The College of Emergency Medicine

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CLINICAL EFFECTIVENESS COMMITTEE

Guideline on the management of alert, adult patients with potential cervical spine injury in the Emergency Department

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Contents

Scope

This guideline provides recommendations on best practice for the initial management of alert, co-operative adult patients whose mechanism of injury has the potential to result in blunt or penetrating injury to the cervical spine. It also provides guidance on which patients should have imaging of the cervical spine performed and the imaging modality of choice.

This guidance does not cover "clearance of the neck" in the following groups:

- unco-operative patients
- patients with a persistently low GCS
- children (16 years or younger)
- assessment in the pre-hospital setting

Reason for development

The previous College of Emergency Medicine (BAEM) guidelines on the management of patients with potential cervical spine injury were last updated in 2005. In 2007 NICE updated their guidelines[1] on the management of adults and children at risk of cervical spine injury following a head injury. This review considered the evidence base for the NICE recommendations and sought new evidence that has been published since 2006. Cervical spine injuries secondary to penetrating trauma was outside the scope of the NICE guidelines and the evidence in this area was reviewed here.

Summary of recommendations

Neck immobilisation/ Cervical collars

Patients deemed at risk of cervical spine injury should have their neck immobilised (level five evidence).

Patients with pre-existing vertebral anatomical abnormalities eg ankylosing spondylitis should have their necks immobilised in a position of comfort. In such cases the use of collar is not compulsory and may be detrimental (level four evidence).

Cervical spine immobilisation should be maintained until full risk assessment including clinical assessment (and imaging if deemed necessary) indicates it is safe to remove the immobilisation device (level five evidence).

Blunt neck injury

Cervical spine imaging should be requested for the following patients that have been subjected to blunt trauma with a mechanism that may have injured the neck:

- GCS<15 on assessment in the ED (level one evidence)
- Paralysis, focal neurological deficit, or paraesthesia in the extremities (level one evidence)
- Patients with abnormal vital signs (systolic BP<90mmHg or respiratory rate outside of the range 10-24 breaths per minute) (level five evidence)
- Urgent requirement to identify a cervical spine fracture (eg prior to surgery) (level five evidence)
- Severe neck pain (≥ 7/10 severity) (level four evidence)
- Patients with neck pain and <u>any</u> of the following high risk factors (level one evidence unless otherwise stated):
    - a fall from greater than one metre or five stairs
    - an axial load to the head eg diving
    - a high-speed motor vehicle collision (combined speed >60mph)
    - a rollover motor vehicle accident
    - ejection from a motor vehicle
    - an accident involving motorised recreational vehicles
    - a bicycle collision
    - age 65 years or more
    - injured more than 48 hours earlier (level five evidence)
    - re-attending with the same injury (level five evidence)
    - known vertebral disease (eg ankylosing spondylitis, rheumatoid arthritis, spinal stenosis, or previous cervical surgery) (level four evidence)
- Patients with a dangerous mechanism of injury (see above) <u>and</u> either a visible injury above the clavicles or a severely painful (≥ 7/10 severity) thoracic injury even if there is no neck pain or tenderness (level four evidence)

If <u>none</u> of the high risk factors above are present and <u>any</u> of the following low risk factors are identified then the patient can have their collar removed and their range of movement assessed (level one evidence):

- simple rear-end motor vehicle collision (but not if pushed into another vehicle, or if hit at high speed or by a large vehicle)
- sitting position in ED
- ambulatory at any time since injury
- delayed onset of neck pain (ie not immediate)
- absence of midline cervical spine tenderness

Patients stratified to a low risk category that can actively rotate their necks 45 degrees to the left and right should be considered to have had a "significant" cervical spine injury excluded without need for imaging. Patients that are unable to rotate their neck 45 degrees in both directions or report severe pain (≥ 7/10 severity) on doing so should have cervical spine imaging performed.

Penetrating neck injury

Neck immobilisation is not required for patients with isolated gunshot wounds to the head, unless the bullet path traverses the neck (level four evidence).

Cervical spine immobilisation is recommended for patients with gunshot wounds to the neck given the association with direct spinal destruction in a proportion of patients. However, this should not take precedent over life-threatening airway and haemorrhage control (level five evidence).

Neck immobilisation is not required for a patient with an isolated stab wound to the neck even if a neurological deficit is identified (level four evidence). The fitting of a cervical collar in this setting may be associated with an increased mortality. (level four evidence)

Collar removal

Staff members should not remove cervical collars unless they have received specific training in the use of a validated cervical spine clinical decision rule. (level five evidence)

Nurses can safely apply clinical decision rules designed for cervical spine clearance following targeted training (level three evidence).

Primary imaging modality

CT should be used as the primary imaging modality for excluding cervical spine injury in adults following blunt trauma if any of the following criteria are met (level two evidence):

- GCS below 13 on initial assessment
- Intubated patients
- Inadequate plain film series
- Suspicion or certainty of abnormality on plain film series*
- Patient's being scanned for head injury or multi-region trauma

**As a minimum the CT should cover the area from the cranio-cervical junction to the thoraco-cervical junction since selective scanning has been shown to miss injuries (NICE head injury guidelines, 2007)*

It is also recommended that CT be used as the primary imaging modality in the following settings:

- Patient has dementia (or a chronic disability precluding accurate clinical assessment) (level five evidence)
- Patient has neurological signs and symptoms referable to the cervical spine (level three evidence)
- Patient has severe neck pain (≥ 7/10 severity) (level four evidence)
- Patient has a significantly reduced range of neck movement (ie unable to actively rotate the neck 45 degrees in both directions) (level four evidence)
- Patients with known vertebral disease (eg ankylosing spondylitis, rheumatoid arthritis, spinal stenosis, or previous cervical surgery) (level four evidence)

Local guidelines should be developed with regard to the primary imaging modality for patients aged over 65 years.

In the absence of an indication for CT, 3-view plain radiographs should be used as the primary imaging modality for excluding cervical spine injury.

Timing of imaging

Imaging of the cervical spine should be performed within 1 hour of a request having been received by the radiology department or when the patient is sufficiently stable (level five evidence).

If the patient is having an urgent CT head performed then the neck should be scanned at the same time (level five evidence).

A radiologist (or clinician specifically trained to perform this task) should formally report the CT cervical spine scan images promptly (level five evidence).

Advanced imaging

MRI should be used to exclude cervical spine injury* in adults following blunt trauma if any of the following criteria are met (level two evidence):

- Neurological signs and symptoms referable to the cervical spine
- Suspicion of vertebral artery injury (eg spinal column displacement, foramen transversarium or lateral process fracture, posterior circulation syndromes).

**MRI should always be used in conjunction with another modality, preferably CT, in order not to miss bony injuries.*

Further imaging is advised for adults with severely restricted neck movement or severe pain ≱ 7/10) despite a normal CT following blunt cervical spine injury (level four evidence). Local guidelines should be developed between emergency physicians, radiologists, and spinal surgeons for the management of this group of patients.

Flexion-extension views cannot reliably exclude unstable cervical spine injuries in the acute setting (level three evidence). Patients without fracture or neurological deficit can be discharged following a negative MRI scan (level two evidence).

When indicated, MRI should be performed as soon as possible as its sensitivity for injury identification may fall after 48 hours(level four evidence)

Patients with injuries identified on MRI should be discussed with spinal surgeons (level five evidence).

Introduction

The prevalence of cervical spine injury following blunt trauma from 65 published studies[2] is 2.8% overall, and ~2% in less selective, prospective studies of consecutive patients[3-4]. Less than 1% of patients will suffer a cord injury but for those that do it can be devastating to both the individual and their family. The practice of immobilising a patient's neck (and body) following potential neck trauma has been widely adopted through fear of causing or exacerbating a spinal injury. However, spinal immobilisation is not without consequence in financial terms, or morbidity, for the 98% or so who do not have a significant cervical spine injury.

Once the patient arrives at the hospital there is a natural tendency for doctors to err on the side of caution with regards to requests for imaging of the cervical spine despite the limitations of plain radiography, whose sensitivity has been reported in a meta-analysis[5] to be only 52% at identifying "significant" cervical spinal injury in high risk groups.

The following questions that are of interest to healthcare professionals who deal with adult patients with potential cervical spine injury are addressed in this review.

- Does cervical spine immobilisation prevent neurological deterioration in patients with potential cervical spine injury following blunt trauma?
- Does cervical spine immobilisation prevent neurological deterioration in patients with potential cervical spine injury following penetrating neck injury?
- In adult patients with potential neck injury secondary to blunt traumatic forces, can existing clinical decision rules reliably exclude significant cervical spine injury without use of imaging? If so, which rule is recommended?
- Which patients require cervical spine imaging?
- Can decision rules be applied safely by nurses in the ED?
- Which primary imaging modality is recommended for excluding cervical spine injury?
- When should imaging be performed?
- What is the recommended management for patients that complain of significant pain or have restricted neck movement despite "normal" CT of the cervical spine?

Contributing Experts

This guideline was prepared by Jason Lee (jason.lee@york.nhs.uk), Consultant in Emergency Medicine, for the Best Practice Subcommittee and ratified by the Clinical Effectiveness Committee of the College of Emergency Medicine.

Limitations of this guideline

Only studies published in English language were considered and although some study authors were contacted directly, an extensive review of the grey literature was not performed. This guideline was developed without input from other (Royal) Colleges.

Review date

November 2015 or sooner if important information becomes available.

Disclaimers

The College recognises that patients, their situations, Emergency Departments and staff all vary. This guideline cannot cover all possible scenarios. The ultimate responsibility for the interpretation and application of this guideline, the use of current information and a patient's overall care and wellbeing resides with the treating clinician.

Research recommendations

This review has identified a lack of robust evidence in specific key areas of neck injury management that future research could address, subject to ethical approval (see below):

1. Randomised controlled trial of collar application versus no collar application for alert co-operative neurologically intact patients with potential cervical spine injury.
- Primary outcome measure – missed significant cervical spine injury (see appendix 4)
- Secondary outcome measure – neurological outcome, patient satisfaction, length of ED stay and cost and incidence of non-neurological complications eg pressure areas, aspiration.

2. Randomised controlled trial of collar application versus no collar application for patients with penetrating neck injury.
- Primary outcome measures – mortality, and neurological outcome in survivors
- Secondary outcome measures: non-neurological complications, length of hospital stay and cost.

3. Prospective cohort trial to validate ability of trained nursing staff to safely implement clinical decision rules for patients in UK ED's.
- Primary outcome measure – missed significant cervical spine injury
- Secondary outcome measures – patient satisfaction, rate of radiology requests, total time patients spent immobilised, length of ED stay.

4. Randomisation of consecutive alert, neurologically intact patients that cannot have their cervical spines cleared clinically but who do not meet the high risk criteria for CT to either CT or plain radiography.
- Primary outcome measure – ability to exclude significant cervical spine injury according to operative findings or follow up at 90 days.
- Secondary outcome measures – adequacy of each imaging modality, time to complete imaging studies, cost per identified unstable injury, cost-effectiveness in

subgroups of interest identified a priori eg patients aged over 65, patients with pre-existing spinal disease, and patients with dementia.

5. Randomised trial of consecutive alert, neurologically intact patients with significant neck pain or reduced range of neck movement. Discharge after exclusion of instability based upon CT vs. CT plus MRI vs. [CT plus follow up at 10-14 days +/- MRI or flexion-extension views].

- Primary outcome measure – ability to exclude an unstable cervical spinal injury according to operative findings or follow up at 90 days
- Secondary outcome measures – length of time to removal of collar, complication rate associated with collars, cost of each of the three protocols per unstable injury identified, sensitivity of MRI performed before and after 48 hours.

Audit standards

There should be a documentation and audit system in place within a system of clinical governance.

Key words for search

Neck injuries
Cervical spine
Spinal injuries
Neck immobilisation
Collar
Emergency Department
X-ray
CT
MRI
Flexion-extension views
Clinical decision rules
Clinical practice guidelines

Discussion

Does cervical spine immobilisation prevent neurological deterioration in patients with potential cervical spine injury following blunt trauma?

Search strategy and results (page 36)

No randomised controlled trial was identified that answered the question posed.

Comment:

Rogers[6] published a case series of 77 patients with significant cervical spine injuries that had been referred to a neurosurgical service between 1940 and 1950. Eight patients (10%), all of whom had anterior spine dislocations, developed either new symptoms or worsening symptoms of cord compression after arrival at hospital. The author suggested that the use of adjustable traction neck braces by first responders on patients with neck injuries could reduce the number of cases of delayed neurological deficit. Bohlman[7] reported that 60% of 300 non-consecutive patients presenting to either Johns Hopkins or Baltimore Hospital between 1950 and 1972 with acute cervical spine fractures or dislocations were paralysed on arrival. This study excluded patients with simple sprains but did include intoxicated, unco-operative and multiply injured patients. In a third of all patients the diagnosis of cervical spine injury was made more than two days after admission. Neurological deterioration after arrival was documented in eleven cases (3.6%), four of whom had neck immobilisation performed and seven of whom did not. During the 1970's when spinal immobilisation was more widely practiced (and seatbelts were more widely worn) the number of paralysed patients fell[8]. This evidence and expert consensus formed the basis for the initial ATLS recommendation[9] that all trauma patients considered to be at potential risk of cervical spine injury should have immediate neck immobilisation performed. Reid[10] reported that secondary neurological injury occurred in 1.4 % patients with cervical spine injury when the diagnosis was made in the ER and in 10.5 % of cases when the diagnosis was missed. Associations with missed diagnoses included intoxication, decreased level of consciousness, multiple level spinal injuries and failure to request imaging. Toscano[11] retrospectively interviewed staff involved in the transfer of patients with cervical spine injuries to a tertiary referral neurosurgical centre in Australia between 1983 and 1984. He concluded that all cases (18 patients) where neurological deterioration occurred between the time of injury to the cervical spine and arrival at the neurosurgical unit (more than 12 hours in 30% of cases) could have been prevented by better immobilisation and transfers. The practice of cervical spinal immobilisation following blunt trauma is now enshrined in clinical practice worldwide but has been questioned in more recent times by a number of authors.

The low prevalence (<2%) of "significant" cervical spinal injuries in patients attending the Emergency Department following blunt trauma[3,4] means that approximately 50-100 patients have their neck immobilised for every patient that has a significant cervical spine injury. Pre-hospital neck immobilisation is usually coupled with immobilisation on an extrication board. The incidence of complications secondary to immobilisation in a cervical collar is not known but reported complications include raised intracranial pressure[12], respiratory compromise[13], aspiration from vomiting[14], decubitus ulceration[15] and an increased difficulty in airway management. Potential benefits of the collar include minimisation of neck movement during transfers[16], increased comfort for a minority of patients, and to alert staff to the fact that the patient may have a significant underlying injury.

In 1998, Hauswald[17] published retrospective data that compared the neurological outcomes of 334 patients with blunt traumatic cervical spinal injury who all had spinal immobilisation performed (New Mexico) with 120 patients with blunt traumatic cervical spinal injury that had no spinal immobilisation performed (Malaya). There was a non-significant increase in neurological disability in the immobilised group. Though this comparison is flawed, the author's argument that any cord injury from blunt trauma occurs at the time of the impact, that subsequent movement is very unlikely to cause further damage, and that alert patient will develop a position of comfort with muscle spasm protecting the spine appears credible. It is widely accepted that it may be harmful for patients with pre-existing vertebral anatomical abnormalities eg ankylosing spondylitis to have their neck forced into an unnatural position[18] and such patients usually have their neck supported in a position of comfort with or without a collar.

A Cochrane review updated in 2009 by Kwan et al[19] concluded that in the absence of any randomised controlled trials the low incidence of unstable injuries of the cervical spine amongst those immobilised raised the possibility that immobilisation may be associated with a higher morbidity and mortality than non-immobilisation. In a recent literature review, Benger and Blackman[20] concluded that alert, co-operative trauma patients do not require cervical spine immobilisation unless their conscious level deteriorates or they find short-term support of a collar helpful.

