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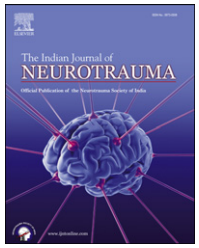

Neurotrauma Oration-Focused Review

Cervical spine clearance in trauma patients

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1. Introduction

Injuries to the cervical spine occur in approximately 4% of trauma patients, including 8% of patients who are unconscious or obtunded, and 3% of alert trauma presentations.[1] Failure in detecting cervical spine injury in an efficient and timely manner in the acute clinical setting can result in catastrophic consequences involving permanent neurologic sequelae. As a result, clinical assessment and radiographic screening protocols exist in order to expedite the identification of primary cervical spine injury promptly, and to protect the patient against secondary injury which may have the potential to compromise spinal integrity. The presence of cervical spine injury is frequently demonstrated by the existence of neurologic deficit or via positive radiographic findings. However, in other cases, where there is no evidence of fracture or malalignment, or when the patient is unable to contribute to clinical assessment due to decreased mentation, the signs and symptoms of cervical spine injury may be subtle.

While initial clinical assessment is generally conducted using one of the most commonly used evidence-based decision rules, the National Emergency X-radiography Utilisation Study (NEXUS) criteria,[2–4] the Canadian C-spine Rule (CCR)[5,6] or the Harborview Criteria,[7] there is continuing debate about the optimal radiographic imaging protocol when clinical clearance alone, according to these assessment criteria, is not possible. Randomised controlled trials have not been conducted to compare imaging strategies for cervical spine clearance due to ethical considerations regarding patient safety in these patient populations,[8,9] and as such, current protocols are informed by observational studies, of which few are prospective cohort studies. This narrative review seeks to provide a brief commentary on the current evidence in cervical spine clearance.

2. Plain X-radiography vs CT imaging

The rapid technological advancements in computed tomography (CT) have resulted in vastly improved imaging quality and reduction in artefact in comparison with plain X-ray. Increased sensitivity by using CT imaging as an adjunct to plain radiography for visualisation of the craniocervical and cervicothoracic junctions, or for areas suspicious for injury on plain films, have been reported by several authors.[10–13] Recently, studies comparing the NEXUS and CCR criteria with CT findings have suggested that clinical examination alone is inadequate to exclude cervical spine fractures, and that CT should be used instead of plain X-ray as first-line imaging.[14,15] Plain imaging has consistently been discredited as being inefficient for the detection of acute, traumatic cervical spine injury due to issues such as suboptimal image quality, incorrect interpretation by clinicians, and inadequacy of imaging as a result of patient obesity, large body habitus or the attainment of incomplete views of the entire cervical spine from the skull base to T1.[16–20] This modality has been reported to have missed 72% of fractures in a prospective study of 1577 patients who were unable to be cleared of injury clinically and had undergone plain five-view X-rays and helical CT.[21] In a further prospective study of 1505 blunt trauma patients, Bailitz et al[20] found that plain three-view imaging resulted in missed clinically significant injury in 64% of patients with at least one NEXUS criterion present, and concluded that CT should replace plain radiography

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regardless of whether the patient was deemed at high or low risk of injury. Such issues suggest that plain X-rays should only be used in geographical areas where CT scanning may not be available, or in children where exposure to unnecessary ionising radiation is not recommended.[22]

The utilisation of CT scanning as first-line imaging for the evaluation of suspected cervical spine injury has become accepted practice and has been shown to be cost effective and efficient, particularly for patients at high and moderate risk of injury.[23] CT images are able to be obtained rapidly, the service is readily available in trauma centres and other institutions, and cervical spine CT can easily be conducted concurrently with CT of the brain[24] or areas of suspected injury. In alert patients for whom clinical cervical spine clearance is not possible, CT has now generally been accepted as the optimal initial radiographic modality to assess for fracture in preference to plain imaging,[25] and is now recommended by the Eastern Association for the Surgery of Trauma (EAST)[26] and the American College of Radiology, which has recently published the 2012 ACR Appropriateness Criteria for Suspected Spine Trauma, based on assessment of the methodologies and findings in 87 published studies.[27] However, the American College of Surgeons, in the most recent Advanced Trauma Life Support Spine and Spinal Cord Trauma guideline in 2008,[28] continues to recommend three-view plain films with targeted axial CT imaging for areas of suspected injury, or if the entire cervical spine is not able to be visualised on plain imaging.

