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The (f)utility of flexion-extension C-spine films in the setting of trauma

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\textbf{KEYWORDS:}
Flexion/extension radiography; Adequacy; Cervical spine injury; Trauma

\textbf{Abstract}

\textbf{BACKGROUND:} Flexion-extension radiographs are often used to assess for removal of the cervical collar in the setting of trauma. The objective of this study was to evaluate their adequacy. We hypothesized that a significant proportion is inadequate.

\textbf{METHODS:} This was a retrospective review of C-spine clearance at a level 1 trauma center. A trauma-trained radiologist interpreted all flexion-extension radiographs for adequacy. Studies performed within 7 days of injury were considered acute.

\textbf{RESULTS:} Three hundred fifty-five flexion-extension radiographs were examined. Ninety-five percent of these studies were inadequate (51% because of the inability to visualize the top of T1, whereas 44% had less than 30$^\circ$ of angulation from neutral). Two hundred ten studies were performed acutely; of these, 97% were inadequate. When performed 7 days or longer from injury, 91% were inadequate.

\textbf{CONCLUSIONS:} Injury to the C-spine may harbor significant consequences; therefore, its proper evaluation is critical. The majority of flexion-extension films are inadequate. As such, they should not be included in the algorithm for removal of the cervical collar. If used, adequacy must be verified and supplemental radiographic studies obtained as indicated.

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Injury to the cervical spine is relatively common after major trauma. Its initial evaluation and diagnosis have changed significantly over the past decade. Numerous studies have documented the inability of 3-view cervical spine radiographs to identify both vertebral fractures and ligamentous injuries reliably. The reported sensitivities of such films range from 30% to 60\%	extsuperscript{1-3} Thus, when patients are unable to be cleared clinically via the National Emergency X-Radiography Utilization Study or Canadian C-Spine Rule criteria, computed tomographic (CT) imaging of the cervical spine is the diagnostic tool of choice.\textsuperscript{4,5} In alert and oriented patients with negative findings on CT imaging, a normal physical examination, and no neck pain, the cervical spine may be cleared clinically.\textsuperscript{6,7}

The presence of midline neck pain or tenderness prevents the clearance of the cervical spine because of potential
ligamentous injuries missed by the CT scan. In the past, flexion-extension radiographs of the cervical spine were used as an adjunct in hopes of better characterizing ligamentous injuries (and vertebral fractures); however, the usefulness of such films performed acutely has been questioned because 30% are deemed inadequate. With CT imaging of the cervical spine now the preferred diagnostic tool for vertebral fractures, flexion-extension series are now used primarily for the identification of ligamentous injuries rather than vertebral fractures. More recent series document the adequacy of acute flexion-extension films at 30% to 60% depending on the stringency of adequacy criteria applied.

The 2009 Eastern Association for the Surgery of Trauma “Practice Management Guideline for Cervical Spine Injuries following Trauma” includes flexion-extension films as an option for clearing the cervical spine “in the neurologically-intact awake and alert patient complaining of neck pain with a negative CT scan.” The objective of this study was to evaluate the adequacy of flexion-extension radiographs obtained for the removal of the cervical collar after trauma. We hypothesized that a significant proportion of these films are inadequate.

Methods

This was a retrospective review of cervical spine clearance after trauma at Bellevue Hospital Center in New York City. Bellevue is a New York State–designated level I trauma center primarily serving the lower half of Manhattan and Western Brooklyn. A trauma radiology database was queried for those patients with both a cervical spine CT scan and flexion-extension radiography from 2002 through 2012. Inclusion criteria included patients suffering blunt trauma who had a negative CT scan, were alert and oriented without neurologic deficits, and had persistent neck pain. The medical record and trauma radiology database were then used to evaluate patient demographics, radiographic imaging, and clinical outcomes.

A single radiologist with a fellowship in trauma and critical care radiology examined all of the cervical spine flexion-extension radiographs for adequacy. Adequacy was defined as visualization of the cervical spine from the base of the occiput to the top of the first thoracic vertebrae (T1) and greater than or equal to 30° of angulation in both flexion and extension. For the measurement of this angulation, 2 straight lines are drawn: one parallel to the bottom of the second cervical vertebrae and a second one parallel to the lowest cervical vertebrae endplate. With flexion, these lines intersect anteriorly, whereas upon extension, they intersect posteriorly (Fig. 1). If any of these criteria were not met, the flexion-extension series was deemed inadequate.

Parameters to diagnose ligamentous instability (a positive flexion-extension series) were extrapolated from cadaver and healthy volunteer studies. The 2 parameters used most frequently are horizontal and angular displacement. Although some groups use 3.5 mm of horizontal displacement as one of the criteria for injury, we chose a more conservative value based on studies cited in the 2009 Eastern Association for the Surgery of Trauma guideline. Ligamentous instability was defined as greater than or equal to 2 mm of horizontal displacement or greater than or equal to 11° of angular displacement. For the purposes of this study, flexion-extension radiographs performed within 7 days of injury were considered acute.

