ANNALES
UNIVERSITATIS MARIAE CURIE-SKŁODOWSKA
LUBLIN — POLONIA
VOL. LII, 17 SECTIO D 1997

II Zakład Radiologii Lekarskiej Akademii Medycznej w Lublinie
Kierownik: prof. dr hab. Stanisław Bryc

WITOLD KRUPSKI, JANUSZ ZŁOMANIEC,
STANISŁAW BRYC, GRAŻYNA ZŁOMANIEC

Bone fragments imaging by means of 3D computerised tomography

Uwidocznianie fragmentów kostnych za pomocą 3D TK

Modern computerised tomography devices have programs enabling the obtention of spatial reconstruction pictures produced from a series of axial sections (1, 16).

The aim of this paper is an assessment of the value of three dimensional reconstructions of 3D CT images in the diagnostics of posttraumatic bone fragments.

MATERIAL AND METHODS

The material comprises 28 patients of both sexes aged from 14 to 76 years examined at our Department in the period from 1995 to 1997. They sustained injuries of the backbone (12 cases), pelvis and hip joints (6 cases), knee joints (3 cases), wrist (3 cases), heel bone (2 cases), shoulder bone (2 cases). Spatial pictures were assessed against data of radiograms, CT axial 2mm sections of high spatial definition performed in generally accepted positions. The tomograph used was Somatom AR.T. by Siemens equipped with 512X512 piksel matrix.

3D reconstructions were produced from computer data of axial sections with bone threshold.

RESULTS

In pelvic fractures 3D images reconstructed the size, shape, inclination degree and direction of bone fragments displacement. In 5 cases of fractures of the acetabular margin with concomitant dislocation of the femoral head, the posterior projection revealed a fragment of the posterior margin (Fig 1). Later projections determined the positions of displaced parts of the acetabular roof and dislocated femoral head (Fig 2). By means of 3D method it is possible to determine the displacement degree and position of free bone fragments. In 4 cases of transverse acetabular fractures fragments on the roof level were shown. They were twice visible in central fractures with displacement. In 3 patients they were localised along a displaced femoral head. Fragments of the anterior acetabular margin were disclosed twice. In the soft tissue program intraarticular chondral fragments were shown. In 12 cases of traumatic backbone damages with the presence of intracanal fragments 3D revealed their topographic localisation and volumetric relations of the canal. In 9 patients vertebral body fractures were multifragmental. Fragments intussuscepting into the canal came from the postero–superior margin in 5 patients. Fragments of considerable sizes were also well seen in multiplanar reconstructions (Fig. 4). Fibular section gave insight to the vertebral canal lumen. Medial canalar section revealed the degree of its narrowing and displacement of fragments (Fig. 5). Superior, anterior and posterior projections 3 times revealed separations and displacement of the arch (Fig. 6). Abscission of the anterior part of the vertebral column and uncovering the canal showed fragments separated from the arch structures (Fig. 7). In 3 cases fragments from the arch were imperceptible in axial sections (Fig. 8). They twice represented detached and rotated articular process.

Selective sections uncovered small fragments, superimposed on bony structures of confined canal spaces. It was essential to determine the optimal position of intracanalar fragments, their horizontal, vertical displacements, torsion and inclination. 3D reconstruction showed the direction of intussuscepted fragments and their margins determining torsion degree. In 3 patients anterior torsion was found with cortial bony margin directed forward.

Axial sections showing a torsion of the posteriorly displaced fragment did not exactly determine its degree. Anterior torsion amounting to below 90 as well as the one of 90–180 looked similarly. In 4 cases vertical displacement was revealed side by side with torsion. In two cases the fragment apart from posterior displacement showed anterior and vertical rotation. This technique lets visualize tiny bone splinters, their torsion to fissures of adjacent bone wall fractures (Fig. 9).

