated to the orthopedic surgeons what may change the management in a significant number of cases. That is why 3D VRT may be sometimes called as orthopedist's "second imagination".

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