Trauma-related injuries of the pelvis and spine-

Does multidetector-row CT increase diagnostic accuracy?

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Objective: To evaluate different multidetector-row CT (MDCT) strategies for adequate classification of spinal and pelvic injuries.

Material and Methods: 70 consecutive patients after severe blunt trauma underwent conventional radiography and MDCT. Examinations included the pelvis (P; n=40), the lumbar (LS; n=24) and the thoracic spine (TS: n= 21). All data were analyzed by two independent observers, using the AO-classification for thoracolumbar injuries and the classification according to Tile for pelvic injuries. Conventional radiographs (CR), 3 mm scans (CT5), 5 mm scans (CT3) and 3 mm scans combined with multiplanar reformations (CT-MPR) were compared with surgical and autopsy results or clinical development. The Chi^2-test, Cross tables, Cohens's Kappa and the Spearman correlation were used for statistics.

Results: MDCT led to significant better results than CR ($p<0.01$). Correlation coefficients for CT-MPR amounted to r=1.0. For CT3 coefficients ranged between r=0.8 (P) and r=1.0 (TS), for CT5 between r=0.80 (P) and r=0.86 (TS) and for CR between r=0.3 (TS) and r=0.69 (P). Fractures were identified by CT-MPR in 100%, by CT3 in 90% (P) -100% (TS), by CT5 in 83.3% (LS) - 90% (P) and by CR in 57.1% (TS) - 87.2% (P). Instable fractures (thoracolumbar spine: $\geq$A3.2; pelvis: $\geq$B) were identified by CT-MPR and CT3 in each 100%, by CT5 in 85.7% (TS) -100% (P, LS) and by CR in 57.1% (TS) - 80% (P).

Conclusion: Only overlapping thin slice reconstruction technique combined with multiplanar reformation allows for adequate classification of spinal and pelvic injuries and therefore is highly emphasized in patients after severe blund trauma.

Key words: Spine, Computed Tomography, Multiplanar reformations, trauma

INTRODUCTION

The advent of multidetector-row technology combined with subsecond rotation and narrow collimation of up to one millimeter resolved the long-lasting trade-off between scan volume and slice thickness, now rendering possible acquisition of very large scan volumes in very small slice thickness [1]. Combination of high in-plane and z-resolution provide near isotropic image reconstruction, thus allowing for high quality multiplanar image reformation in each spatial orientation [1]. This is particularly important in the diagnostics of severe trauma patients, where theoretically the acquisition of continuous whole body data sets [2] in very small slice thickness not only allows for sophisticated inspection of the soft tissue but also of the spine and pelvis. Ideally, both should be cleared within minutes after the admission to the emergency room. Conventional radiography hashistorically been reported as the screening examination of choice for the injured spine [1], whereas computed tomography was regarded as a subordinate technique. This appraisal particularly was derived from the era of single slice CT where many false diagnoses in computed tomography resulted not only from the absence of distinct CT criteria for acute spinal cord injuries but also from the difficulty to judge transverse fractures on transverse CT scans alone. A few authors consequently recommend elective supplementary CT for assessment of the extent and stability of spinal fractures diagnosed at conventional radiography, with the results of conventional radiography enabling the CT examination to be focused on the appropriate region of interest [1]. However, none of these articles concerns CT as a screening examination for thoracolumbar spine fractures, and none specifically addresses multi–detector row CT. However, the latter technique now allows for fast access to sagittal and coronal reformations and therefore for easy orientation in any spatial orientation. With regard to this development the potential of computed tomographic (CT) as a screening examination in the assessment of thoraco-.lumbar fractures has never been evaluated in large series [2,3]. In addition the informational value of conventional radiographs in modern trauma management appears rather questionable. The aim of the present study consequently was to determine if multi–detector row CT can replace conventional radiography and if diagnostic accuracy could be influenced by choice of suited reconstruction parameters. .

MATERIALS AND METHODS

Patients

Seventy consecutive adult patients with sustained severe blunt trauma, who underwent conventional radiography of the thoracolumbar spine and the pelvis as well as thoraco-abdominal multi–detector row CT, were examined in the course of a prospective study. At our institution at this time both examinations systematically were performed in severe trauma patients as part of the trauma admission survey. All CT examinations took place in order to rule out traumatic lesions of either the aorta or visceral organs and no additional imaging was performed because of the study itself.

Since no additional imaging was necessary due to the study and all patients were intubated at the time of image acquisition our institutional review board did not require its approval and no informed consent for the study.

