

MDCT Evaluation of Costal Bone Lesions: Comparison of Axial, Multiplanar, and 3D Volume-Rendered Images

A Retrospective Study

Daocai Wang, MD, PhD, Lei Li, MD, PhD, Naixuan Li, MD, and Jingzhen He, MD, PhD

Abstract: The aim of this retrospective study was to compare accuracies of axial, multiplanar, and volume-rendered 3-dimensional (3D) images in the diagnosis of costal bone lesions.

Forty-one patients, aged from 10 to 72-years old, with costal bone lesions underwent multidetector CT (MDCT). Axial, multiplanar, and 3D-volume-rendered images were reviewed by 3 reviewers for the property of the lesions (fracture, tumor, and tumor-like lesions or inflammation). In case of fracture, the diagnosis was demonstrated with the location of the fracture and the amounts of the costal bone involved. In case of a tumor or tumor-like lesions, the diagnosis was demonstrated pathological property. Final diagnosis was determined by biopsy or surgery. Diagnostic accuracy and interreviewers agreement were evaluated.

For the diagnosis of fractures, average accuracy was 77%, 100%, and 100% for axial, multiplanar, and 3D-volume-rendered images, respectively. For the diagnosis of tumor and tumor-like lesions, average accuracy was 90% for axial, 96% for multiplanar, and 99% for 3D-volume-rendered images. For the diagnosis of inflammation lesions, average accuracy was 100% for all the 3 image formats. Interobserver agreement independence of imaging formats was high.

Multiplanar and 3D-volume-rendered images were superior to axial images in diagnosis of fracture, tumor, and tumor-like lesions; however, for the evaluation of inflammation lesions, there were no difference by 3 image formats.

(*Medicine* 94(22):e889)

Abbreviations: 3D = 3-dimensional, CT = computed tomography, MDCT = multidetector CT, MPR = multiplanar reformation.

INTRODUCTION

Conventional radiology has played an important role in the diagnostic evaluation of skeletal lesions. In complex lesions, especially in irregular bone, however, computed

tomography (CT) is a commonly used imaging modality following radiography. Due to technical breakthroughs, multidetector CT (MDCT) is faster and has better temporal, spatial, and contrast resolution than conventional helical CT.^{1,2} With higher spatial resolution, isotropic viewing can be obtained, in which voxels have sides with equal dimensions. An image set with isotropic properties can be reformatted in any plane, with spatial resolution equivalent to that of the original scanning plane.³ Isotropic MDCT images give much better bony anatomic depiction than conventional thin-slice CT.⁴ Artifacts from metal hardware and obesity can also be reduced or eliminated on MDCT images, especially when postprocessing with multiplanar or 3-dimensional (3D) reconstructions is used, potentially increasing accuracy in lesion detection. Moreover, 2-dimensional reformats (multiplanar reformations, MPRs) and 3D volume renderings are of excellent quality, and with today's fast image processing they can be made almost simultaneously. Many studies have done about performance of axial, MPR, and 3D-volume-rendered images on cardiac and vascular.⁵ However, the performance of axial, MPR, and 3D-volume-rendered images has not been well documented. This retrospective study, therefore, was aimed to assess the diagnostic value of axial, MPR, and 3D-volume-rendered images in costal bone lesions.

MATERIALS AND METHODS

Patient Population

This retrospective study was approved by our institutional review board with written informed consent waived. Forty-five patients (24 males and 21 females; age range, 10 to 72 years; mean age, 38 years) who underwent MDCT examination between October 2012 and March 2013 and had diagnoses of costal lesions were included in this study. Costal lesions were suspected because of abnormal findings on chest radiographs (n = 24), trauma (n = 11), and chest pain (n = 10). Four patients were excluded because of the conditions affecting image evaluation: breath-hold failure (n = 2) or metal implants in the scanning field (n = 2).

