

The Utility of MRI for spinal clearance in blunt trauma. A retrospective cohort study of 539 blunt trauma patients in a level one trauma center in Singapore

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Abstract

Introduction:

The majority of spinal injuries occur secondary to blunt trauma and patients with significant blunt trauma must be assumed to have an unstable spinal injury until complete radiological and clinical assessment. MRI scans are highly sensitive but can be logistically difficult to perform in ICU patients and may prolong duration of spinal immobilization unnecessarily. In this study we investigated the efficacy of MRI scans in changing patient management in blunt trauma patients and the clinical and CT findings which would indicate an MRI spine.

Material and Methods:

This is a retrospective study of patients with significant blunt trauma who had MRI of the spine performed between 2018 to 2023 in the National University Hospital, Singapore. Indications for an MRI spine in our center include the presence of spinal fractures on CT scan, neurological deficits, obtunded patient (unable to cooperate with physical examination), tenderness/pain over the spine on physical examination and underlying ankylosing conditions of the spine. Significant blunt trauma is defined as per the Canadian C spine Rule criteria. Fracture morphology was classified based on the AO spine fracture classifications. Change in patient management was defined as MRI scan leading to decision to operate on patient or change from conservative to operative management. We defined a stable fracture as AO type A0 cervical or thoracolumbar fracture and other fractures as potentially unstable. Univariate and Multivariate Analysis were performed. Number of days in which patients were kept on spinal nursing while awaiting MRI was also recorded.

Results:

In total 539 patients, 135 (25%) female and 404 (75%) males, were identified who had MRI spine performed for spinal clearance. Of these MRI scans performed, 234 (43.6%) led to change in patient management. On multivariate analysis, the presence of a potentially unstable fracture ($p < 0.01$) and the presence of a neurological deficit ($p < 0.01$) were found to be significant predictors of an MRI scan being indicated and leading to a change in patient management. Of note when using the presence of a potentially unstable fracture and/or neurological deficit as a criteria for performing an MRI, 234/419 (55.9%) of scans led to a change in patient management, while in patients who did not meet this criteria 0/110(0,05)% of MRI scans led to a change in management. In patients who had MRI scans which did not change management, a mean of 2 (range 0–14) days was spent undergoing spinal nursing while awaiting MRI.

Conclusion:

In blunt trauma patients with no clear indication for MRI, an additional MRI scan may lead to unnecessary prolongation of spinal nursing with no additional benefit to the patient. Further study to

clearly delineate the indications for an MRI as well as the additional costs and medical complications associated with un-indicated MRI scans are warranted.

Introduction

Spinal trauma is amongst one of the major injuries that can occur in trauma patients, leading to severe neurological deficits that contribute to patient morbidity and mortality. In Asian countries, the incidence of traumatic spinal cord injury has been estimated to be between 18 to 174 people per million inhabitants a year,[1] and in a study conducted in one trauma centre, the 30-day morbidity rate for patients with spinal trauma was as high as 27.7%.[1] A common pitfall contributing to the high morbidity rates is delayed diagnosis, leading to delayed management of the spinal trauma.[2] An early diagnosis is critical for avoiding catastrophic neurological loss, preventing complications of prolonged immobilisation, and enabling timely definitive management, whereby unstable fractures and/or fractures with associated ligamentous injuries warrant conversion to surgical management, as timely surgical decompression and fixation prevent further progression of injury and improve neurological outcomes.[2] Hence, it is widely accepted that early diagnosis in spinal trauma aids in administering appropriate definitive management, mitigating further progression of symptoms, and improving patient outcomes.[2] However, the methods of reaching this diagnosis are often debated.

As it stands, a Computed Tomography (CT) scan is favoured for assessing spinal stability in the context of osseous injuries, being able to characterise and classify the type of fracture, which would aid greatly in management decisions, and whether there is a need for conversion to surgical management. However, a Magnetic Resonance Imaging (MRI) scan can be considered favourable when ligamentous complex and cord injuries are suspected, due to MRI superiority in assessing soft tissue injuries. Most studies point to CT imaging being sufficient for most trauma patients, and MRI being reserved for CT-positive or neurologically ambiguous cases, whereby routine MRI in the absence of these indications are not justifiable.[3–6] Yet, studies have shown that liberal usage of MRI is practiced despite these indications not being met.[29] This liberal usage of MRI may encompass a more sensitive soft tissue assessment than CT,[7] but this is not without its disadvantages. MRIs are relatively costly, cannot be performed on unstable patients in ICU, and awaiting for an MRI scan possibly results in unnecessary prolonging of spinal immobilisation, moreover, MRIs are susceptible to false positives which may lead to potential overtreatments of spinal trauma.[2, 8]

Hence, there is an ongoing discussion among experts regarding the utility of MRI vs CT imaging in spinal trauma and their role in changing the management. In this study, we investigated the efficacy of MRI in changing the management of patients with spinal injuries secondary to blunt trauma and the clinical and CT findings in said patients that will indicate an MRI of the spine.