Image acquisition and reconstruction

Conventional radiographic survey of the spine consisted of antero-posterior and lateral views of the thoracic and lumbar spine with the patient in the supine position. Occasionally, a so-called swimmer's view (a lateral radiograph of the cervical spine acquired with the patient having one arm up and one arm down) was obtained to clarify the status of the spine at the cervicothoracic junction. Conventional radiographs of the pelvis were carried out as antero-posterior views with the patient in the supine position.

Multidetector-row CT (MDCT) examinations were performed on a 4-row spiral CT (Somatom Plus 4 VZ, Siemens Inc., Forchheim, Germany). Scanning parameters were 120 kV voltage and 400 mAs tube current, 500 ms rotation time, 4 x 2.5 mm collimation, and 12.5 mm table feed per rotation. Image acquisition was done in craniocaudal direction by using the helical mode. Each patient received 120 ml (flow: 3.5 ml/s) of a non-ionic contrast medium (Ultravist® 370 mgI/ml; Schering Inc., Berlin, Germany) infused through an 18G intravenous antecubital catheter.

All data sets were reconstructed with both 5 mm slice thickness and increment and 3 mm slice thickness and increment. A medium hard reconstruction kernel was used for image reconstruction and the prevailing field of view was adapted for adequate visualization of both the spine and the pelvis (150 – 350 mm). The 3 mm series in addition was reconstructed in 1.5 mm increment in order to allow for sagittal and coronar multiplanar reformations (MPR).

Image Evaluation

After previously blinding of the patients' data in order to avoid recall bias, all images were reviewed by two independent reviewers without knowledge of the diagnoses in the discharge or autopsy reports. Evaluation was done separately for conventional radiographs, 5 mm transverse MDCT slices, 3 mm transverse MDCT slices and 3 mm transverse MDCT slices in combination with sagittal and coronal MPR. The MDCT images were analyzed on a workstation (Leonardo ®, Siemens Inc., Forchheim, Germany) with 512 x 512 matrix size, the conventional radiographs on plain films (18 x 43 cm [thoraco-lumbar spine] and 35 x 43 cm [pelvis]).

Both reviewers were asked to evaluate the images for the presence or absence of fractures, their location and whether the fractures were stable. Fracture, by this means, stood for a cortical interruption without sclerotic borders. Thoraco-lumbar injuries were graded by using the AO-classification [3], pelvic injuries by using the modified AO classification according to Tile [4]. Unstable was attributed to any fracture of the thoracolumbar spine that was graded A.3.2 or higher and any B, C respectively, fracture of the pelvis (Figure 1 and 2).

The definitive presence or absence of thoraco-lumbar spine and pelvis fractures was determined on the basis of the clinical course, the results of any subsequent imaging examination (conventional radiography, computed tomography, magnetic resonance imaging), the findings of any surgical intervention and the diagnosis as reported in the discharge or autopsy report. In order to also verify the diagnosis in the longer term, all patients were followed up > 12 months after discharge via telephone survey by using a standardized questionnaire.

Statistical Analysis

Statistical analysis was performed by using BiAS, version 7.0 (Epsilon Publishers, Manheim, Germany).

Agreement between the reviewers regarding the classification of the fractures was calculated by means of the κ statistic, interpreting the results according to the κ value as poor (<0.20), fair (0.21 – 0.40), moderate (0.41 – 0.60), good (0.61 – 0.80), very good (0.81 – 0.90), or excellent (0.91 – 1.00). A 95% CI, calculated by a standard method, was assigned to the calculated κ value.

Correlations between imaging method (conventional radiographs, 5 mm transverse slices, 3 mm transverse slices and 3 mm transverse slices combined with MPR) and effective clinical results - as observed by either surgery, autopsy or clinical evolution plus 12 months survey - were determined by using the Spearman's correlation. Coefficients of correlation were calculated regarding the detection of both fractures in general and unstable fractures. The Bowker's test was applied to check the symmetry of the data distribution and to evaluate possible under-/ overestimation of the prevailing imaging methods.

Sensitivity and specificity as well as positive and negative predictive value in the detection of fractures in general and the detection of unstable fractures were determined for each of the imaging method separately by using cross tables. Any differences were tested for significance by using Chi^2 contingency tables.