Imaging Protocol

Examinations were performed with either Somatom Sensation Cardiac16 or Cardiac 64 scanner (Siemens Medical Solutions, Germany), Ten noncontrast examinations, and 31 contrast-enhanced scans in which patients received 2 mL/kg of nonionic contrast medium (300 mL I/mL). Examinations on 16- and 64-slices scanners were performed with 0.75 and 0.6 mm collimation, respectively. Images with the slice thickness of 5 mm were used for routine axial viewing. MPR and 3D images were reconstructed at 1 mm thickness. Standard soft-tissue (eg, width 400–450 H, level 40–50 H) and bone (eg, width

Editor: Bernhard Schaller.

Received: December 4, 2014; revised: April 16, 2015; accepted: May 1, 2015.

From the Shandong Medical Imaging Institute, Shandong University (DW); Shandong University and Qingdao Central Hospital (LL); affiliated Hospital of Binzhou Medical College, Binzhou (NL) and Department of Radiology of Shandong, University Qilu Hospital, Jinan, PR China (JH). Correspondence: Jingzhen He, Department of Radiology of Shandong, University Qilu Hospital, Jinan, PR China (E-mail: hejingzhen@aliyun.com).

LL, NL, and DW contributed equally to this study.

The authors have no funding and conflicts of interest to disclose.

Copyright © 2015 Wolters Kluwer Health, Inc. All rights reserved.

This is an open access article distributed under the Creative Commons Attribution-NoDerivatives License 4.0, which allows for redistribution, commercial and non-commercial, as long as it is passed along unchanged and in whole, with credit to the author.

ISSN: 0025-7974

DOI: 10.1097/MD.0000000000000889

TABLE 1. Number of Missed Lesion and Accuracies for all Lesions by 3 Observers Performing 3 Diagnostic Tasks on 41 Patients with Axial, MPR, and 3D Imaging

Diagnostic Tasks	Observer No.								
	Axial Imaging			Multiplanar Imaging			3D Imaging		
	1	2	3	1	2	3	1	2	3
Fracture	5	6	8	0	0	0	0	0	0
Tumor and tumor like	3	3	1	1	1	1	1	0	0
Inflammation	0	0	0	0	0	0	0	0	0
Total	8	9	9	1	1	1	1	0	0
Percent correct	85%	83%	83%	99%	99%	99%	99%	100%	100%
Mean percent correct		84%			>99%			>99%	

3D = 3-dimensional, MPR = multiplanar reformation.

1000 –2000 H; level, 300 to –500 H) window settings were used to displayed all images.

Image Processing

The reviewers were presented with unlimited MPR images which were reformatted with intervals of 1 mm at the workstation. Oblique MPR images at any planes were reviewed for all patients. 3D images with more opacity and transparency were generated at a separate workstation (Wizard, Volume Wizard, Siemens Medical Solutions, Germany) using volume-rendering techniques. The 2 formats of 3D images were eased to observe the surface and innerstructures of the costal bone, respectively. Patients’ anonyms were maintained during the review sessions. 3D images were reviewed in the workstation in real time, and the reviewers could rotate the images if necessary.

Image Interpretation

Three radiologists with more than 10 years’ experiences in interpreting skeleton CT evaluated all image sets (axial, MPR, and 3D) in 2 review sessions independently in the workstation. In the first review session, the axial CT images and MPR images were reviewed sequentially. To avoid the recall of patient information, the 3D volume-rendered images were reviewed independently at least 2 weeks after the first review session. The property of the lesions was evaluated for all the image sets. In fracture lesions, the location of fracture and the amount of costal

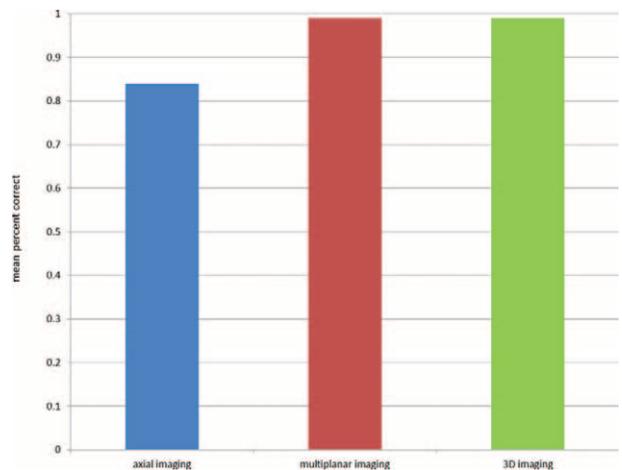


FIGURE 1. Histogram compares mean percent correct of axial, multiplanar images, and volume-render image by observers.