Materials and Methods

A retrospective cohort study was conducted of all patients with significant blunt trauma who underwent an MRI of the spine between 2018 to 2023 at National University Hospital, which is a level 1 trauma centre located in Singapore. The basic demographics of the patients, such as age and gender, as well as the mechanism of injury was also noted down. The inclusion criteria consisted of high energy trauma, and patients aged between 18 to 80 years old. Paediatric patients and patients who fell from standing height were excluded.

In patients who were noted to have a reported spinal fracture on the CT or MRI scan of the spine, the fracture was classified according to the AO classification for spinal fractures. A stable fracture was designated as an AO type A0 cervical or thoracolumbar fracture, while other fractures were classified as potentially unstable.[9] For each patient, other additional parameters were noted down, such as the patient's neurological status, tenderness along the spine on physical examination, whether patients were obtunded and unable to cooperate with physical examination on initial review, as well as the presence of ankylosing conditions of the spine. The neurological status of the patient was classified based on the American Spinal Injury Association (ASIA) classification. The degree of obtundation was defined by any of the following: the patient's Glasgow Coma Scale (GCS) < 15 on initial presentation to the emergency department, unconscious, intubated, altered mental status, inability to comply with physical examination, or not meeting NEXUS guidelines.[10]

After the MRI of the spine was done, it was also noted down whether the findings of the MRI scan led to a change in management of the patient's fracture, which is defined as MRI findings leading to a change from conservative to surgical management

Statistical Analysis

Jamovi version 2.6.45 was used. Continuous variables were summarised as means with standard deviations.

Categorical variables were represented by frequencies and percentages. Univariate analysis was performed with Chi-squared test for categorical variables, alongside independent t-tests and one-way ANOVA tests for continuous variables. Multivariate analysis was subsequently done on variables identified to be significant in the univariate analysis P value < 0.05 was taken to be significant.

Results

A total of 539 patients who had MRI spine performed for spinal clearance after CT spine were identified, of which 135 (25%) were female and 404 (75%) were male. 432 (80.3%) of the patients had at least one vertebral fracture that was found to be present whilst 106 patients (19.7%) did not. The most common fracture pattern was in the Lumbar region only (L) which had 163 patients (30.2%) followed by the Cervical region only (C) which had 125 patients (23.2%). In total, 220 of 539 patients (40.3%) were identified to present with fractures at multiple sites. The least common fracture pattern was the combined Cervical, Thoracic and Lumbar (C + T+L) which was observed in only 3 patients (0.6%). 197

(36.6%) patients reported symptomatic neurological deficits whilst obtundation was observed in only 74 (13.7%) of patients. 12 (2.2%) patients were found to have had ankylosis and 335/539 patients reported experiencing pain. Among the MRI scans performed, 234(43.6%) led to change in patient management. On multivariate analysis, the presence of a potentially unstable fracture ($p < 0.01$) and the presence of a neurological deficit ($p < 0.01$) were found to be significant predictors of an MRI scan being indicated and leading to a change in patient management. Most notably, when using the presence of a potentially unstable fracture and/or neurological deficit as a criteria for performing an MRI, 234/419 (55.9%) of scans led to a change in patient management. In patients who had MRI scans which did not change management, a mean of 2 days (Range 0–14) was spent undergoing spinal nursing whilst awaiting for MRI.

Discussion

Our study examined the relationship between spinal trauma characteristics and MRI findings among surgically managed spine patients in a tertiary centre. Our analysis demonstrated that demographic variables, including age, sex, and mechanism of injury (low- versus high-energy), were not significantly associated with MRI findings that resulted in a change in management. In contrast, the presence and type of fracture identified on CT and presence of neurological deficits in patients without CT findings were significant predictors of clinically relevant MRI findings.

