

Appendix 5

DATA EXTRACTION FOR PAPERS DESCRIBING RULES FOR DIAGNOSIS OF C-SPINE INJURY

Names and evidence level	Rule description	Participants	Outcomes and Gold standard	Specificity	Sensitivity	Investigation ordering rate	Prevalence	Derived using primary data	Derived using prospect. data	Validated using primary data	Validated using prospect. data	Multi-variate modelling	follow-up	Notes
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<p>Panacek et al¹ for NEXUS group (2001)</p> <p>Level 1 evidence</p> <p>Well conducted validation cohort study</p>	<p>Sub-study of NEXUS database to look at each of the 5 criteria identified in the NEXUS study</p> <p>None of the 5 criteria may safely be removed without missing significant Cervical spine injury.</p> <p>Absence of 5 criteria are identified that will classify the patient as low risk:</p> <p>No Midline cervical tenderness</p> <p>No focal neurologic deficit</p> <p>Normal alertness</p> <p>No intoxication</p> <p>No painful distracting injury</p>	<p>N=34,069</p> <p>All levels of alertness</p> <p>Symptomatic and asymptomatic</p> <p>Adults and children</p> <p>21 USA trauma centres</p> <p>Consecutive</p>	<p>Any C-spine fracture on plain radiography</p> <p>Significant C-spine fracture on plain radiography</p> <p>Gold standard: Results of plain radiography and absence of injury on follow up</p>	<p>12.9%</p> <p>C.I. 12.8% - 13.0%</p>	<p>99.6%</p> <p>C.I. 98.6% - 100%</p>	<p>87% of patients require 3 view imaging</p>	<p>818 (2.4%) patients had a cervical spine injury</p> <p>578 (1.7%) patients had a clinically significant cervical spine injury.</p>	<p>Yes</p>	<p>Yes</p>	<p>Yes</p>	<p>Yes</p>	<p>No</p>	<p>As for NEXUS study</p>	<p>Paper is a sub-study of NEXUS study further demonstrating that their 5 criteria are the optimal tool for detecting C-spine injury</p>
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Hoffman et al ² for NEXUS group (2000)	Prospective multi-centre observational cohort study	N=34,069 patients who underwent imaging	Findings as diagnosed after 3 view plain radiography (lateral view, antero-posterior and odontoid peg views) :	12.9% C.I. 12.8% - 13.0%	99.6% C.I. 98.6% - 100%	87% of patients require 3 view imaging	818 (2.4%) patients had a cervical spine injury	Yes	Yes	Yes	Yes	Yes	Records of all centres were reviewed to find any evidence of missed fractures in patients who had not been imaged.	557 plain radiographs had inadequate 3 view films Radiographs interpreted by a designated radiologist at each site
Hoffman et al ³ methodology of NEXUS study (1998)	Absence of 5 criteria are identified that will classify the patient as low risk:	Symptomatic and asymptomatic	Cervical spine injury				578 (1.7%) patients had a clinically significant cervical spine injury.						Power study performed – 737 cervical injuries to require confidence intervals of 0.5% or less. This study did not achieve this number in significant cervical spine injuries	
Level 1 evidence	No Midline cervical tenderness	All levels of alertness	Significant cervical spine injury										Of the two clinically significant missed fractures 1 had an extension-teardrop fracture and self discharged. He was well at 6 months 1 had fracture of right lamina of 6 th cervical vertebra requiring open fixation, but may have been incorrectly classified by the institution as he had LOC and neurology	
Well conducted multicentre validation cohort study	No focal neurologic deficit	Adults and children	Gold standard:										2 patients were categorised by rule as high risk but fractures were initially missed on plain radiography	
	No intoxication	21 USA hospitals	Results of plain radiography and absence of injury on follow up										Only 498 of the 818 cervical spine abnormalities were found by plain radiographs	
	No painful distracting injury	Consecutive											- Stiell et al investigated the NEXUS criteria in their population of 8924 patients and found 10 of 148 important injuries were missed giving a sensitivity of 93%	
													They also criticise the NEXUS rule for the poor reproducibility of ' presence of intoxication' and 'distracting painful injuries'	

Mower et al ⁴ for NEXUS group (2001)	436 missed injuries in 237 patients were in cases where plain radiography was abnormal or inadequate	N=34,069 patients who underwent imaging	Findings as diagnosed after 3 view plain radiography (lateral view, antero- posterior and odontoid peg views):	Not appropriate in this paper	Not appropriate in this paper	Not appropriate in this paper	23 patients had injuries that were not visualised on adequate plain film imaging including 3 potentially unstable injuries.	Yes	Yes	Yes	Yes	No	Records of all centres were reviewed to find any evidence of missed fractures in patients who had not been imaged.	Paper illustrating a major weakness in the NEXUS study	
Level 1 evidence		All levels of alertness	Cervical spine injury												
Well conducted study	But 23 patients were missed with adequate films	Symptomatic and asymptomatic	Significant cervical spine injury												
	Only 498 of the 818 cervical spine injuries were found on plain radiographs.	Adults and children	Gold standard:												
		21 USA hospitals	Results of plain radiography and absence of injury on follow up												
		Consecutive													

Hoffman et al ⁵ (1992)	Prospective exploratory cohort study	N=974	C-spine fracture on plain radiography	37.3%	100%	Rate with this rule would be 63%	2.7%	Yes	Yes	No	No	No	Hospital records of radiology reports were checked	26 incomplete records were excluded from analysis (no fractures in this group)
Level 2 evidence	4 factors were identified that could predict the presence of cervical fracture in alert patients:	All levels of alertness	Gold standard:	C.I. 34-40	C.I. 87-100		27 fractures						Risk management records of potential missed fractures were searched	1,342 c-spine films were taken during the study period, and there were 31 cervical fractures of which 27 were in this study. 2 of the missed C-spine fractures were not seen in A&E and 2 were not entered into the study- retrospectively reviewed and deemed to have one of the risk factors
Well conducted exploratory study	Midline neck tenderness	Adults and children	Results of plain radiography and absence of injury on follow up										All final discharge diagnoses were searched	Paper criticises itself in the discussion for low rate of C-spine fractures leading to wide confidence intervals. They suggest that their power study indicated a number of 7000 patients
	Evidence of intoxication	Single USA trauma centre												? How many views taken
	Altered level of alertness	Consecutive (but see notes)												no comment on quality of films or if C7/ T1 junction always visualised
	Severely painful injury elsewhere													He describes his intent to set up the NEXUS study
	No combinations of symptoms and signs predicted all C-spine injuries but altered level of alertness and midline tenderness identified 25 of 27 fractures													

Pollack et al (2001) ⁶ For NEXUS	Prospective multi-centre observational cohort study secondary analysis: to assess the utility of flexion extension views.	N=818 patients with a fracture All levels of alertness Symptomatic and asymptomatic	Cervical injury diagnosed on flexion Extension views that were not seen on plain imaging	Not relevant	Not relevant	86 of 818 patients with a fracture had F/E views	0.7% of 818 patients who had a Cervical spine injury had an injury seen only on the flexion extension views. 86 FE views had been requested in this group. All these (4) fractures were stable.	Yes	Yes	No	No	No	Hospital records of radiology reports were checked Risk management records of potential missed fractures were searched All final discharge diagnoses were searched	The number of negative F/E views performed in the whole population of 34,000 patients was not assessed 4 of 16 subluxations were also only seen on F/E views, but the plain imaging had other abnormalities that required imaging by CT / MRI which would therefore have resulted in their detection.
Level 2 evidence														
Well conducted observational study	Flexion/ Extension views should be delayed until 10-14 days after injury and MRI should be used to evaluate possible ligamentous instability	Adults and children 21 USA trauma centres This sub analysis is non-Consecutive in that it is only the fracture patients.	Gold standard: Results of all types of radiography and absence of injury on follow up											