bone involved was recorded. In the case of tumor or tumor-like lesions, the reviewers sought to identify the pathologic properties. The reviewers’ confidences in diagnosis score were assessed with a subjective 5-point scale from 1 to 5.⁶

McNemar tests were used to analyze the difference in diagnostic accuracy among reviewers and image formats. The differences for the subjective diagnostic confidence scores of all

TABLE 2. Scores for Confidence Level of 3 Observers for Performing Diagnostic Tasks on 41 Patients With Axial, MPR, and 3D Imaging

Diagnostic Tasks	Confidence Score*								
	Axial Imaging			Multiplanar Imaging			3D Imaging		
	5	4	3	5	4	3	5	4	3
Fracture	74*	6	1	81	0	0	79	2	0
Tumor and tumor like	63	5	1	69	0	0	66	2	1
Inflammation	9	0	0	9	0	0	9	0	0
Total	146	11	2	159	0	0	154	4	1

3D = 3-dimensional, MPR = multiplanar reformation.

*Number of diagnoses with confidence level score 5 used by 3 observers, no observer used confidence level 2 and 1.

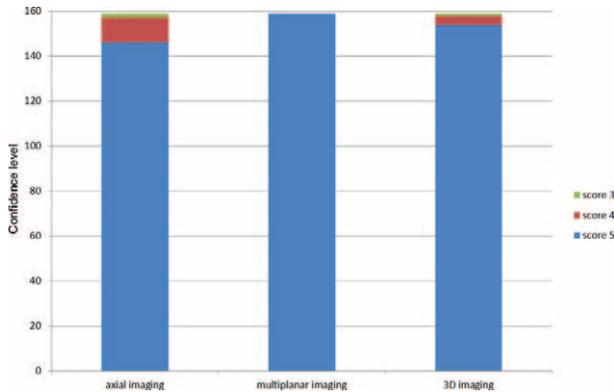


FIGURE 2. Histogram of scores for confidence level of 3 observers for performing diagnostic tasks on 41 patients with axial, MPR, and 3D imaging. 3D = 3-dimensional, MPR = multiplanar reformation.

image sets were tested with the Marginal homogeneity test, and interreviewers variability was also assessed with the κ statistics. Statistical analyses were performed with the statistical software of SPSS for Microsoft Windows.

RESULTS

By biopsy, surgery, and follow-up study, 41 patients with costal bone lesions proved to be 15 cases of fracture, 23 cases of bone tumor and tumor-like lesions (bone fibrous dysplasia $n = 11$, metastasis $n = 9$, and eosinophilic granuloma $n = 3$), and 3 cases of inflammation lesions (specific inflammation $n = 2$, nonspecific inflammation $n = 1$). We took this diagnosis

as reference standard to evaluate the diagnosis made by the 3 reviewers. The average misdiagnosis and accuracies for all lesions by the 3 reviewers were summarized in Table 1. A histogram was used to compare mean percent correct of axial, multiplanar images, and volume-render image by observers (Figure 1). Table 2 and Figure 2 showed scores for the confidence level of 3 observers’ diagnostic performance on 41 patients with axial, MPR, and 3D images, respectively.

In 15 patients with fracture, 27 costal bones identified as fracture. Excellent interobserver agreements were observed with MPR and 3D volume-rendered images but not the axial images for these fracture lesions. Three observers missed 5, 6, and 8 fractures, respectively (Figure 3). Confidence score of 5 was used for 100% cases on MPR images, while 91% and 98% on the axial and 3D images, respectively. All reviewers used confidence level of above 3. The kappa (0.81 ± 0.11) values suggested excellent interobserver agreement among reviewers ($P > 0.99$).