The evidence both for and against cervical spine immobilisation is weak. Although Hauswald's study is intriguing, if we accept a 1-2% prevalence of unstable cervical spine injury following blunt trauma and hypothesise that 1 in 10 patients with unstable cervical spinal injuries would suffer a spinal cord injury as a consequence of non-immobilisation of their neck then only 1 in 500 -1,000 patients would be harmed as a result, which exceeds Hauswald's study population. There is a need for large randomised multi-centre trials to determine the risk:benefit ratio of neck immobilisation. However, the current practice of cervical spine immobilisation has been so widely adopted and the consequence of causing or exacerbating a spinal injury so catastrophic that such trials may not be supported by ethical committees.

NICE cervical spine guidelines (2007) state that cervical spine immobilisation should be maintained until full risk assessment including clinical assessment (and imaging if deemed necessary) indicates it is safe to remove the immobilisation device. Though evidence that the use of cervical collars prevents secondary injury is lacking, no evidence could be found to contradict this statement and it is, therefore, supported.

Recommendation

Patients deemed at risk of cervical spine injury should have their neck immobilised (level five evidence).

Patients with pre-existing vertebral anatomical abnormalities eg ankylosing spondylitis should have their necks immobilised in a position of comfort. In such cases the use of collar is not compulsory and may be detrimental (level four evidence).

Cervical spine immobilisation should be maintained until full risk assessment including clinical assessment (and imaging if deemed necessary) indicates it is safe to remove the immobilisation device (level five evidence).

Does cervical spine immobilisation prevent neurological deterioration in patients with potential cervical spine injury following penetrating neck injury?

Search strategy and results (page 37)

No randomised controlled trial was identified that answered the question posed.

Comment:

Penetrating injuries to the head and neck are uncommon in the UK and the NICE guidelines do not address the need for cervical spine immobilisation in this setting. Spinal immobilisation has been traditionally performed on such patients as an extrapolation of current practice for patients with neck injuries resulting from blunt traumatic forces.

Gunshot wounds to the head

A number of retrospective reviews have failed to identify any survivor with a cervical spine injury following an isolated gunshot wound to the head when the bullet did not traverse the neck:

After excluding patients clinically cleared and those who died, Lanoix et al[21] reported that none of 151 patients with gunshot wounds to the head had a cervical spine injury. A combined number of 383 patients were not found to have cervical spine injuries following gunshot wounds to the head in separate case series reported by Kennedy et al[22], Chong et al[23], and Kaups et al[24]. Kaups et al specifically commented that no patient that was shot sustained blast or a fall related spinal injury.

Although these case series represent only weak (level four) evidence, future randomised controlled trials are unlikely. The 2009 Eastern Association for the Surgery of Trauma (EAST) guidelines[25] advises that spinal immobilisation is not required if the bullet does not traverse the neck. Given that cervical collars are associated with raised intracranial pressure and increased difficulty in airway management spinal immobilisation is not recommended in such cases.

Penetrating injuries to the neck

A retrospective review of casualties from the Vietnam war[26] found that all penetrating cervical cord injuries proved fatal whilst another retrospective military case review from Israel reported that 22% of casualties with penetrating neck trauma had life threatening injuries eg expanding neck haematomas that may have been obscured by a cervical collar. None of the casualties who were not immobilised required spinal surgery. It may be argued that high velocity injuries in the military setting are not representative of civilian injuries.

A number of retrospective reviews have looked at outcomes from cervical spine injuries in civilian populations following penetrating neck trauma:
Medzon et al[27] reviewed thirteen years of data on patients and reported that none of the 81 patients presenting during that time with gunshot wounds to the head or neck required surgical intervention for an unstable spinal injury. Rhee et al[28] reported a low prevalence of cervical spine cord injury (1%) in all patients presenting with gunshot wounds to two level 1 US trauma centres over a 7-12 year period. All patients with cervical cord injury in this review had a neurological deficit on arrival at hospital and none regained significant neurological recovery during hospitilisation. Vanderlan et al[29] more recently (2009) reported

that only 2 out of 196 patients presenting with penetrating neck injuries (all causes) to two level 1 trauma centres had unstable cervical spine fractures. Both patients had complete neurological deficit on arrival. A decreased spine immobilisation rate at one of the centres during the study did not affect neurological outcome. Although interesting, this must be viewed with caution given the small numbers involved. The same lead author has separately published mortality rates from a single centre[30]. Thirty five out of 199 patients with penetrating cervical trauma died over the nine year review period. The odds ratio of dying if the neck was immobilised compared to if it was not was calculated to be 2.8 (95% CI 1.2-6.5). Klein et al[31] reported that 33/183 patients with gunshot wounds to the neck had cervical spine injuries and concluded that all such patients should have cervical spinal immobilisation performed. Only one of the 33 patients did not have a recorded neurological defict on admission. It is not clear whether this injury was stable or unstable. Apfelbaum et al[32] also reported a case of a patient with an unstable fracture of the cervical spine following a gunshot wound to the neck that had no neurological deficit on arrival. The patient had the collar removed to perform haemorrhage control in the Emergency Room. On discharge the patient had a possible C6 root lesion. Neither report convincingly documents a cervical spine cord injury as a result of collar removal.

Few studies have reported on the association between knife wounds to the neck and spinal injury. Bharkana et al's review[33] of all cause penetrating neck trauma included only two cases of stabbing to the neck, neither of whom sustained an unstable spinal injury. Connell et al[34] identified only four cases of cervical cord injury from isolated stabbings to the neck after searching a nine year period the Scottish Trauma Audit Group (STAG) data base. All patients had either clinical evidence of a spinal cord injury on initial assessment or were in traumatic cardiac arrest on arrival. In a retrospective review[27] of over 57, 532 patients presenting to two US level 1 trauma centers over a 7-12 year period the prevalence of cervical spinal cord injury was 0.1% in patients with stab wounds to the neck. All patients with cervical cord injury had a neurological deficit on arrival at hospital and none regained significant neurological recovery during hospitilisation.

A BESTBET[35] published in 2009 concluded that the risk of complications from placing a cervical collar over stab wounds to the neck far outweighed the theoretical risks of exacerbating an unstable spinal injury. Although there are reports of cord injury from stab wounds to the neck, none have demonstrated that spinal immobilisation has prevented neurological deterioration. Reports that 22% of patients with penetrating neck injuries develop potentially life-threatening problems that a collar may obscure and the retrospective review that found more than double the mortality rate in patients in whom cervical spine immobilisation was performed mean that the routine immobilisation of patients cervical spine following stab wounds to the neck cannot be supported.

Recommendation:

Neck immobilisation is not required for patients with isolated gunshot wounds to the head, unless the bullet path traverses the neck. (level four evidence)

Cervical spine immobilisation is recommended for patients with gunshot wounds to the neck given the association with direct spinal destruction in a proportion of patients. However, this should not take precedent over life-threatening airway and haemorrhage control. (level five evidence)

Neck immobilisation is not required for a patient with an isolated stab wound to the neck even if a neurological deficit is identified (level four evidence). The fitting of a cervical collar in this setting may be associated with an increased mortality. (level four evidence)

For adult patients with potential neck injury secondary to blunt traumatic forces, can existing clinical decision rules reliably exclude significant cervical spine injury without use of imaging?

i. **If so, which rule is recommended?**
ii. **Which patients require cervical spine imaging?**

Search strategy and results (page 41)

Two level 1 trials were identified that answered the question posed.

Comment:

Stiell et al reported physician judgement to be 92% sensitive at identification of significant cervical spine injuries[36] whilst other studies have found this to be less reliable[37,38]. A recent one-year prospective study by Duane et al[37] reported on twenty four alert patients that had sustained cervical spine injury following blunt trauma. Clinical evaluation (neck pain, visible trauma to the cervical spine, neurological deficit or spinal tenderness) would have only identified 16 out of the 24 injuries (sensitivity 67%) identified on CT. Four of the "missed injuries" required non-surgical intervention. Given the limitations of clinical evaluation there is a natural tendency to rely on cervical spine radiographs to exclude cervical spine injury. However, the sensitivity of plain radiographs at identifying cervical spine injuries has been reported to be only 52% in a meta-analysis[5] of published studies.

In the last decade, level 1 evidence studies have led to the development of two distinct validated decision rules (NEXUS[3] and Canadian C-spine rule[4]) with near 100% sensitivity for exclusion of significant cervical spine injury. The evidence for and against each rule is considered below, along with the NICE recommendations. An updated search performed in 2010 using a similar strategy to that which NICE employed in their 2007 guidelines identified no new decision rules of similar power that have been validated. The multiple small studies that were identified were, therefore, not considered further in this review.

The National Emergency X-ray Utilization Study (NEXUS) was the first prospective multi-centre (21 trauma centres in the US) observational study to be published on cervical spine radiography in blunt trauma patients. The decision tool derived from this study of 34, 069 patients (including children and adults of any age) stated that if the following five low risk criteria could be met then significant injury to the cervical spine could be excluded without the need for imaging:

1. No midline cervical tenderness
2. No focal neurological deficit
3. Normal alertness
4. No intoxication
5. No painful distracting injury

818 (2.4%) patients had fractures of the cervical spine identified on radiography. Only 8 would have been "missed" using the decision tool and only two of these patients had injuries that were defined a priori as "significant". Of these two patients, one refused treatment but made a full recovery whilst the other required internal fixation of a C6 lamina fracture. The NEXUS rule was then validated by doctors who answered a question about

whether or not the rule classified the patient as high or low risk but who did not necessarily adhere to the rule. The authors, Hoffman et al, concluded that the sensitivity of their rule for exclusion of significant injury approached 100%, (99.6% [95%CI 98.6- 100%]).

In 2001 Stiell et al published a second clinical decision rule based on a set of high and low risk factors. A three year prospective cohort study was conducted in the ED's of ten large Canadian community and university hospitals. The convenience sample consisted of 8,924 alert, stable adult patients who following blunt trauma had either neck pain, or no neck pain but visible injury above the clavicle and were non-ambulatory with a dangerous mechanism of injury. The main outcome measure was "clinically important cervical spine injury", evaluated by plain radiography, computed tomography or a structured follow-up telephone interview. The following Canadian C-Spine Rule, based on three questions, was derived:

1. **Is <u>any</u> high-risk factor present that mandates radiography?**
   - age 65 years or more
   - dangerous mechanism of injury
   - paraesthesia in extremities
2. **Is <u>any</u> low-risk factor present that allows safe assessment of range of motion?**
   - simple rear-end motor vehicle collision
   - sitting position in ED
   - ambulatory at any time since injury
   - delayed onset of neck pain
   - absence of midline C-spine tenderness
3. **Can the patient actively rotate their neck 45 degrees to the left and right?**

A dangerous mechanism was defined by Stiell et al as any of the following:

- a fall from greater than one metre or five stairs
- an axial load to the head eg diving
- a high-speed motor vehicle collision (combined speed >100km/hr.)
- a rollover motor vehicle accident
- ejection from a motor vehicle
- an accident involving motorised recreational vehicles
- a bicycle collision

In the absence of a high risk factor and the presence of a low risk factor, the ability to actively rotate the neck 45 degrees to the left and right was considered to effectively exclude a significant cervical spine injury. Validating this rule on the same derivation set gave a 100% sensitivity (95%CI [98%-100%]) and 42.5% specificity (95% CI, 40%-44%) for identifying the 151 clinically important C-spine injuries. The rule would have also identified 27 out of 28 "clinically insignificant" cervical spine fractures." The NEXUS and Canadian studies broadly agreed on what constituted an "insignificant" spinal injury[39]. Although the injuries in this group do not require stabilisation, many emergency physicians and patients would consider them important.

"Insignificant" cervical spine injuries (Canadian C-spine rule):

- Isolated spinous process fracture not involving the lamina
- Simple vertebral compression fracture (<25% loss of height)
- Isolated osteophyte fracture (not corner or teardrop fracture)
- Isolated transverse process fracture not involving the facet joint

The derivation set of the Canadian rule excluded patients younger than 16 years, patients with isolated minor facial injuries, patients with GCS <15, pregnant patients, patients with abnormal vital signs (systolic blood pressure less than 90mmHg or respiratory rate outside of the range 10-24 breaths per minute), patients injured more than 48 hours earlier, patients with paralysis, patients with known vertebral disease (ankylosing spondylitis, rheumatoid arthritis, spinal stenosis, or previous cervical surgery) and patients re-attending with the same injury. The rule has not been validated for these subgroups and its sensitivity may be less than 100% for such patients. Patients aged 65 or older were instantly considered high risk since the incidence of cervical spine injury has been reported to be significantly higher in this age group[40,41]. Patients that had drank alcohol were not excluded unless one of the explicit exclusion criteria was met eg GCS<15.

The prevalence of clinically significant cervical spine injury was 1.7% in both studies and although the two rules are very different both were highly sensitive at identifying patients with significant injuries. The 2003 NICE guidelines chose to combine the rules to make a highly sensitive rule. They favoured the Canadian on grounds that it had a marginally better sensitivity and a superior sensitivity (42% vs. 13%). This was predicted to reduce the number of radiographs requested (58% cases vs. 87% of cases) and be more cost-effective. The NICE group, however, added the presence of midline tenderness as a high risk feature to the Canadian rule to increase its sensitivity (expert consensus). Midline spinal tenderness has not been found to be specific for the identification of unstable cervical spine injuries (it was present in 58% of patients with no cervical injury in the Canadian study) and combining the rules may reduce the specificity whilst demonstrating no improvement in sensitivity. No evidence could be found to support this modification.

Since publication, multiple head-to head-comparisons have been made between the Canadian and NEXUS rules. Stiell et al performed a comparison in a prospective cohort study[42] conducted across nine Canadian ED's. The Canadian rule missed only one of the 161 significant fractures whilst the NEXUS criteria would potentially have missed sixteen. Dickinson et al[43] (a member of the Canadian group) compared the NEXUS rule on their Canadian rule derivation cohort and reported its sensitivity to be only 93%, with ten important injuries "missed". Furthermore, the Canadian group criticised the ambiguity of distracting injuries and intoxication in the NEXUS rule. The NEXUS authors considered Stiell et al's comparison flawed[44] and in turn stated their concerns about the Canadian rule's exclusion of 577 patients who did not have imaging performed and who were lost to follow up. To date, no independent group has published a robust comparison of the two rules.

Since 2007, the Canadian groups focus has been on how to improve compliance with the rule. A multi-centre Canadian ED cluster-randomised trial[45] involving 11,284 alert, stable patients with blunt trauma to the head or neck published in 2009 reported that compliance with the Canadian rule safely reduced the imaging request rate by ~12%. Prior knowledge of Canadian rule by the physicians involved may have limited the impact of this intervention in this study. Kerr et al[46] reported that use of the Canadian rule safely reduced

imaging requests by 25% in 211 patients with potential neck injury presenting to an Australian ED. The Canadian rule has recently been prospectively validated in a UK population[47] (Coffey et al [awaiting print, personal correspondence]). Over a two year period the ED's of two UK hospitals enrolled 1,420 alert, stable adults with potential neck injury. Doctors were made aware of the components of the Canadian rule but were encouraged to continue their existing practice. Use of the rule would have safely reduced radiograph requests by 17%. Despite the low incidence of significant spinal injuries (0.6%) in this study its results are likely to cement the Canadian rule's current place as the rule of choice in UK ED's.