Standard descriptive statistical tests were used. Numeric data are presented as mean ± standard deviation and median where appropriate. In comparing potential study groups, the Student t test was used for continuous data. Chi-square analysis was used for categorical data. When appropriate, this was substituted with the Fisher exact
test. A P value less than .05 was considered significant. IBM SPSS Statistics Version 19 (Armonk, NY) was used for all statistical analyses. The study was approved by the Institutional Review Board of the New York University School of Medicine.

Results

Over the 10-year period, 459 patients were identified who had flexion-extension radiographs and a CT scan performed to evaluate the cervical spine after trauma. After excluding 83 patients with a CT study positive for cervical spine injury, 3 with penetrating injuries, and 18 with incomplete imaging (defined as a lack of either the flexion or extension film), 355 flexion-extension series were examined for adequacy. The mean age of this cohort was 41.4 ± 17.4 years, 66% were men, and the mean Injury Severity Score was 8.0 ± 7.0. The mechanism of injury and neurologic examination on presentation are shown in Table 1.

To evaluate the adequacy of the flexion-extension radiographs, we initially used the first criterion (ie, complete visualization of the cervical spine from the base of the occiput to the top of T1). The entire cervical spine was not visualized in 51% of the 355 flexion-extension series examined. Only radiographs that passed this first criterion were then assessed for the second criterion (ie, greater than or equal to 30° of angulation in both flexion and extension). Insufficient range of motion eliminated another 44% of studies. Therefore, when both criteria were used, the overall adequacy rate of the flexion-extension radiographs was 5% (Table 2).

In examining the acuteness of the flexion-extension studies (performed <7 days or ≥7 days from injury), there was little difference in adequacy in comparison to the group as a whole (Table 2). However, those radiographs performed 7 days or longer from injury were significantly more adequate than those performed less than 7 days from injury (P = .01). However, increasing the “acute” definition to those performed less than 14 days from injury did not significantly increase the adequacy rate.

Among the flexion-extension radiographs obtained less than 7 days from injury, 86% were the final study performed before cervical spine clearance. Of these films, 97% were inadequate. Magnetic resonance imaging (MRI) of the cervical spine was undertaken in 2% of the patients after flexion-extension radiographs, whereas 12% were either lost to follow-up or removed their cervical collar on their own, effectively clearing themselves. The only case in which the flexion-extension study was positive for injury was among the patients initially excluded. This patient had a cervical spine CT scan documenting a definitive ligamentous injury confirmed by MRI with cord compression (both studies were obtained before the flexion-extension films). Thus, all flexion-extension series considered for adequacy were negative for injury when interpreted by the trauma radiologist.

Of the 459 patients initially evaluated, only 11 required surgical intervention: 7 patients had a CT scan positive for a fracture, 3 patients had chronic cord compression (2 patients had underlying degenerative disc disease whereas 1 had congenital stenosis), and another patient had a negative CT scan but a neurologic deficit prompting surgery. There were no patients identified with a cervical spine injury after clearance.

Table 1  Flexion-extension radiography demographics

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Mean ± SD, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>41.4 ± 17.4</td>
</tr>
<tr>
<td>Male</td>
<td>66</td>
</tr>
<tr>
<td>Injury Severity Score</td>
<td>8.0 ± 7.0</td>
</tr>
<tr>
<td>Glasgow Coma Scale score</td>
<td>14.0 ± 1.9</td>
</tr>
<tr>
<td>Mechanism of injury</td>
<td></td>
</tr>
<tr>
<td>Fall</td>
<td>36</td>
</tr>
<tr>
<td>Motor vehicle collision</td>
<td>21</td>
</tr>
<tr>
<td>Pedestrian versus motor vehicle</td>
<td>19</td>
</tr>
<tr>
<td>Assault; struck with an object</td>
<td>14</td>
</tr>
<tr>
<td>Bicycle versus motor vehicle</td>
<td>5</td>
</tr>
<tr>
<td>Motorcycle collision</td>
<td>2</td>
</tr>
<tr>
<td>Other/not available</td>
<td>3</td>
</tr>
<tr>
<td>Neurologic examination on presentation</td>
<td></td>
</tr>
<tr>
<td>Cervical tenderness</td>
<td>69</td>
</tr>
<tr>
<td>Benign</td>
<td>25</td>
</tr>
<tr>
<td>Altered mental status</td>
<td>2</td>
</tr>
<tr>
<td>Sensory deficit</td>
<td>2</td>
</tr>
<tr>
<td>Paraplegia</td>
<td>0</td>
</tr>
<tr>
<td>Not available</td>
<td>2</td>
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</tbody>
</table>

SD = standard deviation.

