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ORIGINAL ARTICLE

The value of three-dimensional computed tomography reconstructions in diagnosis of shoulder injuries

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Abstract: The anatomical structure of shoulder articulation is complicated and therefore involves complex injuries which often appear in shoulder traumas which are difficult to diagnose precisely with the use of conventional radiograms. The aim of the study was to assess the clinical value of secondary spatial computed tomography (CT) reconstructions in diagnosis of shoulder injuries. The material consisted of 12 patients with shoulder traumas who had undergone CT examinations, supplemented with shaded surface display (SSD), and volume rendering technique (VRT) secondary spatial image reconstructions. It was concluded that three-dimensional (3D) shaded surface display and volume rendering technique spatial reconstructions broadened the diagnostic possibilities of axial computed tomography images, providing an assessment of shoulder structures in additional dimensions. This made possible the identification of free bone fragments, determination of their localization, and spatial relations of the injured bone fragments. Computed tomography examination supplemented with 3D reconstructions is a complementary method in the diagnosis of patients with complex shoulder fractures, especially in cases where the extent of the fracture fissures, as well as localization and place of origin of free bone fragments cannot be determined on a standard X-ray. Inclusion of CT examination with 3D reconstructions into the diagnostic algorithm in shoulder traumas increases significantly the precision of diagnostic imaging.

Key words: shoulder, computed tomography, three-dimensional computed tomography reconstructions, spiral computed tomography technique, fractures

INTRODUCTION

The anatomical structure of shoulder articulation is complicated and therefore involves complex injuries which often appear in shoulder traumas which are difficult to diagnose precisely with the use of conventional radiograms.

In numerous cases of complicated shoulder injuries, the treatment should be complex and include different components of the injury in order to preserve normal movement range and normal articulation structure. In cases of multi-fragmented fractures of the humeral head, a necrosis caused by perfusion disturbances may appear [1].

Numerous projections and radiographic techniques have been elaborated to optimally visualize shoulder traumas [2]; these include: AP, Rockwood, Grashey, axillary, Wast Point, scapular Y, and outlet, Stryker notch.

Magnetic resonance (MR) and MR arthrography are considered the methods of choice in shoulder imaging, but in many pathological processes computed tomography is also of fundamental diagnostic importance [3].

Computed tomography (CT) is the method of choice in showing bone continuity and in identifying and localizing free bone fragments [4, 5]. Multi-planar reconstructions (MPR) and three-dimensional spatial reconstructions, such as shaded surface display (SSD) and volume rendering technique (VRT), are an important complement of axial CT imaging.

The aim of the study was to assess the diagnostic value of three-dimensional (3D) spatial CT reconstructions in complex traumatic shoulder injuries.

MATERIAL AND METHODS

The material consisted of a group of 12 patients (8 men and 4 women, aged 19-81) with traumatic shoulder injuries, who have undergone CT examination with secondary 3D SSD and VRT reconstructions. CT examinations were performed with a spiral CT scanner (Somatom Emotion, Siemens, Germany) equipped with Somaris5 VB10B software. Each examination was performed in axial slices of 2mm, pitch 1.5, and lamp current parameters of 130kV and 90mAs. Axial cross-sectional images were reconstructed with standard indirect algorithm and with high resolution algorithm. Additionally, images of axial cross-sections were processed with soft reconstruction algorithm and later used in creating spatial reconstructions. Three-dimensional SSD spatial reconstructions were carried out with a reconstructive threshold of 150 Hounsfield Units (HU), whereas VRT reconstructions were performed with a grey scale coding at the following parameters: opacity 94% in the range of 427-2000 HU, brightness 47% in range of 132 – 2000 HU.

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RESULTS

A bone defect of the anterior glenoid lip was observed in 3 cases of the anterior shoulder luxation; an additional presence of a free bone fragment dislocated from the caracoid process of the scapula was observed in 1 case (Figures 1 and 2). The bone

Figure 1 Patient KW, age 19. Axial computed tomography cross-section. Free bone fragment of the anterior acetabulum rim of the shoulder articulation (arrow).