The 2007 NICE guidelines recommended a further modification of the original Canadian rule to include mandatory imaging for patients that have a focal neurological deficit or where a definitive diagnosis of cervical spine injury is required urgently (eg before surgery). These suggestions are pragmatic and performing radiographs in these high risk groups is unlikely to significantly reduce the overall specificity of the rule. They also recommended modifying the rule so that patients with non-symptomatic risk factors (aged greater than or equal to 65 years or a dangerous mechanism of injury) should have either neck pain or tenderness before receiving cervical spine imaging. This approach is supported by Gonzalez[48] et al who found a prevalence of cervical spine fracture of only 0.2% in such patients. However, tenderness has been reported in as many as 58% of injured patients who do not have a significant neck injury and cervical spine injuries have been reported in patients who denied neck pain and tenderness in the setting of "distracting injuries". Heffernan et al[49] attempted to define what constituted a distracting injury through a prospective, observational study on 406 patients that were admitted to a single hospital following blunt trauma. Forty patients (10%) had cervical spine fractures. None of the ninety nine patients with a non-tender cervical spine and injuries confined to the lower torso (abdomen, pelvis or lower limbs) had a cervical spine injury. Conversely, seven patients out of 133 who had a non-tender, non-painful cervical spine and upper torso injuries were found to have a cervical spine fracture. All seven had multiple rib fractures and pain scores of at least 7/10. Given that the lower torso group included femoral and pelvic fractures the implication is that it is more the proximity of the injury to the neck than pain severity itself that is "distracting". All 406 patients in the study had been given opiates before initial examination in the hospital which suggests that this practice in itself does not mask spinal injury recognition. Duane et all[38] (2007) also reported the presence of cervical fractures identified on CT in seven alert patients (from a series of 534 patients) following blunt trauma that had no distracting injuries, neck pain or tenderness. Three patients needed intervention and follow up. Modification of the Canadian rule to include neck pain and tenderness as compulsory criteria to warrant imaging may be flawed.

The Canadian rule indirectly limited the effect of distracting injuries by excluding patients with multiple injuries, those aged 65 years or more (who may have communication difficulties and decreased pain perception), and by recommending imaging for patients with no neck pain but who are non-ambulatory with a visible injury above the clavicles and a dangerous mechanism of injury. In view of the studies above, if the rule is to be extrapolated for use on stable, alert and co-operative patients with other injuries (as is occurring in clinical practice), then the rule should be expanded to recommend imaging for patients with no neck pain but a dangerous mechanism and a painful injury of the upper torso. Isolated painful lower torso injuries in alert co-operative patients should not in themselves be considered the primary reason for requesting cervical spine imaging.

Case reports have been published where the "rules" missed significant spinal injuries in adults. These include a type III dens fracture[50] in an elderly patient and a C4 fracture in a

young patient[51] (after a rollover) that would have been missed by the NEXUS criteria. An unstable atlas fracture that would have been missed using either rule[52](2006) has also been reported. Such reports are sporadic and given the many thousands of patients worldwide that have had the rules applied (both reported and unreported) then they remain a valuable tool for reducing the need for radiographs. Since no rule can identify every fracture the use of such rules does not preclude senior clinician judgement over-riding the rules in individual cases.

Recommendation:

Cervical spine imaging should be requested for the following patients that have been subjected to blunt trauma with a mechanism that may have injured the neck:

- GCS<15 on assessment in the ED (level one evidence)
- Paralysis, focal neurological deficit, or paraesthesia in the extremities (level one evidence)
- Patients with abnormal vital signs (systolic BP<90mmHg or respiratory rate outside of the range 10-24 breaths per minute) (level five evidence)
- Urgent requirement to identify a cervical spine fracture (eg prior to surgery) (level five evidence)
- Severe neck pain (≥ 7/10 severity) (level four evidence)
- Patients with neck pain and <u>any</u> of the following high risk factors (level one evidence unless otherwise stated):
    - a fall from greater than one metre or five stairs
    - an axial load to the head eg diving
    - a high-speed motor vehicle collision (combined speed >60mph)
    - a rollover motor vehicle accident
    - ejection from a motor vehicle
    - an accident involving motorised recreational vehicles
    - a bicycle collision
    - age 65 years or more
    - injured more than 48 hours earlier (level five evidence)
    - re-attending with the same injury (level five evidence)
    - known vertebral disease (eg ankylosing spondylitis, rheumatoid arthritis, spinal stenosis, or previous cervical surgery) (level four evidence)
- Patients with a dangerous mechanism of injury (see above) <u>and</u> either a visible injury above the clavicles or a severely painful (≥ 7/10 severity) thoracic injury even if there is no neck pain or tenderness (level four evidence)

If <u>none</u> of the high risk factors above are present and <u>any</u> of the following low risk factors are identified then the patient can have their collar removed and their range of movement assessed (level one evidence):

- simple rear-end motor vehicle collision (but not if pushed into another vehicle, or if hit at high speed or by a large vehicle)
- sitting position in ED
- ambulatory at any time since injury
- delayed onset of neck pain (ie not immediate)
- absence of midline cervical spine tenderness

Patients stratified to a low risk category that can actively rotate their necks 45 degrees to the left and right should be considered to have had a "significant cervical spine injury" excluded without need for imaging. Patients that are unable to rotate their neck 45 degrees in both directions or report severe pain (≥ 7/10 severity) on doing so should have cervical spine imaging performed.

Can cervical spine prediction rules be safely applied by nurses in the ED?

Search strategy and results (page 47)

No randomised controlled trial was identified that answered the question posed.

Comment

Clinical decision rules have been shown to be reliable at identifying patients unlikely to have a significant cervical injury following blunt trauma on the basis of history and examination alone. The original rules were validated using only doctors as decision makers and the role of "clearance of the neck" and collar removal is almost universally one that is performed by doctors in UK ED's. It is extremely common for more than one patient to arrive within a short time frame following a motor vehicle collision and at times when there are few experienced doctors present or there are unstable patients in the department these patients may be left on boards for prolonged periods. If nurses could accurately apply validated decision rules then adoption of this extended role could allow some patients to be mobilised much sooner.

A number of studies have compared the reliability of nurse application of NEXUS criteria with that of doctors in the ED. Sexton[57] reported that senior nurses safely removed the collars of 31 blunt trauma patients (saving 27 minutes in a collar on average compared to doctor clearance). Fourteen patients were assigned to an imaging group that doctors subsequently cleared clinically. Hsieh et al[58] found 83% agreement between nurses and doctors on a series of 221 patients arriving with their necks immobilised. The nurse group would have clinically cleared 35% of patients but ordered 12% more radiographs than the doctor group and "unsafely" cleared 5% of the patients. Meek et al[59] reported that nurses correctly identified NEXUS risk criteria in 94% of cases where the doctor considered one to be present. Kelly[60] reported that doctors and nurses agreed with each other when interpreting the Canadian C-spine rule in 86 out of 88 cases, although the nurses generally did not proceed to the final step of asking the patient to rotate their neck. The level of agreement between nurses and doctors using the Canadian rule was reported to be "good" by Miller et al[61] (254 patients) and substantial (90.5% agreement) by Stiell et al[62] (213 patients). Presence or absence of neck tenderness was the area in which there was least agreement between doctors and nurses in these studies and there are obvious limitations in generalising their results to everyday practice. The doctors and nurses (who had focussed training) involved were generally very experienced and the outcome was more pragmatic (doctor's application of the rule) than gold standard (patient outcome). Pitt et al[63] reported that triage nurses using the NEXUS criteria to "clinically clear necks" in a UK ED reduced the time spent in a cervical collar by an average of 23 minutes for 53 patients arriving with neck immobilisation. Doctors considered seven of these patients to have been "unsafely" cleared but none of the 53 was subsequently diagnosed with a significant cervical spine injury. The study has some flaws in that non-return to the hospital for radiographs was considered to equate to no significant cervical spinal injury and the sample was a convenience one in which 588 potentially eligible patients were not enrolled. However, it does demonstrate that nurses can safely apply the Canadian rule.

The largest and most recent study[64] in this area was a 3 year multi-centre prospective cohort study conducted in 6 Canadian ED's where senior nurses with 2 hours of targeted training applied the Canadian C-spine rules to patients attending with neck injury. The study was a convenience sample based on trained nurse availability and nurses in the study replaced the collar following assessment, only documenting their opinion on whether

they felt the rule had allowed clinical clearance of the neck. Of 3633 patients assessed, 1535 were considered to be safe for collar removal by the nurse at triage. Four patients in this group had "significant" neck injuries (1 requiring surgery). In three cases a dangerous mechanism of injury had not been recognised (vehicle ejection, and two falls down stairs) whilst he other patient reported paraesthesia. These cases occurred early in the study and following further training no "significant" injuries were "missed". Good correlation was present between nurse and doctors assessment in this study.

Existing studies have been conducted with senior nurses who had received targeted training. Whilst some nurses strongly advocate an extension of their roles into this area other nurse commentators have expressed concerns over the use of rules that do not identify every important spinal injuries since nurses are "not supported in the same way as doctors"[65]. The evidence suggests that nurses can apply cervical spine clinical decision rules appropriately but that targeted, ongoing training and doctor review of all assessed patients is essential.

Recommendation:

Staff members should not remove cervical collars in the ED unless they have received specific training in the use of a validated cervical spine clinical decision rule (level five evidence)

Nurses can safely apply clinical decision rules designed for cervical spine clearance following targeted training (level three evidence)

Which primary imaging modality is recommended for excluding cervical spine injury?

Search strategy and results (page 51)

No randomised controlled trial was identified that answered the question posed but level 2 evidence studies were identified.

Comment:

The two most widely employed primary imaging modalities for identification of cervical spine injury in the acute setting are:

- 3 series (lateral, AP and odontoid peg view) plain radiographs with, or without, additional views (eg swimmer's)
- CT

Although MRI is considered the gold standard for imaging soft tissues its use has logistical issues in the trauma setting and would miss fractures if used in isolation[66,67]. CT is far superior to plain radiography at identifying cervical spine injuries with sensitivities of 98-100% reported.[68,70,71]. The true sensitivity of plain radiography for identification of cervical spine injuries is difficult to ascertain for a number of reasons. Many reports have used CT as the reference standard, and a number of studies class inadequate views that do not visualise injured areas as "missed" fractures, whereas in practice further imaging would be requested. The variation in prevalence of fractures between studies (some prospective, some retrospective) precludes reliable meta-analysis of the data, though this work has been done[68]. The meta-analysis derived an overall sensitivity of 58% (range 39-76%) for plain radiographs and 98% for CT at identification of cervical spine injuries in adults following blunt trauma. A recently published systematic review[72] derived similar sensitivities for plain films and CT. Some of the included studies were of obtunded patients and most contained patients at particular high risk of cervical spine injury eg patients with neurological deficit or multiple injuries. It is apparent from these reviews that CT is far superior to plain films for patients with a high pre-test probability of cervical spine injury. This is also true of patients that are intubated following blunt trauma, where the sensitivity of plain radiography may be as low as 39%[73]. NICE (2007) concluded that for patients meeting criteria for cervical spine imaging CT is more cost-effective than plain radiographs in the following high risk groups (level 2 evidence):

- GCS below 13 on initial assessment
- Intubated patients
- Inadequate plain film series (unable to see from the cranio-cervical junction to the thoraco-cervical junction or obtain an open mouth view)
- Suspicion or certainty of abnormality on plain film series*
- Patient's being scanned for head injury or multi-region trauma.

**Barrett et al[74] reported that 27% of the 818 patients with cervical spine injuries in the NEXUS study had a second non-contiguous cervical spine injury not visible on plain radiographs that may have been missed with selective CT. When CT is requested in adults it should include the whole cervical spine from the cranio-cervical junction superiorly to the cervico-thoracic junction inferiorly.*

NICE also advocates CT imaging in cases where there is "continued clinical suspicion of injury despite a normal X-ray" but they do not expand on this comment. If "high" clinical suspicion is present before plain radiographs are requested it appears sensible to forego

plain radiography in favour of CT eg patients with paraesthesia, a focal neurological deficit, severe pain (≥7/10), or a significantly reduced range of neck movement.

Since the publication of NICE guidelines in 2007, several studies have confirmed the inferiority of plain radiographs compared to CT. Many of the authors have concluded that CT should become the primary imaging for all patients with blunt cervical injury that cannot be cleared "clinically"[75-78]. The American College of Radiology Guidelines[79] (2007) and updated EAST guidelines[25] (2009) have both deemed plain radiographs redundant for imaging of the cervical spine.

The proportion of 3-view films that are deemed inadequate has been reported to range from 10-77%[73,80], being higher in more severely injured patients. When this is considered alongside the low sensitivity of plain radiography, CT seems an obvious choice. Few studies, however, have considered cost-effectiveness or radiation exposure risks as NICE did and most have been conducted outside of the UK. Almost all studies comparing plain radiographs with CT have been conducted on high risk patient groups with a high prevalence of cervical spine injuries. On the basis of reported sensitivities between 1 in 2 and 1 in 6 fractures would be expected to be missed by plain radiographs in a high risk group. However, once high risk patients are excluded from plain radiography, the sensitivity of plain radiographs in the remaining group is unclear. The highest reported sensitivity for identification of clinically important cervical spine fractures with adequate, good quality 3-series radiographs is 93%[81] while the most reliable estimate of sensitivity of plain films (89.4%) comes from the NEXUS group[82] who prospectively studied 34,069 consecutive patients. In the Nexus study, plain radiography identified 498 patients of 818 with cervical spine injury. However, of the 320 patients with injuries that were not diagnosed, 273 had further images requested because of inadequate views (237) or "suspicious areas" (36). 47 patients with cervical spine injury had adequate 3-view plain radiographs reported by radiologists as "normal". Half of this group were subsequently diagnosed with SCIWORA whilst the remaining 23 patients (0.07% of all patients) had injuries identified on further imaging, including 3 unstable injuries. The authors calculate that adequate plain radiography would fail to identify only one in 1481 patients with a significant cervical spine injury (negative predictive value 99.9%). Anecdotally, it is uncommon for patients to return to the ED with missed cervical spine injuries after being discharged with "normal" plain films.

The financial cost of a single missed spinal injury (£millions)[83] may still make universal CT more cost-effective if CT was harmless. However, there is an increased risk of cancer from the radiation dose delivered by CT, particularly to the thyroid. The exact risk is based only on mathematical models and beyond the scope of this review but is considered by experts to be real and significant[84-86]. Some authors[87,88] have attempted to stratify the patients deemed not to be at high risk but who meet cervical spine imaging criteria into moderate and low risk groups in order to cost-effectively CT scan the moderate risk patients whilst using plain radiography on the low risk group. This evidence is not yet robust enough to use in practice and further research is required to identify specific subgroups that should have CT performed as the primary imaging modality. One such group may be those aged over 65 who are at a reduced lifetime risk of radiation induced cancer[89]. Elderly patients have an increased prevalence of cervical spine fracture following trauma[90,91], an increased prevalence of "false positive" features on plain films[92,93] and an incidence of missed cervical injuries[56].

Patients with dementia present a specific problem to clinicians as many of the age limitations above are coupled with difficulty in clinical assessment. CT is recommended to "clear the cervical spine" in patients with dementia. Although the possibility of ligamentous

injury remains following a" normal" CT scan, MRI is not desirable, or even feasible in this group of patients. In the absence of a new neurological deficit attributable to cervical cord injury, the prevalence of missed unstable injury is low enough (0.04-0.2% of patients with a normal CT) that the consequences of prolonged collar application may outweigh any benefit in this population (level 5 evidence). The increasing numbers of patients with dementia will present a significant resource challenge to the NHS in the future.

Summary

NICE recommendations that plain radiographs be used as the initial screening method for cervical spine fracture, unless particular criteria (above) are present are still valid for a population based health service such as the NHS until cost-effectiveness studies prove otherwise. CT will almost certainly be used more frequently in the future but until this evidence is forthcoming, local guidelines on imaging requests should be agreed between trauma specialists, emergency physicians and radiologists. Emergency Physicians should acknowledge the limitations of plain radiography and use clinical judgement when considering CT requests in individual cases.