In 3 cases of compound fractures of limb joints with dislocation 3D CT revealed intussusception and torsion of intraarticular fragments. In 4 patients tiny, free intraarticular fragments were disclosed. In bigger fragments morphologic features of 2D sections were correlated with 3D CT images (Fig. 10a and b). In 2 cases of complex traumatic damages of shoulder joints in which a free fragment made up a big part of the humerus head 3D showed its position in relation to the acetabulum and distal end of the broken off bone showing, at the same time, accompanying tiny bone fragments (Fig. 11).

DISCUSSION

Spatial pictures reveal tiny bone fragments poorly visible or indistinct in conventional sections (14). 3D reconstructions show the degree of fragmentation, extent, localisation of displacements and spatial relations of fragments (10). It is important to determine the optimal position of the bone fragment (5). Intussusception and inclination degree of fragments is sometimes erroneously assessed in 2D CT pictures (9).

Heterogeneity of 3D projections results from the possibility of projecting from all directions, torsion in a selected axis and inclination of bony structures at optional angle, which lets observe bone fragments in isolation. Spatial manipulation helps visualise geometry of damages by reconstructing spatial depth. There are difficulties in the assessment of heterogeneous localisation and intraarticular configuration of bone fragments while 3D facilitates identification of free intraarticular bodies (2, 9, 15).

Surgical reductions of intussuscepting intracanalar fragments have decreased the degree of canal narrowing from 61% to 19% on the average in fractures of the anterior column and to 29% when the damage involved the posterior column (12).

The degree of spinal canal narrowing is assessed as small when it ranges from 1 to 20, moderate form 21 to 50 and severe over 50 (4), which is consistent with our observations.

Narrowing of the vertebral canal results from axial compressive fractures (7). 3D determines the position of posteriorly displaced fragments being the consequence of acute axial compression side by side with the assessment of stability and efficacy of operative reposition of fragments (3, 5, 10, 17, 18).

Most fragments result from fragmentation of the upper half of vertebal body with frequent separation in the region of intervertebral foramen. Assessment of the width of intervertebral foramens is essential in backbone injuries.

It is, therefore, of practical importance to visualise narrowings of intervertebral foramens, which are a complex anatomical structure (18).

When flexion is excessive, anterior torsion of intussuscepted fragments occurs side by side with axial compression (17).

Longitudinal posterior ligament can cause anterior rotation of the fragment (reversion due to torsion). The force directed downwards can cause disruption of the ligament in the lateral part on the margin of the intervertebral foramen. Destabilisation of the supero–posterior margin of the vertebral body causes torsion of the fragment.

Modern surgical techniques emphasise effective reduction of intussuscepted fragments (7,13). Rupture, torsion or vertical displacement of the fragment complicates reduction. 3D reconstructions determine the degree of fragment torsion in the vertebral canal and their vertical displacements.

In fragmented fractures of the anterior and posterior acetabular margin 3D reconstructions determined localisation of displaced fragments and mutual spatial relations of the free fragment and articular fissure. A full, three dimensional pattern of displacements was obtained. Measurements of displacements could be done directly from the section for the plan of operative reconstruction. Inclination and torsion degree of intraarticular fragments was determined, i.e. their position and stability. In compound fractures of acetabular roof and margin with dislocation 3D reconstructions made up the conception of planned operative procedure by better understanding of mutual spatial relations (6, 8, 11).

It is necessary to determine a precise configuration of fragments before treatment of compound fractures of the shoulder joint (1, 9). 3D CT imaging graphically reconstructs especially small fragments, as well as the separation of a bigger fragment of humerus tuberosity. Fragment displacement is determined by the magnitude of its displacement and angular positioning within the range to 45 and above (9).

In the material under discussion the presence of fragments in the bone tunnel of the wrist was reconstructed from 2 mm axial sections. Heterogeneity of planes and torsions facilitates the assessment of fragmented fractures of the hamate bone.

In comminutions of the heel bone 3D determines the extent and intussusception degree spatially reconstructing distances between them (9).

