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Added Value of Dedicated Spine CT to Detect Fracture in Patients with CT Chest, Abdomen, and Pelvis in the Trauma Setting

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A B S T R A C T

Purpose: Fractures of the thoracolumbar spine account for up to 90% of spinal fractures, and are associated with significant disability. The advantage of acquiring dedicated spine CT imaging in addition to visceral CT studies of the chest, abdomen and pelvis for detection of spinal fractures has not been definitively established. This retrospective study seeks to determine the contribution of dedicated spine CT in the acute clinical setting.
Methods: Patients who were diagnosed with fractures of the thoracic or lumbar spine at our institution between January 1, 2010 and June 30, 2014 were identified. Additional inclusion criteria included having a CT of the chest and/or abdomen and pelvis followed by a dedicated thoracic or lumbar spine CT within 30 days. Reports were reviewed for accuracy of fracture detection, and missed fractures were retrospectively analyzed on images for detectability.
Results: A total of 102 patients met our inclusion criteria for a total of 312 fractures. Of the 312 fractures, 31 (10%) were missed on the initial visceral CT in 18 of the 102 patients. In all but two cases, at least one fracture was identified on the visceral spine CT. There were no cases in which the newly identified fractures changed patient management.
Conclusion: All fractures requiring surgical intervention were identified on the visceral CT. A dedicated spine CT does detect additional spine fractures but does not clearly alter patient management.

Introduction

Fractures of the thoracolumbar spine account for up to 90% of spinal fractures,[1,2] are increasingly common,[3] and are associated with significant disability.[2] Delayed diagnosis has long been associated with increased morbidity.[4] With the increased emphasis on damage control orthopedics, there is new evidence that early intervention leads to decreased complications.[5–7] Accurate and timely diagnosis of these injuries is of the utmost importance.

The superiority of CT over conventional radiography for diagnosing spinal fractures is well established.[8–11] More recent studies have shown that the data acquired from a multi-detector CT of the chest, abdomen and pelvis is adequate for reconstructing dedicated images of the spine.[12] This is the current American College of Radiology recommendation[13] of standard practice for instances when CT exams of the thoracic and/or lumbar spine are ordered simultaneously or soon after CT exams of the chest, abdomen and pelvis.

A spine CT created from visceral CT data does not increase patient radiation, but it does increase expense and utilize radiology resources. Reconstructing images also utilizes technologist and radiologist time and may decrease turnaround times. This is a significant consideration in a busy trauma center.

Efficient use of resources is an important goal in our evolving healthcare system. It is not entirely clear, however, that dedicated spine CTs can be eliminated without compromising patient care. Slice thickness is not the only difference between visceral CT and spine CT. Spinal fractures are frequently associated with additional injuries,[14] many of which are included on a CT of the chest, abdomen and pelvis. Given the well-known "satisfaction of search" phenomenon, the clinical utility of a dedicated spine CT may be determined by more than just slice thickness and visibility.

This retrospective study seeks to determine the contribution of dedicated spine CTs in the acute clinical setting. We hypothesize that repeating a CT of the thoracic or lumbar spine shortly after a CT of the chest or abdomen and pelvis has been performed does not significantly alter the diagnosis of spinal fracture or patient management.

Methods

Patients

Institutional IRB approval was obtained. All patients who were diagnosed with fractures of the thoracic or lumbar spine at our Level I trauma center between January 1, 2010 and June 30, 2014 were acquired from the institution's trauma registry. Additional inclusion criteria included having a CT of the chest and/or abdomen and pelvis followed by a dedicated thoracic or lumbar spine CT within one month. In cases where the visceral and spine CTs were performed simultaneously, the "exam audit" feature on our PACS system was

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used to determine the chronologic order in which they had been viewed and read. Patients were included in this study if CT exams were read by separate body and neuroradiologists and the final report was entered for the visceral CT prior to that for the spine CT. Cases in which a preliminary report for both studies was issued by a single radiologist or preliminary read by a single radiology resident were excluded.

Patients' electronic medical records were reviewed to evaluate the clinical course and impact of imaging findings on patient care.