Comments

After trauma, inappropriate clearance of the cervical spine can have devastating consequences. In the era of 3-view cervical spine radiographs, flexion-extension radiographs provided complementary information in diagnosing both ligamentous and vertebral injuries.8,9,14 Subsequently, 3-view films have been shown to have little use in diagnosing cervical spine fractures, and CT imaging has become the standard of care.1,2,15,16 Although plain cervical films are no longer used, flexion-extension radiographs are still used in excluding ligamentous injuries in patients with a negative cervical spine CT scan and persistent neck pain. Our contention is that, just as with 3-view radiographs, the inadequacy of flexion-extension films renders them inappropriate for the removal of the cervical collar after trauma. If clinical management, particularly removal of cervical spine immobilization, is based on the results of an inadequate study, there is great risk for patient harm. The concern arises from a potential purely ligamentous cervical spine injury without fracture or malalignment producing a normal-appearing cervical spine CT scan. Complaints of persistent neck pain might then initiate flexion-extension cervical radiographs. Inadequate motion in flexion and/or
extension as a result of muscle spasm could very well mask the true underlying instability, and the result could be removal of the cervical collar and subsequent subluxation and neurologic injury.

The adequacy (and positive diagnosis) of flexion-extension radiographs has primarily been extrapolated from cadaver and volunteer studies. In 1975, White et al used cervical vertebrae from cadaveric spines to measure displacement after a physiologic load of 25% of body weight. With all ligaments intact, displacement did not exceed 2.67 mm and angulation 10.7°. Secondary to these findings, the authors defined cervical spine instability as displacement greater than or equal to 3.5 mm or angulation greater than or equal to 11°. More recent studies have used cadavers with intact cervical spines and obtained flexion-extension series while sequentially cutting the vertebral ligaments. Such studies have documented that displacement of greater than 2 mm was rarely present in the healthy spine; therefore, the authors recommended to decrease the definition of abnormal displacement from 3.5 to 2 mm.13,14

Finally, studies in volunteers have shown that displacement of greater than 3.5 mm did not exceed 2 mm in the healthy spine; therefore, the authors recommended to decrease the definition of abnormal displacement from 3.5 to 2 mm.13,14

Based on these data, we defined the adequacy of flexion-extension cervical radiographs as visualization of the cervical spine from the base of the occiput to the top of T1 and greater than or equal to 30° of angulation. The criteria for an injury positive flexion-extension study were either 2 mm of displacement or angulation greater than or equal to 11°. Increasing the displacement criterion to 3.5 mm would not have decreased the sensitivity of the current study because the only case with a positive flexion-extension series (in and excluded patient) possessed 5 mm of displacement.

The low adequacy rate of the flexion-extension films has previously been reported by Khan et al,10 documenting a 31% adequacy rate using the same criteria for adequacy as the current study used. Their population included patients with a negative CT scan, normal neurologic examination, and neck pain. Duane et al9 used similar criteria and documented a 60% adequacy rate. An additional study using only range of motion greater than or equal to 30° from neutral revealed a 60% adequacy rate.9 The current study documents a dismal 5% adequacy rate using the same criteria as Khan and Duane.

So why do all of these studies document such a poor adequacy rate for flexion-extension radiographs in clearing the cervical spine after trauma? The primary logical reason is pain and muscle spasm, resulting in limited range of motion. As such, it would reason that with time, the inflammation and pain would decrease, allowing a greater range of motion; however, our data do not support this theory. Despite a statistically significant increase in the adequacy rate for those films performed 7 days or longer from injury, the adequacy remained abysmally low at 9%. Similarly, examining those films performed 14 days or longer did not significantly increase the adequacy rate.

An alternative to flexion-extension films for cervical spine clearance is MRI. Duane et al19,20 compared the ability of CT scans, flexion-extension radiographs, and MRI to identify ligamentous injury of the cervical spine. CT imaging was able to identify 7 of 9 ligamentous injuries subsequently identified on flexion-extension radiography (with no management issues in the missed injuries). In comparing 49 flexion-extension series with MRI, the flexion-extension radiographs missed all 8 injuries identified on MRI, 5 of which had an effect on management. The reported adequacy rate of the flexion-extension radiographs in the Duane et al20 study was 70% using the same criteria for adequacy as the current study. Goodnight et al21 documented 8 ligamentous injuries on flexion-extension films that were all missed by CT scans and MRI. Although some consider MRI the gold standard for diagnosing ligamentous injury of the cervical spine, Schuster et al22 have questioned its usefulness in patients with a negative CT scan because their study revealed that all 93 patients with a negative CT scan and persistent neck pain had a negative MRI. In a study of 366 obtunded patients with negative cervical spine CT scans, MRI identified only 4 ligamentous injuries, all of which were stable (involving only 1 level) requiring no surgical intervention.23 Although many of these studies have documented the increased sensitivity of MRI at diagnosing ligamentous injury after cervical trauma, the clinical importance of such injuries is questionable at best. Additionally, it is important to note that MRI loses its sensitivity as time from injury increases.6

Another alternative to flexion-extension studies is the maintenance of cervical immobilization and follow-up clinical evaluation. Follow-up examination could reassess for midline tenderness on palpation of the cervical spine as well as the presence of pain, numbness, or tingling.