In 23 patients with tumor and tumor-like lesions (Figures 4 and 5), 15 patients underwent biopsy, and 8 patients underwent surgery, (bone fibrous dysplasia $n = 11$, metastasis $n = 9$, and eosinophilic granuloma $n = 3$). We take them as reference standard. With MPR and 3D-volume-rendered images, there was excellent agreement among reviewers and with the reference standard ($P > 0.05$). For the evaluation of tumor and tumor-like lesions, axial images performed worst. On axial imaging, 1 observer misdiagnosed 3 cases of fibrous dysplasia as enchondroma. One observer misdiagnosed 2 cases of fibrous dysplasia as enchondroma, and misdiagnosed 1 case of eosinophilic granuloma as metastasis, 1 observer misdiagnosed 1 case of eosinophilic granuloma as metastasis. On multiplanar images, 1 observer misdiagnosed 1 case of fibrous dysplasia as

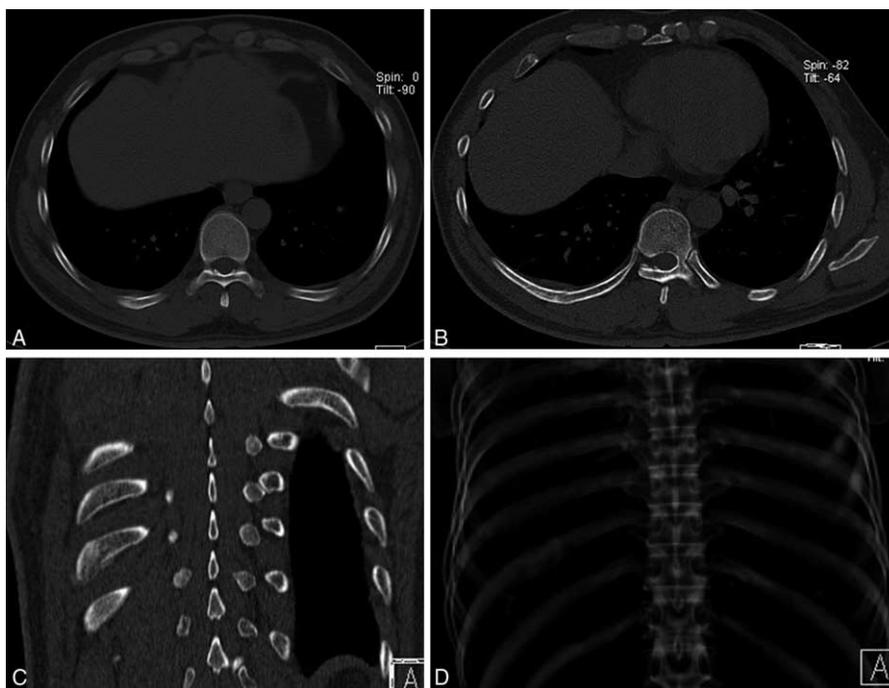


FIGURE 3. A 30-years-old man complained of right chest pain 18 days after trauma, costal bone fracture was suspected. (A) Axial CT only shows cortex collapsed slightly due to formed callus. Two observers missed the fracture, both with a confidence score of 5, only 1 observer diagnosed a fracture with a confidence score of 3. (B, C) Oblique axial and coronal multiplanar images showed fracture line and bony callus clearly, all observers made correct diagnosis with confidence score 5. (D) 3D images clearly show the fracture of right 10th costal bone with bony callus. CT = computed tomography, 3D = 3-dimensional.