Stiell et al' (2001)	Prospective derivation observational cohort study	N= 8924 patients who underwent imaging	Important cervical spine injury on 3 –view plain radiography (All injuries except: isolated avulsion fracture of an osteophyte, isolated fracture of a transverse process not involving a facet joint, isolated fracture of a spinous process not involving the lamina, compression fracture of less than 25% of the vertebral body height	42.5% C.I. 40%-44%	100% C.I. 98% - 100%	58.2% radiography rate would be achieved with this rule.	151 (1.7%) had clinically important Cervical spine injury. Also 28 unimportant injuries were found	Yes	Yes	No	No	Yes	All patients who did not have plain radiography underwent a 14-day proxy outcome measure interview by telephone. 577 could not be reached and were thus excluded from the study	3281 patients out of 12782 were examined by physicians at the study sites but not enrolled representing 25% of possible patients. These patients had a higher rate of C-spine injury (3.2% vs. 2.0%) The 4.5% of patients that were not traced by telephone were not further investigated. Coroner's records or the records of other hospitals could have been checked. If you assume that this group has the same incidence of fracture as the study cohort then 577 x 1.7% = 10 patients would have been missed. If the incidence was actually 10 times less than the cohort 1 patient would still have been missed.
Level 2 evidence	3 questions were derived for categorisation of patients:	Alert, GCS 15 and cardiovascular stability			In addition the rule would find 27 of the 28 unimportant cervical spine injuries									
- N.B. validation study is in press	1. This there any high risk factor present that mandates radiography: age >65, dangerous mechanism, or paraesthesia in the extremities?	Symptomatic and asymptomatic												
Well conducted derivation cohort study	2. Is there a low risk factor present that allows the safe assessment of range of motion (i.e. 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?	Adults over 16 years old 10 large community and university hospitals Consecutive												
	3. Is the patient able to actively rotate neck to 45 degrees to the left and right?		Gold standard: Results of plain radiography and absence of injury on follow up											

Roberge et al ⁸ (1988)	Prospective observational cohort study	N=467 All levels of alertness	Cervical spine injury Gold standard: 5 view cervical spine radiographs interpreted by radiographer, or positive follow up	45% C.I. 45%-50%	100% C.I. 55%-100%	Their rule would have resulted in an 89% ordering rate	8 out of 467 had cervical injury (1.7%)	Yes	Yes	No	No	No	All patients were seen in a follow up clinic	Well-conducted study but low number of positive patients has resulted in an underpowered conclusion.
Level 2 evidence Well conducted study	Alert trauma victims with no complaints of neck discomfort upon questioning and with no tenderness on neck palpation need not undergo Cervical Spine radiography.	Symptomatic and asymptomatic Adults over 16 years old Single USA level 1 trauma centre Consecutive												
Roth et al ⁹ (1994)	Prospective observational study.	N=682 96 Alert and Asymptomatic patients	Cervical spine injury Gold standard: All patients received plain 3 view imaging and follow up (see later)	11% (96/890)	100%	100% of patients were imaged in this study.	16 patients (2%)	Yes	Yes	No	No	No	43% were followed up and of those not followed up, none were readmitted. (This is the only hospital in a 2500 mile radius of Hawaii)	Small study number of alert asymptomatic patients bearing in mind the 2 % prevalence of positives.
Level 2 evidence Well conducted study	Rule Blunt trauma patients do not require cervical imaging if they have: Absence of mental status changes, intoxication, neck pain or tenderness, neurologic signs or symptoms, or simultaneous major distracting injury.	Presumed to be adults Single Hawaiian military hospital Consecutive												

Edwards et al ¹⁰ (2001)	Prospective observational cohort study	N=599 low risk patients out of a population of 1757	Cervical spine injury after 3 view radiography	31% (537/1719)	100%	69%	38 of 1757 (2.1%)	Yes	Yes	No	No	No	Follow up 3 to 6 months after discharge by clinic visit or telephone.	1/3 rd of the total population group was excluded from the low-risk study group from finding on history or examination. This group contained 50 % of cervical spine injuries.
Level 2 evidence	All patients with sub-optimal GCS or revised trauma score (RTS) should have a C-spine series and/or CT scan.	GCS >13											Success of follow up not stated	Success of follow-up not given.
Well conducted study	Low-risk group: Normal GCS, RTS, no distracting injuries, no abnormal laboratory investigations, no abnormal neurology on history and examination, no midline cervical tenderness – These patients do not need plain radiography.	Low risk group defined as no neurologic deficit, not intoxicated, no extremity injuries GCS >13 no abnormal lab tests, Adults and children	Gold standard: All patients had 3-view radiography. Selected CT Universal follow up											
		Consecutive												

Ptak et al ¹¹ (2001) Level 2 evidence Well conducted retrospective derivation cohort study	Retrospective cohort Screening Helical CT scanning is highly sensitive and specific in diagnosing clinically relevant fractures.	N= 676 Alertness and conscious level data not given Single USE trauma centre Consecutive	Fracture on helical CT scanning. A Helical CT scanning protocol was initiated for the identification of patients for scanning. Gold standard: Helical CT and Follow-up	100%	98.3	100%	60/676 (8.8%)	Yes	No	NO	NO	NO	Yes, there was note review of on ward progress	1 patient had a negative CT but had further neck pain and repeat imaging found an undisplaced type II fracture of the odontoid peg
Fischer et al ¹² (1984) Level 2 evidence	Retrospective cohort study Alert patients after head injury with class 1 level of consciousness but without signs or symptoms of cervical injury do not require cervical radiographic evaluation. Class 1 level of consciousness is defined as alert, responds immediately to questions may be disorientated and confused, but follows complex commands	N=333 with blunt head trauma Class 1 level of consciousness Symptomatic and asymptomatic Children and adults (22mths to 77yrs) Single USA hospital Consecutive	Cervical spine injury Gold standard: Cervical spine injury on plain radiographs or cervical injury on follow up	Not evaluated	Not evaluated	Not evaluated	5 of 333 had cervical injury (1.5%) all were symptomatic	Yes	No	No	No	No	3 year follow up of all patients	Note the protocol in their department was for C-spine imaging for all people with head injury that are admitted for observation. But only 68% of patients had this protocol followed in this study. The exact number of followed up patients were not described.

Macdonald et al ¹³ (1990)	Retrospective observational cohort study	N=775 patients post MVA.	Cervical injury on 3-view radiography	97%	83%	Not applicable	92 out of 775 (12%)	Yes	No	No	No	No	All patients are routinely followed up by neurosurgeons. Although they do not state the number of patients that were verified as asymptomatic.	Minimal clinical details were taken regarding the patient's history and examination even though 50% of these patients were GCS 15.
Level 2 evidence	Single lateral C-spine radiograph is not adequate to exclude cervical injury in patients after Motor Vehicle Accidents. Cervical clearance can be obtained by 3 view plain radiography, but there is still a 1 % chance of missing significant injury	All levels of alertness	Gold standard: Cervical injury on all radiography performed. And clinical follow up											
Well conducted study		Symptomatic and asymptomatic. Adults over 18 years old												
		Single USA regional trauma unit. Consecutive												
Gonzalez et al ¹⁴ (1999)	Prospective observational cohort study	N=2176	Results of clinical examination and lateral C-spine radiograph	82% (1765/2143)	91% (30/33)	18%	33 of 2176 (1.6%)	Yes	Yes	No	No	No	All patients admitted for 24 hours. Had repeat neck examination prior to discharge, and outpatient follow up was also performed.	32% of all lateral radiographs were inadequate and required further imaging
Level 2 evidence	Derived rule: Clinical examination of the neck can reliably rule out significant cervical injury in the awake and alert blunt trauma patient. The addition of a lateral Cervical spine X-ray is of no use. Elevated ethanol level is not a contraindication to this rule.	Symptomatic and asymptomatic. Adults over 14 years old	Gold Standard: Results of all imaging. Other investigations were only ordered if the lateral image was inadequate. Results of follow up											
Well conducted derivation cohort study		Single USA level 1 trauma centre. Consecutive												