CONCLUSION

1. 3D reconstructions are of actual value in revealing traumatic bone fragments, assessment of the direction of their displacement and degree of oblique inclination.

2. Considerable benefits were noted in the assessment of displacements of intracanalar fragments. 3D CT imaging is a technique of choice in fragmented fractures of vertebral structures.

3. In traumatic damages of the hip joint and pelvic bone 3D reconstruction revealed the position, degree of inclination, torsion and direction of fragments displacement, especially of intraarticular ones. They optimally reconstructed the size and position of the fragment.

4. 3D reconstructions enabled precise planning of operative procedures by better understanding of mutual spatial relations of complex anatomical structures, reconstructing them in the spatial manner.

REFERENCES

1. Billet F. et al.: Computed tomography in traumatology with special regard to the advances of three-dimensional display. Arch. Orthop. Trauma Surg., 111, 131, 1992.
2. Bryc S. et al.: Złożone uszkodzenia stawów biodrowych i kości miednicy w obrazach trójwymiarowej rekonstrukcji przestrzennej TK (3D). Pol. Przegl. Radiol., 332, 4, 61, 1996.
3. Bryc S. et al.: Trójwymiarowe rekonstrukcje 3D TK w badaniach zmian urazowych kręgosłupa. Pol. Przegl. Radiol. (in press)
4. Brant–Zawadzki M. et al.: High resolution CT of thoracolumbar fractures. AJR, 138, 699, 1982.
5. Fishman E. et al.: Multiplanar (MPR) imaging of the hip. Radiographics, 6, 7, 1986.
6. Fishman E. et al.: Advanced three-dimensional evaluation of acetabular trauma: volumetric imaging processing. J. Trauma, 29, 214, 1989.
7. Guerra J. Jr.: Vertebral burst fractures: CT analysis of the retropulsed fragment. Radiology, 1, 53, 769, 1992.
8. Martinez C. et al.: Evaluation of acetabular fractures with two and three-dimensional CT. Radio Graphics, 12, 227, 1992.
9. Moss A., Gamsu G., Genant H.: Computed Tomography of the Whole Body with Magnetic Resonance Imaging. Chapter 11, The Joints (Stoller D., Genant H.), 446, 1992.
10. Sartoris D., Resnick D.:Computed tomography of the spine: An update and review. Crit. Rev. Diagn. Imaging, 27, 271, 1987.
11. Scott W. Jr. et al.: Acetabular fractures: optimal imaging. Radiology, 165, 537, 1987.
12. Shuman W. et al.: Thoracolumbar burst fractures: CT dimension of the spinal canal relative to postsurgical improvement. AJR, 145, 337, 1985.
13. Sjostrom L. et al.: Spinal canal remodelling after stabilization of thoracolumbar burst fractures. Europ. Spine J., 3, 312, 1994.
14. Stievenart J. et al.: A survey of different high resolution visualization modes of volumetric object with applications. Surg. Radiol. Anat. 15, 47, 1993.
15. Totty W., Vannier M.: Complex musculoskeletal anatomy: Analysis using three-dimensional surface reconstruction. Radiology. 150, 173, 1984.
16. Van Savage J. et al.: Fracture dislocation of the lumbosacral spine: Case report and review of the literature. J. Trauma. 33, 779, 1992.
17. Yang I. et al.: Posterior lumbar apophyseal ring fractures: a report of 20 cases. Neuroradiology. 36, 453, 1994.
18. Złomaniec J. et al.: Wartość opcji przestrzennej 3D TK w ocenie otworów międzykręgowych. Neurol. Neurochir. Pol. (in press)

Otrz.:1997.11.14

STRESZCZENIE

W materiale 28 chorych ze złamaniami kręgosłupa, miednicy i dużych stawów oceniono wartość rekonstrukcji przestrzennych tomografii komputerowej w uwidacznianiu odłamów kostnych. Wykazano korzyści w określaniu przemieszczeń, skręceń i nachyleń skośnych fragmentów, zwłaszcza śródkanałowych. Optymalne uwidocznienie konfiguracji i wzajemnych stosunków przestrzennych było istotne dla redukcji operacyjnej.