The two main areas of current controversy in cervical spine clearance relate to the adequacy of CT imaging for definitive cervical spine clearance in unconscious or obtunded patients, and in alert patients with persisting midline cervical tenderness.

3. Cervical spine clearance in unconscious patients

The risk of cervical spine instability in obtunded patients is estimated at 2.5% if adequate CT imaging (including sagittal and axial reformats from the occiput to the first thoracic vertebral body) is found to be negative in the absence of neurologic deficit.[29] However, while CT is the most reliable imaging modality for the evaluation of osseous injury, diagnostic issues arise in the assessment of patients unable to contribute to clinical assessment, and in whom CT imaging is unremarkable. In the absence of fracture, subluxation or malalignment, which may suggest the potential for associated non-osseous injury, the ability of CT imaging to detect injury to cervical discs, ligaments and associated soft tissue structures is considered to be limited.[21]

Whilst dynamic flexion-extension fluoroscopy has the potential to be an effective modality for the assessment of spinal stability, the modality has been found to be inadequate in a significant proportion of cases.[30,31] The risks associated with extension of injury during passive manoeuvring of the neck in the obtunded patient has led to the refusal to comply by many radiologists,[21] and adverse outcomes have been reported in patients with altered mental status.[32] This imaging modality has also been found to be ineffective in comparison with CT for the detection of instability in this population,[31] and hence cost ineffective.[33,34] In a study conducted by Padayachee et al,[31] there were no new injuries detected on dynamic flexion-extension fluoroscopy in 276 unconscious patients, which had not been detected on prior CT imaging. The inclusion of flexion-extension radiography in the spinal clearance process had also delayed cervical spine clearance, predisposing patients to the increased morbidity associated with the immobilisation of the cervical spine. The American College of Radiologists no longer recommends passive flexion-extension in unevaluable patients.[27]

Whether magnetic resonance imaging (MRI) is necessary to clear the cervical spine in unconscious or obtunded patients is debated, and the risks of failing to detect an injury must be weighed against the risks of secondary brain injury, morbidity due to prolonged immobilisation and the risks associated with transportation to MRI facilities.[29,35,36] Several studies suggest that cervical spine MRI should be routinely included in the assessment of obtunded patients[37–41] while other authors consider the additional imaging to be unnecessary.[42–47] Despite the debate, the published evidence provides essential information on the types and severity of injury undetectable on CT imaging, taking into account the fact that these patients are more severely injured than alert patients and are unable to communicate the presence of pain or sensory deficit.

To assess the ability of CT to detect isolated ligamentous injury, D'Alise et al[48] prospectively assessed 121 blunt trauma patients with altered mental status who underwent cervical spine MRI, with CT used if injury was evident on MRI. The authors subsequently found that there were 25% of patients with serious soft-tissue injury and 5% required operative management. Negative MRI findings led to flexion/extension views. The authors concluded that MRI as a primary cervical spine assessment tool allows soft tissue injuries to be identified early, and limits exposure to ionising radiation from CT imaging. However, this study did not compare CT and MRI in all patients and therefore could not determine the value of CT compared with MRI.[9] Schoenwaelder et al[45] found that while 10/55 unconscious trauma patients with normal single slice CT imaging had injury detected on MRI in a retrospective review, the injuries were minor and clinical management was not required. Similarly, in a further prospective study of 115 obtunded blunt trauma patients with negative 4 or 16 slice CT, Como et al found that injury was detected on MRI in 5.2% of cases, none of which required treatment.[43]

In a prospective study aimed at determining the value of MRI for cervical spine clearance, Benzel et al studied a group of 174 patients with cervical spine injury initially detected on plain X-ray or suggested on clinical examination. Subsequent soft tissue injury was detected on MRI in 36% of patients, two of whom required operative management.[49] Of the 36%, only two patients were diagnosed with cervical spine fracture on subsequent CT imaging. In the authors' opinion, plain radiography and CT scanning would not have detected these occult discoligamentous injuries, and although the majority of discoligamentous injuries were minor, significant injury may be detected, and remains a potential risk to cervical spine integrity.[9,49]