Imaging Protocols

All CT studies were performed on 32 or 64 slice CT scanners (Toshiba Aquilion 32/64; Toshiba Medical Systems, Japan). Visceral CT study images were reformatted in the axial plane at 5-mm intervals, and coronal and sagittal planes at 3 mm intervals. Spine CT studies were reconstructed at 3-mm intervals in the axial plane and 2 mm in the sagittal and coronal planes, regardless of being reconstructed from the visceral data or acquired at a subsequent exam time. Included CT studies were performed with or without the use of intravenous contrast.

Analysis

Original final reports of all CT studies were reviewed to compare the number and location of fractures detected. In cases of discrepant "misses" of fractures, images were retrospectively analyzed by the authors to determine if missed fractures on visceral CT could be confidently detected in an effort to categorize the miss as either related to imaging technique or interpretive technique. The levels of agreement between visceral and spine CT reports were statistically analyzed with kappa scores within 95% agreement intervals.

Results

A total of 1455 patients were admitted to our institution with fractures of the thoracolumbar spine between January 1, 2010 and June 30, 2014. Of these, 102 patients (67 male, 35 female) met the inclusion criteria with a total of 312 fractures. Patient ages ranged from 15 to 101 (mean age 48.8 ± 20.3 years). Time between visceral and spine CTs ranged from 0 to 30 days (mean 3 ± 5). Of the 102 included patients, 47 had the spine CT performed postoperatively following spinal fixation. Time between scans for this group ranged from 0 to 14 days with a median of 2 days and a mean of 3 ± 2.7 days.

As shown in Table 1, the number of fractures per patient ranged from 1 to 13 with a median of 2 and a mean of 3.1 ± 2.6. Mechanisms of injury in order of frequency were fall (46 patients), motor vehicle crash (40 patients), struck by motor vehicle (5 patients), gunshot wound (3 patients), struck by falling object (3 patients), bicycle crash (2 patients), horseback riding accident (2 patients), and assault (1 patient) (Table 1). Falls include 3 suicide attempts and one skydiving accident. Motor vehicle crash includes 30 car accidents, 8 motorcycle accidents, 1 ATV accident and 1 tractor accident.

TABLE 1
Mechanism of traumatic injury for 102 patients meeting inclusion criteria

Mechanism of injury	Number of patients (%)
Fall	46 (45%)
Motor vehicle accident	40 (39%)
Struck by motor vehicle	5 (5%)
Gunshot wound	3 (3%)
Struck by falling object	3 (3%)
Bicycle accident	2 (2%)
Horseback riding accident	2 (2%)
Assault	1 (1%)

Of the 312 fractures, 31 (10%) fractures were not identified on the visceral CT. There were 18 of the 102 patients (18%) who had at least one missed fracture on the visceral CT. Of these 18 patients, the number of missed fractures ranged from 1 to 4 with a median of 1. The number of total fractures within this group ranged from 1 to 11 with a median of 3. There were only 2 patients (2%), with a total of 3 fractures (3%), in which no fracture was identified on the visceral CT, but subsequently discovered on the spine CT. In the first case, nondisplaced fractures of the right T1 and left T4 transverse processes were not visible on the visceral CT when reevaluated. In the second case, a minimally displaced fracture of the T3 spinous process was visible in retrospect.

The majority (19/31) of the missed fractures were in the transverse processes (Table 2). Only 4 of 31 were located in the vertebral body (Table 2). Of the 31 missed fractures, 21 (67%) were deemed visible in retrospect (Figs 1 and 2). There were no cases in which management was changed by the discovery of additional fractures, as none of the patients with initial missed fractures had additional surgical reduction or fixation following detection of additional fracture by spine CT at the time of discharge. Agreement kappa level was −0.082 with a 95% confidence interval of −0.163 to −0.002.

There were a total of 40 fractures in 19 patients that were identified on the visceral CT, but not mentioned in the report of the subsequent dedicated spine CT. In 11 of the 19 patients (26 of the 40 fractures), the spine CT was performed postoperatively with metallic fixation hardware present. Of these 40 fractures, 33 (83%) were visible in on the spine CT in retrospect. The number of missed fractures in this group ranged from 1 to 4 with a median of 2. The number of total fractures per patient in this group ranged from 1 to 13 with a median of 4.5.

