OUR EXPERIENCE WITH 3D CT

Miroslav Pach*[a], Rudolf Ditmar[a], Miroslav Heřman[b]

[a] Department of Orthopaedics, University Hospital, I. P. Pavlova 6, 775 20 Olomouc, Czech Republic
[b] Department of Radiology, University Hospital, I. P. Pavlova 6, 775 20 Olomouc, Czech Republic

Received May 15, 1999

Key words: Three-dimensional CT/ Orthopaedic diseases/ Musculoskeletal traumas

The authors present the results of 9-year work with 3D CT in orthopaedics and musculoskeletal traumatology. In the years 1990–1998, the method was used in the examination of 59 patients (27 males, 20 females, and 12 children). The place of 3D CT in clarifying areas of complex musculoskeletal anatomy for operative treatment is discussed and presented as a contribution to the indication conference. According to the authors' experience, in many cases 3D CT increases the quality of diagnostics. Most of all, it helps the surgeon in operation planning. 3D reconstructions are particularly valuable in proximal humerus fractures, spine fractures and tumours, acetabulum fractures, as well as in conditions after hip dysplasia, LCPD and coxa vara adolescent.

INTRODUCTION

In 1972, Sir Godfrey Newbold Hounsfield introduced a new radiological technique called Computer Axial Tomography Scanning. Soon after introducing computed tomography (CT) into practice, an idea to create three-dimensional images from CT scans appeared. The new approach was accepted to such an extent that by the end of 1980s 3D reconstructions software was supplied together with commercially produced CT appliances as a supplement.

Experience with the appliances and the possible use of 3D reconstructions in clinical practice were published abroad in 1980s and in our country at the beginning of 1990s.[1,3,5,6,11,13,14–21,23–27] Three-dimensional CT scans reconstructions bring impressive and clear images of various areas of the musculoskeletal system. Compared to standard CT scans 3D images usually offer no new diagnostic information. However, their clearness enables easier spatial orientation, which is particularly valuable during manu armata treatment. In co-operation with doctors from the Clinic of Radiology, Teaching Hospital in Olomouc, we examined patients with orthopaedic diseases and skeletal traumas. Several years ago we also started co-operation with doctors from the department of radiology of the Military Hospital in Olomouc.

MATERIAL AND METHODS

In 1990, 3D CT became a part of paraclinical examination methods at the Department of Orthopaedics in Olomouc. By the end of 1998, 59 patients were examined for more exact diagnoses and for determination of proper operation strategies. The group consisted of 27 males, 20 females and 12 children. The patients' ages were between 6 and 59; average 32.6 years. Structure of the group according to indications: 9 spine fractures, 5 proximal humerus fractures, 5 scaphoid fractures, 8 pelvis fractures, 12 acetabular fractures, 8 tumours, 5 Legg – Calve – Perthes disease (LCPD), 4 coxa vara adolescent (CVA), 3 conditions after congenital hip dysplasia (CHD). 46 patients underwent surgery, i. e. 77.8%.

In all patients, conventional radiography was performed at first. After the evaluation, three-dimensional CT was indicated. Stress was placed on useful of the examination for surgical intervention. Certain restraints were imposed in children and mainly in little girls due to gonad protection, that was difficult to deal with. Check-up reconstructions were not performed to decrease the load of radiation.

To examine most patients, original software was used. This enables only registration and imaging of surfaces or structures with the significantly different from that of the surrounding area – the so-called surface rendering.[9,13] At present, 3D reconstruction possibilities are widening. Surface rendering (SR) is being replaced by volume rendering (VR). Thus, all data without a threshold value are processed. However, the threshold value can be added at any time, i. e. images of any tissue can be obtained using special techniques. So from skeleton imaging 3D CT has proceeded to soft tissues reconstructions.[9,10]

Compared to VR, surface rendering offers more effective surface images, but these contain a higher rate of artifacts. Volume rendering is better at imaging subcortical pathology with a minimum of artifacts.[12] There has been a significant increase in the speed of processing which now takes 3–5 minutes. The subsequent manipulation with images such as e. g. a spatial rotation or a threshold change practically takes place in real time.