Two further studies of similar study populations reached opposing conclusions. Hogan et al[44] retrospectively reviewed the cases of 366 obtunded patients who had negative 4 or 16 slice CT, and subsequent MRI. Positive results were evident in 12 patients (3%), of whom 7 had high cord signal intensity. This abnormality, however, was suspected by the authors to have resulted from chronic myelomalacia due to degenerative disc disease. The remaining ligamentous injuries were single column injuries. According to the authors, cervical spine clearance was safe and effective with multislice CT imaging in this group of patients.[44] Conversely, Menaker et al,[38] performed a retrospective review of 203 unevaluable patients (GCS $\leq$ 14) who had negative 16 slice CT imaging and subsequent MRI. There were 16/18 patients with abnormal MRI findings who were clinically managed, two of whom had operative procedures for ligamentous injury and cord contusion respectively. The authors concluded that MRI should be used routinely for cervical spine clearance in patients who are unable to participate in clinical assessment. Further work conducted by Menaker et al[41] found that 15.6% of a study subset of 96 unreliable patients had injury detected on MRI after negative 40 slice CT imaging, including spinal cord compression requiring operative management. The authors concluded that modern, multislice CT imaging was still inadequate for definitive spinal clearance in patients unable to be clinically assessed.

However, in a recent, carefully designed meta-analysis aimed at assessing the effectiveness of multislice CT imaging for cervical spine clearance in obtunded or intubated patients, Panczykowski et al[36] concluded that additional imaging was unnecessary when multislice CT imaging was negative for unstable injury. According to the authors' definition, instability requires orthotic or operative stabilisation for fracture at adjacent levels or spinal columns, osseous malalignment or single level, three-column ligamentous injury. The meta-analysis of 7 prospective and 10 retrospective cohort studies comprising 12,754 patients with negative CT imaging had revealed only 3 unstable injuries, including atlanto-occipital dislocation treated in a halothoracic brace and 2 cases of single level subluxation managed in cervical collars. Despite the negative CT imaging reports, these injuries had been evident on plain X-rays and the authors surmised that inadequate scans or human reporting error had led to the missed injuries on CT imaging.[36] This meta-analysis highlights an additional pertinent point: the significance of the injuries detected using additional modalities following negative CT findings must be considered when interpreting the findings. There were no reported instances of delayed neurologic sequelae in the 12,754 patients, and the authors suggested that the complications from prolonged cervical spine immobilisation occur at a much higher rate than cervical injury, and therefore pose a much greater risk to morbidity.

Serious secondary neurologic deficit, although rarely reported in unconscious patients when adequate CT imaging has been conducted, can be catastrophic. As a result, future research must focus on the clinical or radiographic characteristics associated with progression to injury of this severity, in order to apply additional imaging practices to the patients most at risk, while mitigating the complications and risks associated with conducting MRI in the remaining patients.

4. Cervical spine clearance in alert patients

Alert, asymptomatic patients with negative acute CT findings are able to be safely cleared of injury.[26,27] Regardless of radiographic findings, abnormal motor or sensory deficit should lead to further imaging with MRI. Likewise, alert patients with persisting neck pain or midline tenderness despite negative acute CT findings should be considered as clinically suspicious for ligamentous injury.[37,50] Flexion-extension radiography has been used to exclude ligamentous injury in alert patients, and has been described as safe and effective in terms of stability assessment,[10] but has also been reported as inefficient[51–53] and cost-ineffective[54,55] in terms of overall injury identification. This modality was used more frequently in the acute setting prior to the availability of multislice CT,[56,57] and now is most commonly used in the post-acute setting for the follow-up assessment of patients with enduring symptoms.[25]