In conclusion, injury to the cervical spine is relatively common after major trauma and may have significant consequences; therefore, its proper evaluation is critical. The majority of flexion-extension radiographs obtained are

### Table 2. Flexion-extension radiography adequacy

<table>
<thead>
<tr>
<th>Flexion-extension radiographs</th>
<th>Inadequate (%)</th>
<th>Adequate (%)</th>
</tr>
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<tbody>
<tr>
<td>All flexion-extension radiographs (355)</td>
<td>95</td>
<td>5</td>
</tr>
<tr>
<td>Flexion-extension radiographs &lt;7 days from injury (210)</td>
<td>97</td>
<td>3</td>
</tr>
<tr>
<td>Flexion-extension radiographs ≥7 days from injury (145)</td>
<td>91</td>
<td>9</td>
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References


Discussion

Sharmila Dissanaike, M.D. (Lubbock, TX): Congratulations on a very interesting study; it is always a pleasure to discuss an article that fits my own biases. Your study highlights a very vexing problem, that of clearing the cervical spine in trauma patients. We consider cost:benefit ratios in many aspects of medicine, and I suspect that 1 reason flexion-extension films are still around is their low cost. However, if there is also no benefit, then, of course, the equation fails. My first question for you is you had a high proportion of inadequate films and yet people acted and cleared C-spines based on that. I presume that your other radiologists were not as diligent as the one in the study. Therefore, the question is how should we deal with one person overreading the films and yet another group that is reading them as adequate? How did your group handle that? This brings up the broader issue of are you saying that flexion-extension films cannot be performed adequately so often that it is completely useless as a modality or do we need stricter protocols, stricter criteria, and more rigorous radiologic evaluation off the images to make sure that we get adequate films? Also, it was in your article although I did not see it up there that you had 83 patients who had a flexion-extension radiograph even with positive CT findings of injury. I just want to know if you could explain the thought process behind that if you had data on it. Thank you very much.

Vasiliy Sim, M.D. (New York, NY): Regarding your first question in terms of how we address the fact that the flexion-extension films that have been used were not initially picked up as inadequate, we actually did study and compared both the radiologist who reviewed the films recently and the ones that read them initially; the initial adequacy rate was about 86%. To further pursue that question, we actually went and asked some of the nontrauma radiologists because what we have at Belview is 2 kinds of radiologists who read the flexion-extension films. The first type is a neuroradiologist, and the second is a trauma-trained...
radiologist. When we asked the neuroradiologists about the adequacy criteria, some of them did not know it. Most of their adequacy was based on the fact that yes, it looks like it is enough flexion and enough extension, it looks like it is adequate, let’s take the cervical collar off. For the second question, our bias is that I think that flexion-extension is pretty much becoming useless because of the questionable adequacy of rate even after 7 days, and we actually did further studies looking at 14 days; 14 days did not make any difference whatsoever. So I think it is losing its purpose, and I think it is going the same way as the 3-view x-rays for cervical spine left; CT imaging is becoming more appropriate, and flexion-extension radiography should not be used at all. For the 83 patients who had a positive CT scan and the flexion-extension radiographs were obtained afterward, most of them were done after either some kind of intervention had taken place or later in the process when we evaluated looking for evaluation of stability and they were not done in an acute setting.

Jim Haan, M.D. (Wichita, KS): One thing you do not see in your study that I am curious about. How many of these patients have pre-existing general joint changes, fusions, or things of that nature? Depending on your own patient population, if you have elderly patients, even on their best day, they do not have 30° angulation. I know at least our radiologist will, right or wrong, put in a fudge factor for that. They will look at these areas and say I do not think they can get 30°; I think that is all they have got. That is where you get these clearances that will not make your criteria.

Dr Sim: There were definitely patients who had chronic changes and an inability to do it (flexed/extended neck). But, once again, the fact is it still comes down to the idea that it (films) still is inadequate. Why even get a study that does not help you at all and spend money? Some studies have reported that it is about $300 for flexion-extension films.

Will Fry, M.D. (Columbia, SC): Nice article. I was just wondering despite this how many injuries were missed by these inadequate studies?

Dr Sim: Of all the 459 patients who we have reviewed, there was only 1 patient who had a positive flexion-extension study. That positive patient also had a positive CT scan and MRI performed before the flexion-extension film. So every other flexion-extension film was actually negative. Nothing really was missed.