RESULTS

Patients' characteristics

The data of all 70 (46 men and 24 women) severe trauma patients could be evaluated. The patients' mean age amounted to 42.0 years (range: 23–86 years). 43 had been involved in traffic accidents (26 [37.1%] in car accidents, 4 [5.7%] in motorcycle accidents, and 13 [18.6%] in pedestrian accidents), 17 [24.4%] in falls, 5 [7.1%] in crush accidents and 5 [7.1%] in a trauma of unknown origin (Table 1). A total of 85 fractures were found in 56 patients, of which 40 affected the pelvis, 24 the lumbar spine and 21 the thoracic spine. 30 [60.5%] pelvic fractures, 14 [58.3%] lumbar spine fractures and 7 [33.3%] thoracic spine fractures proved to be unstable (Table 1). Surgery was performed in all patients with unstable fractures and in 5.9% (2/34) of the patients with stable fractures: one A1.2 impaction fracture of the lumbar spine and one A2.1 compound fracture of the pelvis. 37 patients presented with isolated fractures, 28 affecting the pelvis, 5 the lumbar spine and 4 the thoracic spine. The remaining 19 patients showed either multi-segmental fractures or fractures at different heights. One multi-segment fracture was observed in the pelvis, five in the lumbar spine and four in the thoracic spine. Nine patients presented with fractures at different heights: the lumbar spine and the pelvis (5), the thoracic spine and the pelvis (1) or the thoracic spine and the lumbar spine (3). Correlation of radiological findings with either surgery or authopsy results was possible in 33 patients. Surgical results were available for six patients with fractures of the thoracic spine, eight patients with fractures of the lumbar spine and thirteen patients with fractures of the pelvis. Autopsy was performed in each three patients with fractures of the thoracic and lumbar spine. Two patients passed away during hospitalisation due to multiple organ failure. In the remaining 35 patients the effective clinical outcome was determined based on the prevailing discharge reports and telephone surveys twelve month after discharge. Apart from four patients who could not be contacted due to lack of personal data, all other patients reported a after-discharge history without trauma related complaints or the need for re-admission.

Pelvis

The agreement between the reviewers regarding the classification of the fractures amounted to 0.934, thus corresponding to a very good agreement.

Multidetector-row computed tomography showed far better correlation coefficients in grading and detection of fractures than conventional radiographs, however a level of significance was reached only for 3 mm transverse slices in combination with MPR ($p<0.01$). Correlation coefficients for pelvic fractures in general were $r=0.69$ ($p<0.01$) for conventional radiographs, $r=0.80$ ($p<0.01$) for 5 and 3 mm transverse slices and $r=1.0$ ($p<0.01$) for 3 mm transverse slices combined with MPR. Correlation coefficients for unstable fractures were $r=0.73$ ($p<0.01$) for conventional radiographs and $r=0.91$ ($p<0.01$) for any of the CT techniques (Table 2). Bowker's test showed a rather symmetrical distribution of the data for both conventional radiographs ($p=0.99$) and all CT techniques ($p=1.00$). Conventional radiographs underestimated 42% (21/50) and overestimated 8% (4/50) of all fractures, 5 mm transverse slices 16% (8/50) and 4% (2/50), 3 mm transverse slices 14% (7/50) and 4% (2/50) and 3 mm transverse slices in combination with MPR 2% (1/50) and 6% (3/50).

Fractures were detected with 87.2% sensitivity (34/39; CI: 72.6%, 95.7%) by conventional radiographs, 90.0% sensitivity (36/40; CI: 76.3%, 97.2%) by 5 and 3 mm transverse slices with and 100% sensitivity (40/40; CI: 91.2%, 100%) by 3 mm transverse slices combined with MPR. Specificity was 90.0% (9/10; CI: 55.5%, 99.75%) for conventional radiographs and 100% (10/10; CI: 69.2%, 100%) for either

MDCT technique (Table 3). Unstable fractures were identified with 80.0% sensitivity (24/30; CI: 61.4%, 92.3%) by conventional radiographs and 100% sensitivity (30/30; CI: 88.4%, 100%) by MDCT regardless of the technique applied. Specificity amounted to 95.0% (19/20; CI: 75.1%, 99.9%) for conventional radiographs and each 90.0% (18/20; CI: 68.3%, 98.8%) for any CT technique (Table 3). Cross table results for conventional radiographs (p= 0.05 [fractures in general]; p=0.03 [unstable fractures]) were significantly worse than for 5 and 3 mm transverse slices (p= 0.23 [fractures in general]; p=0.35 [unstable fractures]) or 3 mm transverse slices in combination with MPR (p= 1.00 [fractures in general and unstable fractures]).

Lumbar spine

The agreement between the reviewers regarding the classification of the fractures amounted to 0.834, thus corresponding to a very good agreement.

