

RADIOGRAPHIC ASSESSMENT OF THE CERVICAL SPINE IN SYMPTOMATIC TRAUMA PATIENTS

RECOMMENDATIONS

Standards: A three view cervical spine series (AP, lateral, and odontoid views) is recommended for radiographic evaluation of the cervical spine in patients who are symptomatic following traumatic injury. This should be supplemented with computed tomography to further define areas that are suspicious or not well visualized on the plain cervical x-rays.

Guidelines: There is insufficient evidence to support treatment guidelines.

Options:

- It is recommended that cervical spine immobilization in awake patients with neck pain or tenderness and normal cervical spine x-rays (including supplemental CT as necessary) be discontinued following either:

- a) Normal and adequate dynamic flexion/extension radiographs; or
- b) Normal MRI study obtained within 48 hours of injury.

- Cervical spine immobilization of obtunded patients with normal cervical spine x-rays (including supplemental CT as necessary) may be discontinued:

- a) Following dynamic flexion/extension studies performed under fluoroscopic guidance; or
- b) Following a normal MRI study obtained within 48 hours of injury; or
- c) At the discretion of the treating physician.

RATIONALE

Trauma patients who are symptomatic, that is, complain of neck pain, have cervical spine tenderness, or have symptoms or signs of a neurological deficit associated with the cervical spine,

and trauma patients who cannot be assessed for symptoms or signs (those who are unconscious, uncooperative or incoherent, intoxicated, or who have associated traumatic injuries that distract from their assessment) require radiographic study of the cervical spine prior to the discontinuation of cervical spine immobilization. Many authors have proposed strategies and imaging techniques to accomplish x-ray clearance of the cervical spine after trauma, particularly in the symptomatic or the obtunded patient. One, three, and five view static cervical spine x-rays, computed tomography (CT), magnetic resonance imaging (MRI), bone scans, flexion/extension radiographs, dynamic fluoroscopy with or without somatosensory evoked potential monitoring, and other studies have all been described as useful for the determination of spinal injury and potential spinal instability following traumatic injury. (1-9,11-17,19-24,26-28,30-39,41-43,45,46,47-54,56,57,59-73) The purpose of this review is to determine the optimal radiographic assessment strategy necessary and sufficient to exclude a significant cervical spine injury in the symptomatic trauma patient.

SEARCH CRITERIA

A National Library of Medicine computerized literature search from 1966 to 2001 was performed using Medline and keywords “spinal cord injury”, “spinal fractures”, or “spinal injuries”. This resulted in 7994 matches. Combination with the keyword “cervical” resulted in 1844 matches. These references were limited to human studies and the English language, resulting in 1268 articles. Combination with the keywords “clearance,” “diagnosis,” or “radiography” yielded 184 matches. The titles and abstracts of these 184 articles were reviewed. All papers focusing on clinical decision-making with regard to the diagnosis of cervical spine injuries in adult victims of trauma were included. Additional references were culled from the

reference lists of the remaining papers. The members of the author group were asked to contribute articles known to them on the subject matter that were not found by other search means. The practice parameters and reference list developed by the EAST practice parameter workgroup for cervical spine clearance (56) was reviewed as was the reference list developed by the NEXUS (National Emergency X-radiography Utilization Study) group (31, 33). Seventy-three total references form the basis for this review.

Twenty-one manuscripts were identified which specifically provided evidence germane to the topic of this guideline. Four studies provided Class I evidence, seven provided Class II evidence, and ten were individual case series and provided Class III evidence. These 21 manuscripts are summarized in Evidentiary Table format.

SCIENTIFIC FOUNDATION

Patients who are asymptomatic with respect to a potential cervical spinal injury following acute trauma do not require radiographic assessment in order to rule out a significant injury to the cervical spine (see Guideline on Radiographic Assessment of Asymptomatic Patients). Radiographic studies do not increase the sensitivity or specificity of the clinical examination in this specifically defined population of patients.(31,33) There is however, a 2% to 6% incidence of significant cervical spine injury in the symptomatic patient population following acute trauma.(4,31-33,42,53,61,62) These patients require radiographic assessment to exclude cervical spinal injury prior to the discontinuation of cervical spine immobilization. The most significant consequence of premature discontinuation of cervical spine immobilization is neurological injury. Prolonged immobilization, however, is associated with morbidity as well. Decubitus ulcers, increased cerebrospinal fluid pressure, pain and pulmonary complications have all been described

with prolonged immobilization of the cervical spine (18,44,58). For these reasons, a diagnostic algorithm that is highly sensitive and specific for the occurrence of a significant cervical spine injury, and that can be applied in an expeditious fashion is desired.