EXPLANATION TO FIGURES

Fig. 1. 3D reconstructions of the pelvis in posterior projection. Fracture of the posterior margin of the left hip acetabulum with gomphosis of a free bone fragment between the iliac bone and femoral head. Posterior dislocation of femoral head.

Fig. 2. Multifragmental fracture of hip joint acetabulum.

Fig. 3. Posterior dislocation of femoral head and fracture with dislocation upwards of an acetabular roof fragment. Tiny bone fragments in the lumen of articular acetabulum.

Fig. 4. Fibular 2D CT reconstructions. Compressive narrowing of a vertebral body with detachment of bone fragments one of which, displaced to the vertebral canal lumen, causes its narrowing.

Fig. 5. Compressive fracture of the lumbar vertebral body with separation of free bone fragments. A bone fragment displaced to the canal narrows its lumen.

Fig. 6. Axial 3D CT reconstruction. Compressive fracture of a chest vertebra with detachment of the arch and its displacement backwards.

Fig. 7. 3D reconstruction cut off in the frontal plane along the vertebral canal, projection on the posterior wall of the canal composed of vertebral arches. Bone fragment in the vertebral canal separated from an articular process.

Fig. 8. Compressive fracture of a vertebra with angular vertebral kyphosis. Bone fragment in the posterior part of the vertebral canal separated from the arch.

Fig. 9. Fissure of fracture of lateral orbital wall with visible bone fragment in its lumen.

Fig. 10a. Free bone fragment with detachment of intercondylar eminence within knee joint fissure.

Fig. 10b. Frontal 2D CT reconstruction of the same patient.

Fig. 11. Fracture of humerus with complete separation of the head consulting a free bone fragment.

