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FULL PAPER

Reliability and accuracy of scout CT in the detection of vertebral fractures

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Objective: The aim of the present study was to evaluate the reliability of scout CT (sCT) lateral radiograph, in terms of diagnostic accuracy and intra- and interobserver agreement in the detection of vertebral fractures (VFs).

Methods: 300 CT examinations of the thoracic and/or lumbar spine were collected and independently analysed by 3 musculoskeletal radiologists in 2 different sessions. A semi-quantitative approach was used for VF assessment on sCT, and morphometric analysis was performed when a VF was suspected. Results of multiplanar sagittal CT reconstructions interpreted by the most expert radiologist were considered as gold standard. Arthrosis was also scored. Only vertebral bodies assessable by both sCT and gold standard were considered for the analysis. Area under the receiver operating characteristic curve (AUROC), Cohen's kappa statistic and linear-by-linear association were used for statistical analysis.

Results: 1522 vertebrae were considered (130 males and 170 females; ages, 73.0 ± 2.8 years). 73 of 1522 (4.8%) VFs were identified in 34/300 patients (11.3%). In the detection of VFs, the sensitivity and specificity of sCT were 98.7% and 99.7%, respectively. Accuracy (AUROC = 0.992 ± 0.008), as well as interobserver agreement ($k = 0.968 \pm 0.008$), was excellent. Intra-observer agreement was perfect ($k = 1.000$). Performance of this method was independent of arthrosis, vertebral level and type and grade of VFs.

Conclusion: sCT is a simple but very accurate method for the detection of VFs. It should be introduced as a spine evaluation tool for the detection of VFs in examinations that are performed for other diagnostic purposes.

Advances in knowledge: sCT lateral radiograph is an accurate tool for the detection of VFs. This technique may be used with several advantages in clinical practice.

Vertebral body crushing after minor trauma or no reported trauma is one of the most typical signs of osteoporosis. Vertebral fractures (VFs) occur more frequently and earlier than other osteoporosis-related fractures, and they are a hallmark of the disease [1]. It has been shown that more than 50% of VFs may be clinically silent [2] and therefore frequently underdiagnosed. This substantially contributes to leaving osteoporosis underestimated and undertreated.

The total cost of VFs was estimated at €337 million per year in the European Union, although early prevention may reduce costs incurred through treating subsequent VFs [3]. However, the social and economic burden related to VFs is far higher, since they strongly predict risks for further fractures, even at other sites, also independently

from bone densitometric criteria [4,5]. For instance, direct medical costs from fragility fractures to only the UK healthcare economy were estimated at £1.8 billion in 2000 and are expected to rise to over £2 billion by 2020, with most of these costs related to hip fracture care [6].

In the past few years, several imaging techniques have been proposed for the detection of VFs [7,8]. Spine assessment with the aim of VF detection has been performed on the main basis of spine radiographs and dual-energy X-ray absorptiometry scans [9]. In the same way, several methods have been found to semi-quantitatively or quantitatively detect VFs. The visual semi-quantitative assessment on conventional spine radiographs [10] remains the most validated and used method in clinical practice; however, some authors support a combined approach of visual

semi-quantitative and quantitative morphometric methods to overcome limits of single methods side by side [11,12].

Imaging science and the increasing number of imaging examinations are both aiding and submerging clinical practice, providing more and more images with potential clinical information.

The importance of incidental diagnosis of VFs during radiological examinations has been emphasised in the past few decades, with the literature growing exponentially. Results show that detection is still low when VFs are not the intent of the study [13,14]. Radiographs of the chest and abdomen, as well as CT sagittal multiplanar reconstructions (MPRs), have been considered [7,8,15,16] following the widespread use of CT imaging. In recent years, the opportunity to screen for VFs on ancillary sequences of advanced imaging techniques, such as localisation scans of CT and MRI, were also investigated [17–19]. A quick spine assessment using these underrated imaging sequences may be proposed to support the call for a systematic evaluation of the spine and the need to recognise osteoporosis early.

The aim of the present study was to evaluate the reliability of scout CT (sCT) lateral radiograph, in terms of diagnostic accuracy and intra- and interobserver agreement in the detection of VFs.

METHODS AND MATERIALS

300 CT examinations of the spine performed within the last year were retrospectively and randomly collected from the radiology digital archive of our institution. The exclusion criteria set in the image recruitment were limited to (a) patients younger than 40 years, (b) major trauma, (c) CT focused on the cervical spine only, (d) the absence of sagittal reconstructions among the diagnostic sequences, and of course (e) the absence or illegibility of sCT sequences.