Multidetector-row computed tomography showed far better correlation coefficients (p<0.01) in grading and detection of fractures than conventional radiographs, however a level of significance was reached only for 3 mm transverse slices - irrespective if or if not combined with MPR (p<0.01). Correlation coefficients for fractures in general were r=0.58 (p<0.01) for conventional radiographs, r=0.85 (p<0.01) for 5 mm transverse slices, r= 0.92 (p<0.01) for 3 mm transverse slices and r=1.0 (p<0.01) for 3 mm transverse slices combined with MPR. Correlation coefficients for unstable fractures were r=0.75 (p<0.01) and r=0.95 (p<0.01) for any of the CT techniques (Table 2). Bowker's test showed a rather symmetrical distribution of the data for conventional radiographs (p=0.99) and any of the CT techniques (p=1.00). Conventional radiographs underestimated 22.2% (12/54) and overestimated 12.9% (7/54), 5 mm transverse slices 14.8% (8/54) and 1.9% (1/54), 3 mm transverse slices 11.1% (6/54) and 1.9% (1/54) and 3 mm transverse slices in combination with MPR 1.9% (1/54) each.

Fractures were detected with 75.0% sensitivity (18/24; CI: 53.3%, 90.2%) by conventional radiographs, 83.3% sensitivity (20/24; CI: 62.6%, 95.3%) by 5 mm transverse slices, 91.7% sensitivity (22/24; CI: 73.0%, 98.9%) by 3 mm transverse slices and 100% sensitivity (24/24; CI: 85.8%, 100%) by 3 mm transverse slices combined with MPR. The prevailing specificities were 83.3% (25/30; CI: 65.3%, 94.4%) for conventional radiographs and 100% (30/30; CI: 88.4%, 100%) for any of the MDCT techniques (Table 3). Unstable fractures were identified with 76.9% sensitivity (10/13; CI: 46.2%, 94.9%) by conventional radiographs and 100% sensitivity (13/13; CI: 75.3, 100%) by either MDCT technique. The prevailing specificities were 97.5% (39/40; CI: 86.8%, 99.9%) for conventional radiographs and 100% (40/40; CI: 91.2%, 100%) for any of the MDCT techniques (Table 3). Cross table results for conventional radiographs were significantly ($p<0.01$ [fractures in general]), distinctly ($p=0.22$ [unstable fractures]) respectively, worse than for 5mm transverse slices ($p= 0.22$ [fractures in general]; $p=1.00$ [unstable fractures]), 3 mm transverse slices ($p= 0.55$ [fractures in general]; $p=1.00$ [unstable fractures]) or 3 mm transverse slices in combination with MPR ($p= 1.00$ [fractures in general and unstable fractures]).

Thoracic spine

The agreement between the reviewers regarding the classification of the fractures amounted to 0.864, thus corresponding to a very good agreement.

Any of the CT techniques showed significantly better correlation coefficients in grading and detection of fractures than conventional radiographs ($p<0.01$). Correlation coefficients for fractures in general were $r=0.30$ ($p=0.04$) for conventional radiographs, r=0.86 (p<0.01) for 5 mm transverse slices and r=1.0 (p<0.01) for 3 mm transverse slices - irrespective if or if not combined with MPR. Correlation coefficients for unstable fractures were r=0.36 (p=0.01) for conventional radiographs, r=0.91 (p<0.01) for 5 and 3 mm transverse slices and r=1.0 (p<0.01) for 3 mm transverse slices combined with MPR (Table 2). Bowker's test showed a rather symmetrical distribution of the data for conventional radiographs (pelvis and lumbar spine: p=0.99; thoracic spine: p=0.65), 5 mm transverse slices (pelvis and lumbar spine: p=1.00; thoracic spine: p=0.73, 3 mm transverse slices (pelvis and lumbar spine: p=1.00; thoracic spine: p=0.85) and 3 mm transverse slices in combination with MPR (pelvis and lumbar spine: p=1.00; thoracic spine: p=0.99). Conventional radiographs underestimated 39.5% (17/43) and overestimated 13.9% (6/43), 5 mm transverse slices 16.3% (7/43) and 0% (0/43), 3 mm transverse slices 6.9% (3/43) and 0% (0/43) and 3 mm transverse slices in combination with MPR 0% (043) each.

