The value of CT in determining potential instability of simple wedge-compression fractures of the lumbar spine.

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The Value of CT in Determining Potential Instability of Simple Wedge-Compression Fractures of the Lumbar Spine

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PURPOSE: To determine whether plain films alone are sufficient in the evaluation of stability of simple wedge-compression fractures of the lumbar spine. **METHODS:** Plain films and CT scans of 53 consecutive patients seen during a 2-year period with lumbar spine fractures were retrospectively reviewed. Six readers blinded to the CT diagnosis independently read each patient's plain films. Plain-film findings were scored on a five-point graded response scale using criteria proposed by Gehweiler and Daffner. In addition, a fracture was considered to be possibly unstable if there was involvement of more than one vertebral level or greater than 50% loss of anterior vertebral body height. CT findings represented the standard for comparison. CT scans were independently evaluated by three additional readers. Two-column involvement, middle-column involvement alone but with retropulsion, multiple-level involvement, or greater than 50% loss of vertebral height indicated potential instability. **RESULTS:** For 14 stable and 39 potentially unstable lumbar spine fractures, the pooled (mean) plain-film negative predictive value for detection of potentially unstable fractures was 0.62 (95% confidence interval, 0.53 to 0.70), with a sensitivity of 0.83 (95%, confidence interval; 0.78 to 0.87), and specificity of 0.80 (95% confidence interval, 0.70 to 0.87). **CONCLUSION:** Plain films are not adequate for determining stability of lumbar spine fractures.

Index terms: Computed tomography, indications; Efficacy studies; Spine, fractures; Spine, radiography

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Radiologists offer recommendations regarding the need for additional radiographic studies daily. There is abundant literature supporting computed tomography (CT) in the evaluation of spine trauma beyond plain films (1–12). However, many authors have suggested CT may not be necessary in simple compression fractures, particularly when the degree of compression is small (4, 8, 9, 12–14). One study has examined the sensitivity and specificity of plain-film radiography for the diagnosis of burst fractures and wedge compressions (1). This study evaluated both the lumbar and thoracic spine using 25 patients' films read in a blinded fashion. Two of the readers were orthopedic surgeons, and the posterior vertebral line was not used in their evaluation of plain films. They found that 20% of potentially unstable burst fractures were mistakenly diagnosed as stable wedge-compression fractures.

For the purpose of this study, we used the three functional columns of the thoracolumbar spine described by Denis (4, 15). The middle column is composed of the posterior longitudinal ligament, the posterior portion of the annulus fibrosis, and the posterior wall of the vertebral body. This middle column separates the anterior and posterior columns.

Gehweiler, Daffner, and their colleagues (3, 14) have described five plain-film radiographic signs that indicate disruption of the middle or posterior column. It is generally agreed that simple wedge-compression fractures (those not involving the middle or posterior column with single-level involvement and fewer than 50%

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TABLE 1: Plain-film evaluation graded response scale

Grade	Criteria
1	Definite stable single-level simple lumbar wedge compression fracture (<50% loss of anterior body height, all five radiographic signs described by Gehweiler and Daffner [see text] are negative).
2	Probable stable single-level simple lumbar wedge compression fracture (<50% loss of anterior body height, able to evaluate only four radiographic signs, all of which are negative).
3	Possible unstable lumbar fracture (>50% loss of anterior body height, greater than single-level involvement, able to evaluate only one to three radiographic signs or one sign borderline abnormal).
4	Probable unstable lumbar fracture (only one definite positive radiographic sign).
5	Definite unstable lumbar fracture (two or more radiographic signs of instability definitely seen).

decrease in anterior vertebral height) are stable, and fractures involving the posterior column are unstable (1–5, 8, 10, 12, 15–17). Stable spinal injuries are those that can withstand stress without progressive deformity and without causing further neurologic damage. Whether burst fractures (those involving the middle column) are unstable is unclear. We have chosen to call burst fractures "potentially unstable," and not to debate the stability or instability of burst fractures. Regardless, it is important that a burst fracture be recognized.

We felt it may be possible, by using conservative and strict criteria, to predict confidently by plain films lumbar spine fractures that were stable and did not require CT for further evaluation. As such, we wished to assess whether CT was necessary to detect potential instability of lumbar spine fractures called stable by plain film.