The single most common cause of missed cervical spine injury appears to be failure to adequately visualize the region of injury. This can be caused by failure to obtain radiographs, or by making judgments on technically suboptimal films. This occurs most commonly at the extremes of the cervical spine, the occiput to C2 and at the C7-T1 levels.(17,25,59) Davis described 32,117 acute trauma patients.(17) Cervical spine injuries were missed in 34 symptomatic patients. Twenty-three of these thirty-four symptomatic patients either did not have radiographs or had inadequate radiographs which did not include the region of injury. Eight patients had adequate x-ray studies that were misread by the treating physician. Only one patient had a missed injury that was undetectable on technically adequate films, even after retrospective review. The error in two patients with missed injuries was not described.(17) Davis' review and those of other investigators, confirm that it is uncommon to miss cervical spine injuries with adequate plain radiographic assessment of the occiput through T1.(1,6,9,16,17,24,43,47)

The most prevalent initial x-ray assessment of the symptomatic or obtunded patient is the three-view cervical spine series. When adequate visualization of the entire cervical spine is achieved from occiput to T1, the negative predictive value of a normal three-view cervical spine series has been reported to range from 93% to 98% in several Class I studies (1,6,47), and from 85% to 100% in class II and III studies (9,16,24,43). Although the negative predictive value of the three-view cervical spine x-ray series is quite high, the sensitivity of the three-view series is less impressive. The same Class I series referenced above report sensitivity rates for the three view cervical spine series of 84%, 62.5% and 83% respectively (1,6,47). In the best-case clinical

scenario, assuming the highest values for negative predictive value and sensitivity, approximately 98% of patients with a normal three-view cervical spine x-ray series will have a truly normal cervical spine. This same data suggests that the three-view cervical spine series will also be normal in 15% to 17% of patients who have cervical spine injuries. If we assume a 6% incidence of spinal injury in a high-risk population (the head injured multi-trauma patient, for example), then an adequate three-view cervical spine series alone would be expected to correctly identify 5 out of 6 spinal injuries in a group of 100 patients, and correctly identify 94 of 94 non-injured patients. One patient of the 100 with an injured spine would have cervical radiographs interpreted as normal. The addition of oblique views (for a five-view series) does not appear to increase the overall sensitivity of the examination.(24) Oblique views may be useful in lieu of a swimmer's view to visualize C7-T1.(36) Holliman and colleagues have questioned the utility of the AP cervical view, and argue it is not an important addition to the assessment of the acute trauma patient.(34) The data they present is Class III evidence and has not been verified by others.(34) There exist several reports that confirm that the lateral x-ray view alone will miss a substantial portion of cervical spine injuries depicted in a three-view series.(14,26,65)

In order to increase the sensitivity of the radiographic assessment of the cervical spine in trauma patients, multiple authors have described experiences with CT and MRI imaging in the acute setting. Several have reported greater sensitivity using CT to view areas not well visualized on plain films, typically the craniocervical and cervicothoracic junctions, or areas identified as suspicious on plain cervical spine x-rays.(6,9,24,48,67,68) In a small Class I study of 58 patients, Berne et al reported that helical CT of the entire cervical spine identified all clinically significant injuries in a series of patients assessed with plain films, CT, and MRI who were followed clinically for subsequent events.(6) Two injuries were missed, however neither required

any treatment. Berne et al report a negative predictive value of 95% for CT for all spinal injuries and a negative predictive value of 100% for unstable injuries.(6) Other authors report 100% sensitivity for the detection of injuries with CT limited to areas poorly visualized or identified as suspicious on plain films.(24,48,67,68) However, all studies cited provide Class II and III evidence, and most suffer from a common flaw; they treat CT as the “gold standard” for the detection of injury. While they suggest that the addition of CT imaging increases diagnostic sensitivity, the use of CT data as the “gold standard” represents a false endpoint for the true variable of clinically relevant spinal injury.

Although the incidence of significant spinal injury with a normal cervical spine series supplemented with CT is extremely low, missed injuries have been reported. Brohi reported a missed C6-C7 facet dislocation in a patient with persistent neck pain who was studied with plain films and a CT occiput through C7-T1.(11) Sweeney reported an autopsy series of three patients who died of traumatic injuries and were found to have spinal injuries undetected by plain films supplemented with CT through the region of injury.(66) Thin-cut CT images through the entire spine may increase sensitivity somewhat, (6,55) but no direct comparison between the two imaging strategies in an appropriate patient population has been performed to date.