Recommendation:

CT should be used as the primary imaging modality for excluding cervical spine injury in adults following blunt trauma if any of the following criteria are met (level two evidence):

- GCS below 13 on initial assessment
- Intubated patients
- Inadequate plain film series
- Suspicion or certainty of abnormality on plain film series*
- Patient's being scanned for head injury or multi-region trauma

**As a minimum CT should cover the area from the cranio-cervical junction to the thoraco-cervical junction since selective scanning has been shown to miss injuries (NICE guidelines, 2007)*

It is also recommended that CT be used as the primary imaging modality in the following settings:

- Patient has dementia (or a chronic disability precluding accurate clinical assessment) (level five evidence)
- Patient has neurological signs and symptoms referable to the cervical spine (level three evidence)
- Patient has severe neck pain (≥ 7/10 severity) (level four evidence)
- Patient has a significantly reduced range of neck movement (ie unable to actively rotate the neck 45 degrees in both directions) (level four evidence)
- Patients with known vertebral disease (eg ankylosing spondylitis, rheumatoid arthritis, spinal stenosis, or previous cervical surgery) (level four evidence)

Local guidelines should be developed with regard to the primary imaging modality for patients aged over 65 years.

In the absence of an indication for CT, 3-view plain radiographs should be used as the primary imaging modality for excluding cervical spine injury.

How soon should imaging be performed for patients with potential cervical spine injury?

Search strategy and results (page 55)

No studies could be identified that looked at neurological outcome from cervical spine injury and time to imaging.

Comment:

Delayed removal of cervical collars has been associated with an increased incidence of a number of complications[14,15]. NICE offer the following expert opinion which is pragmatic and, in the absence of evidence to the contrary, is supported:

Imaging of the cervical spine should be performed within 1 hour of a request having been received by the radiology department or when the patient is sufficiently stable.

It is counter-intuitive to place a time target for performing a scan and not have a time target for the reporting of that scan. There is no evidence upon which to base a specific timeframe but a radiologist (or clinician specifically trained to perform this task) should formally report the CT cervical spine scan images promptly.

Recommendation:

Imaging of the cervical spine should be performed within 1 hour of a request having been received by the radiology department or when the patient is sufficiently stable (level five evidence).

If the patient is having an urgent CT head performed then the neck should be scanned at the same time (level five evidence).

A radiologist (or clinician specifically trained to perform this task) should formally report the CT cervical spine scan images promptly (level five evidence).

What is the recommended management for patients with severely limited neck movement (new), or severe pain, following normal CT?

Search strategy and results (page 56)

No prospective studies that compared flexion-extension views, MRI or helical CT versus operative findings or clinical follow up >90 days in patients that were alert and neurologically intact were identified. Level 3 studies evidence were identified.

Comment:

This group of patients presents a challenge since the possibility of an unstable spinal injury remains despite a normal CT. Debate exists over the optimum strategy for excluding significant ligament injury. Historically, three different approaches have been employed.

1. **Review in a clinic in 10 -14 days.**
   This is not ideal since the patient has to wear a semi-rigid (eg Philadelphia) collar for up to two weeks. Such collars do not completely immobilise the neck yet are associated with pressure areas, particularly in the elderly[96]. Some patients with purely muscular pain that has resolved may be able to be discharged clinically at review but the remainder will require further imaging. MRI sensitivity for identifying ligamentous injury may be reduced after 48 hours[66,97-100] and flexion-extension views have limitations at all time frames (see below).

2. **Lateral flexion/extension series – immediate or delayed.**
   The vast majority of published studies in the literature have been conducted on obtunded patients and have reported high rates of inadequate studies[101,102], false positives[103], false negatives[104], and one case of a patient developing quadriplegia following dynamic flexion-extension views[105]. Few studies have been conducted on alert patients and those that have are mainly case reports[106] or retrospective reviews[107-111]:

   Wang et al[107] and Insko et al[108] separately reported that a third of flexion extension views were inadequate when performed on alert patients in the acute phase following blunt trauma. Mauldin et al[112] reported adequate flexion-extension views in 92% of patients in a prospective series of alert patients with persistent midline neck pain through use of a bolster which increased neck flexion. However, 9% cases could not complete the study due to pain, 31% of flexion-extension films could not visualise C7/T1 and one person developed a transient neurological deficit during the procedure. Five patients out of 140 had evidence of instability despite normal radiographs and CT. Four were treated in a collar, one required surgery.

   Goodnight et al[113] retrospectively reported that flexion-extension views indicated instability in 16 out of 379 alert, neurologically intact blunt trauma patients that had no cervical spine fracture demonstrated on CT. Five of the sixteen patients subsequently had ligament injury confirmed on MRI. From a retrospective review of 141 patients that had both plain radiographs and flexion-extension views performed Lewis et al[109] identified eleven patients with evidence of cervical spine instability. Ten patients had "significant neck pain" whilst the other was intoxicated. Four of the eleven patients had normal cervical spine radiographs and three required surgical stabilisation. Using similar retrospective methodology Brady et al[110] identified just five

patients out of 372 patients with normal plain radiographs that had abnormal flexion extension views, none of whom required surgery.

Insko et al[108] reported no false negatives in 74 patients (70%) that had a range of flexion and extension motion considered adequate for diagnostic purposes (30 degrees from neutral). Four of the 32 patients (12.5%) with an inadequate range of motion subsequently had injuries, some unstable, detected on CT or MRI.

` The NEXUS group[111] performed secondary analysis on their cohort to assess the accuracy of flexion-extension views and concluded that they added little to the evaluation process. Eighty-six patients out of 818 patients (10.5%) ultimately diagnosed with cervical spine injury had flexion-extension views taken. Six patients had injuries (2 fractures and 4 subluxations) detected only on flexion-extension views, none of which were unstable. All other injuries were detected on plain films supplemented where indicated by CT or MRI.

The small numbers of unstable injuries and the retrospective nature of these studies makes it difficult to draw conclusions from them. Although flexion-extension studies appear relatively safe in alert patients they are of limited value in patients with a reduced range of movement. The ACR has revised its guidelines[79] to suggest that flexion-extension views only have a role for patients with equivocal MRI findings (abnormal signal in spinous ligaments without definite disruption) once the acute phase has passed.

3. Magnetic Resonance Imaging.

MRI scanning is more sensitive than CT at identifying ligamentous injuries and disc herniation, but is inferior to CT at visualising the posterior elements of the spine[114] and the cranio-cervical junction[115]. MRI's sensitivity may fall if performed more than 48 hours after trauma when oedema is resolving[66,97-100] (though the evidence for this is weak) and despite its high sensitivity[116], it cannot readily distinguish between stable and unstable injuries. MRI studies have reported a prevalence of cervical spine injury of up to 23% in obtunded trauma patients[117]. Post mortem studies have confirmed that these are not false-positives although many visible injuries are clinically insignificant[118]. Currently, there are no universally agreed criteria for distinguishing significant from insignificant abnormalities on MRI.

Menaker et al[119] retrospectively reported that out of twenty patients whose only indication for MRI (following normal CT) was ongoing neck pain seventeen scans were normal and three were abnormal. Most MRI's were done as outpatients and one person developed a delayed neurological deficit that required surgery. The other two patients with positive MRI findings were treated in collars for a prolonged period. Diaz et al[120] prospectively reported that six of sixteen patients with normal CT's that had MRI requested solely because of ongoing neck pain or tenderness had abnormal MRI's. Two patients had ligament instability and were treated in collars.

CT resolution has improved dramatically over time and an increasing number of authors now advocate "clearance of the cervical spine" in obtunded patients on grounds of normal helical CT alone[121-127]. A similar number of authors[119,120,128-130] reject this approach citing rates of unstable cervical spine injuries as high as 15-25% in obtunded patients following "normal CT". Goodnight et al reported that CT identified all six cases of instability in series of 379 alert, neurologically intact patients with no evidence of fracture. A further 13

CT scans that suggested instability were subsequently deemed to be false positives. The authors concluded that normal CT excludes an unstable cervical spine injury as none of the 360 patients with no evidence of instability on CT were later diagnosed with instability. Schuster et al[131] identified no significant injuries on MRI in a retrospective series of 93 alert, neurologically intact trauma patients with significant neck pain despite a normal CT.

Summary:

Flexion-extension views have no role in the acute assessment of blunt neck injury. There is currently insufficient evidence to support "clearance of the neck" in patients where there is ongoing clinical concern following a normal CT alone[119,120]. Early MRI is the preferred management for this group of patients. Patients with normal scans can be discharged while those with positive findings should be discussed with spinal surgeons. Local guidelines should be developed between radiologists, neurosurgeons and emergency physicians to manage this group patients in a safe, consistent manner. Patients that are discharged whilst waiting for their MRI scan should be fitted in a Philadelphia collar and advised to return to the ED immediately should they develop any neurological symptoms.

It should be remembered that no imaging modality can identify all unstable cervical spine injuries. Brandenstein et al[132] reported four cases of radiologically occult unstable injuries not identified on a combination of CT and MRI. These are reassuringly rare with an estimated prevalence of 0.04% to 0.20% in alert patients[82,122,132].

Recommendation:

Further imaging is advised for adults with severely restricted neck movement or severe pain (≥ 7/10) despite a normal CT following blunt cervical spine injury (level four evidence). Local guidelines should be developed between emergency physicians, radiologists, and spinal surgeons for the management of this group of patients.

Flexion-extension views cannot reliably exclude unstable cervical spine injuries in the acute setting (level three evidence).

Patients without fracture or neurological deficit can be discharged following a negative MRI scan (level two evidence).

When indicated, MRI should be performed as soon as possible as its sensitivity for injury identification may fall after 48 hours (level four evidence).

Patients with injuries identified on MRI should be discussed with spinal surgeons (level five evidence).

What are the indications for MRI of the cervical spine following blunt trauma?

NICE recommends that MRI is used in the following settings):

- Neurological signs and symptoms referable to the cervical spine
- Suspicion of vertebral artery injury (eg spinal column displacement, foramen transversarium or lateral process fracture, posterior circulation syndromes)
- Assessment of ligamentous and disc injuries suggested by plain films or CT.

No evidence could be found that contradicts the above recommendations, which are supported by level 2 evidence.

MRI should also be used to exclude cervical spine injury* in adults with severely restricted neck movement or severe pain (≥7/10) despite a normal CT (level 4 evidence).

Recommendation:

MRI should be used to exclude cervical spine injury* in adults following blunt trauma if any of the following criteria are met (level two evidence):

- Neurological signs and symptoms referable to the cervical spine
- Suspicion of vertebral artery injury (eg spinal column displacement, foramen transversarium or lateral process fracture, posterior circulation syndromes).

**MRI should always be used in conjunction with another modality, preferably CT, in order not to miss bony injuries.*

Further imaging is advised for adults with severely restricted neck movement or severe pain (≥ 7/10) despite a normal CT following blunt cervical spine injury (level four evidence). Local guidelines should be developed between emergency physicians, radiologists, and spinal surgeons for the management of this group of patients. In the acute phase MRI is the imaging modality of choice (level 2 evidence)

When indicated, MRI should be performed as soon as possible as its sensitivity for injury identification may fall after 48 hours (level four evidence).

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Search strategies and evidentiary tables

Methodology

Where possible, appropriate evidence has been sought and appraised using standard appraisal methods. High quality evidence is not always available to inform recommendations. Best Practice Guidelines rely heavily on the consensus of senior emergency physicians and invited experts.

Evidence Levels (Oxford Centre for Evidence Based Medicine, 2009)

Interventional studies

1. Evidence from a systematic review (with homogeneity) of randomised control trials (RCT), all or none studies, or a well designed randomised controlled trial with narrow confidence intervals.
2. Evidence from a systematic review (with homogeneity) of cohort studies, a good quality cohort study, low quality RCT, or "outcomes research".
3. Evidence from a systematic review (with homogeneity) of case-control studies or a good quality individual case-control study.
4. Evidence from a case series or poor quality case-control or cohort studies.
5. Expert opinion without explicit critical appraisal, or based on physiology, bench research or "first principles".

Diagnostic studies

1. Evidence from a systematic review (with homogeneity) of level one diagnostic studies, validated Clinical Decision Rules (CDR), validated high quality cohort studies, or absolute SpPins and SnNouts.
2. Evidence from a systematic review (with homogeneity) of level 2 diagnostic studies, exploratory cohort studies with good reference standards, or CDR's after derivation or validation on the same database as the derivation sample.
3. Evidence from a systematic review (with homogeneity) of level 3b and better diagnostic studies, non-consecutive studies, or studies with inconsistent reference study application.
4. Evidence from a case-control study or studies with poor or non-independent reference standards.
5. Expert opinion without explicit critical appraisal, or based on physiology, bench research or "first principles".

Search 1

Does cervical spine immobilisation prevent neurological deterioration in patients with potential cervical spine injury following blunt trauma?

Medline (1950 – week 1 May 2010)

1. explode "cervical vertebrae"
2. ("cervical spine" OR neck).ab
3. explode "spinal cord injuries"
4. (injur* OR fracture OR dislocation).ab
5. (immobili* OR collar OR brace OR headblock OR sandbag*).ab
6. #1 OR #2
7. #3 OR #4
8. #5 AND #6 AND #7
9. #8 limited to Human and English language.

701 original references retrieved.

EMBASE (1980 - May 2010)

1. ("cervical spine" OR neck).ab
2. explode "cervical spine injury"
3. (injur* OR fracture OR dislocation).ab
4. (immobili* OR collar OR brace OR headblock OR sandbag*).ab
5. #2 OR #3
6. #1 AND #4 AND #5
7. #6 limited to Human and English language.

463 original references retrieved.

The Cochrane library (issue 2 2010) was also searched using the term "cervical spine"

Searching the references retrieved and the bibliographies of review articles, no randomised controlled trials could be identified that addressed the question posed. A Cochrane review (updated 2009) was found, which also did not identify any randomised controlled trials. Only one study that directly compared the outcome of patients with and without neck immobilisation was identified.

Author, date and country	Patient group	Study type	Outcomes	Results	Comments
Hauswald[17] 1998 USA & Malaya	334 patients with blunt traumatic spinal injuries arriving to the ED of the University of New Mexico Hospital with their spines immobilised 120 patients with blunt traumatic spinal injuries arriving to the ED of the University of Malaya Hospital with no spinal immobilisation	5 year retrospective chart review Neurologic injuries assigned to two categories, disabling or not disabling, by two independent, blinded physicians. Multivariate logistic regression analysis of data performed.	Incidence of spinal cord injury	Less neurologic disability in the non-immobilised Malaysian patients (OR 2.03; 95% CI 1.03-3.99; p = 0.04). This corresponds to a <2% chance that immobilisation has any beneficial effect. The results were similar when the analysis was limited to patients with cervical injuries (OR 1.52; 95% CI 0.64-3.62; p = 0.34).	Types of fracture not described Essentially no emergency medical service in Malaya More motor vehicle collisions in the immobilised group Small sample sizes likely to be underpowered to identify any true difference between the interventions.

Search 2

Does cervical spine immobilisation prevent neurological deterioration in patients with potential cervical spine injury following penetrating injuries to the head or neck?

Medline (1950 – week 1 May 2010)

1. explode "cervical vertebrae"
2. explode "neck injuries"
3. explode "spinal cord injuries"
4. explode "spinal fractures"
5. explode wounds, gunshot
6. explode wounds, penetrating
7. explode wounds, stab
8. (knife* OR bullet* OR blade* OR missile*).ab
9. (immobili* OR stabili* OR collar OR brace OR headblock OR sandbag*).ab
10. #1 OR #2 OR #3 OR #4
11. #5 OR #6 OR #7 OR #8
12. #9 AND #10 AND #11
13. #12 limited to Human and English language.

40 original references retrieved.

EMBASE (1980 - May 2010)

1. explode "cervical spine injury"
2. explode "neck injury"
3. explode "gunshot injury"
4. explode "stab wound"
5. explode "knife cut"
6. explode "penetrating trauma"
7. (knife* OR bullet* OR blade* OR missile*).ab
8. (immobili* OR stabili* collar OR brace OR headblock OR sandbag*).ab
9. #1 OR #2
10. #3 OR #4 OR #5 OR #6 OR #7
11. #8 AND #9 AND #10
12. #11 limited to Human and English language.