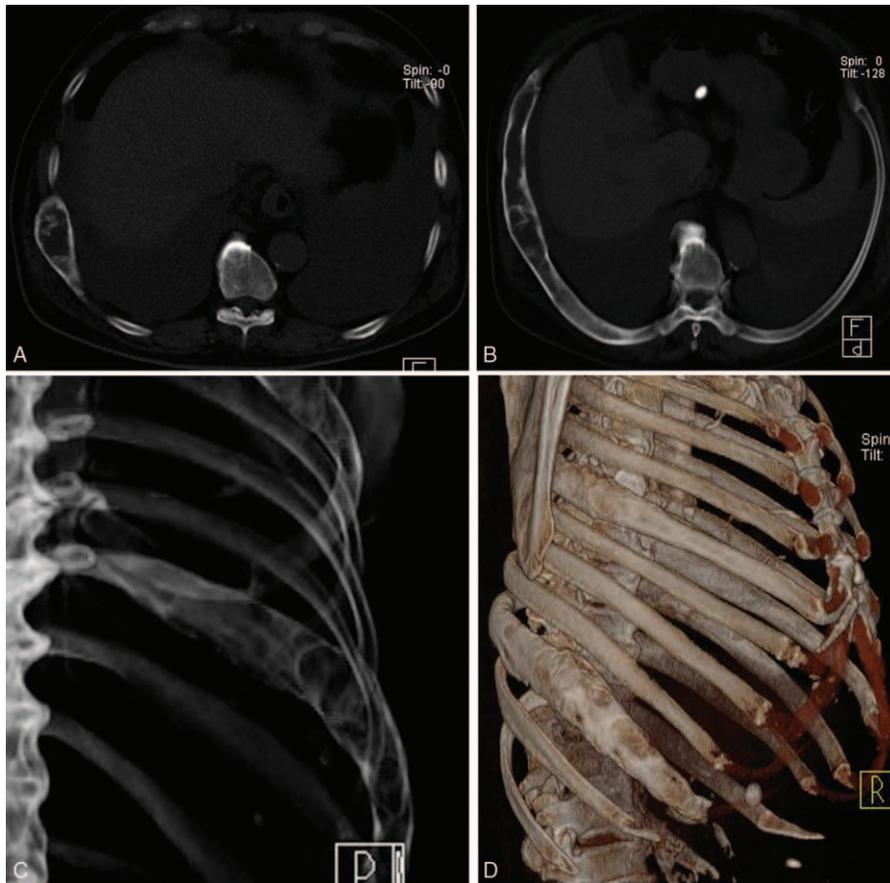


FIGURE 4. Fibrous dysplasia of right 10th costal bone in a 60-year-old man, MDCT was done because of abnormality on chest radiographs. Accuracies for diagnosis for all observers and image types were 100%. (A) Axial CT images show that a diffuse ground-glass appearance and rind lesions. (B) Oblique axial multiplanar images showed almost the whole costal bone is involved, and the lesions appearance were more typical than axial CT. (C, D) 3D-volume-rendering images with more transparency and more opacity, confirmed diffuse ground-glass appearance and rind lesions. CT = computed tomography, 3D = 3-dimensional, MDCT = multidetector CT.

enchondroma, both 2 observers misdiagnosed 1 case of eosinophilic granuloma as metastasis. On 3D volume-rendered images, only 1 observer misdiagnosed 1 case of eosinophilic granuloma as metastasis. Confidence scores of 5 were used in 91%, 100%, and 96% of cases on axial images, MPR, and 3D volume-rendered images, respectively. Five scores of 4 and 1

score of 3 were used by observers for axial imaging, 2 scores of 4 and 1 score of 3 were used by observers for 3D-volume-rendered images. The kappa (0.80 ± 0.12) values suggested excellent interobserver agreement among reviewers ($P > 0.99$).

In 3 patients with inflammation lesions, by follow-up and biopsy, 2 patients proved to be tuberculosis, 1 patient proved to



FIGURE 5. A 72-year-old man with lung cancer left 8th costal bone metastasis complained of left side chest pain underwent MDCT. Axial images show destruction of the bone with soft tissue edema. Oblique axial multiplanar images show the lesions limited in posterior segment of rib with irregular cortical destruction. 3D images with more opacity show the lesions were in left 8th costal bone with irregular bone destruction. 3D = 3-dimensional, MDCT = multidetector CT.