For spinal trauma patients who meet the NEXUS or Canadian C-Spine Rule (CCR) criteria for imaging, a CT is widely regarded as the reference standard in spinal trauma, especially when referring to the 2024 ACR guidelines.[8] This is due to its near-100% sensitivity for detecting spinal fractures and displacements.[2, 8] A study by Bailitz et al. shows that for this population of patients, CT imaging significantly outperforms radiography when it comes to identifying osseous injuries, where CT imaging yielded a 100% sensitivity rating for detecting clinically significant injuries. The study also highlights that MRI did not detect any osseous injuries that CT imaging did not already pick up in said population.[11]

Findings for indications of MRI in negative initial CT scan

In patients with no spinal fractures diagnosed radiologically on X rays or CT scan, only the presence of neurological deficits in the patient proved to be a significant indicator in which an MRI would change the management. Our results show that 69.6% of patients with neurological deficits had a change in management after MRI was done, compared to only 4.2% in patients with no neurological deficits. High resolution MRI detects ligamentous disruption, disc injury, epidural hematoma and cord pathology far more sensitively than CT scans, hence studies done such as by Kumar et al. propose that MRI imaging allows surgeons to identify truly unstable injuries and plan definitive stabilisation via operative management Our results echo this, showing that MRI imaging proved useful in soft tissue evaluation of the spine causing neurological deficits which may not be well visualised on CT of the spine, hence resulting in a change in management. This was consistent with similar findings by Deramo et al., which

found that patients with CT-identified stable thoracolumbar injuries and no neurological deficits did not benefit from an MRI (done in 56% of patients) as it merely confirmed the CT-based stability and did not significantly change the decision for surgical management, where a conversion to surgical intervention was observed in only 26% of the MRI patients compared to 16% of the CT-only group.[12] Other literature, like Hassankhani et al., found that even though MRI is the modality of choice when assessing potential injuries of the ligaments and disk herniation, it may overestimate the severity of ligament and soft tissue injuries when the CT scan is clean with specificity of 64% to 77%, and worse had a 25% to 40% false positive rate, leading to potential overtreatments of the spinal trauma.[2, 8, 12] The paper defines a false positive MRI is an abnormal MRI that identifies an insignificant abnormality such that no further clinical management is pursued and the patient has a normal physical examination upon clinical follow-up or by flexion-extension radiographs.[13] Hence, they as well as the EAST Thoracolumbar Spine Injuries Following Trauma Practice Management Guideline believe that “In the absence of neurological symptoms, the combined use of CT scans and clinical examination often provides sufficient information to rule out clinically significant injuries and may obviate the need for MRI”.[8] The American College of Surgeons Trauma Quality Improvement Program (TQIP) found that ligament injuries that are occult on MDCT and identified on MRI rarely result in significant clinical management changes. MRI was found to be positive for soft tissue injury in 6 to 49 percent of patients with an unreliable clinical examination and negative MDCT.[3] However, most injuries were minor, requiring either no change in management or only extended cervical collar placement. Hence, it can be concluded that in the absence of a fracture seen on the CT scan, the presence of neurological deficits is the only significant predictive factor in which an MRI would cause a change in management.

Findings for indications of MRI in positive initial CT scan

In patients with spinal fractures diagnosed on CT or X ray of the spine, several factors were identified in which an MRI of the spine would change the management of a patient. Namely, these are the presence of neurological deficits, the level of energy of trauma sustained by the patient, as well as the presence of an unstable fracture pattern on CT or MRI.

The 2024 ACR guidelines (Variant 5: Subacute blunt head trauma with cognitive or neurologic signs/symptoms) highlight the preference for MRI imaging when there is suspected or confirmed ligamentous, spinal cord, or nerve root injury, with or without CT-identified trauma, hence warranting the MRI to be the investigation of choice when these indications line up.[8]

In patients with spinal fractures noted on CT, the presence of neurological deficits was highly predictive of an MRI leading to a change in management of the patient, compared to patients with no neurological deficits (76.1% vs 27.1%). The presence of neurological deficits likely indicates that the patient sustained an injury to the spinal cord or nerve root, and hence surgery was indicated in order to prevent worsening neurological deterioration. For preoperative planning, it is also necessary to evaluate for other associated injuries aside from the fracture, such as disc herniation, retropulsion of fracture fragments, epidural or cord hematomas as well as ligamentous injuries, which may influence the operative plan[5].