Special reconstruction procedures provide a number of clear images that are close to the reality.[10]

RESULTS

When comparing examinations of various areas included in our set, 3D CT proved to be the most valuable in proximal humerus fractures, spine fractures and tumours, acetabular fractures, as well as in pelvis fractures and tumours. 3D reconstruction was also useful detailed description of intra-articular interrelations – CHD etc. It was less valuable examination of the hip in children with LCPD and CVA. 3D CT seemed to have no practical value in scaphoid fractures and pseudoarthroses. During the pelvic and iliac examination of children two fundamental problems were observed. The first was to find a compromise between imaging quality and the necessity of strict gonadal protection which is particularly difficult especially in little girls. The other problem was to ensure absolute patient's calmness during the exposition. Therefore, we recommend examining children under sedation. Higher quality reconstructions can be obtained by processing data from spiral CT appliances that shorten the examination and lower the risk of artifacts caused by both voluntary and involuntary movements of the patient. The last series of our examinations were performed on spiral CT.

Check-up examination could be performed only after metallic material extraction. Otherwise CT scan 3D reconstructions show a "melting metal" phenomenon and the images are difficult to analyse. No discrepancy was found in the set after radiological and perioperative findings were compared.

3D CT examples from the set – see figs. 1, 2, 3 and 4.

DISCUSSION

First 3D CT images in domestic literature specialized in orthopaedic diseases and musculoskeletal trauma were published by members of our team in 1991–1992.[6,15] Over the last 9 years and in agreement with literature, we could verify that, in case of correct indication, this is a valuable radiological method.[1,2,7,9,13,16, 23,28,29] Radiologists state that 3D reconstructions provide standard data in a different way rather than giving new information.[10,13] Other authors claim that the difference between 2D and 3D CT is analogous to that between mono and stereo sound in music or to that between coloured and black and white photographs.[29]

We would like to emphasise that, as well as other authors, 3D CT is a valuable help in preoperative preparation when it functions as a database for surgical navigation.[2,7,14,15] At present, radiological departments are being equipped with new fast spiral CT appliances of the 3rd and 4th generations that provide larger amounts of high-quality overlapping scans. This has a favourable effect on the final 3D-image quality.[22] Equipment providing 3D images is no longer part of CT appliances but is designed as a separate console. Data for it can be also loaded from diskettes, not only from CT but also from MR, US and nuclear medicine examination.[28] Further development and wider possibilities can thus be expected.[28,29] The development will be supported by higher-quality data, new 3D processing procedures and various examination modalities data integration. Most of all, there will be communication between working stations using 3D reconstructions of all modalities for more exact study of individual cases, production of exact models of different parts of a skeleton and simulated operations in virtual reality.[4,8] Thus, 3D CT is becoming of greater importance not only for science and research but also for education.[29]

There is a question of comparison between CT / 3D CT and MR / 3D MR. Generally, an opinion is accepted that 3D CT has the merit of high spatial accuracy and good quality of bone imaging. MR more sensitively differentiates between soft tissues and bone marrow.[10] Magnetic resonance is more useful in femoral head necrosis in adults, LCPD, chondral fractures, ruptures of menisci, tendons and ligaments including knee anterior cruciate ligament, foot area tendons and talus articulation. MR is exact in describing synovial fluid distribution as well as rheumatoid arthritis pannus.[28,29]

CONCLUSION

It is very difficult to define an overall contribution of 3D CT to orthopaedics and musculoskeletal traumatology. Most radiologists claim that there is only little importance. Based on our results, we believe 3D CT may occasionally serve as the main diagnostic method influencing the patient's treatment. 3D reconstructions are particularly valuable in proximal humerus fractures, shoulder joint luxations, spine fractures and tumours, acetabulum fractures, pelvis fractures and tumours as well as in conditions after hip dysplasia. Lower value was noted in LCPD and coxa vara adolescent and low value in scaphoid fractures and pseudoarthroses. At present, 3D reconstructions serve as a basis for simulated operations in virtual reality, production of exact models of joints and bones, robotization of total hip arthroplasty. They are becoming of greater importance not only for science and research but also for education.

Fig. 1a. Left acetabulum luxation fracture with femoral head posterior luxation and off-broken posterior edge proximal dislocation.

Fig. 1b. View from below of empty acetabulum and luxated femoral head.

Fig. 1c. Similar view from below taken at a side angle.