Discussion

In our series, 18% of patients with thoracic or lumbar fractures had at least one fracture missed on original reporting of the CT chest, abdomen, and pelvis, missing 10% of all fractures. However, none of the missed fractures were unstable fractures or required surgical management. Fractures requiring surgical intervention were detected on both scan types. However, fractures of the spinous and transverse processes were more likely to be detected initially on the spine CT.

Our results of an overall miss rate of 10% of spine fractures on CT chest, abdomen and pelvis are within range of previous reports citing miss rates between 3 and 36%.[16,17,18,19] Several recent studies have evaluated the advantage of reconstructed dedicated spine CT over visceral CT images for detection of spinal fractures without consensus. The 2009 study by Smith et al. found a 94% sensitivity for spine fracture detection on abdomen and pelvis CTs and a 73% sensitivity on chest CT for all fractures and 100% sensitivity for identifying patients with any fractures. They concluded that a visceral CT was sufficient for initial evaluation.[15] However, this study focused mainly on visibility of fractures as studies were reinterpreted by a radiologist who was blinded to the initial interpretation. The probability of a fracture being identified in the acute clinical setting can be affected by multiple additional factors such as the satisfaction of search phenomenon in patients with additional injuries.[16]

TABLE 2
Location of fractures missed on body CT

Location of fracture	Number of missed fractures	Number visible in retrospect
Transverse process	19	11 (58%)
Body	4	3 (75%)
Spinous process	3	3 (100%)
Lamina	3	2 (67%)
Articular surface	1	1 (100%)
Pedicle	1	1 (100%)

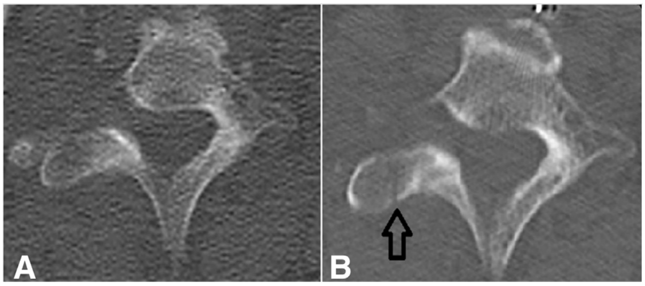

FIG 1. Transverse process fracture occult on body CT. Images shows the T1 vertebra of a trauma patient on the body CT (A) and the spine CT (B). A fracture through the right transverse process was identified on the spine CT, but is not clearly visible on the body CT.

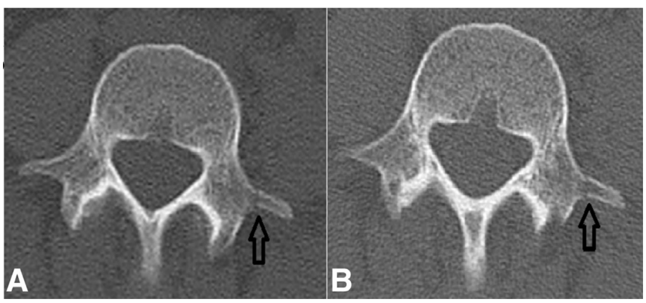

FIG 2. Transverse process fracture missed on body CT. Images from the body CT (A) and lumbar spine CT (B) at the level of the L4 vertebra. A fracture through the left transverse process (arrow) was identified only on the spine CT, but, in retrospect, is visible on both studies.

Two recent studies have focused on the likelihood of a fracture being detected in clinical practice. A 2015 study by Carter et al. found that body CT had a 63.6% sensitivity for detecting patients with fractures and a 71.4% sensitivity for patients requiring intervention. They concluded that dedicated spine reconstructions should be performed routinely.[17] Another study had similar results.[18] A similar study by Rozenberg et al. found a 94% sensitivity for spine fractures on body CT and a 97% sensitivity on dedicated spine reformats. They concluded routine spine reformats were unlikely to be useful.[19] In both studies, the body and spine CTs were dictated by separate divisions but acquired simultaneously. Cases in which the body radiologist had viewed the spine images were not excluded. Thus, successful reporting of fractures on the body CT may have been related to the availability of the spine reformats.