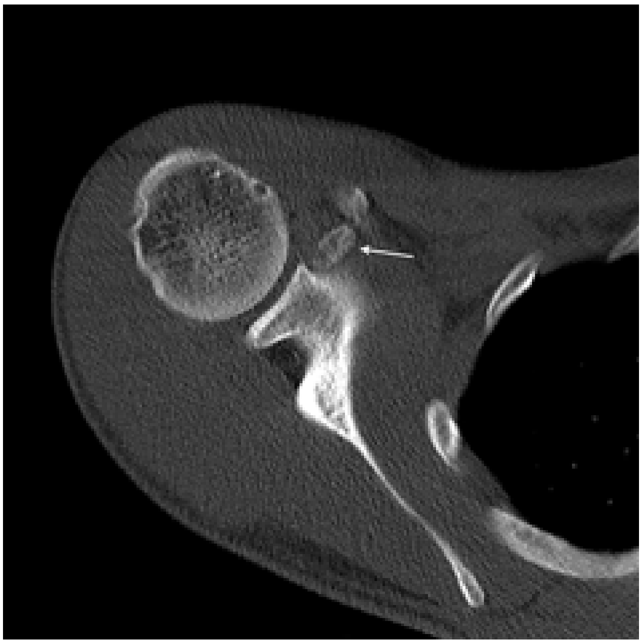

Figure 2 Patient KW, age 19. Axial computed tomography cross-section. Free bone fragment of the caracoid process of the scapula (arrow).

fragments were clearly seen on 3D SSD reconstructed images (Figure 3), whereas on VRT reconstructions, the size of free bone fragments were smaller compared to SSD reconstructions (Figure 4).

Acetabulum injury accompanied the fracture of the humeral head in 7 cases (Figure 5). Three-dimensional SSD

Figure 3 Patient KW, age19. Three-dimensional shaded surface display. Bone fragments of the anterior acetabulum rim → and caracoid process ➔ are visible.

Figure 4 Patient KW, age 19. Three-dimensional volume rendering technique. Visible bone fragments of the anterior acetabulum rim → and caracoid process ➔ appear smaller than on 3D SSD reconstruction.

reconstructions showed the surface of the injured humeral head (Figure 6), whereas VRT reconstructions clearly showed the trajectory of fracture fissures within the head (Figure 7). In 3 cases, the humeral head was dislocated posteriorily (Figures 8 and 9). In 2 other cases, however, fractures included the humeral head, acetabulum, and also the scapula. Fracture fissures were visible on axial CT images in all 12 cases, but were more distinct on high resolution images. It was very difficult to determine the presence and precise localization of a free bone fragment in relation to neighbouring bone structures on axial cross-sectional images. Spatial 3D SSD and VRT reconstructions made possible the visualization of

Figure 5 Patient DH, age 66. Multi-fragmented fracture of the humeral head ➞, calcification of surrounding soft tissues ⇾ and fracture fissure of the posterior acetabulum rim.

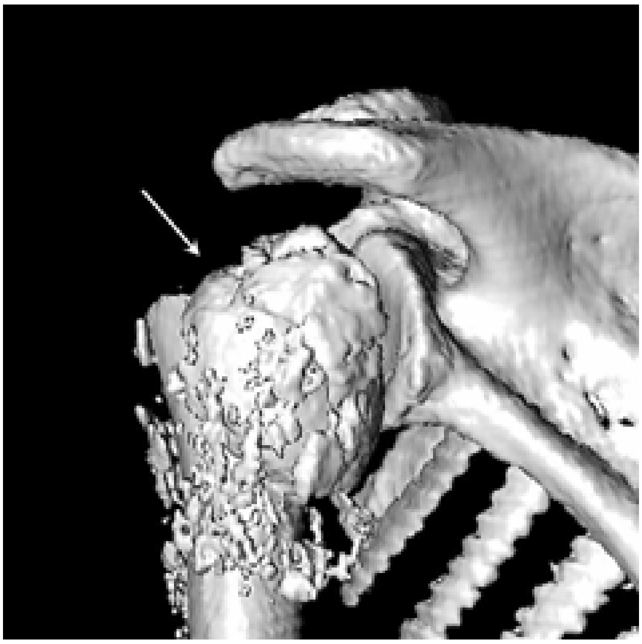

Figure 6 Patient DH, age 66. Three-dimensional shaded surface display technique. Multi-fragmented fracture of the humeral head (arrow) and calcification of surrounding soft tissues cover the run of fracture fissures. Small bone fragment of the posterior acetabulum rim.