Subjects and Methods

Retrospective plain-film evaluation of lumbar spine fractures was performed using a graded response scale. CT evaluation was used as the standard for comparison. We designed the criteria for plain-film analysis (Table 1) such that if there was any doubt in the reader's mind as to the stability of a fracture, it would be categorized as potentially unstable (a grade of 3, 4, or 5). We included in our study all patients with both plain films (posteroanterior and lateral) and CT of a lumbar spine fracture seen at our hospital over a 2-year period. It is routine at our institution to perform CT on all lumbar spine fractures. Patients with previous spine surgery were excluded, as were those with CT scans degraded by metal or other artifact. Additionally, 5 patients were withheld from the study and used for a teaching session. A total of 53 subjects with lumbar spine fractures were thus evaluated.

The lumbar spine plain films were evaluated independently by six readers blinded to the identity of the patients. The plain films were randomly distributed to each reader (as generated by computer) in two blocks of eighteen and one block of seventeen on 3 different days. Before the first test reading, a training session was held with five examples of lumbar spine fractures to acquaint the readers with the five-point graded response scale (Table 1). The readers were told that all films depicted fractures, and they were to categorize them as "stable" or "unstable" according to the criteria in Table 1. The readers were given five radiographic signs of instability as described by Gehweiler and Daffner (3, 14). These five signs are (*a*) displacement of the vertebral bodies, (*b*) widening of the interlaminar or interspinous space, (*c*) widening of the facet joints, (*d*) widening of the interpediculate distance, and (*e*) disruption of the posterior vertebral line. Each of these five signs, as well as the other signs of potential instability described by other authors (two levels of fracture and greater than 50% loss of anterior vertebral body height), was demonstrated during the teaching session, and these demonstrations remained available for each reader throughout the study. A grade of 1 or 2 constituted definite or probable stability, and a grade of 3, 4, or 5 implied possible, probable, or definite instability. Even if only one sign was "borderline abnormal," the plain-film readers were instructed to categorize that case as at least a grade of 3 (see Table 1). The six readers included two musculoskeletal radiologists, one neuroradiologist, one general radiologist experienced in interpreting trauma radiographs, and two neuroradiology fellows.

The CT scans of the 53 lumbar spines were interpreted separately and independently by three other readers (two neuroradiologists and one neuroradiology fellow). Each reader was blinded to the patient's identity. The CT scans were distributed randomly to the three readers as generated by computer. Before the first test reading, a training session was held with five examples of lumbar spine fractures to acquaint the readers with the evaluation form (Table 2). Any fracture with evidence of middle column disruption or posterior column fracture (excluding spinous process and transverse process) was to be graded as potentially unstable, as were fractures at multiple levels, or fractures with greater than 50% loss of anterior vertebral body height. The CT cases that did not have consensus agreement among the three individual readers were presented again to the three readers as a group. A group consensus decision then determined if the fracture was stable or potentially unstable, again using the criteria in Table 2.

Sensitivity, specificity, positive predictive value, and negative predictive value were calculated as outcome measures in our study. Confidence intervals were obtained

TABLE 2: CT evaluation form

Stable single-level lumbar spine fracture
No evidence of two-column or middle-column involvement. Incidental transverse process and spinous process fractures, as well as nondisplaced articular process fractures at any level, are to be included in this category. Simple linear nondisplaced fractures of the middle column with no involvement of the anterior or posterior column and no retropulsion are to be classified here.
Potentially unstable lumbar spine fracture
Two-column, or middle-column alone with retropulsion, involvement; or >50% loss of vertebral height or multiple level vertebral body fracture. Hence, all burst fractures will be classified as potentially unstable.

using methodology as described by Berry (18). A true-positive was a plain-film response of 3, 4, or 5 (Table 1) that was diagnosed as potentially unstable by CT (Table 2), and a true-negative was a plain-film evaluation of 1 or 2, read as stable by CT.

The number of plain-film misinterpretations for each case was tabulated. Each case with two or more plain-film misinterpretations was reviewed with both the plain films and CT available and the findings summarized. Additionally, the number of false-negative and false-positive interpretations for each plain-film reader was tabulated.