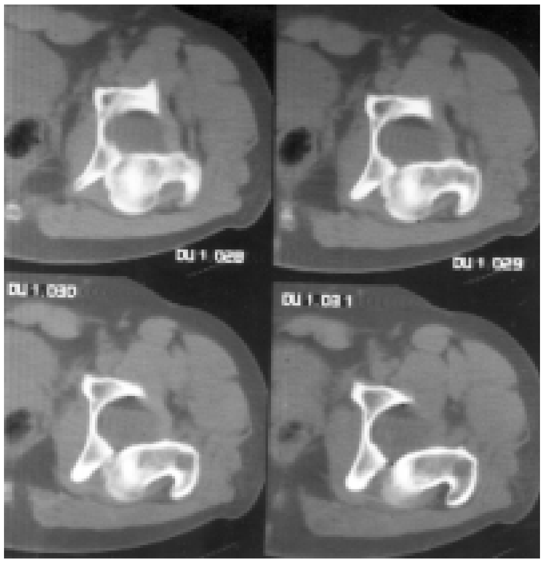

Fig. 1d. Comparative CT scans of acetabulum and luxated femoral head.

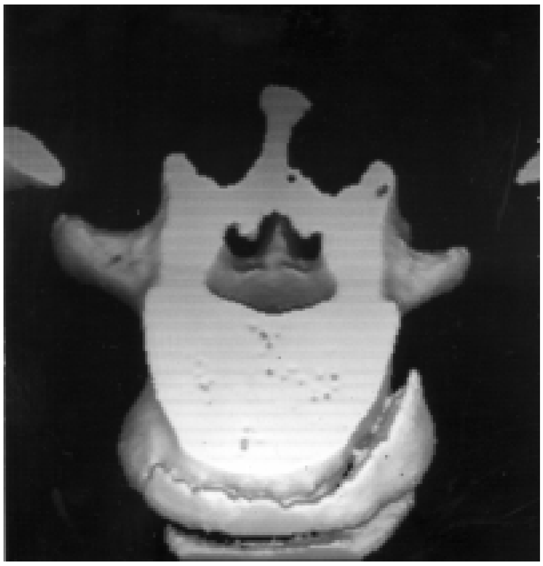

Fig. 2a. Vertebral body burst fracture with L1 end plate off-broken edge.

Fig. 2b. L1 body 3D reconstruction with clear fracture lines and with a fragment dislocated dorsally to spinal canal. A view from below.

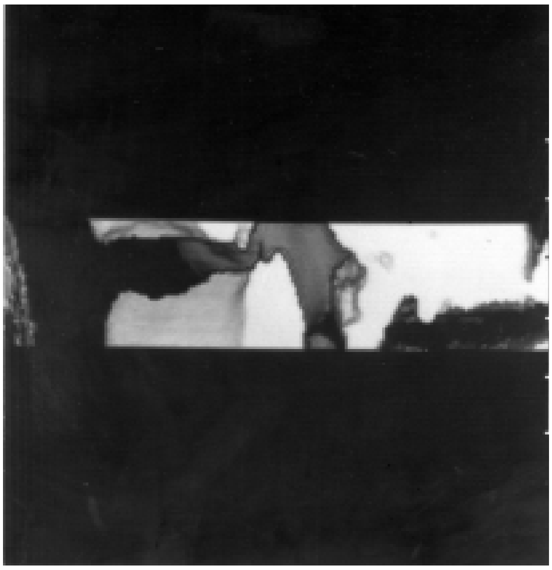

Fig. 2c. 3D reconstruction with deformed end plate and a spinal canal narrowing fragment.

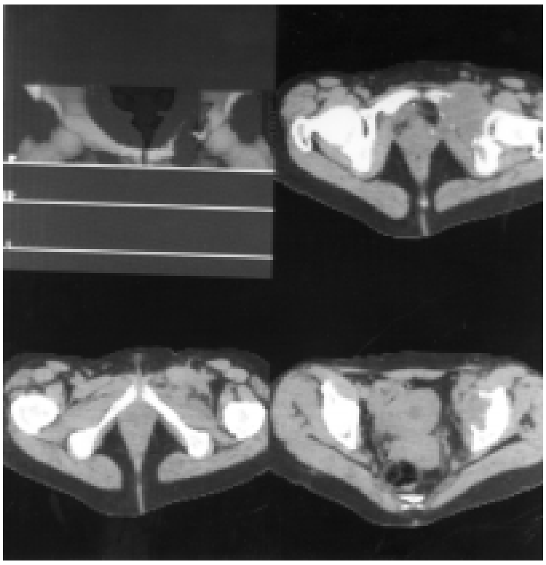

Fig. 3a. Clear 3D image + scans at different planes. Osteolytic process affecting left pubis and reaching as far as acetabulum.