CT technique

Images were acquired from 64-slice VCT LightSpeed® scanner (GE Healthcare, Milwaukee, WI), using a slice thickness of 0.6 mm. The sCT consisted of frontal and lateral low-energy two-dimensional scans extending on average from the upper thoracic to sacral vertebral levels, depending on the area of interest to be covered in the diagnostic scan. Parameters of standard CT for spine imaging were as follows: 120 kVp, variable mAs (from 100 to 700 mAs; average, 400 mAs) to achieve a noise index of 18. Sagittal MPRs were performed routinely (0.6 mm thick, non-overlapping reformats at 0.3 mm spacing) (Figure 1).

Imaging evaluation

Prior to the investigation, sCT of 50 subjects randomly selected outside the study were used as a training set for the readers enrolled in the study.

3 radiologists, with 9 years' 5 years' and 3 years' experience in skeletal field, independently read sCT images of the 300 patients selected for the investigation and repeated the evaluation after 15 days. On the other hand, the most expert skeletal radiologist evaluating the patients' series by conventional CT (sagittal MPR) after 30 days represented the gold standard (GS). The two

Figure 1. Spine evaluation on scout CT (sCT) lateral radiograph (a) and on CT multiplanar sagittal reconstruction (sagittal MPR) (b) of the same patient.

younger physicians also performed a subsequent reading session on sagittal MPR. The evaluation was carried out using CARESTREAM PACS v. 11.0 (Carestream Health, Rochester, NY). Another physician was responsible for data collection and blinding. Images were stripped of demographic and any other identifying information, and they were presented with different arrangements in the two sessions. Details of the reliability study were not revealed to readers. The study was carried out conforming to the Declaration of Helsinki.

The target spine segment to detect VFs was conventionally set on T4–L4, independently from the spine segment under examination, and only the vertebral levels included by each of the two CT scan modes (sCT and sagittal MPR—GS) were considered for the analysis of diagnostic performance. The semi-quantitative diagnostic approach as described by Genant et al [10] for spine radiographs was used to detect VFs on sCT images and on conventional CT imaging. A vertebral deformity >20% of loss in height with a reduction in vertebral height of >10–20% was defined as a fracture; the corresponding four-grade scoring system was also used to grade the severity of VFs: mild fracture, reduction in vertebral height of 20–25% compared with adjacent normal vertebrae (Grade 1); moderate fracture, reduction in height of 25–40% (Grade 2); and

severe fracture, reduction in height of more than 40% (Grade 3). Quantitative morphometric evaluations were only performed to confirm the presence and grading of fractures when visually suspected. In the event of disagreement between the semi-quantitative method and morphometry in

grading VFs, the morphometric measurements were considered for the final classification (Figure 2). Vertebral deformities owing to causes other than fractures were classified as non-osteoporotic deformities. These were considered to be non-fractured in the analysis.

Figure 2. Vertebral fracture (VF) assessment by sCT (a–c) and CT sagittal multiplanar reconstruction (d–f) images. Mild VF (a, d: broken white arrows), moderate VF (b, e: white arrows) and severe VF (c, f: white arrowheads).

Moreover, the expert radiologist was also asked to score the grade of arthrosis on sCT: Grade 0 (no arthrosis), Grade 1 (the presence of mild osteophytosis), and Grade 2 (the presence of severe osteophytosis with bone bridge).

The scan quality was recorded according to the most expert reader's evaluation as "good", "sufficient" or "poor". The range of vertebral levels accessible for diagnostic purpose was counted and registered. The time spent to evaluate sCT and CT sets per single patient was also separately recorded.

Reliability assessment, data analysis and statistical methods

Reliability was evaluated in terms of sensitivity, specificity and accuracy, as well as of inter- and intra-observer agreement on a lesion- and patient-based analysis.

Prevalent VFs were defined for deformities from Grade 1. Secondary, we used a more restrictive classification of VFs, defined as moderately to severely deformed (Grade 2–3).

Sensitivity, specificity and accuracy of sCT in the detection of VFs (or fractured patients) were calculated considering the expert radiologist's evaluation of CT images as GS, as previously mentioned.

Accuracy was expressed by means of the area under the receiver operating characteristic curve (AUROC) $\pm$ standard error of the means. An excellent accuracy was defined for AUROC values >0.900 , good accuracy for values between 0.800 and 0.900, fair accuracy for values between 0.700 and 0.800, poor accuracy for values between 0.600 and 0.700, and fail accuracy for values between 0.500 and 0.600 [20]. Intra- and interobserver agreement was evaluated by means of the Cohen's kappa statistic; standard error of the mean of kappa values was also estimated. Kappa values were compared by means of z distribution. An excellent agreement was defined for kappa values >0.750 according to Fleiss [21,22]. Data were analysed by Mann–Whitney test and by linear-by-linear association. Continuous variables were tested by means of a non-parametric method (the Wilcoxon matched pairs test). Two-tailed p -values <0.05 were considered significant. Data were reported as frequencies and mean $\pm$ standard deviation. The SPSS® statistical package (v. 13.1 for Windows; SPSS Inc., Chicago, IL) was used for statistical analysis.