Results

The total number of stable fractures as determined by CT was 14, and the total of unstable and potentially unstable fractures as determined by CT was 39. The three CT readers were in agreement after individual assessment for 45 of the 53 cases. The 8 cases in which one reader disagreed were resolved by consensus. The pooled (mean) sensitivity of detection by plain film when using the criteria outlined in Table 1 of an unstable or potentially unstable lumbar spine fracture was 0.80 (95% confidence interval, 0.70 to 0.87), with a specificity of 0.83 (95% confidence interval, 0.78 to 0.87). The pooled (mean) negative predictive value of plain film when using the criteria outlined in Table 1 for the detection of a potentially unstable lumbar spine fracture was 0.62 (95% confidence interval, 0.53 to 0.70), with a positive predictive value of 0.92 (95% confidence interval, 0.87 to 0.95). The mean and individual plain-film readers' sensitivity, specificity, and negative and positive predictive values are reported in Table 3. Each plain-film reader had between 0 and 4 false-positives and 5 and 13 false-negatives. Each reader's false-positive and false-negative rates are reported in Table 4.

Of the 53 cases, 30 had no false-negative or false-positive interpretation by any of the six plain-film readers. Eight cases had one plain-film reader misinterpretation, four cases were missed by two plain-film readers, and another four cases by three plain-film readers. Three cases were missed by four plain-film readers, and another three cases by five of the six plain-film readers. One case was missed by all six plain-film readers.

Ten of the 15 cases missed by two or more readers had two or more false-negative plain-film interpretations, with 5 cases having two or more false-positive plain-film interpretations. In 7 of the 10 cases that had two or more false-negative interpretations, we found it difficult, even in retrospect with the aid of CT, to be certain the plain film had evidence of potential instability. This was attributable to fewer than 50% displacement of the middle column into the spinal canal (burst fractures) not seen on plain film (3 cases), a second level of fracture not easily seen by plain film (1 case), displaced posterior column fractures not able to be seen on plain film in large part because of anatomic/physiologic phenomenon causing obscuration of the posterior element involvement (2 cases),

TABLE 3: Plain-film sensitivity, specificity, and negative and positive predictive value for the detection of potentially unstable lumbar spine fracture

Observer	Sensitivity	Specificity	Negative Predictive Value	Positive Predictive Value
1	0.79	0.86	0.60	0.94
2	0.87	0.79	0.65	0.92
3	0.87	0.71	0.67	0.89
4	0.90	0.71	0.67	0.89
5	0.85	0.71	0.59	0.89
6	0.69	1.00	0.52	1.0
Pooled (mean)	0.83	0.80	0.62	0.92
95% confidence interval	0.78–0.87	0.70–0.87	0.53–0.70	0.87–0.95

Note.—Standard of evidence by CT consensus panel: 14 stable fractures and 39 potentially unstable fractures.

TABLE 4: Plain-film reader false-positive and false-negative rate

Reader	Incidence	
	False-positives (of 14 negatives)	False-negatives (of 39 positives)
1	2	8
2	3	6
3	4	5
4	4	5
5	4	7
6	0	13

or a gunshot injury with a fragment of the middle column within the spinal canal not detectable on plain film in addition to an endplate fracture (1 case). The gunshot injury was the only case missed by all six plain-film readers. Three of the 10 cases that had two or more plain-film false-negatives probably could have been categorized as potentially unstable if strictly following the criteria given in Table 1 and as outlined in the teaching session given to the plain-film readers. Each of these 3 cases had either one plain-film sign of instability that was "borderline abnormal", or had two or more of the signs obscured. All 3 of these fractures were burst fractures with less than 50% canal compromise. The 5 cases called positive by two or more plain-film readers but that had no evidence of instability on CT all had one or more signs of instability that were borderline abnormal or difficult to evaluate.