Ross et al ¹⁵ (1992)	Prospective observational study	N=410	Cervical injury on 3 view plain radiography	49%	100%	51%	13 out of 410 (6%) had unstable injuries.	Yes	Yes	No	No	No	All patients were followed up for at least 2 weeks after discharge	Number of patients successfully followed up not stated
Level 2 evidence	Immediate radiographic investigation of the cervical spine is mandatory in all patients with: Loss or defect in conscious level, neurological deficit, neck tenderness.	All levels of consciousness	Gold standard: Positive radiological findings or positive findings at follow up	196/397	13/13									
Well conducted observational study	Imaging is not necessary in the absence of these signs.	Symptomatic and asymptomatic Adults and children over 12 years old Single USA trauma centre Consecutive												

Hanson et al ¹⁶ (2000)	Retrospective validation study	N=4285	C-spine fracture on helical CT	87%	92%	601 underwent helical CT the remainder had Plain radiography , 462 of 4146 direct presentations	47 of 4146	Yes	No – article states that rule derived by published and retrospective data	Yes	No – the discussion states that the extraction of clinical data from the notes was retrospective	No	Patient data was obtained retrospectively. No attempts at follow up of those not undergoing Helical CT are documented.	107 (23%) had helical CT without an indication by their criteria Abnormality rate in the low risk group was 0.2% (all low risk patients had plain imaging) 7 out of the 3684 who only had plain radiography had a cervical spine injury. But these patients were not followed up and no gold standard was applied to them to exclude a missed fracture. The additional fractures revealed by CT were 11 upper thoracic spine fractures 32 proximal rib fractures 12 skull base fractures 1 mandibular fracture and Hyoid fracture.
Level 3 evidence	Decision rule:	All levels of alertness												
No universally applied gold standard	High risk patients for Helical CT scanning:	Symptomatic and asymptomatic	Cervical Spine fracture on plain radiography											
	1. High-speed (>35mph combined impact) motor vehicle accident.	Adults over 16 years old												
	2. Crash with death at scene of motor vehicle accident	Single USA trauma centre												
	3. Fall from height > 3m	Consecutive												
	4. Significant closed head injury (of ICH on CT)													
	5. Neurologic symptoms or signs referred to the cervical spine.													
	6. Pelvic or multiple extremity fractures.													
	Note all patients receive plain radiography even if prior to Helical CT													
	Patients only has Helical CT if also undergoing Head CT													

Roberge et al ¹⁷ (1992)	Prospective observational study	N=480 All levels of alertness (considered separately) Symptomatic and Asymptomatic Adults over 16 years Single USA trauma centre Consecutive	Cervical spine injury Gold standard: Cervical spine injury as diagnosed by a radiologist after 5 view plain radiography	16% C.I. 13%-20%	93% C.I. 75% - 100%	100% received 5 view plain radiography (3 view plus oblique views)	17 had cervical spine injury (3.5%)	Yes	Yes	No	No	No	Discharged patients were scheduled for follow up by their own private physician or surgery clinic. Their good outcome was not verified by this study.	Underpowered study. Plain radiography but not follow up was used as gold standard
Bayless et al ¹⁸ (1989)	Retrospective observational cohort study	N=176 All levels of alertness Symptomatic and asymptomatic Adults and children over 12 years old Single USA county hospital Consecutive	Cervical spine injury on plain radiography Gold standard is injury on plain radiography or abnormality after 24 hours admission	70% (122/173)	100% (But only 3 cervical injuries found)	100% of patients received in this study Only 30% were symptomatic or non-alert.	3 cervical spine injury (1.7%)	Yes	No	No	No	No	All patients admitted for 24 hours Clinical records were reviewed to look for readmission	Only 3 fractures found in this study. No power study is presented and therefore the null findings are not supported by the authors statistical confidence in these findings.

Woodring et al ¹⁹ (1993)	Retrospective cohort study	N=216	Cervical spine injury	Not applicable	Not applicable	Not applicable	Plain radiography detected only 33% of fractures and 55% of subluxations on initial evaluation. 85% of the fractures were deemed to be present on the plain films retrospectively	Yes	No	No	No	No	No	Retrospective analysis of case notes to determine the presence of clinical symptoms and signs on presentation to the emergency department. However these 'asymptomatic' patients still had further imaging after plain radiography so there must have been clinical indications for these.
Level 3 evidence	Cervical radiography cannot be relied upon to determine the extent of cervical injury. High risk patients, and all those with positive or inconclusive plain films should all have CT scanning	87% were asymptomatic and alert	Method for identifying their cases not stated											
Non-consecutive study		Ages not stated	Gold standard: 100% of patients received lateral AP and odontoid views. 100% received CT scanning. Films assessed independently by two radiologists											

Harris et al ²⁰ (2000)	Prospective validation cohort study	N=153	Cervical injury	0%	100%	100%	Only 3 occult spinal injuries were found.	No – questionnaire survey of 550 surgeons in USA	No	Yes	Yes	No	All were inpatients. No outpatient follow up described	8 fluoroscopic evaluations could not clear the C7-T1 junction The study states that their protocol has not yet recruited enough patients to validate this protocol Therefore this paper is acknowledged to be underpowered
Level 3 evidence	Protocol for patients with polytrauma, closed head injury or distracting injuries:	Patients who could not be cleared due to altered sensorium, significant distracting injuries, or intubation.	Gold standard;			118 of 153 received intra-operative fluoroscopy								
This study acknowledges that it is under-powered	C-spine trauma series, lateral, AP, Dens. If normal: NO surgery indicated: Remain in collar until MRI performed. SURGERY indicated CT scan of C-spine. If C7-T1 junction not visualised: Fluoroscopic intra-operative stretch test, followed by F/E views if stretch test negative	Ages not stated? Adults only Single USA trauma centre												

Holliman et al ²¹ (1991)	Retrospective cohort study	N=148	Cervical fracture on lateral, odontoid peg and antero-posterior views	N/A	N/A	N/A	100%	Yes	No	No	No	No	None although all imaging and inpatients progress was collated	Small study only, no power study or confidence limits constructed to provide further evidence for not performing Antero-posterior radiography.
Level 3 evidence	No cases of cervical spine injury were found on the AP view without an obvious injury on either lateral or odontoid peg views.	All levels of alertness Symptoms not reported												
Non-consecutive study		Age 1-89 years Single USA level 1 trauma centre and a rehabilitation centre Non-consecutive	Gold standard: All images reviewed by a radiologist blinded to the original diagnosis											

Barba et al ²² (2001)	Retrospective observational cohort study	N=324	Cervical spine injury	N/A	N/A	N/A	15 cervical spine injuries (4.6%)	Yes	Yes – the EAST guidelines were used except for CT after Head CT.	Yes	No	No	Not described	6 patients had an injury detected only on CT scanning and not on plain radiography
Level 3 evidence	Rule;	All levels of alertness												
Non universal gold standard	Alert patients with no neurology, alcohol or distracting injury may have their C-spine cleared clinically	Symptomatic and asymptomatic	Gold standard: No uniform gold standard. Protocol was followed but negative results were not followed up											Out of 316 patients 7 % had C-spine cleared clinically, 45% cleared by 3- view radiography. (Although 30% of this group then needed CT to clarify poorly visualised areas) 47% had lateral radiography and CT
	Any patients not satisfying above criteria but not needing head Ct should have 3 view plain imaging and CT of any unclear areas	Adults only												This paper's main conclusions are that patients undergoing a Head CT should also have a C-spine CT and that this would save 17 minutes in assessment.
	Any persisting cervical pain should also have flexion- extension views	Single USA trauma centre												This paper is of little relevance to us
	Any further persisting pain or neurology should have MRI scan	Consecutive												
	All of the above is in accordance with the EAST protocol													
	In addition:													
	All those undergoing a Head CT should also have a full helical CT scan of the C-spine, and lateral plain radiography													
	Their conclusion is that CT scanning using their protocol saved 17 minutes in the clearance of the C-spine													