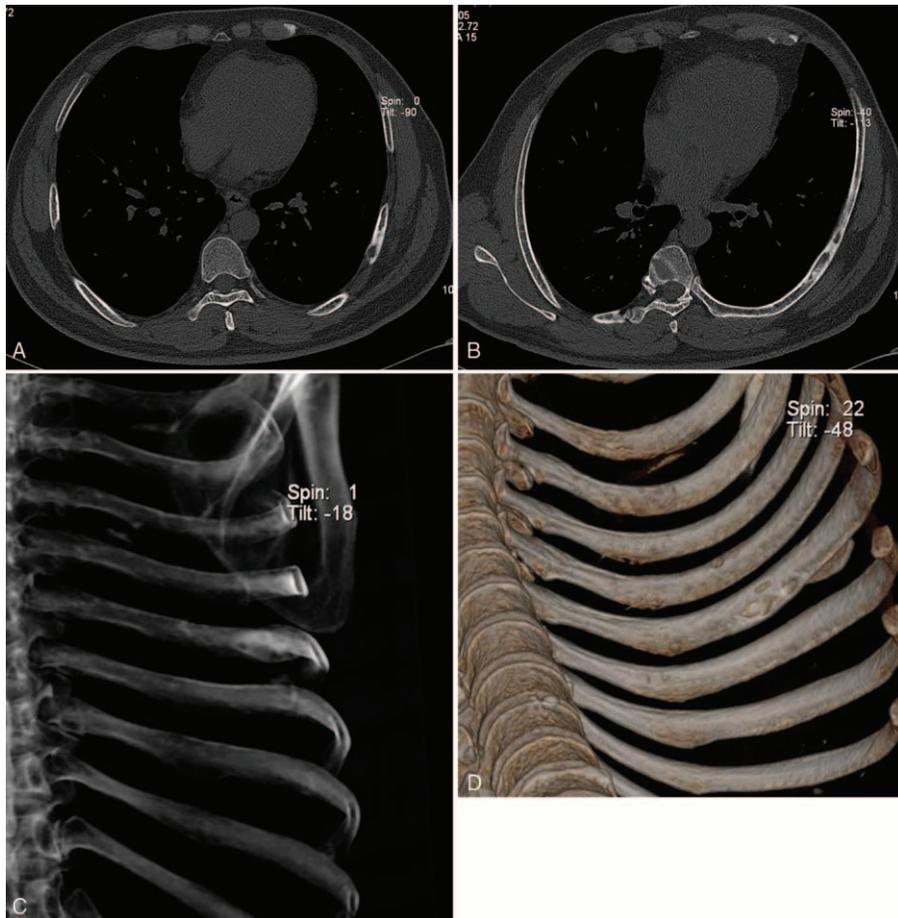


FIGURE 6. An 18-year-old girl with left 7th costal nonspecific inflammation. Accuracies for diagnosis for all observers and image type were 100%. (A) Axial CT shows bone destruction and hyperplasia, and more hyperplasia lesions than destruction lesions imply a chronic process. (B) Oblique axial multiplanar images show extent of the lesions, and the lesions mainly in the middle of the bone. (C, D) 3D volume rendered images clearly show the lesions in the left 7th costal bone, and bone destruction and hyperplasia is displayed. CT = computed tomography, 3D = 3-dimensional.

be nonspecific inflammation. All observers made correct diagnosis with confidence score of 5 with 3 image formats (Figure 6).

DISCUSSION

Several special radiographic views are considered to be better for image costal bone due to our experience. Although these special views do increase diagnostic accuracy, in these special radiographic views the position of the patient was important; however, this can be painful and difficult for some patients especially for thoracic traumatic patient. Due to the extent of the costal bones being not parallel to the scanning plane, it is difficult to display the long axis of the costal bone by conventional axial CT; MDCT with MPR in any plane and 3D-volume-rendering images shows the costal bone anatomy without superimposed structures. Occult lesions are therefore more easily displayed. In MDCT scans, the position of patient is not crucial because of the high-quality reformatting images could be obtained easily. This high-quality MPR and volume-rendered capability is especially useful in analyzing costal bone lesions. Limited literatures were found to compare the accuracy of axial CT, MPR, and 3D-volume-rendering images in the

evaluation of costal bone lesions. Our study was aimed to compare the efficacy of these 3 imaging formats.