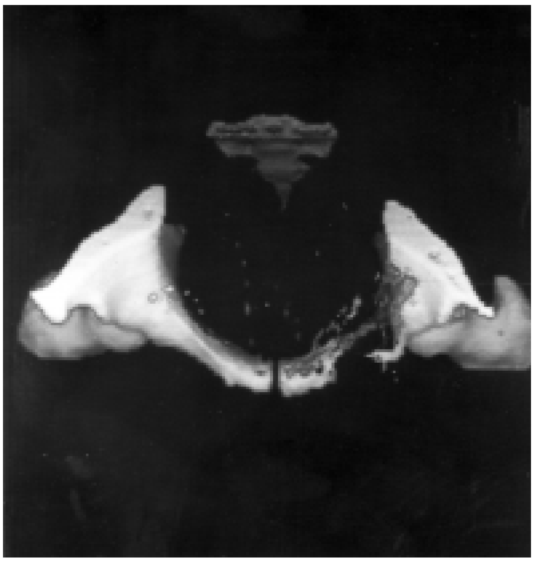

Fig. 3b. 3D image with complete lytic dissolution of pubis.

Fig. 3c. Similar image.

Fig. 3d. Osteolytic process from left below. Central luxation.

Fig. 4a. 3D reconstruction of left hip joint with clear acetabulum insufficiency. Front and right views.

Fig. 4b. Front view and view from below of postdysplastic acetabulum.

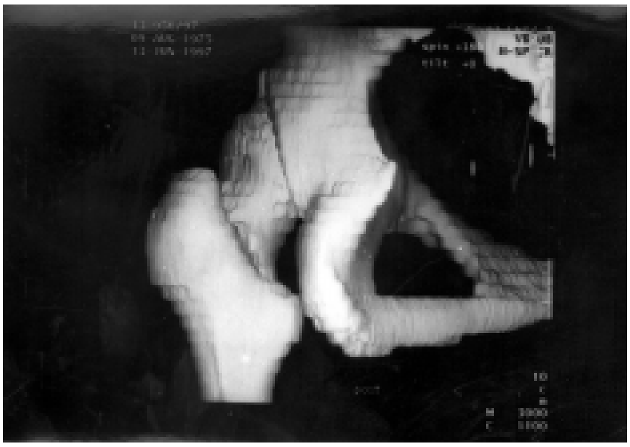

Fig. 4c. Rear view of left hip joint 3D reconstruction.

Fig. 4d. Side angle view from rear, above and left of left hip joint 3D reconstruction. Clear acetabulum insufficiency.