Davis et al ²³ (1993)	Retrospective case series.	N=740 patients with cervical injury	Missed cervical spine injury in admitted patients defined as diagnosis being made after cervical immobilisation had been removed (but prior to discharge)	Not appropriate for this type of study	Not appropriate for this type of study	Not appropriate for this type of study	34 of 740 cervical injuries had a delayed diagnosis (4.6%)	Yes	No	No	No	No	No- no search for readmission seems to have been done. No search for those who may have been discharged with missed injury has been done	This study describes the reasons for missed cervical spine fracture No rule described
Level 3 evidence	Of 34 missed fractures	All levels of alertness												
Non consecutive study of missed fractures	15 were due to inadequate imaging 16 were due to inadequate interpretation of films 1 had adequate films that were negative for injury 2 were of indeterminate cause	Symptomatic and asymptomatic Adults over 18 years old. 1 level 1 and 5 level 2, USA trauma centres. Non-consecutive. Cervical injuries were found on a database of admitted patients.	Gold standard: Discharge without missed fracture discovered in clinical records											

Link et al ^{24,25} (1994- in German) and (1995) Level 3 Non consecutive study	Study to evaluate the usefulness of routine CT of the cranio-cervical junction in unconscious patients with severe head injury. 28 patients had a C-1 or C-2 fracture, and 11 of these were missed on plain radiographs. Recommend CT of cranio-cervical junction in all patients with severe head trauma.	N=202 patients with substantial cranial trauma GCS 3-6 Without obvious symptoms indicating cervical trauma Age 3-86 Single German hospital Non-consecutive cohort	C1 or C2 fracture on CT Gold Standard : Fracture on CT. Images were reviewed by attending trauma team and radiologist then a second blinded radiologist reviewed the films	N/A	N/A	100% CT	18.3% atlas, axis or occipital condyle fractures.	Yes	Yes	No	No	No	None described	Unclear as to what percentage of patients had plain radiography.
Schroder et al ²⁶ (1995) Level 3 evidence Non consecutive study	Retrospective cohort study MRI is the investigation of choice after primary imaging except if the patient is undergoing CT for other reasons	N=39 Case mix unknown Ages unknown Single German hospital Non consecutive	Cervical injury on Ct or MRI scan Gold standard Results from CT or MRI only, follow up unknown	N/A	N/A	N/A	100%	Yes	No	NO	No	No	Unknown	CT found 100% of all osseous injuries but only 33% of longitudinal ligament injuries MRI identified all the soft tissue injuries but only 50% of C2 fractures, 89% of transverse process fractures, 92% of lamina fractures This paper is in German

Borock et al ²⁷ (1991)	Prospective observational cohort study	N=179 Alert	Cervical spine injury	Not applicable	Not applicable	100% CT for all inconclusive plain radiographs or continued symptoms	41 of	Yes	Yes	No	No	No	Not described	The conclusion that plain radiography does not find all cervical injuries is a legitimate conclusion, but the conclusion that CT scanning is 100% sensitive is unsound as CT scanning was the gold standard and no further follow up or imaging was universally applied or described.
Level 3 evidence	In patients symptomatic after negative plain radiography, or where radiographs are inconclusive, inadequate or suggestive of cervical injury, CT scanning is 100% sensitive at detecting cervical injury	Symptomatic Patients after plain radiography Adults and children Single level 1 trauma centre Non-Consecutive Only patients selected after plain radiography	Gold standard: Cervical injury on plain radiography or CT scan											
Non consecutive cohort study														

Kreipke et al ²⁸ (1989)	Prospective observational cohort study	N= 860 All levels of alertness	Cervical spine fracture	39% (324/836)	100%	Their ordering rate would be 62% with this rule.	24 out of 860 had fracture or dislocation (2.8%)	Yes	Yes	No	No	No	No	
Level 3 evidence Non-consecutive study	Cervical spine radiography should be performed in patients with abnormal neurologic findings or symptoms referable to the neck. In alert asymptomatic patients, cervical spine radiography may be omitted.	Symptomatic and asymptomatic Assumed to be Adults only Single USA level 1 trauma centre Non - Consecutive as the study is only of patients who were sent for radiography (criteria not detailed)	Gold standard: Findings on lateral, A-P, open mouth and Weir pillar views interpreted by one of the three radiologist authors of this paper.											
Jen et al ²⁹ (2001)	Retrospective Cohort study	N=604 Alertness and conscious level data not given Single USA trauma centre Non consecutive	Fracture of 4 view plain radiography Fracture on Helical CT Gold Standard: Fracture on Helical CT	Not given	33%	N/A	30/604 (5%) had a fracture Only 10 of these seen on plain films	Yes	No	No	No	No	None	Only 604 of 3684 patients undergoing plain radiography also underwent helical CT scanning. These patients were selected for the study.
Level 3 Evidence Non consecutive study	Plain radiography is less sensitive than helical CT scanning and should therefore be considered to be the standard modality in these cases													

Schnarkowski et al ³⁰ (1991) Level 3 evidence Non-consecutive	Retrospective cohort To rule out cervical injuries in patients with incomplete visualisation of the cervical spine, cervical CT should be performed in addition to 3 view radiographs	N=100 Unclear alertness or GCS Single German Hospital Non Consecutive	Fracture on Plain radiography or CT Gold standard CT of C-spine	Unclear	Unclear	Unclear	15/100 (15%) 3 of these were only found by CT	Yes	No	No	No	No	Unclear	This article is in German
Neifeld et al ³¹ (1988) Level 3 evidence No independent and universal gold standard	Prospective observational cohort study Rule: All patients with altered mental status, abnormal examination findings distracting injury, or pain or tenderness over the cervical spine need plain radiography. Asymptomatic patients or those with tenderness limited to the trapezius may be cleared clinically.	N=886 All levels of alertness Symptomatic and asymptomatic (244) Adults over 14 years old 4 Canadian Hospitals Consecutive	Cervical spine fracture or dislocation Gold standard: Cervical spine injury diagnosed by a radiologist after 5 view plain radiography.	19%	100%	All patients were radiographed in this study. Rule would require 73% plain radiography	28 out of 886 (3%)	Yes	Yes	No	No	No	No follow up but all patients got 5 view radiography	30 patients excluded due to incomplete datasheets

Baker et al ³² (1999) Level 4 evidence Case series	Case series of patients with cervical spine injury Findings Neck or neurological findings in conjunction with high risk mechanism identifies all cervical spine injury 3 view plain radiographs fails to detect all injuries.	N=72 All levels of alertness Asymptomatic and symptomatic Children aged 1 month to 15 years Single USA paediatric trauma centre. Non consecutive – positives only	Radiographically evident cervical spine injury (RESCI) Spinal cord injury without radiographic abnormality (SCIWORA) Defined as neurology with normal investigations Gold standard: None	Not possible with this study type	Not possible with this study type	Not relevant	Not possible with this study type	Yes	No	No	No	No	No	This paper is a case series of positive injuries only
Mcnamara et al ³³ (1990) Level 4 evidence Non-independent gold standard	Retrospective observational cohort study Rule: Alert non-intoxicated, asymptomatic victims of blunt trauma do not need plain radiography.	N=286 GCS 13-15 Symptomatic and asymptomatic (178) Adults only Single USA level II trauma centre Consecutive	Cervical spine fracture Gold standard: The radiologists interpretation of all cervical radiography or other diagnostic imaging	63% (178/281)	100%	Would require a 63% ordering rate	5 fractures (1.7%)	Yes	No	No	No	No	No follow up (see notes)	115 patients excluded due to poor documentation, Inadequate follow up 45% of the asymptomatic patients had any imagines and 37% of these were just single lateral c-spine views. Gold standard not applied to large number of patients Poor study

McNamara et al ³⁴ (1988)	Prospective observational cohort study	N= 351 All levels of alertness Symptomatic and asymptomatic Adults only 3 USA urban hospitals Non-Consecutive as physician participation was voluntary among those collecting the data	Cervical injury Gold Standard: Plain radiography and post discharge follow up.	No rule derived	No rule derived	No rule derived	7 cervical injuries (2%)	Yes	Yes	No	No	No	Followed up by phone or letter 58% successfully followed up	66 % of all discharged patients were pursuing litigation over accident. The authors stated that this severely limited their ability to identify further factors related to cervical injury. 446 patients met entry criteria but did not have radiography were not adequately followed up.
Bachulis et al ³⁵ (1987)	Retrospective review of a trauma database of 4941 patients and description of those with fracture	N=94 All levels of alertness Symptomatic and asymptomatic Adults only Single USA trauma database Consecutive	Fracture on plain films or follow up Gold standard: fracture on plain radiography or found after follow up	Not reported	99%	40%	94/1823 (5%)	Yes	Yes	No	No	No	No formal follow up as part of registry	One patient was missed who had his C6 fracture picked up 30 days later and needed surgery after this. No Gold standard No reported follow up mechanism