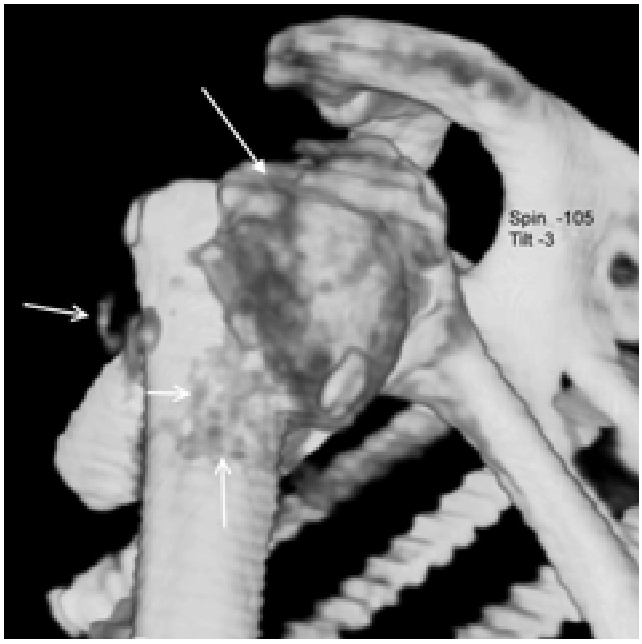

Figure 7 Patient DH, age 66. Three-dimensional volume rendering technique. Multi-fragmented fracture of the humeral head ➞, well visible run of fracture fissures within the humeral head. The bone fragment of the posterior acetabulum rim is not visible. Calcification of surrounding soft tissues ⇾.

Figure 8 Patient KG, age 81. Multi-fragmented fracture of the humeral head ➞. The fractured humeral head is dislocated posteriorly. Small bone fragment of the anterior acetabulum rim ⇾.

free bone fragments and their precise localization. In 9 cases of humeral head fractures, 3D SSD reconstructions enabled precise assessment of the head localization, as well as the degree of its dislocation and rotation. On the other hand, VRT reconstructions presented smaller dimensions of free bone fragments, and in 2 cases tiny fragments of the glenoid lip were not visualized. In 3 cases, VRT reconstructions spatially illustrated the irregular trajectory of fracture fissures within the humeral head, making their course more understandable.

DISCUSSION

Conventional radiography remains the first diagnostic method in traumatic shoulder injuries. The use of numerous projections permits precise assessment of the shoulder bone structures. Accurate evaluation of X-ray images, however, is essential for adequate choice of a further imaging method [2].

Magnetic resonance imaging (MRI) is considered a method of the highest diagnostic value in imaging of shoulder structures [3]. Computed tomography and CT arthrography

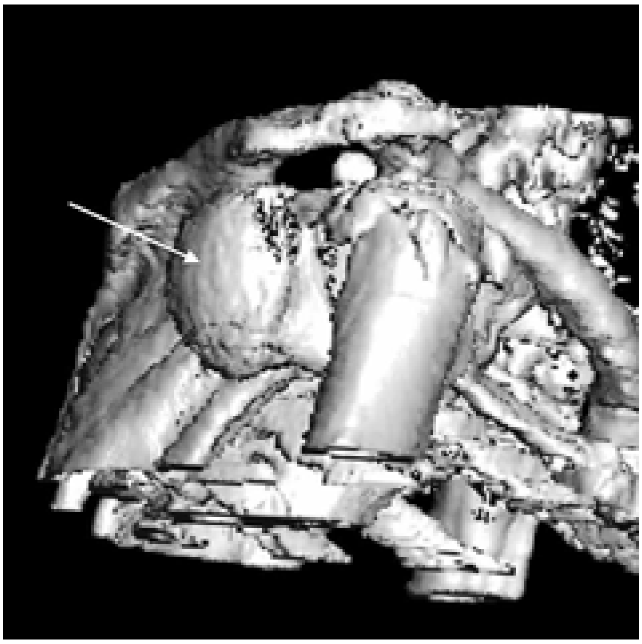

Figure 9 Patient KG, age 81. Three-dimensional shaded surface display technique. Multi-fragmented fracture of the humeral head. The fractured humeral head (arrow), the degree of its dislocation, rotation and angular deviation are well visible.