Discussion

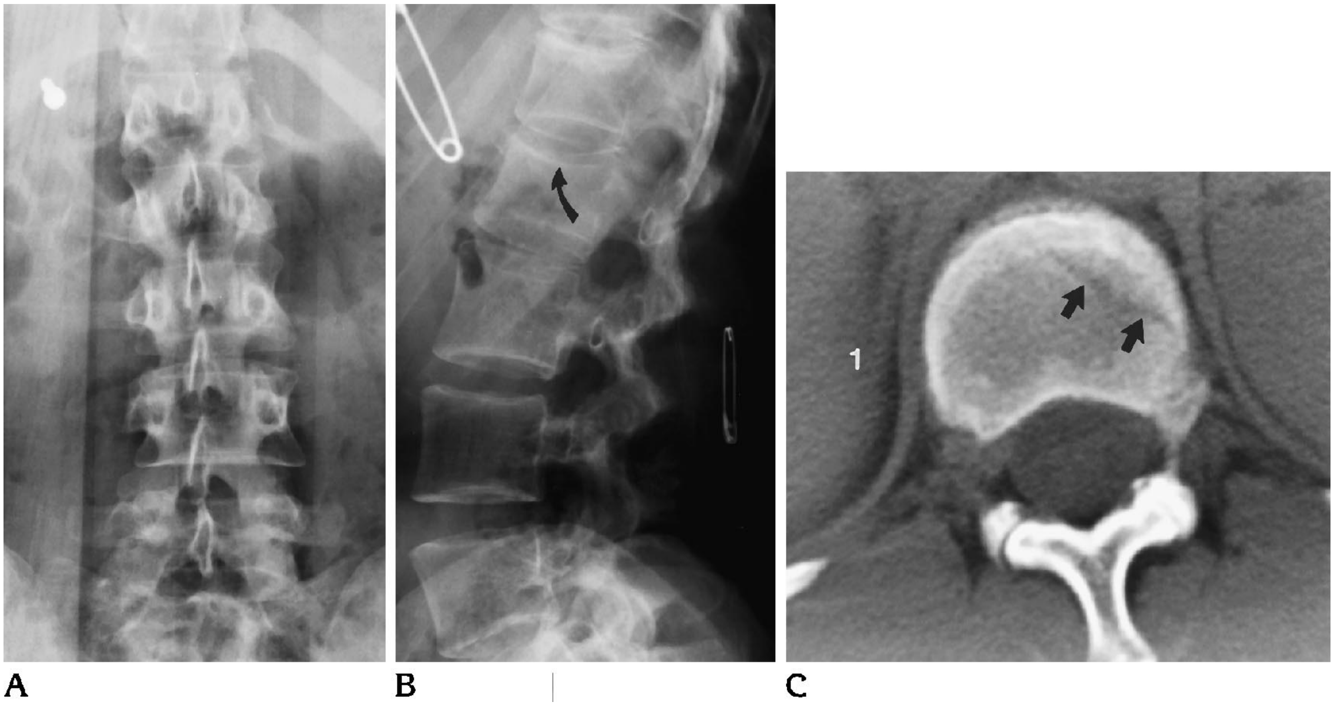
In this era of managed care and demands for cost containment, it is imperative that the use of additional radiologic exams be evaluated through supporting research. After we reviewed the literature, it was unclear to us whether additional evaluation by CT for apparent simple wedge-compression fractures of the lumbar spine diagnosed by plain film was necessary.

We thought it would be possible, using very strict criteria for potential instability of a fracture on plain film (Table 1), to predict unstable or potentially unstable lumbar fractures with acceptable sensitivity and specificity. In other words, if strictly interpreted plain films of a lumbar compression fracture detected no evidence of middle column or posterior column involvement or only single-level involvement with less than 50% loss of vertebral body height, we hypothesized that CT would confirm stability. The prior study that might refute this hypothesis did not evaluate posterior cortical disruption on plain film and did include the thoracic spine (1). Ribs and the scapula would not be a factor in evaluation of the lumbar spine by plain film. Even if bowel gas obscured detail, use of stringent criteria theoretically would result in a diagnosis of "possibly unstable."

Wedge-compression fractures of the lumbar spine are the most common type of spine fracture, comprising 48% of spine fractures in one large study (15). If CT were not necessary for further evaluation of this subset of spine fractures, a significant cost savings would result. By using conservative criteria to classify fractures of the lumbar spine by plain film (Table 1), we hoped to eliminate false-negative plain-film interpretation, with the understanding that the false-positive rate would increase. However, we were willing to accept this trade-off with the understanding that although some simple wedge-compression fractures (and therefore stable) would be scanned, no (or extremely few) potentially unstable fractures would be misdiagnosed as stable on plain film. We felt that the potential cost savings still would be significant if this hypothesis was proved. However, the mean negative predictive value for the six plain-film readers for the detection of potentially unstable lumbar spine fractures was 0.62 (95% confidence interval, 0.53 to 0.70), with a mean specificity of 0.80 (95% confidence interval, 0.70 to 0.87) and a mean sensitivity of 0.83 (95% confidence interval, 0.78 to 0.87). These results refuted our original hypothesis.