Our study evaluates both visibility and clinical likelihood of fracture diagnosis. By using the exam audit function to exclude cases in which the radiologist interpreting the body CT had viewed the spine images, we evaluated whether or not the body CT alone was enough to reliably diagnose spine fractures at the time of injury. By reevaluating missed fractures, we sought to determine whether misses were related to visibility or other factors.

Possible explanations for missed fracture on body CT include having the spine CT read by a neuroradiologist focused exclusively on the spine. Although body radiologists evaluate the spine on all studies, they focus on all the organ systems, many of which are affected in a trauma case. It is possible that this reduces the time spent on the spine secondary to the “satisfaction of search” phenomenon.[16,20] This is in keeping with the 2013 study by Berbaum et al. which found that subtle fractures were more likely to be missed when more serious fractures were also present.[16]

Although 10% of the spinal fractures were missed on the initial visceral CT, there were only 2 cases (2% of patients) in which fractures were only identified on the dedicated spine CT. This suggests that visceral CT is a useful screening tool and that patients are unlikely to benefit from a dedicated spine CT in the absence of fractures on the initial visceral CT. However, our study is limited by a small pool of patients with wholly missed spine fractures.

The benefit of a dedicated spine CT in cases where a fracture was found is not entirely clear from this study. Although it is ideal for all fractures to be identified, the majority of missed fractures were located near more serious fractures, and in the transverse processes, where surgical intervention was not required. There were no cases in which management was changed based on the findings of the subsequent spine CT.

Interestingly, many fractures were less likely to be included in the report of a postoperative spine CT even when they remained visible. This may be due to decreased visibility secondary to streak artifact from hardware. Given the availability of preoperative body CT reports discussing these fractures, it is also possible that the interpreting neuroradiologist shifted the interpretive focus on the CT from fracture detection to evaluate hardware positioning. However, this raises the possibility that additional subtle fractures were missed on the visceral CT.

Our study found overall low interobserver correlation between body and neuroradiology reports regarding spine fractures with a kappa level of −0.082 and 95% confidence interval of −0.163 to −0.002. This confirms prior reports of low interobserver agreement in overall radiology reporting via analyzing peer review data. Reported agreement kappa values range from 0.06 to 0.27 according to one analysis using the RADPEER system,[21] and were 0.17-0.23 in a second.[22] Our lower values may relate to under-reporting of discrepancies in the peer review process, and our data is a subset of trauma CT scans rather than the whole of radiology peer review which limits comparison.

There are several limitations to the study. Variable timing of the dedicated spine CT is a limitation of this study. Since CT spines can be reconstructed from initial visceral CT, it remains possible that CT spine images were at least briefly analyzed by the body radiologist at the time of the report. Informal consultation between the radiologists reading the body and spine CTs cannot be excluded in cases where the scans were performed simultaneously. The setting of an academic level 1 trauma center may also have influence on the rate of fracture detection, compared to other centers that do not have both dedicated body and neuroradiologists reading studies separately.

Comparison of initial body CT with a postoperative spine CT also has limitations. In cases where laminectomies were performed, spinous process fractures may no longer be present. Other fractures may be obscured by hardware. Conversely, with time elapsing between studies there is an opportunity for healing callous formation to form and increase detection rate of fractures, especially transverse process fractures.

A larger sample size might include more preoperative spine CTs. Including data from other institutions in which both studies are ordered routinely might also provide more preoperative spine CTs for additional evaluation.

Conclusion

Body CT is likely an adequate screening tool to determine the presence of any spinal fracture in a patient and for fractures requiring surgical intervention. Subsequent dedicated spine CT in these patients may reveal additional fractures, but are not likely to alter management.

Conflict of Interest

The authors declare that they have no conflict of interest.

Ethical Approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. For this type of study formal consent is not required.

This article does not contain any studies with animals performed by any of the authors.

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