Our study demonstrated that there was no difference in diagnosis of the inflammation lesions of costal bones by 3 types of images. However, in the evaluation of fractured, tumor and tumor-like lesions, multiplanar, and 3D-volume-rendering images were superior to axial images, especially in fracture lesions. MPR had shown essential effect in other bone fractures, too.⁷ Some researchers described MPRs alone are a feasible approach for correct assessment of vertebral fractures and classifying them into stable/unstable, if done properly.⁸⁻¹⁰ With the advances of CT, MPR and 3D images were easily generated in workstation. We did not exactly record the time which took to interpret each type of images; however, interpreting the multiplanar and 3D volume rendering images only added about 2 to 5 minutes in clinical routine and did not add significant time to interpretation in our experience.

Our study has several limitations: first, the number of patients who had costal lesions was small, and true statistical significance may be achieved with a larger patient population. However, our results are important and different diagnostic efficacy was found by 3 imaging sets, particularly in fracture lesions of costal bone. Second, in our study MPR and axial

images were assessed at the same review session and recall effect may be occurred. However, the patients' information maintained anonymous and the review order was random.

In conclusion, MDCT can provide reliable diagnostic information about costal bone lesions. Although axial images are diagnostic for the evaluation of costal bone lesions, they may be limited for the evaluation of some specific costal bone lesions especially regarding fractures. In patients with costal lesions, multiplanar and 3D volume-rendered images can enhance the diagnostic value of CT. Additional multiplanar and 3D volume-rendered images may be performed in clinical routine in these patients.

REFERENCES

- Rydberg J, Buckwalter KA, Caldemeyer KS, et al. Multisection CT: scanning techniques and clinical applications. *Radiographics*. 2000;20:1787–1806.
- Novelline RA, Rhea JT, Rao PM, et al. Helical CT in emergency radiology. *Radiology*. 1999;213:321–339.
- Buckwalter KA, Rydberg J, Kopecky KK, et al. Musculoskeletal imaging with multislice CT. *Am J Roentgenol*. 2001;176:979–986.
- Vyhnánek F, Skála P, Skrabalová D. A contribution of multidetector computed tomography to indications for chest wall stabilisation in multiple rib fractures. *Acta Chir Orthop Traumatol Cech*. 2011;78:258–261.
- Kim EY, Yang HJ, Sung YM, et al. Multidetector CT findings of skeletal chest injuries secondary to cardiopulmonary resuscitation. *Resuscitation*. 2011;82:1285–1288.
- Lee EY1, Siegel MJ, Hildebolt CF, et al. MDCT evaluation of thoracic aortic anomalies in pediatric patients and young adults: comparison of axial, multiplanar, and 3D images. *AJR Am J Roentgenol*. 2004;182:777–784.
- Haapamäki VV1, Kiuru MJ, Mustonen AO, et al. Multidetector computed tomography in acute joint fractures. *Acta Radiol*. 2005;46:587–598.
- Begemann PG, Kemper J, Gatzka C, et al. Value of multiplanar reformations (MPR) in multidetector CT (MDCT) of acute vertebral fractures: do we still have to read the transverse images? *J Comput Assist Tomogr*. 2004;28:572–580.
- Arthur E li, Elliot K. Fishman Cervical spine trauma: evaluation by multidetector CT and three dimensional volume rendering. *Emerg Radiol*. 2003;10:34–39.
- Sangster GP, González-Beicos A, Carbo AI, et al. Blunt traumatic injuries of the lung parenchyma, pleura, thoracic wall, and intrathoracic airways: multidetector computer tomography imaging findings. *Emerg Radiol*. 2007;14:297–310.