Williams et al ³⁶ (1992) Level 4 evidence Poor reference standards	Retrospective observational cohort study Trauma to the head, face or clavicles is not associated with higher rate of C-spine injury. GCS less than 14 is associated with an increased risk of injury No rule derived	N=5021 All levels of alertness Symptomatic and asymptomatic Age not stated Single USA level 1 trauma centre Consecutive	Cervical spine injury as coded by ICD-9 on database. Gold Standard: None	No rule	No rule	Not studied	227 had cervical spine injury (4.5%) GCS 14 and 15 – 3.9% GCS under 14 – 6.7% cervical spine injuries	Yes	No	No	No	No	No	Only 3915 patients had a GCS score recorded, with head injured patients more likely to have the GCS recorded on their database. Minor trauma patients who were not admitted were not included, as they are not entered into the database. Fatal victims were also included.
Jacobs et al ³⁷ (1986) Level 4 evidence Poorly applied gold standard	Prospective observational cohort study 9 factors predict C-spine injury: HISTORY: fall less than 10 feet is protective. EXAMINATION: Numbness, loss of sensation, Weakness. SIGNS: Neck spasm, Neck tenderness, loss of power, decreased sensation, loss of anal tone Any of these factors requires 3 view C-spine views.	N=233 All levels of alertness Symptomatic and asymptomatic Adults only Single USA trauma centre Consecutive	Cervical spine injury Gold standard: Minimum of lateral view and AP view – assessed independently by two radiologists.	Physicians can predict C-spine injury with specificity of 94%	Physicians can predict C-spine injury with sensitivity of 46%	73% of patients in this study received imaging	24 out of 233 had cervical spine injury (10.4%)	Yes	Yes	No	No	Yes	No follow up described. Of note only 73% received imaging	A quarter of patients did not have the gold standard applied.

Klein et al ³⁸ (1998) Level 4 evidence	Retrospective case series To compare MRI to CT scanning for Bony injuries	N=42 Patients with cervical fracture confirmed on CT scan	Posterior element cervical fracture	97%	Sensitivity 11.5%	100%	76%	Yes	No	No	No	No	No	No	Demonstrates that MRI misses 90% of posterior element fractures in the cervical spine
Non- consecutive Case series,	MRI is neither as sensitive nor as specific as CT scanning for bony abnormality.	Adults over 15 years Single USA level 1 trauma centre	Gold standard: CT scanning evaluated by 2 radiologists.												
		Non consecutive													
Benzel et al ³⁹ (1996)	Prospective observational cohort study.	N=174	Cervical soft tissue injuries on MRI	N/A	N/A	N/A	36% had soft tissue abnormaliti es. 1 patient had surgical fusion, 35 had a cervical collar for 1 month, and 27 had a Minerva jacket for 2 months.	Yes	Yes	No	No	No	No follow up of negative MRI patients to verify good outcome		No gold standard
Level 4 evidence	MR imaging is useful for early acute post-trauma assessment in a very select group of patients.	Patients with equivocal cervical spine plain imaging or positive physical examination.	Gold standard: None												
No gold standard to verify good outcome in MR pts		Adults only													
		Single USA university Hospital													
		Non- consecutive – selected group.													

Freemyer et al ⁴⁰ (1989)	Prospective observational cohort study	N=53 Level of alertness and symptoms not described Adults over 14 years old Single level 1 trauma centre Consecutive	Cervical spine injury on 5 –view cervical plain imaging Selected patients also had CT scanning Gold standard: Results of 5 –view image, as assessed by 2 radiologists No follow up	N/A	N/A	N/A	33 of 53 patients (62%) The two oblique views did not find any additional injuries	Yes	Yes	No	No	No	No follow up described in this paper	No application of a gold standard so there could have been injuries that were missed on both 3 and 5 view films.
Zabel et al ⁴¹ (1997)	Retrospective cohort study	N=353 GCS >13 Symptomatic and asymptomatic Adults over 15 years old. Single USA level 1 trauma centre Consecutive	Cervical injury on plain radiography Gold standard: None	58% for lateral radiograph	67% for lateral radiograph	42%	9 out of 353 (2.4%) had cervical injury, only 6 found on lateral C-spine	Yes	No	No	No	No	No follow up reported	379 out of a possible 1807 were deemed to be eligible for inclusion in the study Only 63% of lateral cervical spine radiographs were deemed adequate. Poor study due to lack of Gold standard or follow up so the absence of missed cervical injury cannot be excluded.

Ersoy et al ⁴² 1995	Retrospective cohort study	N=303 GCS 15	Cervical injury on plain X-ray	85%	100%	19%	13 out of 303 (5%)	Yes	No	No	No	No	None	They have not described what cervical radiographs are done in their department for suspected cervical injury. No follow up so unknown if there are any false negative plain radiographs. Poor study
Level 4 evidence Poor reference standards	In alert and stable patients, the presence of pain or tenderness on history or examination is adequate to select people for plain radiography	Symptomatic and asymptomatic Adults and children over 5 years old Single Turkish Hospital Consecutive	Gold standard: All plain X-rays were reviewed by a radiologist and a neurosurgeon, but types of plain X-rays not described and no follow up											
Saddison et al ⁴³ (1991)	Retrospective case series	N=79 Class 1 level of consciousness (alert, responds to questions, may be disorientated or confused)	Cervical spine injury on discharge diagnosis retrospectively found from hospital records. Gold standard:	N/A	N/A	N/A	100%	Yes	No	No	No	No	No	No discussion of how the diagnoses were made or if any patients were discharged with a missed diagnosis. Also no attempt to verify that the hospital discharge diagnosis was 100% accurate. Poor study
Level 4 evidence Small retrospective with poor reference standards	All alert patients with cervical injury can be detected by imaging only those with cervical pain or tenderness.	Symptomatic or asymptomatic Age range 10 to 84 years old Single USA medical centre Non consecutive	None											

Keenan et al ⁴⁴ (2001)	Irrelevant study. This study looks at the reduction of plain radiographs to clear the C-spine are ordered when a full CT of the C-spine is done. NO assessment of the sensitivities or specificities of each modality																			
Harris ⁴⁵ (1994)	This is a brief review (With 3 references)																			
Rosenberg ⁴⁶ (1994)	No original data in this article – case studies.																			
Kriss et al ⁴⁷ (1996)	This is a review																			
Maurice et al ⁴⁸ (1996)	This paper investigates the effects of implementing C-spine guidelines in a UK Emergency department In terms of X-ray requests Irrelevant to our review																			
Hoffman et al ⁴⁹ (1991)	This is a brief letter, with references to papers written by Hoffman, Mower et al																			
Emery et al ⁵⁰ (1989)	Study of MRI scanning after cervical injury. MRI scans were performed 10 days after injury on average and so this paper does not address guidelines for the initial triage of injured patients																			
Crim et al ⁵¹ (2001)	This is a review paper. However it is a comprehensive recent review with a treatment algorithm presented in the multi trauma patient.																			
Brillhart ⁵² (2000)	This is an abstract of the NEXUS study																			
Ghen et al ⁵³ (1992)	This is a sparsely referenced personal view on the investigations a patients with neck pain should undergo in the weeks after injury - irrelevant																			

The Utility of Flexion/Extension views

Names and evidence level	Rule description	Participants	Outcomes and Gold standard	Specificity	Sensitivity	Investigation ordering rate	Prevalence	Derived using primary data	Derived using prospect. Data	Validated using primary data	Validated using prospect. Data	Multi-variate modelling	Follow-up	Notes
Ralston et al ⁵⁴ (2001) Level 3 evidence Small study non-consecutive	Retrospective cohort study In patients with normal plain radiography, flexion Extension views are of limited value. In a subset of patients with suspicious findings on standard cervical spine views, Flexion Extension views are useful in ruling out ligamentous instability	N=129 patients who had undergone plain and F/E radiography No injury severity reported CHILDREN under 16 Single USA children's trauma hospital Non-consecutive	Cervical injury on plain (AP and lateral only) and Flexion Extension views Gold standard: Final diagnosis given by radiologist blinded to patients results, with all images available to him	N/A	N/A	N/A	83 of 129 (64%)	Yes	No	No	No	No	Not reported	F/E views had one false positive F/E views showed no abnormalities in 75 of 83 patients with suspicious plain radiography Note this study includes cervical strain, indeterminate plain radiography, cervical disc disease and SCIWORA in its group of positive final diagnoses. Only 3 fractures were found in this study!