Fractures were detected with 57.1% sensitivity (12/21; CI: 34.1%, 78.2%) by conventional radiographs, 85.7% sensitivity (18/21; CI: 63.7%, 96.9%) by 5 mm transverse slices and 100% sensitivity (21/21; CI: 83.9%, 100%) by 3 mm transverse slices – irrespective if or if not combined with MPR. The prevailing specificities were 72.7% (16/22; CI: 49.8%, 89.3%) for conventional radiographs and 100% (22/22; CI: 84.6%, 100%) for either MDCT technique (Table 3). Unstable fractures were identified with 57.1% sensitivity (4/7; CI: 18.4%, 90.1%) by conventional radiographs, 85.7% sensitivity (6/7; CI: 42.1%, 99.6%) by both 5 and 3 mm transverse slices and 100% sensitivity (7/7; CI: 59.0%, 100%) by 3 mm transverse slices combined with MPR. The prevailing specificities were 92.1% (35/38; CI: 78.6%, 98.3%) for conventional radiographs and 100% (38/38; CI: 90.8%, 100%) for either MDCT technique (Table 3). Cross table results for conventional radiographs (p<0.01 [fractures in general]; p=0.01 [unstable fractures]) were significantly worse than for

5mm mm transverse slices (p= 0.35 [fractures in general]; p=0.77 [unstable fractures]), 3 mm transverse slices (p= 0.1.00 [fractures in general]; p=0.77 [unstable fractures]) or 3 mm transverse slices in combination with MPR (p= 1.00 [fractures in general and unstable fractures]).

DISCUSSION

To our knowledge this is the first study on the diagnostic benefit of different multi–detector row CT (MDCT) image reconstruction protocols in the detection of traumatic spine fractures. The significant advantage of computed tomography over conventional radiography in contrast has previously already been demonstrated by others [5-10]. With regard to MDCT one of the study groups surprisingly observed high sensitivities for unstable thoraco-lumbar fractures but rather low sensitivities for thoraco-lumbar fractures in general. Careful review of their methodology shows that this difference may at least partly be due to fact that lumbar and thoracic spine fractures were analyzed as one single entity even though image reconstruction parameters for both were rather heterogeneous: 2.5 mm slice thickness and 2.0 mm reconstruction increment for the thoracic spine, 5.0 mm and 5.0 mm for the lumbar spine respectively. Particularly the latter values appear rather inappropriate for multiplanar reformation [11]. Our results in addition indicate that not only the use of MPR but also the thickness of the transverse slices per se can markedly influence sensitivity. In fact, for 5 mm slices we observed sensitivities that were comparable to those of Wintermark et al, whereas for 3 mm slices sensitivity never fell below 91.0 %, regardless of the nature of the fracture, if or if not combined with MPR respectively. Thus sensitivity in both the detection of lumbar and of thoracic spine fractures may be markedly increased by simply reducing the slice thickness. This observation is of particular importance as common multidetector-row CT protocols for thoraco-abdominal imaging anyway use collimations that allow for at least 3.0 mm slice thickness and additional scanning for thin slice imaging consequently would not be necessary [2, 7, 8]. In a more recent survey Schröder et al. reported sensitivities between 20.5% and 97.4% for multidetector-row computed tomography depending on both the type of fracture (Magerl A, B, C) and the reconstruction technique (transversal slices, multiplanar reformation, surface shaded [SSD] 3D reconstruction or volume rendering technique [VRT]) [10]. 3-D techniques proved to be superior in the detection of C fractures, a finding that was largely attributed to the more concise spatial representation as compared to transverse or multiplanar imaging [10]. Although these results strongly encourage the use of VRT or SSD, the sensitivities observed for multiplanar reformations or transverse images appear rather low as compared to our own results as well as those of others [12, 13]. The high percentage of C fractures in the patients' collective of Schroeder at al. may at least partly account for this divergence but also that MPR and transverse scans were treated as separate entities, whereas in our study they were used in combination. However, 3-D techniques certainly help to simplify appraisal of complex fractures [12] and allocation of fragments [12, 13]. Unfortunately they appear less favourable for A and B [12] fractures of the spine and they are associated with an augmented post-processing, which often is not feasible in case of trauma patients [10]. Our data in contrast suggest that simple multiplanar reconstructions combined with transverse slices allow for an equally reliable assessment of all fractures and thus may be sufficient for therapy-relevant decisions at the time of admission. Any additional information may then be derived from 3-D data sets while the patient is transferred to the surgical theatre. However, regardless of the technique that is applied, exclusive restriction to transverse slices must be regarded obsolete since significantly more fractures are missed than by using of reformatted data sets [12, 13].