An MRI can also prove useful in assessing for the presence of canal encroachment, which assists in preoperative planning in these patients.[4] In such cases, an MRI is indicated to carry out such evaluations.[5] Similarly, the presence of high-energy trauma predicted an increased likelihood of undergoing MRI, as such mechanisms are associated with a greater incidence of ligamentous disruption, multi-column injury and occult soft-tissue damage not reliably detected on CT.[5] Our results are backed by the East Association for Surgery of Trauma, where Diaz et al. explains how it is extremely important to obtain an MRI for patients with neurological deficits and/or abnormal CT scans as early decompression of mass lesions, such as traumatic herniated discs or epidural hematomas, is likely to improve neurologic outcome.[3]

In patients with spinal fractures noted on CT, the presence of a potentially unstable spinal fracture pattern warranted an MRI which resulted in a change to surgical management. Patients with unstable fracture patterns identified on CT are likely to have associated ligamentous and other soft tissue injuries, which MRI can detect with high sensitivity. This observation is consistent with existing literature. The Congress of Neurological Surgeons and the American College of Radiology recommend MRI as a complementary modality to CT in cases of potentially unstable spinal fractures due to its superior capability for assessing soft tissues and spinal cord integrity[8]. With respect to thoracolumbar fractures in particular, it has also been reported by Mohamed et al. that an MRI may result in significant change in fracture classification, as well as the change from conservative to surgical management.[14] Moreover, these unstable fracture patterns often require surgical stabilisation, and further evaluation with an MRI aids in preoperative planning.[12] Consequently, the MRI not only confirms the presence of occult soft tissue injury but also informs the decision to proceed with surgical stabilisation. This is consistent with previous findings by Malacon et al., stating that non-operative care in patients with unstable spinal fracture patterns confer a 60% higher mortality risk than operative patients (adjusted HR = 1.60, 95% CI 1.40–1.78, $p < 0.001$) and this survival advantage persists across all age groups up to 2 years post injury.[15] It is also worth noting that there have been studies which show a positive association between unstable fracture patterns and the presence of neurological deficits, which will eventually warrant surgical management as discussed previously.[4, 5, 16] Therefore, CT-demonstrated unstable fracture patterns is a factor that points toward escalation of the surgical management plan, warranting an MRI for assessing soft-tissue injuries and the need for surgical stabilisation.

In previous studies such as Mohamed et al., the presence of obtundation is an indication to do an MRI in trauma patients, primarily to look for potential spinal cord injury missed on the CT.[14] In our cohort, an obtunded neurological state was not an indication to predict clinically significant MRI findings. This is consistent with earlier work by Khanna et al., who reported no unstable injuries on MRI and no subsequent change in management among 150 obtunded patients undergoing MRI after a normal CT.²⁸ This is also supported by similar related studies by Tomycz et al. and Como et al., highlighting the 2015 EAST Cervical Spinal Guidelines, suggesting that if CT scan of the cervical spine is noted to be negative in an obtunded patient, an MRI is unlikely to find significant spinal injuries that warrant surgical management as they yield a near-100% negative predictive value for unstable injury.[6, 17] Even so, a study by Chaudhary et al. found an increased odds ratio of 1.77 (95% CI 1.49–2.09) for MRI usage in

these obtunded spinal trauma patients in the years following the implementation of the 2015 EAST Cervical Spinal Guidelines despite it advising against the use of routine cervical spine MRI in said population.[18] This is also backed by Variant 7 of the 2024 ACR guidelines, highlighting that usage of MRI has no added value and usually does not warrant any change in diagnosis or management when compared to CT imaging in the obtunded patient.[8] However, a study done by Yong et al. showed that 17% of spinal trauma patients with negative CT had occult cervical injuries detected on subsequent MRIs, whereby 4% of these patients required a change in management.[19] Moreover, a study by Dion et al. concluded that 6% of obtunded spinal trauma patients with negative CT scans had missed clinically significant injuries, and 7% of such patients required a conversion to surgical management, urging clinicians to consider MRI when CT is negative.[20] This may point to the value in performing an MRI in the obtunded spinal trauma patient, but therein lies the controversy of how a clinician should go about making decisions regarding the ideal imaging for obtunded spinal trauma patients. A possible reason for this is that the state of "obtundation" is often generalised from author-specific definitions and this encompasses a wide range of patient presentations. Some of these presentations range from Glasgow Coma Scores < 15, unconscious patients, intubated patients, intoxicated patients, and patients with unreliable examination findings. These presentations have largely varied implications on the patient's clinical state. Hence, encompassing everything under an umbrella term of "obtundation" is not a reliable indication for routine MRI in the absence of spinal cord injuries on CT.[14]