MRI has been used to evaluate patients at risk for acute spinal injury. Results have been mixed. Benzel and colleagues studied 174 symptomatic patients with low field MRI within 48 hours of injury. Soft tissue abnormalities were visualized on MR in 62 patients. Two of these 62 were felt to have unstable injuries. Both had plain film and CT abnormalities which revealed the injuries. The 60 patients with MRI abnormalities not felt to be significant were immobilized for 1-3 months and then studied with flexion and extension radiographs. Not one was found to have an

unstable injury. Patients with “negative” MRI studies were cleared of spinal precautions and no adverse events were reported.(5) D’Alise and colleagues reported their results of a Class III evidence study of MRI in 121 obtunded patients. Ninety patients had normal studies and were cleared. Follow-up flexion/extension radiographs did not reveal a single abnormality in this group. Thirty-one patients had injuries to soft tissues of the cervical spine identified by MRI not detected by plain radiographs. Eight of these patients ultimately required surgery.(15) Katzberg and colleagues and White et al have also described increased sensitivity of MRI for the detection of soft tissue injuries of the cervical spine following trauma.(39,72)

These studies demonstrate that MRI abnormalities are visualized in a substantial number of cervical spine studies performed on patients following trauma. It is impossible to determine the true incidence of clinically significant ligamentous injury in this group examined with MR, as all patients with MRI abnormalities were treated with immobilization. The incidence of significant cervical spine injury in previous studies looking at similar patient populations is between 2% and 6%, yet the incidence of MR imaging abnormalities is reported to be between 25% and 40%. MRI appears to “overcall” significant injury. It should be noted that the optimal time frame for MRI assessment of the cervical spine is limited. MRI studies are preferred within the first 48 hours after injury. (5,15,21,39,72) Even then some injuries are poorly visualized. Emery and colleagues used MRI to study 37 patients with known cervical spinal injury and found that MRI missed ligamentous injury in two of 19 patients known to have ligamentous injury (abnormal flexion/extension films or surgical confirmation). These images were obtained an average of 10.8 days following injury (21). Klein et al, comparing CT and MRI images obtained from the same patients, demonstrated that MRI was not as effective for the recognition of bony abnormalities as was CT (41). It appears that MRI when used early after trauma in conjunction with plain

radiographs and CT is exquisitely sensitive for the detection of soft tissue abnormalities of the cervical spine. The importance of these findings for the majority of patients is, however, unknown.

Flexion extension radiographs have been used to rule out ligamentous injury of the cervical spine. In the awake patient, this maneuver is generally considered safe and effective. Numerous series have used flexion/extension films as the gold standard for the exclusion of ligamentous injury in this population and no serious adverse events have been reported (1,3,5,10,11,15). Brady et al used dynamic flexion-extension spine films to study 451 awake patients with blunt trauma evaluated in an urban emergency room.(10) Flexion/extension views detected abnormalities in 5 of 372 patients in whom static plain cervical spine films were felt to be normal. None of these patients required “invasive stabilization,” indicating that the abnormal examinations may have been false positives.(10) It should be noted, however, that false negative examinations also occur, although infrequently. Lewis et al reported one false negative examination in a series of 141 patients studied with dynamic flexion/extension films. These authors report the negative predictive value for the combination of plain films and flexion/extension films to be over 99%. (43)

The obtunded patient is not able to actively flex or extend the neck for dynamic radiographic evaluation. Dynamic fluoroscopy has been used to clear the cervical spine in these patients and results of several series are available (16,64). Ajani et al, reported an unstable cervical spine injury detected by flexion/extension radiographs in a patient with normal plain films and CT (one of 100 patients studied).(1) Davis et al used dynamic fluoroscopy to study 116 obtunded patients who had normal cervical radiographs. Only one patient was found to have an

injury not visualized on plain films or CT. The significance of this injury, a 2 mm subluxation in a patient who was treated in a collar and subsequently lost to follow-up, is questionable.(16) Sees et al studied 20 obtunded patients with normal three-view cervical spine series. They performed bedside flexion/extension under fluoroscopy and found 1 patient with C4-5 subluxation due to a facet injury not appreciated on plain films but later confirmed with CT.(64) It should be noted that 30% of the patients in the Sees et al series could not be cleared because of difficulty visualizing the lower cervical spine, whereas Davis et al, using radiology staff in the fluoroscopy suite, were able to visualize the entire spine in virtually all patients.(16,64)