Tehranzadeh et al ⁵⁵ (1994)	Retrospective cohort study	N=100	Cervical spine injury on CT	N/A	N/A	N/A	3 out of 100 had cervical injury	Yes	No	No	No	No	Article states that records were reviewed for any complaints referable to the spine, and the patients were contacted where possible	These 100 patients are 2.5% of patients who underwent plain radiography in this department in the study period.
Level 3 evidence	Patients who do not have their C7-T1 spine adequately cleared on plain radiography may safely undergo clearance by CT scanning	Patients after blunt injury and non-visualisation of C7-T1 on plain radiography who had a CT for this reason.	Gold standard											Follow up rate not reported
Non-consecutive study		Average age 36 years unclear as to whether any children included	CT scan performed in 100%											In a very small subset of patients the C7-T1 can be followed up safely
		Single USA hospital	Follow up performed											
		Non-consecutive												

Anglen et al ⁵⁶ (2001)	Retrospective cohort study	N=837 patients after Flexion Extension view radiographs	Cervical spine injury	Not applicable	Not applicable	Not applicable	4 patients with negative plain films and/or CT scanning had positive F/E views. 1 false positive, 1 lost to follow up 2 had good outcome with conservative Rx	Yes	No	No	No	No	No	1484 Flexion extension views were done at this institution. 407 were deemed inadequate 57 were missing 919 were negative
Level 4 evidence	Flexion Extension is not a useful part of a protocol for clearance of the cervical spine in the obtunded or comatose patient.	Extension view radiographs	Gold standard:											There were 39 positive reports but only 4 of these reports met the study inclusion criteria of coma, and negative other imaging.
Non-independent reference standards		Obtunded or comatose patients	No uniform gold standard applied. Only positive F/E results were followed up.											No confirmatory test was applied to those with negative F/E views and no follow up
		Ages not stated												
		Single USA trauma centre												
		Non consecutive												
Lewis et al ⁵⁷ (1991)	Retrospective cohort study	N=141	All Patients had F/E views performed after 3 view plain series	93%	99%	100%	11 out of 141 had cervical instability (8%) 4 of these not seen on plain views	Yes	No	No	No	No	No follow up protocol was described	No gold standard, No follow up protocol described
Level 4 evidence	No conclusion drawn. Authors call for larger study.	All levels of alertness	Gold standard:				1 false negative result							One patient with a negative F/E view went on to need cervical stabilising surgery.
Non-independent Gold standard	Flexion Extension found 4 patients who required surgical stabilisation who had normal plain radiography, but there was one false negative F/E view also	Adults only	None. Other radiological tests were performed at the discretion of the physician. No follow up											
		Single USA level 1 trauma centre												
		Non-consecutive – F/E views were ordered at physicians' discretion.												

Brady et al ⁵⁸ (1999) Level 4 evidence Non- consecutive study , without adequate gold standard	Retrospective cohort study Blunt trauma patients with abnormal static radiography are more likely to have abnormal dynamic radiography that requires stabilisation.	N=451 All levels of alertness Symptoms not reported Adults over 18 years old Single USA trauma centre Non consecutive	Cervical injury on lateral, AP, peg and flexion Extension views. Gold standard: None applied	N/A	N/A	N/A	79 out of 451 (17.5%) 2 patients with SCIWORA	Yes	No	No	No	No	None performed	No gold standard applied and authors acknowledge this deficiency and call for further larger studies with a universal gold standard
West et al ⁵⁹ (1997) Level 4 evidence Case-control study	Retrospective matched case control study Three-view radiography allows most readers to detect a few more fractures than a single view radiograph.	N=92 Patients with clinically proven cervical fractures	Cervical injury diagnosed on 1 and then 3 view radiography interpreted by 20 radiographer s of a variety of grades Gold standard for fracture was discharge diagnosis of cervical fracture	81.9% with 1 view 79.7% with 3 views	81% with 1 view, 83.3% with 3 views	100%	100%	Yes	No	No	No	No	No	This is a study that assesses 20 radiologists' ability to diagnose a known fracture on either 1 or 3 view radiographs.

Woods et al ⁶⁰ (1998) Level 4 evidence Non- consecutive study with inadequate gold standard	Retrospective study of paediatric flexion extension views There were no complications from the use of flexion- Extension views, and they were a useful addition to plain radiography.	N=133 All alert Symptoms or no symptoms Children 0- 16 Single USA centre Non Consecutive	Fracture on 3 view plain radiography or Flexion Extension views Gold standard: negative radiology and discharged	N/A	N/A	100%	0% fractures, 5% abnormal F-E views but all discharged home. 2 cases of SCIWORA	Yes	No	No	No	No	No	No positive cases found. This study has selective cases and is underpowered
Palmer et al ⁶¹ (1995)	This study looks at the effect of ATLS training in the implementation of cervical spine protocols. There is no derivation of a rule or validation.													
Mirvis et al ⁶² (1995)	This is a review article													
Clancy ⁶³ (1999)	This is a UK review article but is pre NEXUS and Stiell's work													

Treatment of the intubated or severely injured patient

Names and evidence level	Rule description	Participants	Outcomes and Gold standard	Specificity	Sensitivity	Investigatio n ordering rate	Prevalence	Derived using primary data	Derived using prospect. Data	Validated using primary data	Validated using prospect. Data	Multi- variate modelling	Follow-up	Notes
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Ajani et al ⁶⁴ (2002)	Prospective observational cohort study	N=100	Cervical spine injury	0%	100%	79 normal plain radiographs , 48 had passive flexion/extension views	6 out of 100 (6%) had unstable injuries	Unclear as to how protocol was devised, probably after literature review	Unclear	Yes	Yes	No	Follow up not described but presumably performed in this ICU unit	91 patients survived to complete evaluation. This protocol was assessed after it had been implemented for several years in this institution. Philadelphia collars remained in place for mean 65 hours (range 1.5 to 240 hours)
Level 1 evidence	All patients suffering major trauma should have 3-view plain radiography, swimmers views if further evaluation of C7-T1 is needed and CT and /or MRI for abnormal areas. Flexion/Extension views to exclude cervical spine instability due to soft tissue trauma were performed if clinical examination was not possible.	Patients admitted to the ICU after major trauma. Symptomatic and asymptomatic Adults over 15 years old Single Australian Intensive care unit. Consecutive	Gold standard: Abnormality after conduction of protocol. Presumably follow up also performed											
Well conducted validation cohort study – with the assumption that follow up was adequate						12 had active flexion/extension views 1 CT scan performed								
Schenarts et al ⁶⁵ (2001)	Prospective cohort study	N= 1356	Cervical injury	Not assessable	100% sensitivity of EAST guidelines	Not investigated	70 out of 1356 (5.2%)	EAST guidelines	EAST guidelines	Yes	Yes	No	No readmissions or lawsuits have been filed in the study population	Validates the EAST guidelines in patients with altered mental status The clinical history seems to have been gained from the hospital records and trauma registry and not prospectively collected on admission.
Level 1 evidence	Rule: The EAST guidelines identified all patients who had cervical injury	Altered mental status requiring CT scan of 2 or more body systems Age over 14 years old Single USA trauma centre Consecutive	Gold standard: All patients received 5 view plain radiography and CT scanning. Assessed by 2 radiologists.				32 of these were missed on plain radiography 3 were missed by CT but seen on plain films							
Well conducted validation cohort study														