REFERENCES

1. Andre, M. P., Horn, R. A., Bielecki, D. (1985) Patient Dose Considerations for Three-Dimensional CT Displays. Radiology *157*, 177.
2. Billet, F. P., Schmitt, W. G. H., Gay, B. (1992) Computed Tomography in Traumatology with Special Regard to the Advances of Three-Dimensional Display.Arch. Orthop. Trauma Surg. *111*, 131–137.
3. Bonnier, L., Ayadi, K., Vasdev, A. (1991) Three-Dimensional Reconstruction in Routine Computerized Tomography of the Skull and Spine. J. Neuroradiol. *18*, 250–266.
4. Bozic, K. J., Keyak, J. H., Skinner, H. B. (1994)Three-Dimensional Finite Element Modeling of a Cervical Vertebra An Investigation of Burst Fracture Mechanism. J. Spinal Disord. *7*, 102–110.
5. Burk, D. L., Mears, D. C., Kennedy, W. H. (1985) Three-Dimensional Computed Tomography of Acetabular Fractures. Radiology *155*, 183–186.
6. Dostál, M., Zmrzlík, P., Pach, M. (1992) Trojrozměrné zobrazení při CT vyšetření u coxa vara dospívajících. Acta Chir. orthop. Traum. čech. *59*, 173–178.
7. Englmeier, K. H., Wieber, A., Milachowski, K. A. (1990) Methods and Applications of Three-Dimensional Imaging in Orthopedics. Acta Orthop. Trauma Surg. *109*, 186–190.
8. Fuchs, H.: System for Display of Three-Dimensional Medical Image Data. In: Hohne, K. H., Fuchs, H., Pizer, S. M.(1990) 3D Imaging in Medicine. Algorithms, Systems, Applications. Berlin, Sptinger-Verlag,
9. Hemmy, D. C., Zonneveld, F. W., Lobregt, S. (1994) A Decade of Clinical Three-Dimensional Imaging : A Review. Part I. Historical Development. Invest. Radiol. *29*, 489–496.
10. Heřman, M., Tarjan, Z., Pozzi-Mucelli, R. S. (1995) Nové možnosti trojrozměrných rekonstrukcí skenů výpočetní tomografie. Čes. Radiol. *49*, 397–403.
11. Kněžek, J., Dutka, J.(1994) Některé možnosti CT 3D zobrazování v traumatologii skeletu. Rozhl. Chir. *73*, 59–65.
12. Kuszyk, B. S., Heath, D. G., Bliss, D. F. (1996) Skeletal 3-D CT: Advantages of Volume Rendering over Surface Rendering. Skeletal Radiol. *25*, 207–214.
13. Marsh, J. L., Vannier, M. V. (1984) Surface Imaging from Computerized Tomographic scans. Surgery *94*, 159–165.
14. Pach, M., Zmrzlík, P., Dostál, M. (1993) Přínos třídimensionálního CT pro diagnostiku ortopedických onemocnění a traumat. Čs. Radiol. *47*, 150–156.
15. Pach, M. (1991) Přínos 3 dimensionálního CT pro diagnostiku ortopedických onemocnění a traumat. Atestační práce, Olomouc, 1991.
16. Pate, D., Resnick, D., Andre, M. (1986) Perspective: Three-Dimensional imaging of the Musculoskeletal system. Amer. J. Roentgenol. *147*, 545–551.
17. Pate, D., Resnick, D., Sartoris, D. J. (1987) 3D CT of the Spine: Practical Applications. Appl. Radiol. *12*, 86–94.
18. Post, M. J. D., Green, B. A. (1983) The Use of Computed Tomography in Spinal Trauma. Radiol. Clin. North Am. *21*, 327–375.
19. Pozzi-Mucelli, R. S. (1986) Three-Dimensional computed Tomography of the Acetabulum. Eur. J. Radiol. *6/3*, 168–177.
20. Sartoris, D. J., Resnick, D., Gershuni, D. (1986) Computed Tomography with Multiplanar Reformation and 3-Dimensional Image Analysis in the Preoperative Evaluation of Ischemic Necrosis of the Femoral Head. J. Rheumatol. *13*, 153–163.
21. Sherry, R. G., Kieffer, S. A., Black, J. A. (1985) Trauma to the Spine. Arch. Clin. Imaging *1*, 86–93.
22. Toliopoulos, P., Costello, P. (1995) Helical (Spiral) CT of the Thorax. Radiol. Clin. North Amer. *33*, 843–861.
23. Vannier, M. W. (1987) Despite its Limitations, 3-D Imaging Here to Stay. Diagn. Imag. *9*, 206–210.
24. Weeks, P. M., Vannier, M. W., Stevens, W. G. (1985) Three-Dimensional Imaging of the Wrist. J. Hand. Surg. *10a*, 32–39.
25. Zinreich, S. J., Rosenbaum, A. E., Wang, H. (1986) The Critical Role of 3-D CT Reconstructions for Defining Spinal Disease. Acta Radiol. Suppl. *369*, 699–702.

26. Zmrzlík, P., Jemelík, R. (1992) Zobrazení krční páteře metodou trojrozměrné rekonstrukce CT scanů. Čs. Neurol. Neurochir. *55/88*, 198–199.
27. Zmrzlík, P., Jureček, B., Fialová, J. (1990) Využití trojrozměrného zobrazení při CT vyšetření úrazů obličejového skeletu. Čs. Stomat. *90*, 398–401.
28. Zonneveld, F. W., Fukuta, K. (1994) A Decade of Clinical Three-Dimensional Imaging: A Review. Part 2: Clinical Applications. Invest. Radiol. *29*, 574–589.
29. Zonneveld, F. W. (1994) A Decade of Clinical Three-Dimensional Imaging. A Review. Part III. Image Analysis and Interaction, Display options, and Physical Models. Invest. Radiol. *29*, 716–725.