Because of the high negative predictive value of plain films and supplemental CT, application of MRI or flexion/extension fluoroscopy for clearance of the cervical spine is probably not indicated for every obtunded patient. Use of these modalities should be guided by clinical judgment based on patient history and physical examination. Subgroups of obtunded trauma patients exist with a very low likelihood of cervical spine injury, and exhaustive study is not indicated for these patients. Hanson et al found that the incidence of cervical spine injury in a series of 3684 patients without high-risk criteria was 0.2%, and that all of these injuries were detected by plain radiographs supplemented with CT for poorly visualized or suspicious areas.(29) The high risk criteria cited were: a high speed motor vehicle accident (>35 mph); an automobile crash with a death at the scene; a fall from greater than 10 ft; a significant traumatic closed head injury or traumatic intracranial hemorrhage; neurological signs or symptoms referable to the cervical spine; or pelvis or multiple extremity fractures.(29) In support of this issue, Kaups and Davis did not identify a single cervical spine injury in a group of 215 victims of gunshot wounds to the head.(40) Similarly, Patton et al used MRI and flexion/extension

fluoroscopy as a supplement to x-rays to assess the cervical spines of a series of patients with isolated head injuries suffered as a result of assault.(57) They found no undiagnosed injuries.

SUMMARY

In summary, no single radiographic study can adequately rule out cervical spinal injury in all symptomatic patients. A three-view spine cervical spine series supplemented with CT through areas difficult to visualize and “suspicious” areas will detect the vast majority of spinal injuries. This combination of studies represents the minimum required for clearance of the cervical spine in the symptomatic patient. The negative predictive value of this combination of studies is reported to be between 99% and 100% in several Class II and III evidence studies. (9,11,24,48,67,68)

In the awake patient, dynamic flexion/extension views (with at least 30° excursion in each direction) are safe and effective for detecting the majority of “occult” cervical spine injuries not identified on plain x-rays. The negative predictive value of a normal three view series and flexion/extension views exceeds 99%.(43) Patients who are unable to cooperate with active flexion/extension radiographs due to pain or muscle spasm may be maintained in a cervical collar until they are able to cooperate, or may be studied with MRI. A negative MRI within the first 48 hours of injury in addition to normal radiographs and supplemental CT appear to be sufficient for the clearance of the cervical spine. The significance of a positive MR study is currently unclear. It is suggested that cervical immobilization be continued in these patients until delayed flexion/extension views can be obtained.

In the obtunded patient with a normal three-view x-ray series and appropriate CT of the cervical spine, the incidence of significant spine injury is less than 1%. Based upon mechanism of injury and clinical judgement, the cervical spine in selected patients may be considered cleared

without further study. In the remainder of cases, flexion/extension performed under fluoroscopic visualization appears to be safe and effective for ruling out significant ligamentous injury, with a reported negative predictive value of over 99% (16). Because the incidence of occult injury diagnosed with dynamic flexion/extension fluoroscopy in the setting of normal plain cervical spine x-rays and CT images is low, it is probably most efficient for these procedures to be performed by staff in the department of radiology, although variances in local experience should be respected. MRI represents another option for clearance of the spine in this patient population, and a negative MRI within 48 hours of injury appears to effectively eliminate the likelihood of a significant ligamentous injury. However, MRI evaluation will result in a large number of false positive examinations, and the consequences of prolonged unnecessary immobilization in the obtunded patient are not insignificant.(18,44,58)

KEY ISSUES FOR FUTURE INVESTIGATION

The significance of positive MRI findings following cervical trauma should be evaluated using flexion/extension radiographs and clinical follow-up as the gold standard.

The incidence of abnormal findings on flexion/extension fluoroscopic studies in obtunded patients should be evaluated in a prospective fashion with appropriate clinical follow-up.

A comparison between the three-view cervical spine series supplemented with selective CT through poorly visualized or suspicious areas, and CT of the entire cervical spine should be accomplished in a prospective fashion.