Of note, our study has found that in patients with underlying ankylosing spondylitis (AS) who sustain spinal fractures, performing an MRI of the spine does not significantly change the decision for surgical management. In our review of the literature surrounding spinal fractures in patients with ankylosing spondylitis, the mainstay of management for these fractures tends to lean more towards operative management rather than nonoperative management.[21–23] However, with regards to the role of performing an MRI of the affected region of the spine, and its utility in changing the decision for operative or nonoperative management, the evidence has been heterogenous. Tavoraro et al. found that only 3.2% of patients with AS who presented with a spinal fracture had a change in their management plan after an MRI was performed, resulting in them advocating for MRI at nonankylosed regions where a disco-ligamentous injury has occurred, or in patients with neurological deficits.[24] However other studies have supported the use of MRI in AS patients with spinal fractures.[21, 25, 26] Koivikko et al. came to a slightly more nuanced conclusion, mentioning that with regards to fracture morphology, CT proved to be superior to MRI, however, with regards to soft tissue injuries and evaluating the condition of the spinal cord, MRI proved to be of more benefit.[27] Overall, the role of MRI in the evaluation and determining the management of spinal fractures in patients with ankylosing spondylitis continues to be controversial, and hence provides avenues for further investigation to shed more light on the question.

Contrary to several earlier studies that promoted liberal MRI use, our data results reinforce the principle of selective imaging. Routine MRI in the absence of clinical or the above indications would increase the hospital length of stay. A mean of 4.6 days between CT and getting an MRI was reported, which translates to delays in collar clearance, ultimately prolonging spinal precautions and nursing care with no meaningful clinical benefit.⁶ Our cohort similarly reflected that indiscriminate MRI ordering contributed

to longer inpatient stays of an average of 2 days and prolonged spinal nursing, without any additional therapeutic benefit. Morris et al. theorises that these delays also subject patients to recognised risks of prolonged immobilisation and spinal precautions, including pressure ulceration (reported in up to 55% of patients), impaired venous drainage, and aspiration leading to pneumonia (typically ventilator associated), reduced physiotherapy (increasing thromboembolic risks), and increased cross infections due to prolonged and more difficult log rolls for these patients.[28]

Taken together, these findings support a pragmatic, evidence-based imaging algorithm:

1. If a fracture is seen on CT scan, the MRI is only indicated in the presence of a neurological deficit or an unstable spinal fracture pattern.
2. If a CT scan is deemed to be normal, MRI is indicated only in the presence of a neurological deficit.

Adherence to such criteria can optimise resource utilisation, minimise patient immobilisation time, and reduce hospital burden, while maintaining diagnostic safety.

Limitations

The present study is limited by its retrospective design and single-centre cohort, which may affect its generalisability to different settings. MRI indications and reporting are subjective and may vary between clinicians, and outcome assessment was restricted to in-hospital management decisions. Furthermore, there were also instances where patients were indicated for an MRI of the spine, but due to other concomitant injuries and comorbidities that rendered it unstable for patients to undergo the MRI, the scan could not be performed. On the treatment front, patient preferences may have led to the refusal of surgical management, and similarly as above, concomitant injuries and comorbidities may have rendered some patients unfit for surgery, and they may have never gotten fit enough for the indicated surgery, causing a potentially under-representation of the role of the MRI in changing management in spinal trauma. Future prospective multicentre validation studies should ideally seek to reinforce these findings and develop formal MRI triage algorithms in spinal trauma.

Conclusion

In conclusion, our study advocates for the targeted use of MRI of the spine in trauma patients to guide the decision for surgical management. These include the presence of neurological deficits in patients with no fracture reported on CT of the spine, whereas in patients with reported fracture, the presence of neurological deficits or the presence of an unstable fracture pattern. In the long term, the targeted use of MRI in these patients will possibly be able to benefit patients by reducing hospital stay, reduce the morbidity and mortality associated with prolonged spinal immobilization, as well as reduce hospital costs, which will benefit patients particularly in low and middle income countries.

Declarations

Ethics Approval:

Institutional review board (IRB) approval was obtained prior to the commencement of this study namely IRB No: 2020/00495 and 2022/00866 approved by Domain Specific Review Board (DSRB) under the purview of National Healthcare Group (NHG).

Consent to participate:

The approval was waived off informed consent. Data was collected from operating theatre records and hospital electronic medical records by a member of the research team not involved in data analysis and anonymised prior to analysis.

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