A negative predictive value of 0.62 (95% confidence interval, 0.53 to 0.70) is clearly unacceptable. In a significant number of cases, there will be a middle column fracture with displacement or retropulsion, a posterior column fracture, or a second-level of fracture that will not be seen on plain film. Whereas the stability of burst fractures with middle column disruption is controversial, some burst-type fractures develop progressive deformity or result in further neurologic damage with stress (2–4, 8–10, 19).

Examples of cases that were called probably or definitely stable by at least two of the six plain-film readers are shown in Figures 1 through 5. In Figure 1, two levels are fractured, perhaps more obvious in retrospect on plain film. The CT scan clearly shows a second vertebral body fracture. Fractures at two levels are associated with an increased risk of instability,



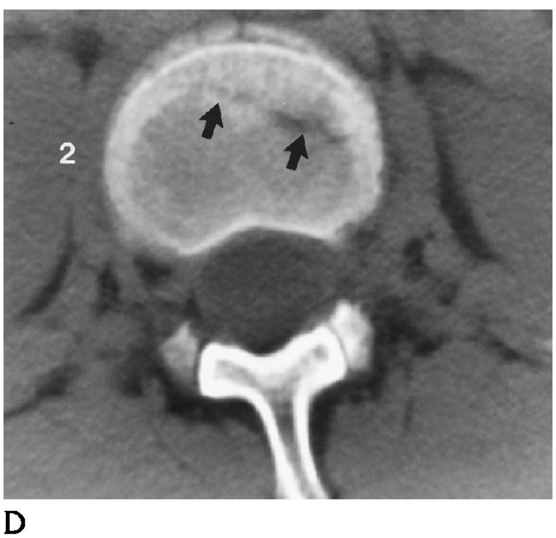
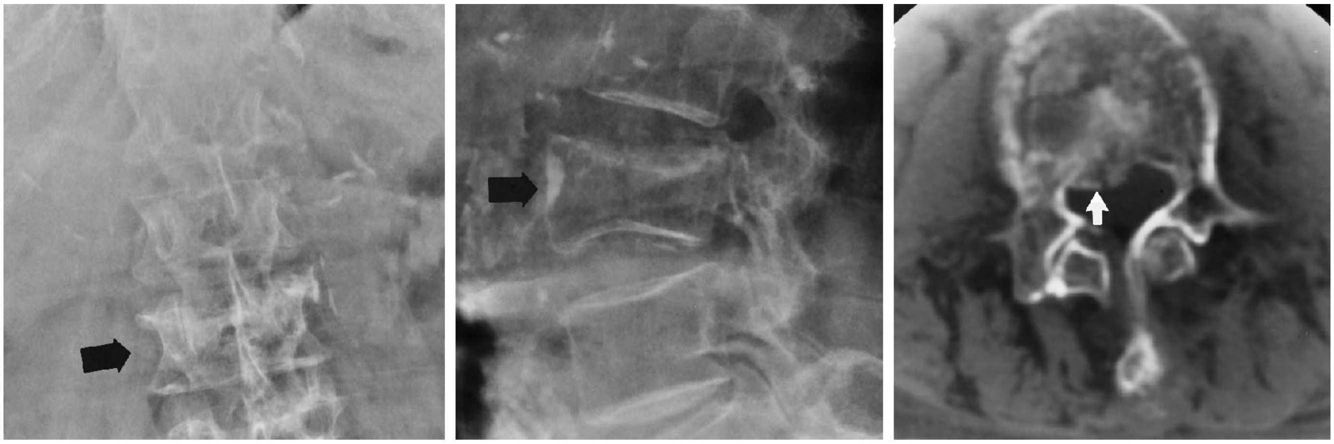


Fig 1. *A* and *B*, Plain films (anteroposterior and lateral) of an L-2 fracture. Three of six readers scored this as a probable or definite stable single-level lumbar fracture. The superior endplate of L-2 (*curved arrow*) obviously is abnormal on the lateral view.