3 original references retrieved.

The Cochrane library (issue 2 2010) was also searched using the term "cervical spine". No articles of relevance were identified.

Searching the references retrieved and their bibliographies no randomised controlled trials could be identified that addressed the question posed. Thirteen original publications were found that had relevance to the question posed.

Author, date and country	Patient group	Study type	Outcomes	Results	Comments
Vanderlan et al[30] 2009 USA	199 patients presenting to a level1 US trauma centre with penetrating neck injuries over a nine year period	Retrospective chart analysis of trauma database	Mortality rates for patients with penetrating neck injuries: neck immobilisation versus no immobilisation	35 patients died over the nine year period. The odds ratio of dying if the neck was immobilised compared to if it was not was	Single centre Possibly contains same cohort as study below

Author, date and country	Patient group	Study type	Outcomes	Results	Comments
				2.8 (95% CI 1.2-6.5).	
Vanderlan et al[29] 2009 USA	196 patients presenting to one of two level 1 US trauma centres with penetrating neck injuries	Retrospective chart analysis of trauma database	Incidence of unstable cervical spine fractures following penetrating neck injury	No patient could be identified that benefited from spine immobilisation since the only 2 patients found to have unstable cervical spine fractures were completely neurologically devastated at the time of presentation. Decreased cervical spine immobilization rates at one institution did not affect neurologic outcome.	Retrospective Possible selection bias
Rhee et al[28] 2006 USA	24,446 patients presenting following blunt or penetrating assault to two level 1 trauma centres over a 7-12 year period	Retrospective cohort	Incidence rates for Cervical spine fracture	1.35% of gunshot wounds 0.12% of stab wounds	Large study Retrospective
			Incidence rates for Cervical spinal cord injury (CSCI)	0.94% of gunshot wounds 0.11% of stab wounds All patients with CSCI following penetrating trauma had neurological deficit at the time of presentation. No penetrating injury patient with CSCI regained significant neurologic recovery during hospitalisation	
			% neurologically intact patients requiring surgical or halo stabilisation:	0% of patients with stab wounds 0.03% of patients after gunshot wounds	
Klein et al[31] 2005 USA	228 patients that survived >24hours following a single gunshot wound to the head, neck or trunk	Retrospective cohort	Incidence of spinal injury in neurologically intact patients	33 of 183 (18%) patients with gunshot wounds to the neck had a spinal injury 17/33 (51%) injuries were classed as "significant" ie cord involvement, spine-related surgical procedure or prolonged spinal immobilisation needed. One patient (3%) had an unsuspected significant spinal injury (ie proven spine injury with no neurologic finding at admission)	Spinal damage probably established at presentation. Sparse information given on the patient with unsuspected significant injury. Not all injuries classed as significant were unstable
Medzon et al[27] 2005 USA	81 patients with gunshot wounds to the head or neck presenting to a single centre over 13 years.	Retrospective review of a trauma registry	Incidence of cervical spine fracture (CSF)	19/81(23%) patients had a cervical spine fracture	Single centre Small numbers with outcome measures of interest
			Incidence of acute neurologic deficit	11/81 (13%) patients had an acute neurologic deficit	
			Incidence of unstable fracture among alert patients (65) without	No patient (0%; 95% CI 0-5.5%) was found to have unstable CSF 3 patients had stable cervical	

Author, date and country	Patient group	Study type	Outcomes	Results	Comments
			neurological deficit	spine fractures	
			Incidence of unstable fracture among patients (11) with a neurological deficit	3 patients had unstable cervical spine fractures 8 patients had stable cervical spine fractures	
Connell et al[34] 2003 UK	35,000 patients who were entered in to a Scottish trauma database over 7 year period	Retrospective analysis of prospectively collected trauma data	Incidence of mechanically unstable spinal column and spinal cord injuries in patients with penetrating trauma	All patients (12) with spinal cord injury either had obvious initial evidence of a spinal cord injury or were in traumatic cardiac arrest. No neurologically intact patient subsequently found to have a cord injury or unstable CSF	Large population with low incidence of penetrating injury. Also looked at thoracic injuries. 10/11 of patients with purely cervical injuries sustained stab wounds.
Barkana et al[33] 2000 Israel	44 casualties with penetrating neck inuries over a 4 year period, none of whom had their neck immobilised	Retrospective study	Potentially life-threatening signs and incidence of unstable neck injuries	8 of 36 (22%) hospitalised casualties had a life-threatening sign (large/expanding haematoma, or subcutaneous emphysema) diagnosed in the exposed neck, which may have been hidden by a collar. No casualty required internal surgical stabilisation of the c-spine	Population not typical of that presenting to UK ED's. The force of injury is more severe than that expected in a civilian setting
Apfelbaum et al[32] 2000 USA	A patient with an unstable cervical spine injury from a gunshot wound and no recorded neurological deficit on arrival in the ED.	Case report		The cervical collar was removed by paramedics to control bleeding. In the ED the patient was neurologically intact. The C-spine was re-immobilised after radiographs revealed a comminuted C5 fracture and subluxation of C5 on C6. At discharge the patient had a possible C6 nerve root injury.	Single case report No evidence that the root lesion was a consequence of removing the collar
Lanoix et al[21] 2000	174 patients with gunshot wounds to the head	Retrospective chart review	Incidence of C-spine injury (CSI) associated with gunshot wounds to the head. Cervical clearance was by clinical/ radiologic criteria in survivors, and autopsy in non-survivors.	90 had C-spine radiographs (complete series [49], lateral only[33], and computed tomographic scan [8]) 84 with no radiographs, 29 were clinically cleared, and 55 died (32 cleared at autopsy). Twenty-three died before evaluation. None of the remaining 151 (87%) had CSI.	Patients with penetrating face and neck injury were excluded 33/90 patients who had imaging performed had a lateral radiograph only performed.
Kaups et al[24] 1998	215 patients admitted with gunshot wounds to the head over a 5 year period. Those with gunshot wounds to the neck and those who were dead on arrival were excluded.	Retrospective review of patient records and autopsy reports	The incidence of indirect spinal column injury in patients sustaining gunshot wounds to the head.	215 patients were included in the study. Cervical spine clearance was determinable in 202 patients (93%) either clinically, radiographically, or by review of post-mortem results. No patients sustained indirect (blast or fall-related) spinal column injury. 3 patients sustained direct spinal injuries, all had evidence of the	Retrospective Potential selection bias 13 patients excluded because of lack of data Lateral radiograph only is some cases

Author, date and country	Patient group	Study type	Outcomes	Results	Comments
				bullet trajectory traversing the neck.	
Chong et al[23] 1998	53 patients presenting to a level 1 trauma centre with a gunshot wound to the head.	Retrospective chart review	Incidence of cervical spinal injury.	No patient had a cervical spine injury.	Small sample. Retrospective. Patients with face and neck wounds were excluded.
Kennedy et al[22] 1994 USA	157 consecutive patients with gunshot wounds to the head that survived to CT and who also had a complete lateral x-ray film of the cervical spine performed.	Retrospective chart review	Incidence of spinal injury in patients with gunshot wounds limited to the cranium	None of the 105 patients who had gunshot wounds limited to the cranium had a cervical spinal cord injury. 5/52 patients whose bullet path extended below the cranial vault had cervical spinal cord injuries.	Possible selection bias as 308 patients had CT head performed following gunshot wounds to the head during the study period.
Arishita[26] 1989 Vietnam	Vietnam casualties	Retrospective data analysis	Outcome of patients with penetrating cervical spine injury	No patient with penetrating injury of the cervical spinal cord survived.	Part of a larger anaylsis looking at the "benefit" of cervical spine immobilisation on the battlefield

Search 3

In adult patients with potential neck injury as a result of blunt traumatic forces, can existing clinical decision rules reliably exclude significant cervical spine fractures without use of imaging?

Medline (1950 – week 1 May 2010)

1. exp Tomography, X-Ray Computed
2. exp Tomography, X-Ray
3. exp Radiography
4. exp Neuroradiography
5. exp Magnetic Resonance Imaging
6. ((comput* ADJ tomograph*) OR ct OR radiograph* OR xray* OR MRI OR (magnetic ADJ resonance ADJ imaging)).ti,ab
7. exp Spine
8. exp Cervical Vertebrae
9. exp Neck
10. exp Spinal Injuries
11. exp Spinal Cord Injuries
12. exp Neck Injuries
13. ((trauma OR injur*) AND WITH AND (neck OR spin*)).ti,ab 12. 7 OR 8 OR 9 OR 10 OR 11
14. (guideline* OR protocol OR consensus).ti,ab
15. exp Practice guideline OR exp guideline OR exp Guideline Adherence
16. #1 OR #2 OR #3 OR #4 OR #5 OR #6
17. #7 OR #8 OR #9
18. #10 OR #11 OR#12 OR #13
19. #14 or #15
20. #16 and #17 and#18 and #19
21. Limit #20 to Human AND English language

104 articles were retrieved.

EMBASE (1980 – May 2010)

1. exp Cervical Spine OR exp Cervical Spine Dislocation OR exp Cervical Spine Fracture OR exp Cervical Spine Injury OR exp Neck Injury
2. exp. Cervical Spine Radiography OR exp Radiography OR exp. Computer-Assisted-Tomography OR exp Nuclear-Magnetic-Resonance-Imaging
3. guideline*.ti,ab
4. exp Practice guideline OR exp Clinical Protocol OR exp Consensus
5. #1 AND #2 and (#3 OR #4)
6. Limit #5 to Human AND English language

275 articles were retrieved.

NICE comprehensively published tabulated details of relevant studies regarding "clearance" of the neck following blunt traumatic injury in their 2003 review. They can be seen at http://www.nice.org.uk/guidance/index.jsp?action=download&o=37794. An updated search performed in 2010 using a similar strategy (above)to that NICE employed in their 2007 guidelines identified no new decision rules of similar power to those that have been validated (NEXUS and Canadian C-Spine Rule). Review articles were excluded but

bibliographies searched to identify additional articles. Finally, one article was obtained with permission through personal correspondence. Details of 16 articles published since 2003 that are relevant to decision rules for clearance of the cervical spine following blunt trauma are tabulated here. Studies on children and those performed out-of-hospital were excluded.

Author, date and country	Patient group	Study type	Outcomes	Results	Comments
Coffey et al[47] 2010 UK	1,420 patients presenting to 2 UK ED's over a 2 year period. Inclusion/exclusion criteria same as original Canadian study.	Prospective observational study. Doctors trained in Canadian C-spine rule but asked to continue normal practice with respect to radiograph requests. Significant cervical spine injury excluded by radiologist or follow up phone call	Potential of the Canadian C-spine rule to reduce radiograph request rate in patients presenting following blunt neck trauma.	8 patients had a cervical spine injury, the Canadian rule would have identified all as high risk. 69.5% patients had radiographs requested. Use of the Canadian rule would have reduced the imaging rate by 17.4% to 57.4%.	Patients aged 17 or older. Low incidence (0.6%) of cervical spine injury. 1,375 eligible patients not enrolled. High request rate in this cohort that had a low incidence of spinal injury may have exaggerated the potential impact of rule introduction. This may have been due to the fact that >80% patients were seen by junior doctors.
Anderson et al[53] 2010 USA	Patients with blunt neck trauma who met the following criteria: • enrolled in prospective studies that evaluated clearance protocols • had CT or 2 week follow up phone cal • had reported outcomes	Meta-analysis of studies published between 1966 and 2004	Identification of criteria that would allow clinical clearance of the neck without imaging	The following conclusion was reached: Alert, asymptomatic patients without a distracting injury or neurological deficit who can complete a functional range-of-movement on examination do not need imaging of the spine. Sensitivity = 98.1% Negative predictive value 99.8%	Potential for case selection bias: Patients with true positives, true negatives, false positives and false negatives were excluded. Sensitivity of rule lower than existing prediction rules and confidence intervals wider.
Stiell et al 2009[45] Canada	11, 824 alert, stable adults presenting with blunt trauma to the head or neck to one of 12 Canadian ED's.	Matched pair cluster randomised trial. 6 hospitals randomly allocated to the intervention, 6 to the control. Intervention: education, and reminders on radiology requests used to encourage compliance with the Canadian C-Spine Rule.	Diagnostic imaging rate of the cervical spine during two 12 month before-and-after periods.	The intervention group showed a relative reduction in cervical spine imaging of 12.8% (95%CI 9%-16%; p=0.01) The control group showed a relative increase of 12.5% (7%-18%; p=0.03). No fractures were missed and no adverse outcomes identified.	The request rates before the study were higher in the intervention groups (61.7%) than the non-intervention group (52.8%). The awareness that the non-intervention group were being studied may have influenced their practice. It is also unlikely that the control group were unaware of the Canadian rule which may have diminished the magnitude of the intervention effect.
Gonzalez et al[48] 2009 USA	1,687 alert patients with possible cervical spine injury from blunt trauma over a 26 month period.	Prospective cohort.	Prospective evaluation of a protocol to assesses the efficacy and sensitivity of clinical examination in complement with CT for cervical spine	1,439 had GCS >13 897/1439 (62%) had a negative clinical examination of the c-spine and had cervical collars removed.	Single centre. Included patients aged 13-16 years. Considered patients with a GCS as 14 to be alert.

Author, date and country	Patient group	Study type	Outcomes	Results	Comments
	Patients with posterior neck pain or tenderness and patients with GCS <14 had CT of the c-spine requested. The remainder had their collar removed and asked to flex/extend the neck and rotate 45 degrees laterally. If they experienced no pain during these manoeuvres their necks were considered clinically cleared.		injury.	2/897 patients (0.2%) whose clinical examination results were negative were later found to have a c-spine injury. For patients with c-spine injury and a GCS score >13, the sensitivities of both clinical examination and CT scan were 99%.	Examination of the neck was performed regardless of distracting injuries. The patients with the 2 fractures missed did not have "distracting injuries": Type III odontoid fracture that was identified 3 months later at follow-up and required surgery (C6 vertebral fracture in a patient that complained of neck pain (with no neurological deficit) 45 minutes after initial clinical clearance of the neck. Treated conservatively in a collar.
Rethnam et al[54] 2008 UK	114 alert and stable patients who had cervical spine radiographs for suspected neck injuries at 2 hospitals were included in the study.	Retrospective review	Ability of the Canadian C-Spine rule to safely reduced the need for radiography.	28 patients were high risk according to the Canadian Cervical Spine rule, 86 patients were low risk. 86/114 patients (75.4%) would not have needed cervical spine radiograph according to the rule. 2/114 patients who had significant cervical spine injuries would have been identified using the rule.	Small study (only 2 significant cervical spine injuries). Potential reduction in radiograph request rates was great because of 100% request rate during the study, which is much higher than other centres. 6 patients excluded because of missing data. Patients with other low risk factors were assumed to have full range of neck movements since the ability to rotate the neck 45 degrees was not universally documented.