EVIDENTIARY TABLES

First Author Reference	Description of Study	Data Class	Conclusions
Banit, <i>Journal of Trauma</i> 49: 450-456, 2000.	Combined retrospective/prospective study 4,460 patients evaluated 2,217 felt to require radiographs 6 month clinical follow-up and subsequent CT/MRI used as gold standard for plain radiographs (authors claim no missed injuries, credible claim) 5 view series used in all patients	Class III	In symptomatic patients, sensitivity of plain films was 88% (68/77) before institution of protocol and 84% (71/84) False positives not given Protocol had sensitivity of 100% and included use delayed exam of patients with tenderness/pain with flexion/extension radiographs (false positives not given)
Berne, <i>Journal of Trauma</i> 47:896-903, 1999	Prospective study of select population of patients (unevaluable, multi-trauma, having CT done for another reason) 58 patients, all underwent 3 view series followed by helical CT of entire spine “Suspicious but not diagnostic” examinations were evaluated with MRI, flexion/extension views, or repeated clinical examination	Class I	20/58 (34%) had injuries detected Plain films identified 12 for a sensitivity of 60%, positive predictive value of 100%, negative predictive value of 85% CT missed 2 injuries (both “stable”) for sensitivity of 90%, specificity 100%, positive predictive value of 100%, negative predictive value of 95%.
D’Alise, <i>J Neurosurg</i> , 91 (Spine 1):54-59, 1999	121 obtunded patients with normal X-rays studied with MRI CT used to study areas of MRI abnormality All patients with negative MRI underwent flexion/extension imaging immediately upon “clearance”	Class III	31/121 (26%) had injuries detected on MRI 90/121 (74.4%) had no injury and were cleared (verified with flex/ext) 8 patients determined to have spinal instability (clinical, CT, etc.) No flex/ext performed on patients with abnormal MRI Cannot determine significance of MRI findings in 23/31 patients Seems to indicate that negative MRI equi-valent to negative Flex/ext.
Katzberg, <i>Radiology</i> 213: 203-212, 1999.	Prospective study of 199 patients who underwent MRI in addition to standard radiographic study. Half of patients were selected because of suspected high probability of injury.	Class III	MRI detected injuries in a higher fraction of these patients than did conventional radiographs and CT. Significance of these injuries? Gold standard?
Klein, <i>Spine</i> , 24:771-774, 1999.	Retrospective review of 32 patients with 75 known spine fractures Blinded review of MRIs by radiologists	Class II, select population	Posterior/Anterior element injuries: Sensitivity: 11.5%/36.7% Specificity 97.0%/98% Positive predictive value 83%/91.2% Negative predictive value 46%/64% MRI NOT good for evaluating bony pathology

Tan, <i>Journal of Spinal Disorders</i> 12: 472-476, 1999	Retrospective review of 360 patients treated for blunt injury who underwent 3 view C-spine films supplemented with CT because of nonvisualization of C7-T1. CT findings considered gold standard for detection of fracture	Class III	11 injuries detected by CT which were not visible on plain films Sensitivity of inadequate plain films relative to CT for this purpose: 97%
White, <i>British J Radiology</i> :818-823, 1999	31 patients with known or suspected spine injury evaluated with MRI	Class III	Pre-vertebral hematoma picked up more often by MRI than by plain films (24/31 vs. 14/30) Suggests that sensitivity of plain films for prevertebral hematoma is 66%
Ajani, <i>Anaesth Intensive Care</i> 26: 487-491, 1998	100 consecutive patients studied prospectively All radiographed (3 view) Follow-up clinical examination, CT, MRI, and flexion extension views performed	Class I	1/6 injuries missed by X-Ray (sensitivity 84%), 7/12 X-Ray abnormalities found to be insignificant Positive predictive value 45% Negative Predictive value 98.9% 1 missed injury detected by flexion/extension views
Sees, <i>J Trauma</i> 45: 768-771, 1998.	20 patients underwent bedside flex/ext under fluoro after 3 view C-spine films normal	Class III (for fluoro) Class II for 3 view c-spine with fluoro as gold standard	One patient found to have subluxation No gold standard for flex/ext Sensitivity of plain films with flex/ext as gold standard 95%
Benzel, <i>Journal of Neurosurgery</i> 85: 824-829, 1996	174 patients suspected of having cervical spine injury (equivocal plain films/CT or positive symptoms) Underwent MRI CT's obtained through area of injury defined by MRI	Class III	36% (62/174) had MRI evidence of injury 61/62 managed with immobilization for 1-2 months All patients with negative MRIs were cleared, no instances of late instability Negative predictive value of MRI 100% Positive predictive value ? Specificity?
Davis JW, <i>Journal of Trauma</i> 39:435-438, 1995.	116 patients with GCS<13 and normal radiographs evaluated with flexion/extension views under fluoro	Class I for plain films vs. flex/ext as gold standard Class III (follow-up questionable) for flex/ext ruling out injury.	113 patients had no abnormality detected 2 patients had "stable" facet fractures 1 patient had 2mm of subluxation and was treated in a collar (no follow up on this patient) No patient had referable neurological injury with clinical follow-up Decubiti ulcers found under collars in 44% of patients with mean collar time of 6 days NPV FE: 100%
Holliman, <i>J Emerg Med</i> 9:421-425, 1995	Retrospective series of 148 patients with known spine injuries. Lateral and odontoid films retrospectively reviewed separately from AP film. 60 sets of film available for review.	Class III	In these 60 patients, all injuries noted on AP films were also detectable on lateral or odontoid films.