CT scan reveals fracture of both L-1 (*C*) and L-2 (*D*) vertebral bodies (*arrows*). Neither fracture has evidence of middle or posterior column involvement.

even if both fractures are wedge-compression fractures without middle or posterior column involvement. In Figure 2, there is no plain-film evidence of instability even in retrospect, yet CT scan reveals a burst fracture with 25% to 50% compromise of the spinal canal. An example of plain-film false-negative interpretation attributable in part to difficulty interpreting the radiograph secondary to degenerative changes and scoliosis is shown in Figure 3.

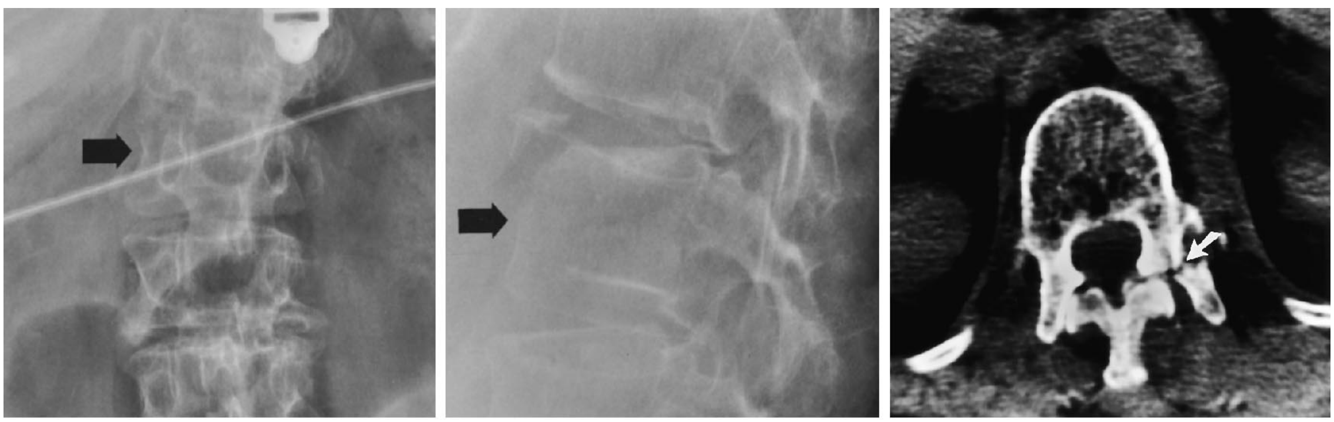
Figures 4 and 5 reveal cases that were called stable by three and five of six readers, respectively, yet had CT evidence of burst fractures. For these two cases, if the criteria discussed in "Methods" for plain-film evaluation had been strictly followed, many would find one of the plain film signs of instability "borderline abnormal," yielding a grade of possibly unstable. However, the term "borderline abnormal" is difficult to define. The range of what experienced plain-film readers interpret as "borderline abnormal" when using plain film is relatively broad and may partially explain why there were so many false-negative plain-film interpretations. However, in many cases of false-negative plain-film interpretation, it is not reasonable to expect



A B C

Fig 2. *A* and *B*, Plain films (anteroposterior and lateral) do not reveal any evidence of instability of this L-3 fracture (*black arrows*). There is just less than 50% compression of the vertebral body. This case was called stable by three of six plain-film readers.