RESULTS

The threshold of 300 spine examinations was reached after screening 354 examinations. Thus, 54 examinations were ruled out owing to one of the exclusion criteria, as previously described.

The population enrolled in the study consisted of 130 males and 170 females aged 73.0 ± 2.8 years (range, 41–92 years). The study data package included 284/300 (94.7%) lumbar spine, 6/300 (2.0%) thoracic spine and 10/300 (3.3%) thoracic-lumbar spine CT. 1522 vertebrae satisfied the match between CT and sCT fields of view.

According to the evaluation of spine CT diagnostic examinations by the expert radiologist (GS evaluation), 34 patients were found

to be affected by VFs (11.3%), and a total of 73 VFs were identified (4.7% of all evaluable vertebrae; grade: 44 mild, 18 moderate, 11 severe; type: 35 wedge, 26 biconcave, 12 crush; level: 1 T7, 2 T8, 4 T9, 2 T10, 5 T11, 11 T12, 21 L1, 10 L2, 9 L3, 8 L4) (Figures 3 and 4). Moderate to severe arthrosis was found in 103 (34.3%) patients.

Scan quality of sCT was recorded as "good" in 174 (58.0%) cases, "sufficient" in 83 (27.7%) cases and "poor" in 43 (14.3%) cases, for diagnostic purpose.

The mean time spent for a single examination was 32.2 ± 3.4 s and 72.5 ± 4.1 s for sCT and CT, respectively ($p < 0.001$), with small differences between the expert and young observers ($p > 0.05$).

Diagnostic accuracy

On a lesion-based analysis, scout-CT sensitivity and specificity were 98.7% and 99.7%, showing an excellent accuracy (AUROC = 0.992 ± 0.008); positive and negative predictive values were 94.9% and 99.9%, respectively. Performance of sCT on a patient-based evaluation achieved similar results: sensitivity, 99.2%; specificity, 99.8% and great accuracy (AUROC = 0.997 ± 0.007) (Figure 5).

The experience of the radiologists did not significantly influence sCT accuracy, sensitivity and specificity both on lesion- and patient-based analysis ($p = 0.315$ and $p = 0.286$ respectively). Sensitivity of sCT for mild and for moderate to severe VFs was 98.7% and 100%, respectively, whereas specificity and accuracy were similar (specificity, 99.7% vs 100%; AUROC, 0.992 ± 0.008 vs 1.000 , mild vs moderate to severe; $p = 0.734$).

Intra-observer agreement

Intra-observer agreement in the detection of VFs was perfect for both sCT and CT (lesion-based: $k = 1.000$; patient-based: $k = 1.000$). Lesion-based (and therefore also patient-based) intra-observer agreement for VFs grading and typing was also perfect for both techniques ($k = 1.000$).

Figure 3. The number and grade of vertebral fractures (VFs) per spine level identified on CT examinations used as gold standard in our study population.

Figure 4. Upper and lower limits of spine assessment by scout CT and “diagnostic” CT images.

Interobserver agreement

Interobserver agreement among the three observers on the presence/the absence and grading of VFs was excellent (lesion-based: $k=0.968\pm0.008$ and 0.923 ± 0.007 for sCT, $k=0.972\pm0.006$ and 0.936 ± 0.008 for CT; $p=0.564$ and $p=0.658$, respectively; patient-based for the presence/the absence: $k=0.984\pm0.005$ for sCT, $k=0.986\pm0.007$ for CT; $p=0.842$) (Table 1).

Figure 5. Two vertebral fractures of D10 and D11 (grade mild and moderate, respectively), detected on CT sagittal multiplanar reconstruction scan (b, white arrowheads). The first fracture could not be identified by three expert radiologists on sCT (a, white broken arrow), whereas the second fracture was correctly diagnosed (a, white arrow), with a complete interobserver agreement.

sCT diagnostic performance as well as reproducibility and repeatability of sCT and CT evaluations and results among readers were independent from sex, age, grade of arthrosis, or vertebral level, both on lesion and patient basis ($p>0.05$).

DISCUSSION

In recent years, many authors have investigated VFs using different imaging modalities, such as radiography, dual-energy X-ray absorptiometry and CT [9,14,17,23].

The first authors to assess the potential role of sCT in the diagnosis of VFs were Takada et al [18], concluding that sCT had lower capacity than conventional radiographs for the detection of VFs, but that sCT may have been helpful for this application.

In the recent past, few authors have continued to evaluate the ability of sCT in the diagnosis of VF, including our previous study [13] in which we proposed sCT as a spine evaluation tool in examinations that are performed for other clinical purposes.