Tehranzadeh, <i>Skeletal Radiol</i> 23:349-352, 1994	Retrospective review of 100 patients with blunt injury and non visualized C7-T1 on plain films CT findings considered gold standard	Class III	3 patients found to have injuries on CT not visualized by plain films Sensitivity of inadequate plain films: 97%
Borock, <i>Journal of Trauma</i> 31: 1001-1006, 1991	Used CT to evaluate cervical spine in 179 patients who were symptomatic with normal films (2), whose entire cervical spine could not be visualized (123) or who had equivocal (13) or abnormal (41) x-rays. Plain film sensitivity calculated using CT as gold standard, authors claim no missed injuries	Class II, possible false end-point	39/54 X-Ray abnormalities were verified with CT (Positive predictive value of 72%) X-rays missed both injuries in symptomatic patients and 1 C7 transverse process fracture (Negative predictive value of 97.6%)
Cohn, <i>Journal of Trauma</i> 31: 570-574, 1991	60 patients prospectively studied with lateral film in ED Full radiographic work-up (3 or 5 view) followed Results of lateral view to full series compared	Class II, possible false end-point (Class I if used only as comparison)	Lateral view missed 3/7 total injuries Lateral view positive predictive value 100% Negative predictive value 94% Sensitivity 57%
Lewis, <i>Annals of Emergency Medicine</i> 20:117-121, 1991.	Retrospective review of 141 patients with active F/E films performed after three view series was normal	Class II for plain films vs. F/E as gold standard Class II for F/E views	11/141 F/E sets read as unstable, 4 of whom had normal 3 view series (remainder were questionable) All patients with instability had pain or were intoxicated One false negative F/E study For plain films vs F/E and plain films: Sens: 71% 99% Spec: 89% 89% NPV 93% 93% PPV 67% 99%
MacDonald RL, <i>J Trauma</i> 30: 392-397, 1990	775 patients Three views compared against gold standard of all other studies performed and clinical outcome	Class I	Three view series Sensitivity: 83% Specificity: 97% Positive Predictive Value: 81% Negative Predictive value: 98%
Emery, <i>Journal of Spinal Disorders</i> 2: 229-233, 1989	MRI used to study 37 patients with known spine injuries All patients also studied with some combination of plain films/CT/tomograms/surgical exploration/clinical follow-up	Class II, select population	19 patients found to have ligamentous injury MRI detected 17/19 MRI was negative in 18/18 patients with intact ligaments Positive predictive value 100% Negative predictive value 90% Sensitivity: 89.5%
Freemyer, <i>Annals of Emergency Med</i> , 18: 818-821, 1989.	Prospective study of "high risk" symptomatic patients imaged with 5 view series Radiographic review of three views compared to five views Computed tomography used as gold standard	Class II Select population	58 patients studied 68 injuries detected in 33 patients Sensitivity of three view series was 83% compared to tomography Addition of oblique views had no effect on overall sensitivity

Reid, <i>J Trauma</i> 27:980-986, 1987	253 patients with 274 spinal injuries evaluated 38 had delay in diagnosis Evaluated cause for delay in diagnosis	Class III	20 injuries missed despite adequate films Sensitivity 92.3%
Shaffer, <i>Ann Emerg Med</i> 10:508-513, 1981	Retrospective analysis of all C-spine injuries detected in community emergency rooms Evaluated reading of lateral film to reading of three view series (three view series gold standard) Authors claim no missed injuries with 3 view series	Class III	35 injuries detected 9 cases missed with lateral view alone Sensitivity of lateral view compared to 3 views: 74%

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