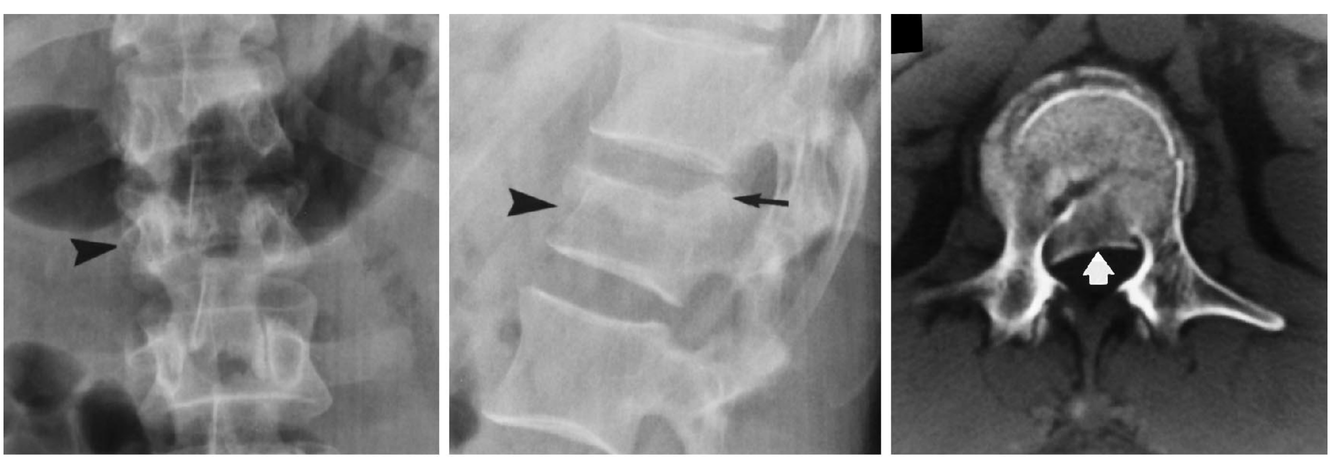
C, CT scan of L-3 reveals a burst-type fracture with 25% to 50% compromise of the spinal canal (*white arrow*).



A B C

Fig 3. *A* and *B*, Plain films (anteroposterior and lateral) of an L-1 fracture (*black arrows*) are difficult to interpret because of scoliosis and degenerative changes. Three of six plain-film readers called this stable.

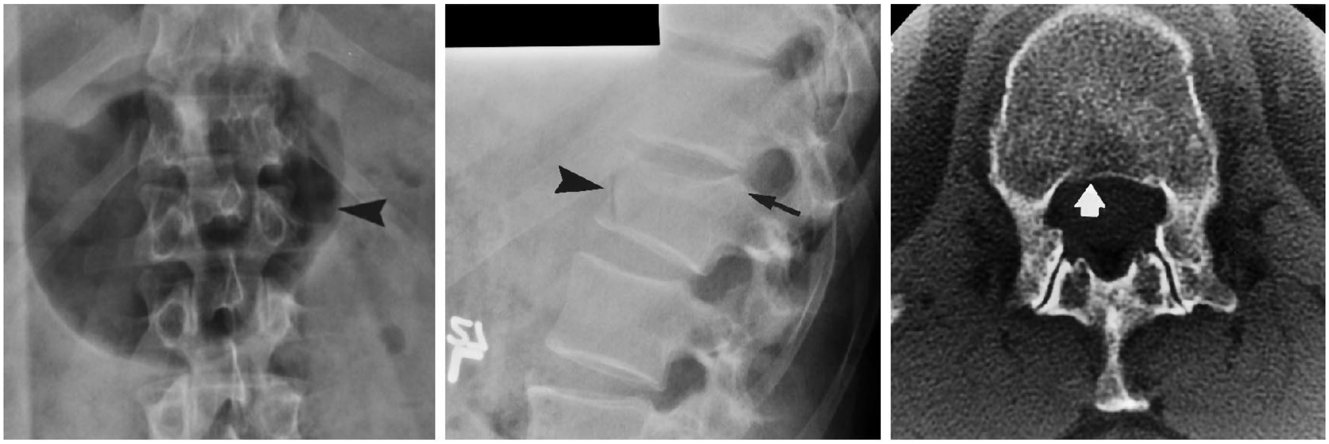
C, CT scan of L-1 reveals a displaced fracture at the junction of the left pedicle and facet (*white arrow*).



A B C

Fig 4. *A* and *B*, Plain films (anteroposterior and lateral) of an L-1 fracture (*black arrowheads*). The posterior vertebral line is indistinct (*black arrow*), and the facet joints are not clearly seen. This was called stable by three of six plain-film readers.

C, CT of L-1 reveals a burst fracture (*arrowhead*) with 25% to 50% spinal canal compromise.