In this study, however, we evaluated the reliability of sCT images in VF detection using a semi-quantitative approach, by comparing them with diagnostic CT scans dedicated to the study of the thoracolumbar spine as GS.

sCT offers some considerable advantages than MPR images. A wider field of view is always available on sCT. For instance, in our study population, 28 VFs were suspected in 12/300 (4%) patients, only on ancillary sequences (Figure 6).

sCT is also a fast and available tool. Despite the sagittal MPR images, it does not need thin-slice CT acquisitions or any post-processing reconstructions. Moreover, sCT images are always stored on picture archiving and communication systems and can always be evaluated on a second reading time. In addition, sCT images are very similar to the standard lateral radiographs, which are the most common tool used to assess VFs. Although image quality of CT scout views is lower than that of a conventional radiography, sCT offers some advantages in terms of parallax distortion absence because of the fan-beam imaging of CT images compared with the cone-beam imaging of conventional X-rays, which may increase vertebral dimension accuracy measurements [16].

In the series reported by Takada et al, the population included only females aged 56 years and older, with more than half of them involved in a clinical trial that required a T-score ≤ -2.0 . By contrast, our study population was absolutely heterogeneous, with almost equal gender representation and age between 40 and 92 years. For this reason, with a wider population range, fewer fractures were encountered and a greater prevalence of mild fractures than moderate and severe fractures was found.

Furthermore, our analysis was performed only on vertebrae included in both methods, excluding those not included in the field of view of the scan, to compare both techniques equally.

Table 1. Interobserver agreements on vertebral fracture (VF) assessment

Observer	VFs per vertebra			VFs per patient		
	sCT	CT	<i>p</i> -value	sCT	CT	<i>p</i> -value
1 vs 2	0.953±0.018	0.962±0.015	0.483	0.980±0.013	0.985±0.009	0.696
1 vs 3	0.993±0.007	0.995±0.008	0.795	0.995±0.008	0.994±0.007	0.865
2 vs 3	0.959±0.017	0.971±0.013	0.560	0.973±0.011	0.977±0.008	0.587

sCT, scout CT.

Cohen's kappa values ± standard error of the means are shown.

Samelson et al [16] and Kim et al [17] have recently evaluated reliability in terms of repeatability and reproducibility of sCT as a potential diagnostic approach in the detection of VFs. Their conclusions stated that sCT with both semi-quantitative and quantitative morphometric approach could be useful in clinical research settings to assess VFs.

Although our study population was larger (300 patients vs 100 patients by Kim et al and Samelson et al vs 56 patients by Takada et al), we have encountered a similar number of VFs (low prevalence), as we did not build the population with the aim of predetermining the rate of VFs, but with the aim of including the general population submitted to CT. We intentionally used a random selection of patients to not affect the daily clinical setting, which is potentially the most important stage for the use of such an easy tool.

To our knowledge, no study considered the evaluation of sensitivity, specificity and accuracy of sCT compared with that of a GS such as MPR CT.

Figure 6. Scout CT (sCT) lateral radiograph (a) and CT multiplanar sagittal reconstruction (b) of the same patient. sCT allows the detection of a wedge vertebral fracture (grade mild—white arrow) that cannot be identified by sagittal multiplanar reconstruction because of limited CT scan field (white broken arrow).

In our population, we analysed vertebrae included both in sCT and diagnostic CT images exclusively, which explains the small number of total vertebrae considered. However, the high number of VFs found with an excellent inter-observer agreement led to a good reliability of the method, which was excellent in the assessment of moderate to severe VFs, in accordance with the latest work by Kim et al [24].

Also, experience-related performance on VF diagnosis was evaluated. Results show that experience did not significantly influence sCT accuracy, demonstrating the high reliability of the technique in patients of daily clinical practice. However, a few limitations to our study deserve considerations.

This is a retrospective study, with restricted capability to investigate and to collect accurate history of all patients. Thus, osteoporotic or non-osteoporotic bone metabolic status and body mass index have not been considered. Moreover, aetiology of entities addressed to VFs may not completely exclude patients with old traumatic VFs. Nevertheless, all imaging and anamnestic efforts have been made to find any reference to VFs and fractured patients detected in the study. The unbalanced use of lumbar vs thoracic CT examinations for patient recruitment is also a point to be recalled; however, today, very few CT examinations focused on the higher spine are performed in our hospital with a dedicated scan mode—especially, if major trauma are excluded.

In conclusion, sCT scans are always performed before any CT study, although in the past, data obtained from these images have rarely been considered.

Instead, the additional information given by sCT can be usefully utilised, especially in terms of VF assessment.

Our results indicate good to excellent agreement between sCT and MPR, showing high accuracy and reliability of this technique in the detection of VFs.

Our opinion is that sCT can complement the current methods for identifying VFs and is suitable for clinical practice.

Furthermore, it may be introduced as a systematic spine evaluation tool in the detection of VFs in CT examinations performed for every diagnostic purpose.

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