Author, date and country	Patient group	Study type	Outcomes	Results	Comments
Duane et al[38] 2007 USA	534 blunt trauma patients presenting over a one-year period that had CT of their neck requested.	Prospective cohort Positive clinical examination was defined as : neck pain, external trauma of the c-spine, neurological deficit, tenderness, or abnormalities to palpation over the cervical spine.	Reliability of clinical examination compared to CT. Reliability of EAST guideline for C-spine clearance versus CT.	52 patients with, and 482 patients without, c-spine fractures. EAST guidelines would have missed identified 10 of 17 cervical spine fractures (sensitivity 59%) In alert (GCS 15) patients with no distracting injuries 7 of 17 cervical spine fractures were not identified by clinical examination (sensitivity 59%)	Only study to have evaluated clinical examination versus CT. Included patients with GCS<15. 10 of the 52 fractures would have been missed using the EAST guidelines for C-spine clearance. 4/7 patients with fractures not identified using the EAST guidelines required non-surgical intervention. "Missed fractures" included: • 3 tansverse process fractures • Hangman's fracture • Lateral mass fracture C1 • Occipital condyle fracture • C3 transverse foramen fracture
Barry et al[52] 2006 UK	An alert 26 year old patient involved in a motor vehicle accident. Delayed neck pain but no midline cervical tenderness and a full range of movement of the neck.	Case report	Nexus criteria would have indicated that no imaging was required. Canadian rule would have indicated that no imaging was indicated based upon the mechanism of injury.	Fractures of the atlas.	No collision, rollover. Airbags deployed, speed unknown. Treated in a Philadelphia collar
D'Costa et al[51] 2005 UK	Alert 44 year old woman rolled car, pain in her neck but no midline cervical tenderness.	Case report	Nexus criteria would have indicated that no imaging was required. Canadian rule would have indicated that a scan was indicated based upon the mechanism of injury.	Fracture C4 body and facet joint	Part of a larger cases series of spinal fractures that had no spinal tenderness on examination Treated in a rigid collar
Barry et al[50] 2005 USA	Elderly patient with neck injury but no midline cervical tenderness	Case report	Nexus criteria would have indicated that no imaging was required.	Type III dens fracture	Problems assessing patients mental status meant that the treating physician did not strictly follow the NEXUS criteria Patient would have been imaged due to age using the Canadian rule.

Author, date and country	Patient group	Study type	Outcomes	Results	Comments
Heffernan et al[49] 2005 USA	406 alert, adult patients with no acute neurological deficit who were admitted following blunt trauma and who had a minimum of 3-view c-spine radiographs requested.	Prospective observational study. Examination was performed by research team independent of the trauma team and who were unaware of radiograph results	Ability of patients with upper or lower torso injuries to complain of pain or midline tenderness relative to cervical spine fractures.	40 patients had cervical spine fractures. No patient with lower torso injury and a non-tender neck had a c-spine fracture. 7 patients with cervical spine fractures denied neck pain or tenderness. All had rib fractures.	Single centre All patients had received opiates before examination. Potential for lack of blinding of researchers to radiographs.
Chang et al[55] 2005 USA	4,698 patients undergoing radiographic evaluation of the cervical, thoracic, or lumbar vertebrae after blunt trauma at a Level 1trauma	Prospective cohort study physician evaluated the patient for the following before imaging was performed: tenderness to the cervical, thoracic, or lumbar spine, distracting injuries, altered mental status, alcohol or drug intoxication, neurological deficits.	To describe the prevalence and type of distracting injuries associated with vertebral injuries at all levels of the spine in blunt trauma patients.	206 patients had vertebral fractures, 55 of whom had distracting injuries 336 (7.2%) patients had distracting injuries as the sole indication for obtaining radiographs. 8/336 (2.4%) had vertebral injuries. All had non-spinal fractures as the distracting injury. 2 cervical spine injuries identified in the distracting injury group: a spinous process fracture, a rotatory subluxation	Multiply injured patients Looked at all vertebral fractures Unable to extract data from the study paper to determine the exact circumstance and particular injuries sustained by the patient with the "silent" significant cervical spine injury (rotatory subluxation).
Kerr et al[46] 2005 Australia	211 alert, stable adult patients presenting to an Australian ED with potential neck injuries who were immobilised in hard cervical collars	Before-and –after study	1.The impact of implementation of the Canadian C-spine rule on radiograph request rates 2. The impact of implementation of the Canadian C-spine rule on length of time spent in hard collars	Radiograph request rates decreased from 67% to 50% (25% relative reduction). Time in hard collar was reduced from a median of 128 min to a median of 103 min (statistical significance.	Single centre. Before-and-after study. May be other temporal factors that affected request rates.
Bub et al[56] 2005 USA	104 Patients aged 65 years or older that were admitted to a trauma centre with a cervical spine fracture as a result of blunt trauma between 1995 and 2002. Control group consisted of 107 patients aged 65 years or more that were either admitted or not following blunt trauma and who had no cervical spine fracture.	A retrospective case-control study of a trauma register and use of multi-variate logisitic regression to develop a clinical prediction rule for fracture probability.	Prediction rule in over 65 year olds. Odds ratios of risk factors Probability of fracture in each of risk stratified groups	Composite predictors of fracture in the elderly included: focal neurologic deficit (adjusted odds ratio, 17.7; 95%[CI]: 3.8,-83.4), severe head injury (OR 3.2; 95 CI: 1.5,-7.1), high-energy mechanism (OR6.7; 95% CI: 3.1-14.8), moderate-energy mechanism (OR 3.3; 95% CI: 1.3- 8.3). The prediction rule stratified patients into risk groups with fracture probabilities ranging from 0.4% (95% CI: 0.1%-1.3%) to 24.2% (95% CI: 5.7%-100%).	Rule designed to identify fracture probability not exclude them. Confidence intervals too wide for use in clinical practice. Clinical indicators of fracture eg midline cervical spine tenderness were not assessed because these indicators were not reliably recorded. Not validated. CT gold standard. Patients who died before imaging were excluded.

Author, date and country	Patient group	Study type	Outcomes	Results	Comments
Dickinson et al[43] 2004	8,924 patients from original Canadian C-spine derivation cohort	Retrospective application of NEXUS criteria	Accuracy and reliability of the (NEXUS) low-risk criteria for cervical spine radiography.	NEXUS criteria ability to identify important cervical spine injury: Sensitivity 92.7% (95% CI 87%-96%) Specificity 37.8% (95% CI 37%-39%	11 patients with important injuries not identified, 2 were treated with internal fixation and 3 with a halo. Problems assessing distracting injury and intoxication retrospectively. Did not strictly use same definitions proposed by NEXUS.
Bandiera et al[36] 2003 Canada	6265 ambulatory or immobilised adult patients presenting to 10 Canadian ED's who were Stable, alert (GCS 15), and had either: 1. neck pain from any mechanism of injury OR 2. no neck pain but non-ambulatory with a visible injury above the clavicles from a dangerous mechanism of injury.	Prospective cohort study Physicians prospectively estimated the probability that the patient would have a clinically important c-spine injury based on history and examination without use of decision rule and before radiographs.	Physician judgement at predicting probability of clinically important c-spine injury. Gold standard was plain radiography (with or without flexion and extension views and CT imaging) as requested by treating physician or lack of symptoms at 14 day telephone follow up interview.	Sensitivity 92.2% (95% CI 82% to 96%) Specificity 53.9% (95% CI 82% to 96%) Prevalence 64 (1.0%)	64/6265 (1%)had a significant C-spine injury 16/6265 (0.3%)had a clinically unimportant C-spine injury Researchers were involved in developing the Canadian rule.
			Canadian rule ability to identify clinically important c-spine injury.	Sensitivity 100% (95% CI 94% to 100%) Specificity 44.0% (95% CI 43% to 45%) Prevalence 64 (1.0%)	
Stiell et al[42] 2003 Canada	8283 ambulatory or immobilised adult patients presenting to 9 Canadian ED's who were stable, alert, inured <48 hours earlier and had: 1. neck pain OR 2. no neck pain but non-ambulatory with visible injury above the clavicles from a dangerous mechanism of injury	Prospective Cohort	Ability of NEXUS low risk criteria and the Canadian C-Spine rule to identify significant C-spine injuries compared to plain radiography as requested by judgement of the treating physician.	**NEXUS** 147/162 injuries correctly identified Sensitivity 90.7% (95% CI, 85-94) Specificity 36.8% (95% CI, 36-38) **Canadian rule** 161/162 injuries correctly identified Sensitivity 99.4% (95% CI, 96-100) Specificity 45.1% (95% CI, 44-46)	3603 eligible patients not enrolled and 635 had data forms but no outcome assessments (not imaged) 45 cases of clinically unimportant injuries were identified. The Canadian rule would have identified 97.8% of these and the NEXUS criteria 80%. Indeterminate patients were excluded from the final analysis
			Potential effect on radiography request rates.	NEXUS: 66.6% Canadian rule: 55.9%	Researchers were involved in developing the Canadian rule.

Search 4

Can cervical spine prediction rules be safely applied by nurses in the ED?

Medline (1950 – week 1 May 2010)

1. explode cervical vertebrae OR exp neck OR exp neck injuries OR exp spinal cord injuries
2. cervical spine.ab
3. (immobili* OR collar* OR "neck brace" OR headblock* OR sandbag*).ab
4. (nurs*).ab
5. (guideline* OR protocol OR criteria).ab
6. exp Practice guideline OR exp guideline OR exp Guideline Adherence
7. NEXUS.ab,ti
8. Canadian.ab,ti
9. #1 OR #2 or #3
10. #4 AND #9
11. #5 OR #6 OR #7 OR #8
12. #10 AND #11
13. #12 limited to Human and English language.

35 articles retrieved.

EMBASE (1980 - May 2010)

1. exp Cervical vertebrae OR exp Spinal Injuries OR exp Neck Injuries OR exp Neck
2. (cervical AND spine).ab,ti
3. (immobili* OR collar OR brace OR headblock OR sandbag*).ab
4. guideline*.ti,ab
5. exp Practice guideline OR exp Clinical Protocols
6. NEXUS.ab
7. Canadian.ab
8. (nurs*).ab,ti
9. #1 OR #2 OR#3
10. #4 or #5 OR #6 OR #7
11. #8 AND #9 AND #10
12. #11 limited to Human and English language.

10 articles retrieved

CINAHL *(1981 - May 2010)*

1. exp Cervical vertebrae OR exp Spinal Injuries OR exp Neck Injuries OR exp Neck
2. (cervical AND spine).ab
3. (immobili* OR collar OR brace OR headblock OR sandbag*).ab
4. exp NURSING PROTOCOLS OR exp CLINICAL ASSESSMENT TOOLS OR *RESEARCH PROTOCOLS OR *PRACTICE GUIDELINES
5. NEXUS.ab
6. Canadian.ab
7. (nurs*).ab,ti
8. #1 OR #2 OR#3
9. #4 OR #5 OR #6
10. #7 AND #8 AND #9

18 articles retrieved

The Cochrane library (issue 2 2010) was also searched using the term "cervical spine", no articles addressing the question posed were identified. When duplicates and articles that did not address the question posed six articles remained. Searching articles that had cited these studies identified a seventh paper.

Author, date and country	Patient group	Study type	Outcomes	Results	Comments
Stiell et al[64] 2010 Canada	3633 stable adult patients presenting to one of six Canadian ED's with neck pain or on an ambulance backboard. Trained triage nurses evaluated each patient for the Canadian C-spine criteria and recorded findings on a data form but did remove the collar . A second clinician (nurse or doctor) performed inter-observer patient assessments independently in 498 cases.	Prospective cohort validation study	Agreement between the nurse and a second observer as to the Canadian C-spine criteria. k >0.60 was considered to indicate substantial agreement.	191 triage nurses enrolled & assessed 3633 patients. 4 According to the Canadian C-spine rule interpretations, 40.7% of patients could have had their c-spine cleared by the triage nurse. Inter-observer assessments for need to maintain immobilisation showed good agreement (k 0.78). Results were similar whether the second observer was a nurse or doctor. 4 patients out 1535 assigned by the triage nurse to the clinically cleared group had significant fractures.	Multi-centre Doctor assessment considered the gold standard Convenience sample 4 "significant" cervical spine injuries were not identified by nurses using the rule at the start of the study, mainly failing to recognise a dangerous mechanism of injury. Following further training no further injuries were "missed"
Meek[59] 2007 Australia	One of 22 senior ED nursing staff and one of 26 senior ED medical staff trained in use of the NEXUS rule independently applied the NEXUS criteria to a convenience sample of patients who had been placed in a hard cervical collar prior to arrival in the ED.	Prospective cohort study	Level of agreement between trained ED nursing staff and senior ED medical staff in the application and interpretation of the NEXUS criteria.	83 patients were recruited. The level of "safe agreement"' where nursing and medical staff agreed that the collar should be left in place was 94% (95% CI: 89–97%). Agreement with regard to individual NEXUS criteria varied from good to fair. The median times from patient arrival to completion of study nurse and doctor assessments were 14 min. & 29 min. respectively.	Single centre Convenience sample Doctor assessment considered the gold standard
Stiell et al[65] 2007 Canada	345 adult patients presenting to one of six Canadian ED's with neck pain or on an ambulance backboard. Trained triage nurses evaluated each patient for the Canadian C-spine criteria and recorded findings on a data form. A second clinician (nurse or doctor) performed inter-observer patient assessments	Prospective cohort study	Agreement between the nurse and a second observer as to the Canadian C-spine criteria. k >0.60 was considered to indicate substantial agreement.	112 nurses enrolled & assessed 345 patients. 213 patients were then assessed separately by a doctor and the remainder by a second nurse. According to the Canadian C-spine rule interpretations, 47.5% of patients could have had their c-spine cleared. Inter-observer assessments for need to maintain immobilisation showed agreement of 90.5% (k 0.81 [95%CI = 0.74-0.88]). Results were the same whether the second observer was a nurse or doctor. The agreement for assessing the	Multi-centre Doctor assessment considered the gold standard

Author, date and country	Patient group	Study type	Outcomes	Results	Comments
	independently.			9 CCR component findings had these k statistic: Age 65 - 0.97 Dangerous mechanism - 0.79 Paraesthesia - 0.71 Rear-end MVC - 0.76 Upright position - 0.78 Ambulatory - 0.71 Delayed neck pain - 0.66 Midline tenderness - 0.54 Able to rotate - 0.81	
Pitt et al[63] 2006 UK	112 patients attending an ED with neck immobilisation that were assessed for the presence of NEXUS criteria by both a nurse and doctor independently.	Prospective cohort study	1. Concordance with doctor assessment 2. Time spent in a cervical collar	59 patients had their collar removed at triage assessment. 53 patients had radiographs requested. The mean reduction in time spent in a collar was 23 minutes (95%CI 20-26). Doctors felt that 7 patients had been "unsafely cleared", none of these had a significant injury.	Single centre. Possible selection bias (588 eligible patients not recruited). Patients considered to need immediate medical attention were excluded. Non-return for radiographs was considered to equate to the absence of a significant injury. Children were included in the sample.
Miller et al[61] 2006 UK	460 adult patients presenting to one UK ED with potential cervical spine injury were evaluated by trained nurses using the Canadian C-spine criteria. 112 trained triage nurses evaluated each patient for the Canadian C-spine criteria A doctor performed inter-observer patient assessments independently in 254 cases.	Prospective cohort study	The level of agreement between nurse and medical judgement was calculated (k).	254 patients were assessed independently by both a doctor and nurse. The inter-rater reliability (k) was 0.6 (95%CI 0.50-0.62) indicating a 'good' level of agreement. The majority of nurses indicated they were comfortable using the rule. 25% reduction in immobilisation rates would have been achieved if the rule had been followed.	Single centre. Convenience sample Possible selection bias (206 patients assessed by nurses were not independently assessed by doctors). 18% trained nurses were uncomfortable using the rule. Doctor assessment considered the gold standard
Kelly[60] 2005 Australia	88 patients with potential C-spine injury assessed at a single Australian ED. Data were entered onto separate data sheets by doctors and nurses.	Prospective cohort study	Inter-rater agreement between doctors and nurses regarding eligibility for application of the Canadian C-Spine Rule (CCR) and assessment of the criteria of the CCR.	Doctors and nurses agreed on which patients were eligible for CCR application in 96.6% of cases. Inter-rater agreement for most CCR criteria was good (k>0.61), with the exception of midline tenderness (k=0.58) and range of motion, which most nurses did not test.	Single centre Convenience sample Doctor assessment considered the gold standard Nurses reluctant to test neck rotation despite educational training.