A B C

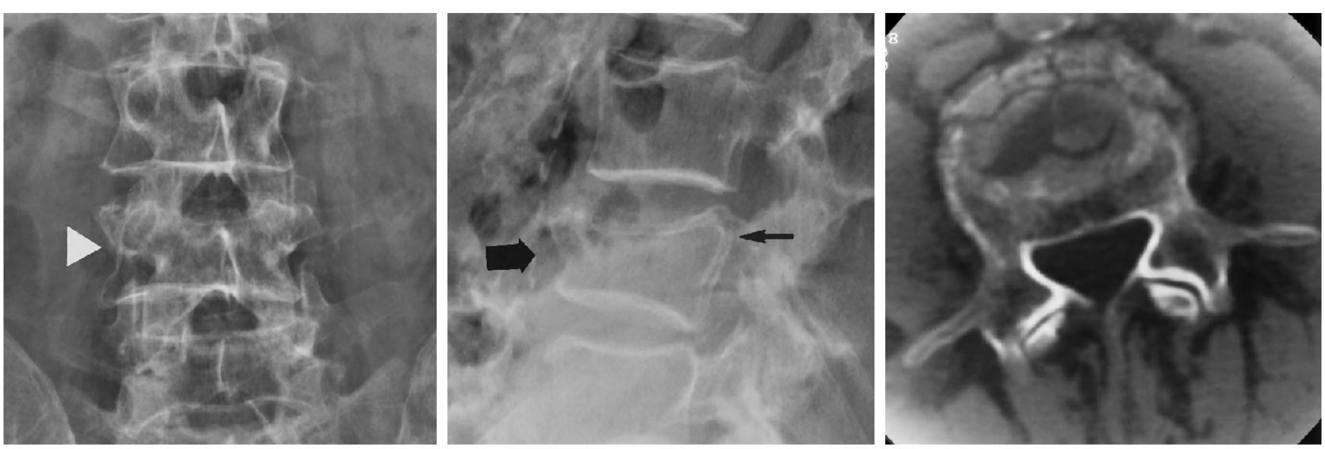
Fig 5. *A* and *B*, Plain films (anteroposterior and lateral) of an L-1 fracture (*large arrowheads*). Five of six plain-film readers called this stable. However, the posterior vertebral line is indistinct (*black arrow*) and could have been scored as a 3 (possibly unstable) if strictly following plain-film criteria.

C, CT scan reveals a minimally displaced burst fracture (*white arrow*).

even the most conservative plain-film reader to have diagnosed potential instability by plain film alone.

Our plain-film criteria were designed to minimize the rate of false-negatives. We have shown that despite using conservative criteria, the plain-film false-negative rate for determination of stability of lumbar spine fractures is unacceptably high. We have included one example (Fig 6) of a false-positive case in which four of six plain-film readers diagnosed potential instability, yet the CT revealed no evidence of potential instability.

This study evaluated the ability of plain films to detect potential instability in a patient with a known lumbar spine fracture. We did not attempt to determine the ability of plain films to detect fractures in patients with spine trauma. As a result, this study design (all subjects had fractures, and the readers were told this at the outset) may not be readily generalizable to all clinical settings. Additionally, the proportion (72%) of potentially unstable lumbar spine fractures in our study is higher than usually reported in the literature. This disparity probably is attributable to the referral pattern of our hospital,



A B C

Fig 6. *A* and *B*, Plain films (anteroposterior and lateral) of an L-4 fracture (*thick black arrow* and *large white arrowhead*). Four of six plain-film readers called this "potentially unstable." The posterior vertebral line appears disrupted (*thin black arrow*), and the interpediculate distance appears widened.

C, CT of L-4 reveals no evidence of middle or posterior column involvement.

which is a tertiary care center. Predictive value is dependent on prevalence, sensitivity, and specificity. Thus, given the same sensitivity and specificity, our negative predictive value of 0.62 may slightly underestimate the true value obtained from a patient sample with a lower instability rate. However, we feel the 95% confidence interval (0.53 to 0.70) is still far enough below 1.0 that our conclusions are not appreciably altered.

In summary, although plain films are the accepted first step in evaluating lumbar spine trauma, CT is necessary to evaluate completely lumbar fractures that appear to be simple wedge compression, because many cases will have evidence of potential instability not detected on plain films.

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