MPR technique also proved to be superior in the detection of fractures of the pelvis, leading to significant better results than conventional radiographs and marked better results than transverse slices alone. Similar results just recently have been reported by Wedegärtner et al [14]. However, no comparison as to the diagnostic benefit of different CT techniques has been undertaken and no correlation was made to clinical data such as surgical outcome, autopsy results or discharge reports. Without this information any conclusive appraisal of the effective diagnostic accuracy unfortunately is impossible. All other comparable studies either rely on data that were derived from single slice computed tomography [5, 7, 15, 16], were evaluated in a retrospective manner [17] or used matched data from single slice and multislice CT [18, 19] However, all authors independently reported far better results for CT and postulated that in case of suspected pelvic trauma computed tomography should replace plain radiographs. Even though multidetector-row CT as a single method distinctly exceeds conventional radiography in terms of the effective dose the gain in diagnostic accuracy may legitimate such an approach. Abandonment of conventional radiographs may reduce the total effective dose by 24.7% as compared to the use of both imaging techniques [9]. Our results further indicate that thin slice technique helps to increase diagnostic accuracy up to 100% and that by use of common thoraco-abdominal CT protocols [2, 8]this information can be gained without any additional scanning. An indeed highly interesting approach has just recently been proposed by Ptak et al. who showed that by choice of a single-pass continuous whole-body CT protocol total dose reductions of up to 17% were feasible [20]. It seems that technical developments such as 16-row CT [1] as well as improvements in detector configuration [21] will help to even further reduce the radiation dose in the near future. Next to a reduction in effective dose, omission of conventional radiographs in severe trauma patients affords several other major advantages such as markedly shortened examination times, less patient manipulation and finally cost containment. With time savings of up to 32% [9] the duration of preoperative screening markedly is reduced and so are any adverse effects on the patient’s prognosis [6]. Diminishing of patient manipulation in addition avoids the hazard of iatrogenic spinal cord injuries which are observed in up to 5–10% of all patients in the early postfracture period [22, 23]. From a economic point of view, US-based studies showed that eliminating conventional radiography in severe trauma patients may lead to a substantial saving of $145 per patient in terms of direct resource cost [9].

We acknowledge that our study is limited in several ways. The main limitation relates to the absence of a real standard of reference for the diagnosis of fractures in those thirty-seven patients which neither had surgery nor autopsy. For evident ethical reasons, it was not possible to perform systematic imaging studies in all surviving patients just for the purposes of this study. We consequently chose clinical evolution as well as any follow-up imaging examination as recorded during the patient's hospitalization as a standard of reference. However, in all cases and at all imaging examinations performed during follow-up, strict criteria were used in the diagnosis of spine fractures, and experienced reviewers were involved. The underlying rationale to perform a long-time follow-up twelve months after discharge consequently was to verify if any of the fractures that were potentially missed involved pain or secondary complications and thus necessitated further treatment.

The small number of patients included unfortunately also limits the informational value of our results. The authors tried to make allowance for this by including confidence intervals for all relevant values. Their sometimes large variability indicates that accuracy for sensitivity, specificity NPV and PPV partly was low.

We conclude that in severe trauma patients multidetector-row CT proved to be far superior in the detection and classification of traumatic fractures of the spine and pelvis. Particularly thin slice technique combined with multiplanar reformation lead to significant better results than conventional radiographs or transverse images alone. Common thoraco-abdominal multidetector-row CT protocols normally are based on collimations that allow for such a thin slice approach and thus this gain in accuracy can be achieved without additional scanning. Since conventional radiographs provide no extra information they may be omitted in order to reduce needless radiation dose for the patient.

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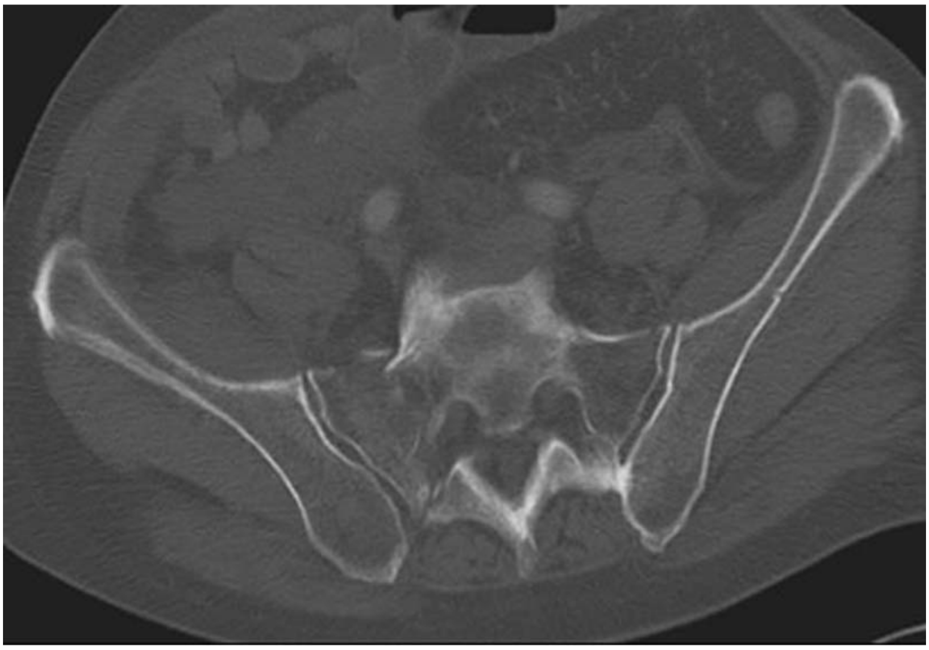