Author, date and country	Patient group	Study type	Outcomes	Results	Comments
Hsieh[58] 2000 UK	112 patients attending an ED with neck immobilisation following blunt trauma that were assessed independently for the presence of NEXUS criteria by both a nurse and doctor in.	Prospective cohort study	Inter-rater reliability between emergency nurses and doctors at identifying NEXUS criteria.	Physicians and nurses agreed on the presence or absence of the combined criteria in 175 of 211 patients (82.9%κ, 0.65). Agreements on individual criteria were as follows: 1)intoxication—203 patients (96.2%κ, 0.82) 2)altered consciousness— 197 patients (93.4%κ, 0.60); 3) neck pain- 185 patients (87.7%κ, 0.75) 4)distracting injury- 160 patients (75.8%κ, 0.36) 5)neurologic deficit- 198 patients (93.8%κ, 0.45). Nurses would have cleared 35% of the patients before the physicians but ordered 12% more radiographs and unsafely clinically cleared 5% of the patients.	Single centre Convenience sample Doctor assessment considered the gold standard Included some children aged >12
Sexton[57] 2000 US	107 eligible patients attending an ED with neck immobilisation following blunt trauma. 35 patients were independently assessed by nurses and doctors using modified NEXUS criteria.	Prospective cohort study	Proportion of patients that were safely cleared by nurses. Total time neck immobilised when nurses cleared the neck compared to when doctors cleared the neck.	21/21 cases cleared by nurses were considered correct by "doctors". Average time in a collar when nurses cleared the neck was 17 minutes. Average time in a collar when doctors cleared the neck was 44 minutes.	Single centre Convenience sample Probable selection bias as all nurse assessed patients were eventually clinically cleared Doctor assessment considered the gold standard Senior nurses only 14 patients assigned to imaging group cleared clinically by doctors

Search 5

Which primary imaging modality is recommended for excluding cervical spine injury?

A search was performed to identify articles that compared the accuracy of plain radiographs and CT at identification of cervical spine injury in alert, blunt trauma patients.

Medline (1950 – week 1 May 2010)

1. Tomography-X-Ray-Computed.DE OR Tomography-X-Ray.DE OR Radiograph*.DE OR Neuroradiograph*.DE OR Magnetic-Resonance-Imaging.DE
2. (flexion WITH extension).ti,ab
3. ("cervical spine" WITH injur*).ti,ab
4. exp NECK INJURIES/
5. exp Cervical-Vertebrae/
6. whiplash.ti,ab
7. ((senistivity OR specificity OR likelihood OR (predictive value) OR diagnos* OR accuracy)).ab
8. #1 0R #2
9. #3 OR #4 OR #5 OR#6
10. #8 AND #9
11. Trauma*.ab
12. #10 AN #11
13. limit #12 to Human AND English Language

957 references were retrieved.

Embase *(1980 – May 2010)*

1. exp Cervical spine OR exp Spine injury OR exp Neck Injury
2. whiplash.ab
3. exp (Computer assisted tomography OR Spiral computer assisted tomography OR Cervical spine radiography OR Neuroradlology OR Nuclear magnetic resonance imaging)
4. radiograph*.ab
5. (flexion WITH extension).ti,ab
6. ((senistivity OR specificity OR likelihood OR (predictive value) OR diagnos* OR accuracy)).ab
7. #1 0R #2
8. #3 OR #4 OR #5
9. # 6 AND #7AND #8
10. Trauma*.ab
11. #9 AND #10
12. limit #11 to Human AND English Language

655 references were retrieved

The search retrieved one systematic review and one meta-analysis, which included retrospective studies with heterogeneous results. Retrospective studies were excluded except one study* where all patients presenting to a single trauma centre had both 3-view plain radiographs and CT performed as the departmental standard. Studies on intubated

patients or patients on ICU were excluded. The study characteristics of the remaining seven studies have been tabulated below.

CT versus plain radiographs (meta-analysis and systematic reviews)

Author, date and country	Patient group	Study type	Outcomes	Results	Comments
Cain et al[72] 2009 UK	4116 Patients with potential neck injury that were included in 10 reported studies.	Systematic review of cohort studies which compared plain radiography and CT for the detection of cervical spine injury.	Sensitivity of plain films and CT at identification of cervical spine injury.	Sensitivity of plain radiographs ranged from 38.9-93.3%. CT sensitivity was 95-100%.	Studies that used non-helical CT were excluded. Studies that did not include adequate 3 view plain radiographs were excluded Data extracted by single reviewer. 3 studies were retrospective and 4 prospective studies only included high risk patients (prevalence of fractures as high as 34%, therefore not representative of a population presenting to the ED), The remaining 3 studies had a high prevalence of cervical spine injury (6.8-9.5%)despite including all patients undergoing cervical radiography. Selection bias is a possibility here. Most studies included patients with reduced conscious level. Significant heterogeneity between studies.
Holmes et al[68] 2005 USA	3834 patients with potential neck injury that were included in 7 reported studies.	Meta-analysis of cohort studies which compared plain radiography and CT for the detection of cervical spine injury.	Pooled sensitivity of plain radiography and CT for C-spine injury detection.	Pooled sensitivity for plain radiography was 52% (95%CI 47-56%). Pooled sensitivity for CT was 98%.(95%CI 96-99%).	No study included an independent reference standard. Marked heterogeneity in results. High prevalence of cervical spine injury.

CT versus plain radiographs

Author, date and country	Patient group	Study type	Outcomes	Results	Comments
Bailitz et al[75] 2009 USA	1505 blunt adult trauma patients that had C-spine imaging performed as indicated by NEXUS criteria over a 2 year period at a single US level 1 trauma centre. All patients had both 3 view plain radiographs and CT performed.	Prospective cohort study	Accuracy of plain films and CT for identification of cervical spine injury.	78/1505 patients (4.9%) had a cervical spine injury. 50 injuries (3.3%) were considered significant. Plain films identified 18/50 "clinically significant" injuries (sensitivity 36%). The sensitivity was 62% when inadequate radiographs were excluded. CT identified 50/50 "clinically significant" injuries (sensitivity100%)	Plain radiographs and CT were interpreted by radiologists independently of each other. High prevalence of cervical spine injury. The sensitivity of plain radiographs was low even in patients categorised as low risk for cervical spine injury.
Mathen et al[70] 2007 USA	667 blunt adult trauma patients that had C-spine imaging performed as indicated by NEXUS criteria over a 4 month period at a single US level 1 trauma centre. All patients had both 3 view plain radiographs and CT performed.	Prospective cohort study	Accuracy of plain films and CT for identification of cervical spine injury.	60/667 (9%) patients had cervical spine injuries, 23 injuries were significant (9 required surgery and 18 haloes) Plain films identified 27/60 injures (sensitivity 45%, NPV 94.7%) CT identified 60/60 injuries (sensitivity100%, NPV 100%). 3 false positive findings (ligamentous injury)were found on CT that were negative on MRI.	Results included in the systematic review by Cain et al Average GCS of patients was 13. High prevalence of cervical spine injury.
McCulloch et al[94] 2005 USA	407 adult patients injured by high energy trauma presenting to a level 1 trauma centre. 3 interventions: 1. standard 3 view plain radiographs 2. standard 3 view plain radiographs (plus helical CT if radiographs were inadequate 3. helical CT of the spine	Prospective case series	Accuracy of plain films and CT for identification of cervical spine injury after exclusion of inadequate radiographs.	58/407 (14.2%)patients had a cervical spine injury. 3 view plain radiography: Sensitivity 52% Specificity 98% Helical CT: Sensitivity 98% Specificity 98%	Plain radiographs and CT were interpreted by radiologists independently of each other. High prevalence of cervical spine injury. Patients were not consecutive, possible selection bias. Part of a cost-accuracy study. Reference standard was radiographs plus case notes.
Nguyen et al[81] 2005 USA	219 Consecutive patients with blunt trauma presenting to a US level 1 trauma centre over a period of 70 days. Patients stratified into very low risk, low risk or high risk of cervical spine injury. 112 patients that were low or high risk had both 3 view	Prospective cohort study	Accuracy of plain films and CT for identification of cervical spine injury.	No fractures were found in the very low risk and low risk groups (185 patients) 15 /34 patients in the high risk group had a fracture identified. Plain radiographs identified 14/15 fractures in the high risk group (sensitivity 93.3%)	High prevalence of cervical spine injury (15%). Included patients with altered conscious level. High risk: Major trauma, high clinical suspicion, neurological signs, reduced conscious level or inadequate radiographs.

Author, date and country	Patient group	Study type	Outcomes	Results	Comments
	plain radiographs and CT performed.				CT reference standard.
Griffen et al[71] 2003 USA	1199 blunt adult trauma patients with either posterior neck tenderness, altered mental status or neurological deficit that had C-spine imaging performed over a one year period at a single US level 1 trauma centre. All patients had both 3 view plain radiographs and CT performed.	Retrospective review*	Accuracy of plain films and CT for identification of cervical spine injury.	116/1199 patients (9.5%) had a cervical spine injury. 3 view plain radiography: Sensitivity 65% Helical CT: Sensitivity 100%	Plain radiographs and CT were interpreted by radiologists independently of each other. High prevalence of cervical spine injury. Average GCS was 13. Authors determined that no significant injuries were missed as no discharged patients returned to the trauma centre
Diaz et al[95] 2003 USA	1006 haemo-dynamically stable adult patients with either altered mental status or distracting injury who had both 5 view films and CT of the cervical spine performed.	Prospective cohort study	Sensitivity of plain films and CT for identification of "unstable" cervical spine injury.	116 patients had 172 cervical spine injuries 29 patients had unstable injuries 5 view plain radiography: Sensitivity 82.7% Helical CT: Sensitivity 97.4% CSX missed 90 of 172 (52.3%) CSIs in 65 of 172 (56.0%) patients.	Only most severely injured patients included Unstable fractures were defined as requiring surgical or halo stabilisation. Plain radiographs missed 14/15 occipital condyle fractures. Plain films missed a total of 90 fractures.
Mower et al[82] (NEXUS) 2001	34,069 patients with blunt trauma selected for radiographic cervical spine imaging at 21 participating institutions underwent a standard 3-view series as well as any other imaging deemed necessary by their physicians	Prospective cohort study	Accuracy of plain films and CT for identification of cervical spine injury.	818 patients (2.4%) had cervical spine injuries. Plain films identified injures in 498/818 patients (sensitivity 61%) CT identified all injuries (100% sensitive) Plain radiographs identified 932 injuries in 498 patients. 564 cervical spine injuries (identified on further imaging)were not diagnosed on plain radiographs in 320 patients for the following reasons: • 237 inadequate series • 36 abnormal but "non-diagnostic" • 47 adequate films appeared normal., 24 of these had SCIWORA, 23 had osseo-ligamentous injuries	Injuries detected by plain radiography compared with final diagnosis following review of all radiographic studies. Included children. Potential verification bias. 23 patients (0.07% of all patients; 95% CI 0.05% to 0.09%) had 35 injuries (including 3 potentially unstable injuries) that were not visualised on adequate films (2.8 % of all injured patients) Overall, adequate plain radiography for identification of cervical spine injury was 89.4% sensitive and NPV 99.9%.

Search 6

How soon should imaging be performed for patients with potential cervical spine injury?

Search 5 was repeated. No articles were retrieved that answered to the question posed.

Search 7

What is the recommended management for patients with severely limited neck movement (new), or severe pain, following normal CT?

Search 5 was repeated. No prospective studies that compared flexion-extension views, MRI or helical CT versus operative findings or clinical follow up >90 days were identified.

Flexion-extension views

Seven studies that included alert patients in the ED were identified but only one was prospective.

Author, date and country	Patient group	Study type	Outcomes	Results	Comments
Goodnight et al[113] 2008 USA	Adult patients that presented to a level 1 trauma centre over a 2-year period following blunt neck trauma that had had flexion-extension views requested after a normal CT. Children, obtunded patients and those with neurological deficits were excluded.	Retrospective analysis of prospectively collected data	Ability of flexion-extension radiographs and CT to exclude cervical spine instability	4125 trauma patients seen in the study period, 1809 of whom had CT. 379 patients that had no fracture on CT had flexion-extension views performed. 16 flexion-extension views suggested instability: • 8 patients had an abnormal CT, suggesting instability. 2 of these were negative on MRI. • 8 patients had a normal CT, all of these were negative on MRI. 11 flexion-extension views were negative in patients with CT features suggestion of instability. (false positives) **Overall** **CT** 360 true negatives, no false negatives 6 true positives, 13 false positives **Flexion-extension views** 363 true negatives, no false negatives 6 true positives, 10 false positives	Retrospective "All available evidence", both clinical and MRI imaging, was considered the gold standard" for final diagnosis Timing of flexion-extension views unclear. Authors concluded that a negative CT effectively excludes cervical spine instability.

Author, date and country	Patient group	Study type	Outcomes	Results	Comments
Mauldin et al[112] 2006 USA	140 alert adult patients with blunt neck trauma that had flexion-extension views performed on the first presentation following normal 5 series plain radiographs because of persistent midline neck pain. 129 patients had a bolster to increase flexion. 11 did not use the bolster.	Prospective cohort study	Accuracy, safety and adequacy of flexion extension views.	(92%) studies were considered adequate with the bolster and (94%) using an active range of motion. However, only 69% films could visualise C7/T1. 5/140 had evidence of instability on flexion-extension views despite normal plain radiographs and CT. 4 were treated in a collar, 1 had surgery. No false negative studies were identified using flexion-extension views. One patient developed a transient neurological deficit during the flexion-extension study but made a full recovery.	Convenience sample 9% could not complete the study due to pain. Clinical follow up inadequately described. Not all patients had MRI.
Insko et al[108] 2002 USA	106 blunt adult trauma patients that were awake and had neck pain but normal C-spine images . All patients had flexion-extension views attempted.	Retrospective cohort study	Accuracy, safety and adequacy of flexion extension views.	9/106 (9%) patients had cervical spine injuries identified on imaging, clinical diagnosis or follow up. 70% patients (5 of whom had a fracture) had adequate views) No false negative studies were identified in this group. 30% of flexion-extension views were considered inadequate. Four of these patients (12.5%) subsequently had cervical spine injuries identified on CT or MRI	Retrospective 228 patients not adequately followed up that were excluded. Not all patients had the same imaging modalities requested eg CT/MRI. Adequate range of movement was considered 30 degrees from normal.
Pollack et a[111] 2001 USA	86 patients with blunt cervical spine injury demonstrated by any imaging modality that had injuries flexion-extension views performed.	Secondary analysis of prospectively collected data from the NEXUS study	Incidence of spinal instability identified by flexion-extension views on patients with cervical injuries identified by any imaging modality..	Six patients had instability that was identified on flexion-extension views alone. None were considered clinically significant.	Post-hoc analysis. Various imaging strategies employed to exclude injuries.
Brady et al[110] 1999 USA	451 adult patients that had both plain radiographs and flexion-extension views of their cervical spine performed following blunt trauma.	Retrospective review	Incidence of spinal instability identified by flexion-extension views. Incidence of neurological complications associated with flexion–extension views.	372 patients had normal plain 3-view radiographs. 5 (1.3%) of these demonstrated instability on flexion-extension views, none of whom required surgery. 16/79 (20%) with abnormal plain radiographs demonstrated instability on flexion-extension views, 4 of whom required surgery. No neurological complications were reported.	Retrospective,. Non-consecutive patients, possibility of selection bias High prevalence (5.1%) of significant spinal injury Clinical follow up inadequately described.

Author, date and country	Patient group	Study type	Outcomes	Results	Comments
Wang et al[107] 1999 USA	290 alert, neurologically intact adult patients with neck pain secondary to blunt trauma that both plain radiographs and flexion-extension views of their cervical spine performed at a level 1 trauma centre.	Retrospective review	Incidence of spinal instability identified by flexion-extension views. Incidence of neurological complications associated with flexion–extension views.	Only one case (0.3%) of instability detected. 33% of studies were deemed inadequate for diagnostic purposes. No neurological complications were reported.	Retrospective Images interpreted by radiologists Cilinical follow up inadequately described.
Lewis et a[109] 1991 USA	141 consecutive patients presenting to a US level 1 trauma centre hat had both flexion-extension views and plain radiographs of the cervical spine perfomed for blunt trauma.	Retrospective cohort study	Incidence of spinal instability identified by flexion-extension views. Prevalence of neurological complications associated with flexion–extension views.	11/141 demonstrated instability on flexion extension views. 7 of these had abnormalities detected on plain films. One false negative case. 3/4 patents with normal plain radiographs but instability on flexion-extension views required surgery. No neurological complications were reported.	Retrospective High prevalence (8%) of unstable spinal injury Flexion-extension views not interpreted blindly of results of other imaging, which included CT in some cases. Ten of 11 patients with radiographic instability had significant neck pain by history; the remaining patient was intoxicate

CT/MRI

Nine studies that included alert patients in the ED were identified but none were prospective. Five studies were excluded because individual data for alert, neurologically intact patients could not be extracted.