Davis et al ⁶⁶ (2001)	Retrospective cohort study	N=301	Cervical injury as determined by fluoroscopy.	Not assessable	100% sensitivity of EAST guidelines	Not investigated	2 of 301 patients had cervical injury diagnosed on fluoroscopy. (0.7%) – both treated conservatively.	EAST guidelines	EAST guidelines	Yes	No	No	Neurological examination daily to discharge, post-mortem, and review of all notes 60 to 90 days after discharge.	Fluoroscopy was performed a mean 6 days after admission (SD +/- 0.2 days)
Level 1 evidence	The cervical spine may be cleared after a normal C-spine plain series and CT scanning according to EAST guidelines. Fluoroscopy is of little use and may be dangerous	GCS <13 for more than 48 hours.	Gold standard: All patients received 5 view plain radiographs, CT scanning and follow up				Also 1 false positive and 1 false negative.							This study provides evidence for the validation of the 1998 EAST protocol in the subset of moderate and severe head injuries.
Well conducted validation cohort study		Assumed to be adults only as mean age 34.												
		Single USA trauma centre.												
		Consecutive												

Brooks et al ⁶⁷ (2001)	Retrospective cohort validation study.	N=78 patients undergoing dynamic screening.	Cervical injury	Not applicable	Not applicable	Not applicable	5 of 78 (6%)	Not stated	Not stated	Yes	Yes	No	Patients seem to have been followed up to discharge or post mortem although 100% post mortem or follow up is not confirmed	Plain radiographs would have missed 30% of fractures
Level 2 evidence	All patients remaining unconscious or clinically inaccessible for >24 hours the following should be performed:	Unconscious or intubated trauma patients.	Gold standard:											
Well conducted but small study.	AP and Lateral films of the cervical, thoracic and lumbar spine	Age range 11 to 90 years old	Results of all imaging or of neck examination on recovery or post mortem											
	CT scan of C1/C2 and no peg views obtained.	Single UK hospital												
	Dynamic flexion and extension views of the cervical spine performed under image intensification by a trauma consultant.	Consecutive												

Davies et al ⁸⁸ (1995) Level 2 evidence Well conducted cohort study	Prospective cohort study of dynamic fluoroscopy in obtunded patients. Dynamic fluoroscopy can safely clear the C-spine in the obtunded patient.	N=116 Obtunded patients, GCS <13 Adults only Single USA trauma centre Consecutive	Fracture on fluoroscopy or 3 view radiography Gold standard: Fracture on any imaging or on follow up	N/A	N/A	100%	No missed clinically significant fractures	Yes	Yes	No	No	NO	Yes	Decubitus ulcers were common and occurred in 44% of patients, due to the collar remaining in place for long periods.
Albrecht et al ⁸⁹ (2001) Level 2 evidence Well conducted cohort study	Retrospective review of patients receiving MRI scanning in ICU MRI provides a safe and risk free method for clearing the cervical spine in obtunded patients in ICU	N=150 Obtunded patients only Adults only Single USA trauma centre Consecutive	Fracture on radiography Gold standard: Fracture on MRI scanning or follow up	N/A	N/A	100%	41/150 (27%) Only those who had no fracture on plain radiography had MRI, none of these had a fracture	Yes	No	No	No	No	Notes were reviewed for follow up	Of the 108 patients with negative plain radiography who went on to have MRI, only 21 had a normal MRI allowing removal of the collar.

<p>Berne et al⁷⁰ (1999)</p> <p>Level 2 evidence</p> <p>Small but well conducted study</p>	<p>Prospective observational cohort study</p> <p>In patients who cannot have their C-spine evaluated due to the following: Head injury, shock, alcohol, illicit drugs, or sedated/paralysed for ventilation, who are admitted to the ICU and are undergoing CT of other body systems:</p> <p>Helical CT scanning is superior to plain radiography in clearing the cervical spine.</p>	<p>N=58</p> <p>Patients admitted to ICU, C-spine unable to evaluate clinically</p> <p>Adults over 17 years old</p> <p>Single level 1 trauma centre</p> <p>Consecutive</p>	<p>Cervical spine injury</p> <p>Gold standard</p> <p>All patients had 3- view C-spine radiography and Helical CT</p>	<p>Plain radiographs : specificity 100: %</p> <p>CT specificity: 100%</p>	<p>Plain radiographs: sensitivity: 60%</p> <p>CT sensitivity: 90%</p>	<p>100% CT and plain radiographs recommended</p>	<p>20 of 58 (34%)</p>	<p>Yes</p>	<p>Yes</p>	<p>No</p>	<p>No</p>	<p>No</p>	<p>Not described</p>	<p>Small study</p> <p>Of 67 eligible for the study, 9 did not get the radiographic studies as stated in the protocol</p>
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Holly et al ⁷¹ (2002)	Retrospective cohort study	N=447	Cervical spine injury	Not done	Not done	Not done	24 of 447 patients (5.4%)	Yes	No	No	No	No	Results of GOS reported for those with cervical fracture but follow up not described	Study is of limited relevance to us
Level 3 evidence	Patients with moderate to severe head injury are at increased risk of cervical fracture and should have full plain radiography with CT and Flexion/extensions views and necessary.	Patients with moderate or severe head injuries. GCS 3-12 or >12 with abnormal head CT	GCS Glasgow outcome score											
Non-consecutive study		Symptomatic patients 2 level 1 trauma centres Non-consecutive	Gold standard: ICD coding of spinal injury											
D'Alise et al ⁷² (1999)	Prospective observational cohort study	N=121	Cervical injury on MRI scanning	N/A	N/A	N/A	31 of 121 (25%) had significant injuries not seen on plain radiography, 8 required surgery	Yes	Yes	No	No	No	None reported	No follow up was reported so that there was no attempt to verify that the MRI scan did not miss any injuries
Level 3 evidence	Using MR imaging in obtunded or intubated patients allows clearance of the cervical spine.	Patients all intubated due to head or multi-system injury	Gold standard:											
Non consecutive study		Adults and children Single USA trauma centre Non consecutive	None – MRI was used in 100% of cases and selected suspicious cases also had a CT. No follow up											

Katzberg et al ⁷³ (1999)	Prospective cohort study	N=199	Cervical injury	N/A	N/A	N/A	58 out of 199 patients (34%)	Yes	Yes	No	No	No	Not stated	No decision rule given. This is a study looking at the ability of MR scan to detect additional images to CT scanning
Level 3 evidence	MRI scans can more accurately detect a wide range of neck injuries compared to conventional CT	All levels of alertness	Gold standard:											
Non consecutive study		Symptoms not stated	CT and MRI in all patients											
		Adults and children over 9 years												
		Non consecutive												
Cohn et al ⁷⁴ (1991)	Prospective cohort study	N=60	Fracture on radiography	N/A	N/A	N/A	7/60	Yes	Yes	No	No	No	NO	
Level 3 evidence	Lateral C-spine films are falsely reassuring and methods for intubation should treat the spine as unstable until 3 view clearance.	Intubated or multiply injured patients	Gold standard: all patients had 3 view plain radiography and also other investigations at the clinician's discretion				Lateral C-spine films missed 3 of these injuries							
Non-consistent gold standard		Adults and children												
		Single USA trauma centre												
		Consecutive												