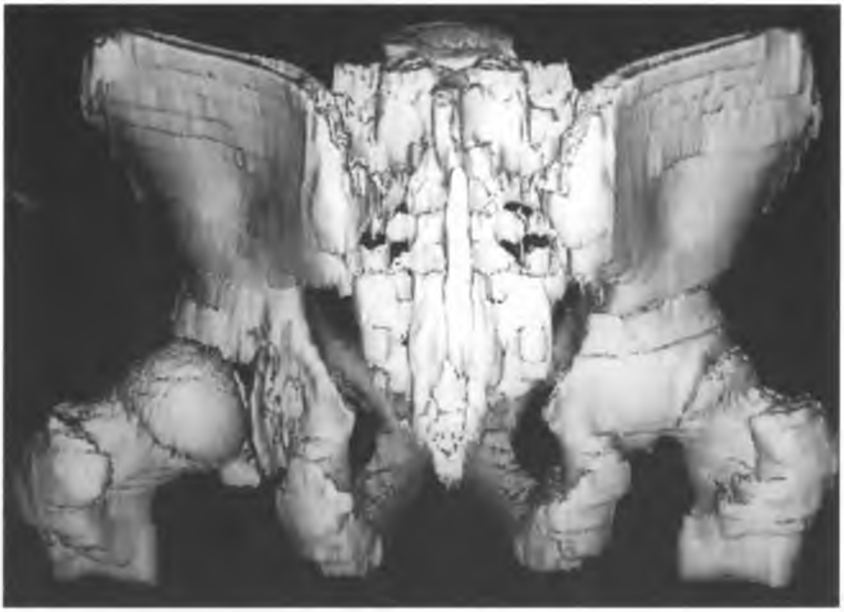

Fig. 1

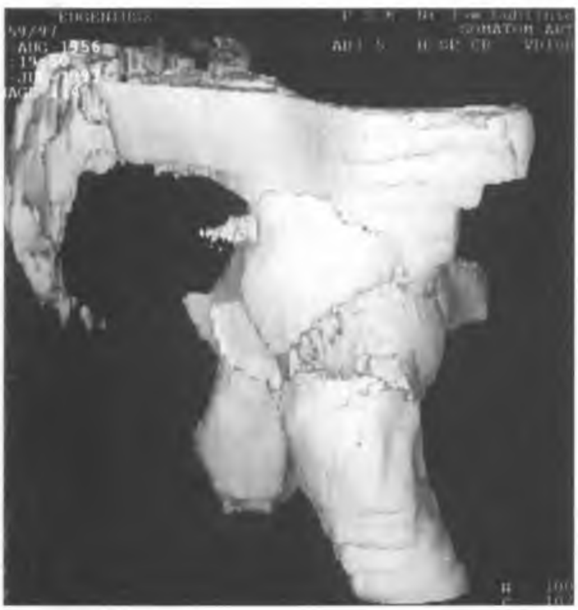

Fig. 2

Fig. 3

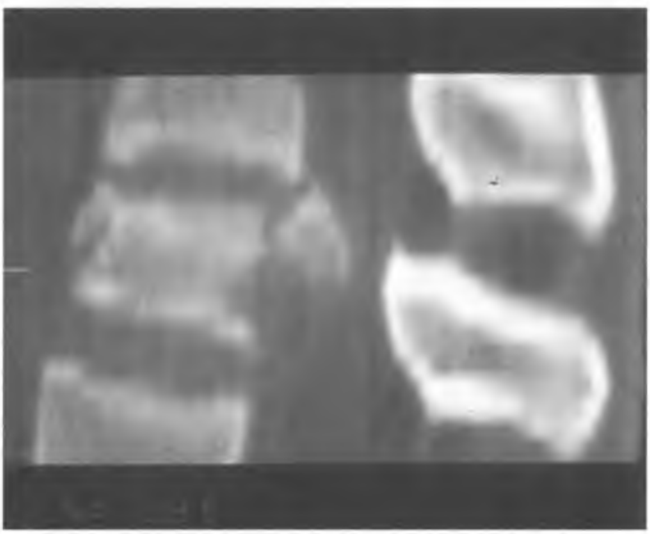

Fig. 4

Fig. 5

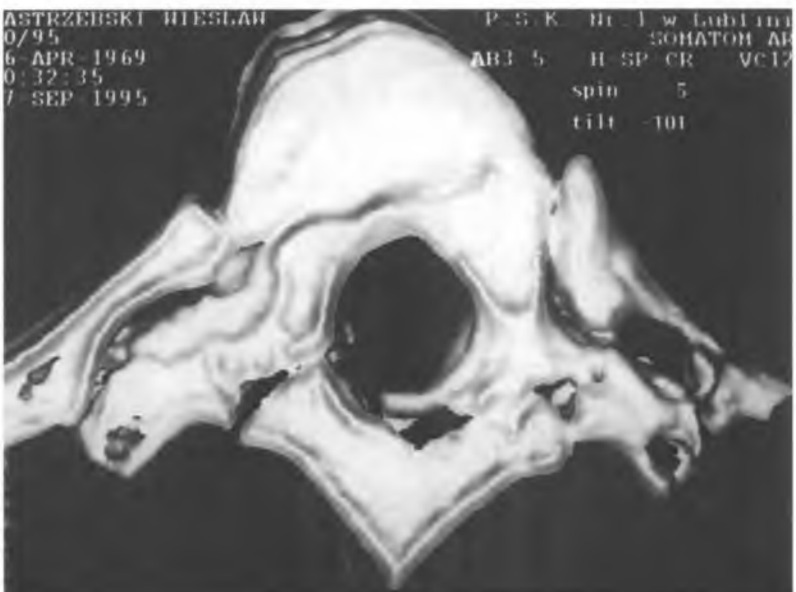

Fig. 6

W. Krupski, J. Złomaniec, S. Bryc, G. Złomaniec