Author, date and country	Patient group	Study type	Outcomes	Results	Comments
Menaker et al[119] 2010 USA	Patients with blunt trauma that presented to a level 1 trauma centre over 2 years that had MRI requested following normal CT.	Retrospective chart review	Incidence of spinal instability identified by MRI following normal CT and plain radiographs.	6347 patients attended. 117 patients that were GCS 15 patients underwent MRI following normal CT's. (for ongoing pain or neurological deficit) In 20 patients the only reason the MRI was request was for ongoing neck pain. 17 scans were normal, 3 were abnormal. 1 patient developed delayed neurological deficit whilst waiting for MRI and required surgery, the other 2 were treated in a collar.	Retrospective. 40 slice multi-detector CT. Most patients in whom the only indication for MRI scan was pain were discharged in a collar and had the MRI done as an outpatient.

Author, date and country	Patient group	Study type	Outcomes	Results	Comments
Goodnight et al[113] 2008 USA	Adult patients that presented to a level 1 trauma centre over a 2-year period following blunt neck trauma that had had flexion-extension views requested after a normal CT. Children, obtunded patients and those with neurological deficits were excluded.	Retrospective analysis of prospectively collected data	Ability of flexion-extension radiographs and CT to exclude cervical spine instability	4125 trauma patients seen in the study period, 1809 of whom had CT. 379 patients that had no fracture on CT had flexion-extension views performed. 16 flexion-extension views suggested instability: • 8 patients had an abnormal CT, suggesting instability. 2 of these were –ve on MRI. • 8 patients had a normal CT, all of these were –ve on MRI. 11 flexion-extension views were negative in patients with CT features suggestion of instability. (false positives) **Overall** **CT** 360 true negatives, no false negatives 6 true positives, 13 false positives **Flexion-extension views** 363 true negatives, no false negatives 6 true positives, 10 false positives	Retrospective "All available evidence", both clinical and MRI imaging, was considered the gold standard" for final diagnosis Timing of flexion-extension views unclear. Authors concluded that a negative CT effectively excludes cervical spine instability.
Schuster et al[131] 2005 USA	93 patients seen in a level 2 trauma centre with a normal motor examination and negative CT result, that had MRI requested for persistent cervical spine pain.	Retrospective analysis of prospectively collected data	Incidence of spinal instability identified by flexion-extension views.	2,854 trauma patients seen in the study period, 100 of whom had cervical spine injuries, 7 of which were seen on MRI only. No clinically significant abnormality was identified on the MRI of the 93 patients who had a normal admission motor examination result, a negative CT result for trauma, and persistent cervical spine pain.	Part of a larger study on imaging in trauma that included obtunded patients. Large proportion of head injured patients in the study (56%). Retrospective. The timing of the MRI is unclear. MRI not follow up was considered the gold standard.

Author, date and country	Patient group	Study type	Outcomes	Results	Comments
Diaz et al[120] 2005 USA	Consecutive blunt adult patients that had 5-view plain radiographs, CT and MRI requested following blunt trauma presenting to a level 1 trauma centre.	Prospective cohort study	Incidence of spinal instability identified by MRI following normal CT and plain radiographs.	1577 patients attended. 85 patients underwent MRI 16 patients with normal CT and no neurological deficit had MRI requested because of cervical spine pain or tenderness. 6 of these had abnormal MRI's and 2 (33%) had ligament instability Neither required surgery (were treated in collars). Overall prevalence of unstable cervical spine injury was 0.06% in the cohort.	Included obtunded patients 2001-2002 Include patients aged >14 years. Average 2.5 days to MRI. Final outcome was the radiological diagnosis by neuroradiologists and not clinical outcome.

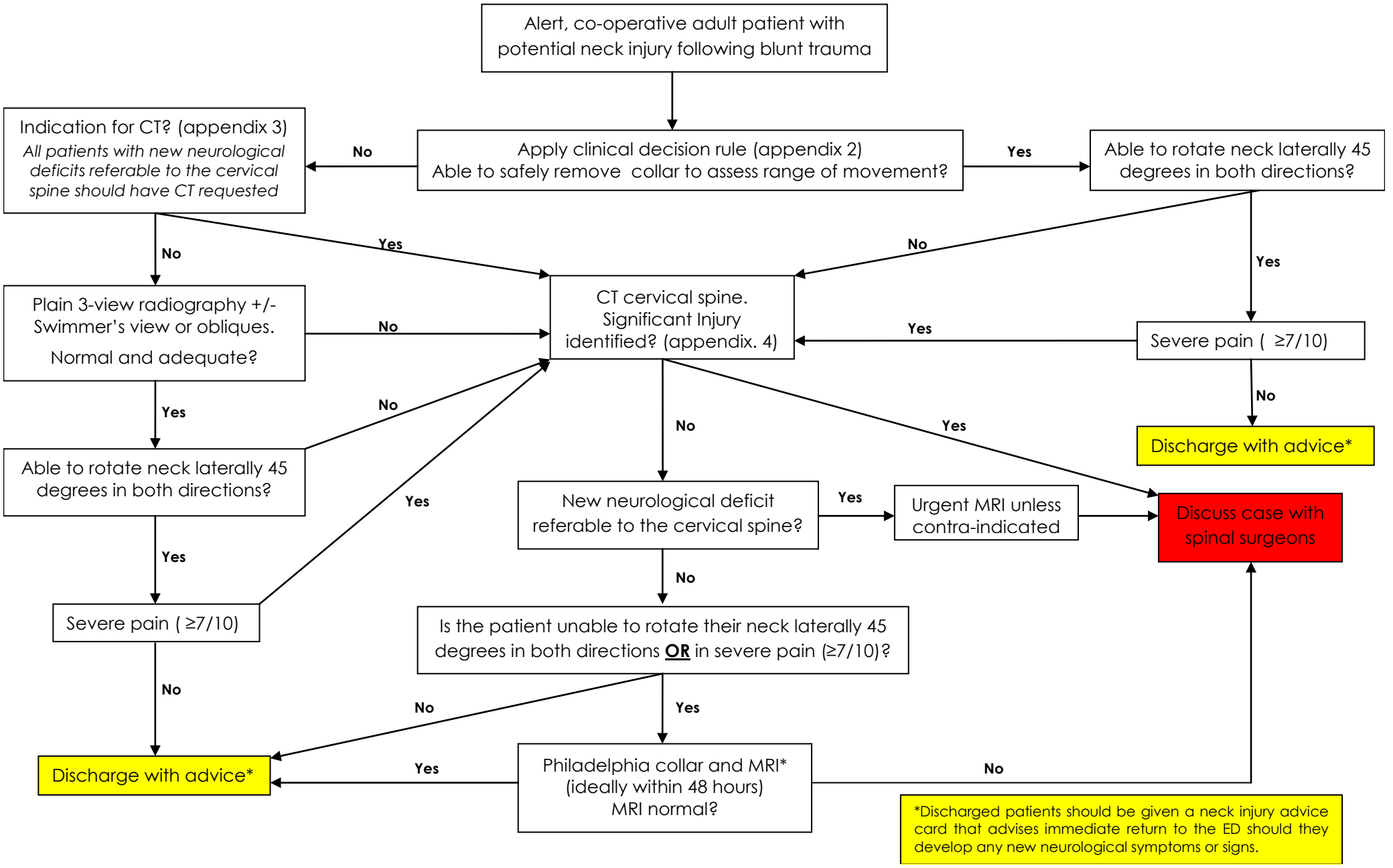
Excluded CT/MRI studies

The following studies were excluded because individual data for alert, neurologically intact patients could no be extracted

Author, date and country	Patient group	Study type	Outcomes	Results	Comments
Sekula et al[122] 2008 USA	12 patients that required surgical stabilisation of the cervical spine over a 3 year period at a single level 1 trauma centre. During this period all patients with blunt neck trauma had CT and plain lateral radiographs of the neck requested.	Retrospective review of imaging on the identified patients.	Ability of CT at identifying unstable cervical spine injuries (interpreted by neurosurgeons and radiologists)	6588 trauma patients seen in the study period, 447 of whom were excluded because of documented C-spine fractures. Of the 12 patients that required surgery the diagnoses were as follows: • 3 fractures • 3 central disc herniations • 3 facet dislocations • 3 "soft tissue injuries" All injuries were visible on CT. Incidence of unstable cervical spine injuries in the absence of a fracture was 9/6108 (0.15%)	Retrospective Follow up (gold standard) inadequate Scans reviewed by experts, blinding questionable. Unable to separate obtunded and alert patients to perform subgroup analysis Patients groups included 15-16 year olds.
Labattaglia et al[133] 2007 Australia	134 patients that presented to a level 1 trauma centre over a year period and had MRI requested following normal 3-view plain radiographs and CT.	Retrospective review	Prevalence of abnormalities identified on MRI after normal CT.	Of 68 patients that had ISS<10: 62 MRI requests were because of neck tenderness (20 were abnormal) 6 MRI requests were because of neck pain (1 was abnormal) Only 2 patients in the study required surgery.	Retrospective Unable to separate data for patients who were GCS 15. MRI not follow up was considered the gold standard Single slice CT. Median time to MRI was 3 days.

Author, date and country	Patient group	Study type	Outcomes	Results	Comments
Sarani et al[134] 2007 USA	254 patients that had both CT and MRI performed following blunt neck trauma	Retrospective review of prospectively collected data from a trauma register.	Prevalence of abnormalities identified on MRI after normal CT.	111/ 201 patients that were "examinable" had normal CT. 70/111 patients with normal CT and no neurological deficit had MRI requested because of neck pain or tenderness. 38 /142 examinable patients (with and without neurological deficit) had MRI abnormalities, some requiring surgery.	Retrospective Unable to separate patients with and without neurological to perform subgroup analysis of results MRI not follow up was considered the gold standard High proportion of injuries in the normal CT group (16%)
Platzer et al [135] 2006 USA	118 polytrauma patients recorded as having a significant cervical spine injury that attended a single level 1 trauma centre over a 25 year period.	Retrospective review of prospectively collected data from a trauma register.	Prevalence of unstable injuries identified on MRI after normal CT.	Overall, 3 disco-ligamentous injuries were missed on CT (out of 81) that were identified on MRI. 98 patients had a reduced GCS 20 patients (17%)were conscious and responsive of which:16 had radiological abnormalities identified and4 had normal radiographs.	Retrospective Quality of imaging machines changed with time Mixture of alert and obtunded patients Included children Unable to extract outcome for 4 alert patients with normal radiographs. MRI not follow up was considered the gold standard MRI performed in most cases within 6 hours.
Benzel et al[136] 1996 USA	174 consecutive blunt trauma patients presenting to one centre over a 4 year period that had both plain radiographs and MRI requested. (some also had CT). MRI was requested for ; neck pain or tenderness, reduced GCS or equivocal x-rays. Patients with neurological deficits or abnormal radiographs or CT were excluded from further analysis.	Retrospective review of prospectively collected data from a trauma register.	Prevalence of abnormalities identified on MRI after normal CT.	62/174 patients had "abnormalities". 2 of these patients required surgery. Retrospectively it was determined taht both injuries were visible on CT. 112/174 patients with negative MRI scans were discharged with no adverse outcomes reported.	Retrospective Unable to separate alert patients with neck pain to perform subgroup analysis of results Conducted 1993-1996, Older CT scanner Included some children Follow up of patients unclear. MRI not follow up was considered the gold standard

Appendix 1 - Management of alert, co-operative adult patients with potential neck injury following blunt trauma



Appendix 2 - Modified Canadian cervical spine rule

Cervical spine imaging should be requested for the following patients that have been subjected to blunt trauma with a mechanism that may have injured the neck:

- GCS<15 on assessment in the ED (level one evidence)
- Paralysis, focal neurological deficit, or paraesthesia in the extremities (level one evidence)
- Patients with abnormal vital signs (systolic BP <90mmHg or respiratory rate outside of the range 10-24 breaths per minute) (level five evidence)
- Urgent requirement to identify a cervical spine fracture (eg prior to surgery) (level five evidence)
- Severe neck pain (≥ 7/10 severity) (level four evidence)
- Patients with neck pain and <u>any</u> of the following high risk factors (level one evidence unless otherwise stated):
    - a fall from greater than one metre or five stairs
    - an axial load to the head eg diving
    - a high-speed motor vehicle collision (combined speed >60mph)
    - a rollover motor vehicle accident
    - ejection from a motor vehicle
    - an accident involving motorised recreational vehicles
    - a bicycle collision
    - age 65 years or more
    - injured more than 48 hours earlier (level five evidence)
    - re-attending with the same injury (level five evidence)
    - known vertebral disease (eg ankylosing spondylitis, rheumatoid arthritis, spinal stenosis, or previous cervical surgery) (level four evidence)
- Patients with a dangerous mechanism of injury (see above) <u>and</u> either a visible injury above the clavicles or a severely painful (≥ 7/10 severity) thoracic injury even if there is no neck pain or tenderness (level four evidence)

If <u>none</u> of the high risk factors above are present and <u>any</u> of the following low risk factors are identified then the patient can have their collar removed and their range of movement assessed (level one evidence):

- simple rear-end motor vehicle collision (but not if pushed into another vehicle, or if hit at high speed or by a large vehicle)
- sitting position in ED
- ambulatory at any time since injury
- delayed onset of neck pain (ie not immediate)
- absence of midline cervical spine tenderness

Patients stratified to a low risk category that can actively rotate their necks 45 degrees to the left and right should be considered to have had a "significant" cervical spine injury excluded without need for imaging. Patients that are unable to rotate their neck 45 degrees in both directions or report severe pain (≥ 7/10 severity) on doing so should have cervical spine imaging performed.

Appendix 3 - Indications for CT of the cervical spine

CT should be used as the primary imaging modality for excluding cervical spine injury in adults following blunt trauma if any of the following criteria are met:

- **GCS below 13 on initial assessment** (level two evidence)
- **Intubated patients** (level two evidence)
- **Inadequate plain film series** (level two evidence)
- **Suspicion or certainty of abnormality on plain film series*** (level two evidence)
- **Patient's being scanned for head injury or multi-region trauma** (level two evidence)
- **Patient has dementia** (or a chronic disability precluding accurate clinical assessment) (level five evidence)
- **Patient has new neurological signs or symptoms** (level two evidence)
- **Patient has severe neck pain (≥7/10 severity)** (level four evidence)
- **Patient has a significantly reduced range of neck movement** (level four evidence)
- **Patients with known vertebral disease** (eg ankylosing spondylitis, rheumatoid arthritis, spinal stenosis, or previous cervical surgery) (level four evidence)

**As a minimum the CT should cover the area from the cranio-cervical junction to the thoraco-cervical junction since selective scanning may miss injuries.*

Guidelines should be agreed with local radiologists as to the most appropriate primary imaging modality for patients aged ≥ 65 years.

Appendix 4 – "Insignificant" cervical spine fractures

Use of the clinical decision rule may lead to patients being discharged without imaging with the following "insignificant" cervical spine injuries:

- Isolated spinous process fracture not involving the lamina
- Isolated osteophyte fracture (not corner or teardrop fracture)
- Isolated transverse process fracture not involving the facet joint
- Simple vertebral compression fracture (<25% loss of height)