Jelly et al ⁷⁵ (2000) Level 3 evidence Non-consecutive study	Prospective observational cohort study Routine CT of intubated and ventilated patients after blunt trauma can detect occult fractures of the cervico-thoracic junction, missed by plain radiography.	N=73 Intubated and ventilated at the site of injury Adults and children 2-94 years Single UK hospital Non-Consecutive	Cervical spine injury on 3 view radiography (lateral and 2 oblique views) And spiral CT scanning of C6 to T2	N/A	N/A	N/A	20 out of 73 (27%) 12 were of cervico-thoracic junction. 5 seen by plain radiography.	Yes	Yes	No	No	No	No	Only 73 of 204 trauma patients attending their unit were studied, as only 73 had both CT and plain radiography. Only 25 of 73 radiographs visualised C7-T1 space. Most of the fractures detected were not significant.
Gerrelts et al ⁷⁶ (1991) Level 4 evidence Non-independent Gold standard (patients received CT on basis of plain radiography and clinical opinion)	Retrospective observational cohort study In patients after severe blunt trauma plain radiography alone is not adequate to exclude spinal injury.	N=1331 Severe blunt injury patients all levels of alertness Symptomatic Adults over 17 years old Single USA level 1 trauma centre. Consecutive	Cervical injury on 5 view radiography Delayed Diagnosis of cervical injury after negative complete C-spine series. Gold standard: All patients received 5 film plain views, and selective CT and MRI scans done. Final results diagnosed by the author – radiologist.	Not reported	Sensitivity of plain radiography 85.2% in the group that had fractures	No rule	61 out of 1331 (4.6%) 5 had delayed recognition of injury	Yes	No	No	No	No	None described	Cervical spine injury was missed in 5 patients by plain radiography. All were due to incomplete or inadequate plain radiography

Nunez et al ⁷⁷ (1996)	Retrospective case series	N=88 Patients who had a cervical fracture, plain radiography and helical CT	Cervical injury on 3 – view radiography and on helical CT	N/A	N/A	N/A	32 out of 88 (36%)	Yes	No	NO	NO	No	Clinical follow up to 4 months	Small case series
Level 4 evidence.	Helical CT can demonstrate cervical injuries not shown by plain radiography in polytrauma victims	GCS and symptoms not reported Age not reported Single USA trauma centre Non consecutive - Selected at random.	Gold standard: Images all independently reviewed and 4 month follow up also available				Had injuries missed by plain radiography							

Malomo et al ⁷⁸ (1995)	Retrospective Cohort study	N=457	Cervical spine injury on 5-view radiography.	N/A	N/A	N/A	76 out of 457 (17%)	Yes	No	No	No	No	None described	31 of the 76 spine injuries were unexpected clinically. No follow up to verify the absence of injury in these patients
Level 4 evidence	Cervical Radiography should be performed on all patients after head injury associated with loss of consciousness who are above 10 years old.	Patients following Head injury with at least Loss of consciousness	Gold standard. 5 view radiography. No follow up no other imaging											
Poor reference standards		All age groups												
		Single Nigerian University Hospital												
		Consecutive												
Kirshenbaum et al ⁷⁹ (1990)	Retrospective case series	N=53	Cervical injury on 3-view plain radiography or CT.	N/A	N/A	N/A	7 out of 53 patients had cervical injury detected on CT that were not visible on plain radiography	Yes	No	No	No	No	No follow up described	3 of these positive cases were an individual case series that stimulated the authors to conduct a study on the next 50 patients having Head CT after head injury with a severity determined by the admitting physician. Cervical CT is the test diagnostic tool but also the gold standard, as no follow up was done to exclude missed injury by CT
Level 4 evidence	Routine CT of the upper cervical vertebrae should be routinely performed in all patients with significant head injury.	Patients after significant head injury	Gold standard: Cervical CT scanning											
Inadequate reference standards		No symptomatic status reported												
		Age not stated	No follow up											
		Single USA trauma centre												
		Non-consecutive												

Sees et al ⁸⁰ (1998)	Retrospective case series	N=20	Cervical spine injury	N/A	N/A	N/A	1 patient had a cervical injury	Yes	No	No	No	No	No	Very small study
Level 4 evidence	Fluoroscopy in obtunded patients is a safe procedure and easy to perform. In addition it may give reassurance that no cervical injury is present	Obtunded trauma patients admitted to an intensive care unit who had fluoroscopy	Gold standard: Patients had a range of CT, and clinical examinations, all had 3 view radiography											
Small retrospective non consecutive study		Age 40 +/- 3.6 years												
		Single USA army medical centre												
		Non consecutive												
Hindman et al ⁸¹ (1998)	This paper is a review of Cervical Clearance in obtunded patients, advocating MRI followed by Dynamic Fluoroscopy													

The Paediatric patient

Names and evidence level	Rule description	Participants	Outcomes and Gold standard	Specificity	Sensitivity	Investigation ordering rate	Prevalence	Derived using primary data	Derived using prospect. Data	Validated using primary data	Validated using prospect. Data	Multi-variate modelling	Follow-up	Notes
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Laham et al ⁹² (1994) Level 3 evidence Retrospective study, with no universally applied gold standard.	Cervical spine X-rays are only indicated in high risk paediatric patients with a head injury who either complains of neck pain or cannot voice such complaints because of significant head injury or preverbal age.	N=268 Children with significant head injury defined as one with clinical and radiographic evidence on CT. Symptomatic and asymptomatic Children 0-19 years old Single USA children's hospital intensive care unit. Consecutive patient that were admitted to the PICU.	Cervical injury on 3 view radiography Gold standard: 3-view radiography only (only 80% of children received this) No follow up	52%	100%	48%	10 out of 268 (3.7%)	Yes	No	No	No	No	No	The entry criteria of: significant head injury needing admission was made at the discretion of the PICU triage officer. GCS was not consistently recorded in these children 215 children had cervical radiographs (80%)
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Schwartz et al ⁹³ (1997)	Retrospective case series	N=did not state how many patient's charts were reviewed – total of 44 centre-years of notes were searched	ICD-9 codes for cervical vertebral injury, cervical cord injuries and cervical vertebra and cord injury were considered as positive	Not appropriate for this type of study	Not appropriate for this type of study	Not appropriate for this type of study	8 children were found with cervical spine injury after a fall from a low height	Yes	No	NO	No	No	No	This is a large case series
Level 4 evidence	Radiographic investigation is not necessary in asymptomatic children under 6 after a short fall.	All levels of alertness	Symptomatic and asymptomatic Children younger than 6 years old	Gold Standard: No gold standard applied to exclude injury.										33 children with cervical spine injury were excluded from the study as they did not meet the criteria for mechanism of injury
Case series		4 USA hospitals	Non-consecutive – all patients with injury were looked for but only positive cases were studied											This study is of little value

Dietrich et al ⁸⁴ (1991)	Retrospective case series	N=50 patients with cervical fracture	Cervical spine injury as documented in hospital medical records	Not applicable	Not applicable	Not applicable	100%	Yes	No	No	No	No	No	83% of children had no neurology on initial physical examination Lateral Cervical spine radiograph identified 98% of children
Level 4 evidence	All children with neck pain or tenderness need full radiographic evaluation of their cervical spine	All levels of alertness												
Case series		Symptomatic and asymptomatic	Gold Standard None											
		Children, aged 2 to 19 years old												
		Single USA children's Hospital												
		Non-consecutive.												

Dwek et al ⁸⁵ (2000)	Retrospective cohort study	N=247 patients who had plain radiography and flexion / extension views	Cervical injury on 3 view radiography (no peg view in under 4 year olds)	N/A	N/A	N/A	23 or 247 (9%)	Yes	No	No	No	No	The notes were reviewed of each admission to look of any missed injury. No outpatient follow up done	4 patients with questionable findings on plain radiography had their spine cleared on flexion / Extension views. Other than this no useful information was gained from F/E views. There was no gold standard applied to the Flexion/Extension views or to the plain views so the true number of false negatives is not known unless progress until discharge is an acceptable gold standard.
Level 4 evidence	In children with a history of trauma and normal findings on cervical spine radiographs, additional flexion-extension radiographs are of questionable value.	All levels of alertness – 775 normal GCS	Or on F/E views				All of these found on plain radiographs.							
No gold standard applied		Symptomatic and asymptomatic	Gold standard: Abnormal results of radiography or abnormality recorded in the notes while admitted											
		CHILDREN ONLY, under 18years old												
		Single USA trauma centre												
		Non-consecutive												

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