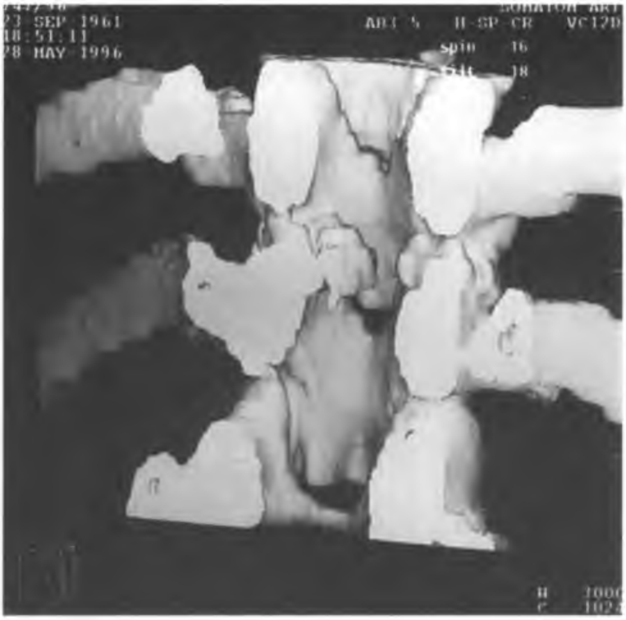

Fig. 7

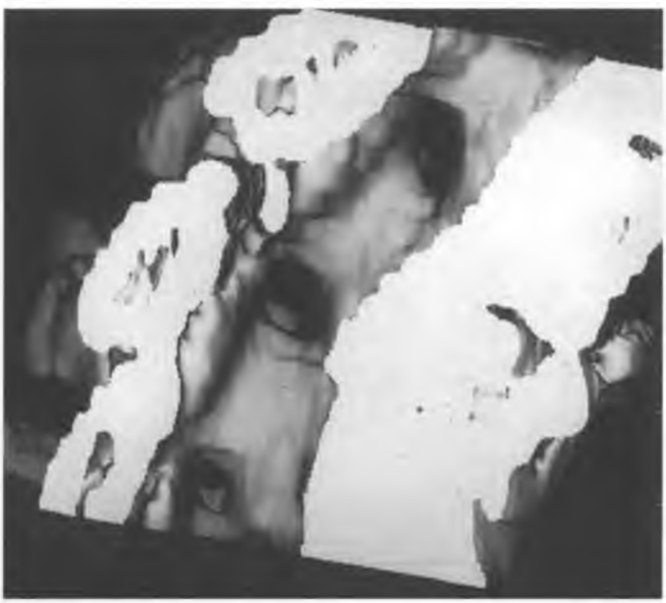

Fig. 8

W. Krupski, J. Złomaniec, S. Bryc, G. Złomaniec

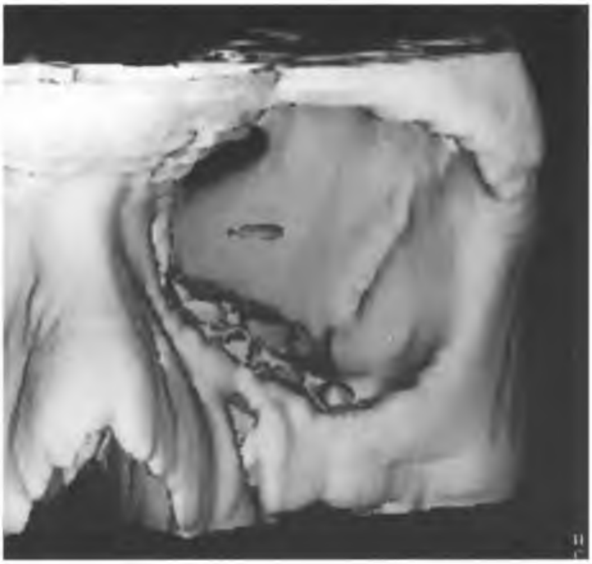

Fig. 9

Fig. 10a

Fig. 10b

Fig. 11