Figure 1 Images of a 68-year-old woman who was involved in a high-speed car accident. On conventional anterior-posterior radiographies (top) only the right pubic bone seems to be disrupted, pretending a merely stable fracture of the pelvis. Additional transverse CT slices (middle) allow for the detection of a trans-foraminal fracture of the right-side of the sacrum which commonly is referred to as an open book fracture. This combination represents an unstable fracture which still can be treated conservatively. However, the almost horizontal fracture of the left-side of the sacrum was visible only on paracoronal secondary reformations (below) and lead to the diagnosis of a bilateral ventral and dorsal disruption of the pelvic ring. This is a highly complex situation which demands for immediate surgical repair.

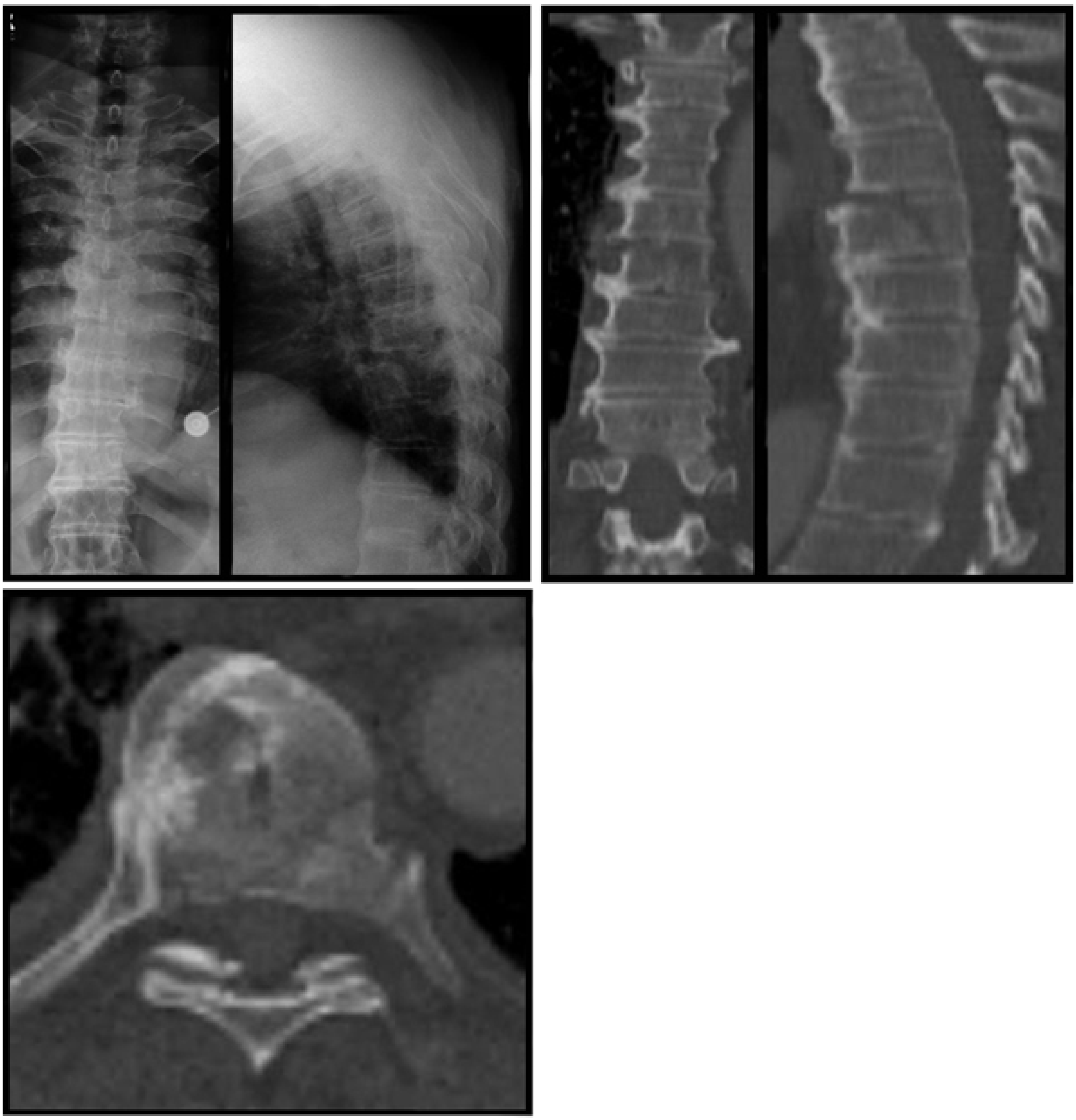

Figure 2 Images of a 74-year old man who was involved in a crash accident. On conventional radiographs merely a sagittal split fracture is identified. Based on this finding alone the fracture would have been graded as stable. CT imaging in this patient clearly proved that often only a combination of transverse slices and secondary reformations allow for proper classification of spine fractures. Thus the sagittal split fracture through the vertebral body is visible only on sagittal reformations whereas the unstable trailing edge was diagnosed on transverse slices only.

TABLE 3 Cross table results for the detection of fractures in general and unstable fractures. Conventional radiographs in comparison to different Multidetector-row CT techniques.

		conventional radiographs		5 mm slices (transverse)		3 mm slices (transverse)		3 mm slices (transverse) plus MPR	
		%	n	%	n	%	n	%	n