can successfully solve many important diagnostic dilemmas [1]. Computed tomography, introduced to medical diagnostics by Sir Godfrey Hounsfield in 1972, has been undergoing a steady, dynamic development and popularization for the last 30 years. It has revolutionized contemporary medical diagnostics, especially in the field of bones and joints imaging [6]. Three-dimensional images can be generated from datasets of axial CT cross-sections using different reconstruction algorithms. Three commonly used techniques include: SSD, MIP (maximum intensity projection) and VRT [7-10]. Three-dimensional imaging has been developing systematically and is nowadays widely used in diagnostic imaging [11-14]. Three-dimensional volume imaging creates clinically exact and immediately available images from the complete CT dataset. It enables a radiologist and clinician to make a specific clinical evaluation of the case during an interactive analysis of different aspects of the collected dataset. In contrast with an increasing problem of information overcharge, 3D imaging facilitates simplification of a standard CT examination, making it easier to efficiently interpret large datasets [7, 10]. Three-dimensional applications generate a spatial form on the basis of digital datasets of CT axial cross-sections, which is often easier to interpret than axial images. The use of 3D imaging techniques derived from images generated with SSD technique is of the greatest diagnostic importance [5]. Computed tomography images are of a higher diagnostic value than standard X-rays in diagnosis of shoulder injuries and determination of the size of glenoid lip injuries. Axial CT images are considered an auxiliary method in pre-operative planning of treatment in complex fractures of the proximal part of the humerus [1]. Classical radiography appears to be an insufficient method to precisely assess extensive and serious traumas, especially those including shoulder, elbow, knee, wrist and tarsal articulations, which have a complex anatomical structure [15]. Performing 3D examination helps in understanding mutual spatial relations between injured structures, which is important in classifying fractures and planning their treatment [1, 15]. In the presented study, 3D reconstructions rendered mutual spatial relations between bone structures, and allowed a precise assessment of the number of bone fragments, as well as the dislocation direction of the fragments of the fractured humeral head. Considering shoulder injuries, computed tomography is useful in diagnosing fracture fissures, determining their course, assessing the number of fracture fissures and bone fragments, and the degree of dislocation and axial deviation of the fractured bone fragments [15, 16]. Computed tomography is a valuable method in the diagnosis of peripheral skeleton traumas, especially in assessing intra-articular and complex joint fractures [15, 17]. Computed tomography examination is especially valuable when axial images are supplemented with 3D reconstructions. Compared to axial CT cross-sectional images, however, volume reconstructions do not increase the number of diagnosed fracture fissures and should be considered as methods complementary to radiography and axial CT images in the assessment of complex fractures [17]. Axial CT does not provide a possibility for determining the bone fragment dislocation in the caudo-cranial direction [18]. Therefore, it is assumed that in shoulder fractures CT examination should be complemented with spatial reconstructions on a regular basis.

In tuberculum fractures and their dislocations, CT is of a higher diagnostic value than conventional radiography [19]. Computed tomography visualizes dislocations and rotations of bone fragments better than radiography, and also provides clinically useful information which is helpful in planning the treatment of complex fractures of the proximal humeral epiphysis [18].

In complex fractures of the proximal humeral epiphysis, bone fragment dislocation greater than 1 cm, and angular axial deviation of the free bone fragment of 45º, may be clinically important [19]. We deduce that computed tomography together with 3D reconstructions is a diagnostic method which can precisely assess such parameters. In fractures of the proximal humeral epiphysis, it is sometimes difficult to assess the precise location of the fractured bone fragment by using X-ray. That fact may also result from the difficulty in optimal positioning of a patient to make a precise X-ray [19].

Computed tomography is highly valuable for assessing rare splitting fractures of the humeral head. It provides clinically helpful information which is useful in planning the operative treatment in splitting fractures of the humeral head. It may also be useful in early post-operative assessment [16]. Three-dimensional CT image manipulation in diagnosing post-traumatic shoulders with interior glenohummeral instability can graphically visualize the articulation in order to easily see all abnormalities and to provide necessary clinical information. Three-dimensional SSD CT proved to be useful in showing defects of the humeral head and anterior acetabulum rim present in post-traumatic shoulder instabilities [20]. In our material, 3D SSD reconstructions proved to be especially useful in assessing the glenoid lip edges. Three-dimensional CT may be also useful for surgeons as an accessory diagnostic method in planning operative treatment and patient counseling [21].

CONCLUSION

In complex shoulder traumas it is difficult to assess the extent of injury, determine localization and position of bone fragments, and diagnose and localize glenoid lip injury. The complex structure of the bones which form the shoulder results in a diverse character of shoulder injuries. The three-dimensional character of injuries to the shoulder bone structure requires spatial reconstruction in some cases. Three-dimensional technique is useful in precise localization of free bone fragments and determining their place of origin. Computed tomography examination supplemented with 3D reconstructions is a complementary method in the diagnosis of patients with complex shoulder fractures, especially in cases where the extent of fracture fissures, as well as localization and place of origin of free bone fragments, cannot be determined on a standard X-ray. Inclusion of CT examination with 3D reconstructions into the diagnostic algorithm in shoulder traumas increases the accuracy of imaging diagnostics. Spatial 3D SSD and VRT reconstructions broaden the diagnostic possibilities of axial computed tomography by adding a possible assessment of shoulder structures in additional dimensions. Three-dimensional SSD reconstructions allow the identification of free bone fragments, precise determination of their localization, and spatial relations of injured bone elements, whereas VRT reconstructions are useful in assessing spatial configuration of the trajectory of fracture fissures.

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