The evidence available regarding the detection of occult injury on MRI in alert patients generally pertains to patients with self-reported neck pain, neurologic deficit or post-acute MRI, conducted weeks to months after the incident trauma.[47,58,59] There have been several pertinent studies conducted in patients with self-reported neck pain. In a prospective group of 93 alert patients without neurologic deficit and with normal CT findings, Schuster et al[47] found that there were no patients with clinically significant injury detected on subsequent MRI. These findings concurred with those of Borchgrevink et al[60] who also found a dearth of acute pathology in a group of 40 alert trauma patients with neck pain in a prospective study aimed at the assessment of occult spinal cord injury in trauma patients with 'neck sprain.' Conversely, in a prospective cohort study of 178 alert and neurologically intact trauma patients with negative CT findings and persistent midline tenderness, we recently found that MRI-detected injury requiring clinical management was present in 21% of the cohort.[61] We concluded, however, that in particular, advanced degenerative disease detected on CT was a statistically significant risk factor for occult discoligamentous injury, and as such, these patients required MRI prior to spinal clearance.

Further studies have also reported MRI-detected injury in alert patients. Sarani et al[39] suggested that MRI should be used for cervical spine clearance in patients with pain or tenderness and normal CT imaging following a study in which 37 of 118 patients in the alert subset had injury detected on MRI. Seventy patients in the cohort reported cervical tenderness or neck pain, and a change in management in 31% of the total cohort occurred. Five of the alert patients were managed operatively for unstable ligamentous injury and cord compression. Similarly, in 40 retrospective patients with normal CT findings, Kihiczak et al[62] found that 4 patients had cervical spine injury detected on MRI, two of whom required further management. Oedema of the C5—C6 disc as a result of hyperextension injury was managed in a cervical collar in one case, while another patient had interspinous ligamentous

injury of unspecified severity at C5–C7 treated surgically following a period of time in a collar. Similarly, Chiu et al[63] reported that ligamentous injuries were found in 15% of reliable patients without fracture, in a large retrospective study of 11,972 patients aiming to assess the effectiveness of three-view plain films plus CT imaging of the upper cervical spine. The authors concluded that pure ligamentous injury was extremely rare, and that plain X-ray and CT imaging were sufficient for clearance in alert patients,[63] but as MRI was not conducted in this study, soft tissue injury may have been missed.

In a group of 166 predominantly conscious patients with CT imaging negative for acute injury, Horn et al,[64] found that 42% of patients had high signal ligamentous and disc abnormalities detected on MRI. Subsequent dynamic flexion-extension plain radiography confirmed the absence of instability, and the authors concluded that MRI was falsely positive in these cases, and should not be used as the primary modality for the assessment of stability. In contrast, however, the authors also concluded that if CT and MRI findings are negative, the cervical spine can be safely cleared. Despite the over-sensitivity of MRI, stable injuries detected during assessment for instability should probably not be dismissed as falsely positive. Such injuries may result in enduring neck pain and disability, and should be considered for management and/or future monitoring to prevent such morbidity. We recently found, however, that imaging abnormalities did not correlate with 12 month outcomes in a prospective cohort of 162 alert patients, but rather depression, compensation status and income level were associated with poorer neck-related disability outcomes.[65]

It is now fairly widely appreciated that the early multislice CT technology, the 4 and 16 slice scanners, continue to fail in the identification of subtle injuries when neither fracture nor malalignment is evident. Brown et al[37] suggest that newer CT technology, including 64, 128 and 256 slice scanners, may be sensitive enough to suggest the presence of soft tissue injury to such an extent that MRI may not be required for cervical spine clearance in alert patients with persistent cervical tenderness or neck pain, however further evidence is required.

5. Conclusion

The most appropriate cervical spine clearance protocol for trauma patients remains a matter of debate. While the adoption of multislice CT as first-line imaging in suspected cervical spine trauma is supported by an abundance of evidence, the lack of CT scanning availability in rural or remote areas continues to necessitate the use of three or five-view plain radiography, which has consistently been reported as inefficient for the detection of fractures. Similarly, controversy exists in regard to the efficiency and appropriateness of CT imaging to clear the cervical spine in obtunded patients who are unable to be assessed clinically, and in alert and neurologically intact patients with persisting neck pain or midline cervical tenderness. In an area of medicine where randomised controlled trials may not be appropriate, the use of large multicentre prospective cohort studies aimed at ascertaining the optimal imaging strategies for cervical spine clearance are essential in providing definitive solutions to these current clinical controversies.

Conflicts of interest

All authors have none to declare.

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