Pelvis									
Fractures in general									
(A/B/C-Fractures)	**Sensitivity**	87.2	(34/39)	90.0	(36/40)	90.0	(36/40)	100	(40/40)
	Specificity	90.0	(9/10)	100	(10/10)	100	(10/10)	100	(10/10)
	NPV	64.3	(9/14)	71.4	(10/14)	71.4	(10/14)	100	(10/10)
	PPV	97.1	(34/35)	100	(36/36)	100	(36/36)	100	(40/40)
Unstable fractures									
(B/C-Fractures)	**Sensitivity**	80.0	24/30	100	(30/30)	100	(30/30)	100	(30/30)
	Specificity	90.0	(18/20)	100	(20/20)	100	(20/20)	100	(20/20)
	NPV	76.0	(19/25)	100	(18/18)	100	(18/18)	100	(18/18)
	PPV	96.0	(24/25)	93.7	(30/32)	93.8	(30/32)	93.8	(30/32)
Lumbar Spine									
Fractures in general									
(<A.3.2-Fractures)	**Sensitivity**	75.0	(18/24)	83.3	(20/24)	91.7	(22/24)	100	(24/24)
	Specificity	83.3	(25/30)	100	(30/30)	100	(30/30)	100	(30/30)
	NPV	80.7	(25/31)	88.2	(30/34)	93.8	(30/32)	100	(30/30)
	PPV	78.3	(18/23)	100	(20/20)	100	(22/22)	100	(24/24)
Unstable fractures									
(≥A.3.2 Fractures)	**Sensitivity**	76.9	(10/13)	100	(13/13)	100	(13/13)	100	(13/13)
	Specificity	97.5	(39/40)	100	(40/40)	100	(40/40)	100	(40/40)
	NPV	90.7	(39/43)	97.6	(40/41)	97.6	(40/41)	97.6	(40/41)
	PPV	90.9	(10/11)	100	(13/13)	100	(13/13)	100	(13/13)
Thoracic Spine									
Fractures in general									
(<A.3.2-Fractures)	**Sensitivity**	57.1	(12/21)	85.7	(18/21)	100	(21/21)	100	(21/21)
	Specificity	72.7	(16/22)	100	(22/22)	100	(22/22)	100	(22/22)
	NPV	64.0	(16/25)	88.0	(22/22)	100	(22/22)	100	(22/22)
	PPV	66.7	(12/18)	100	(18/18)	100	(21/21)	100	(21/21)
Unstable fractures									
(≥A.3.2 Fractures)	**Sensitivity**	57.1	(4/7)	85.7	(6/7)	85.7	(6/7)	100	(7/7)
	Specificity	92.1	(35/38)	100	(38/38)	100	(38/38)	100	(38/38)
	NPV	91.7	(33/36)	97.3	(36/37)	97.3	(36/37)	100	(38/38)
	PPV	42.9	(3/7)	100	(6/6)	100	(6/6)	100	(7/7)