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ABSTRACT

BACKGROUND AND PURPOSE: Imaging stewardship in the emergency department (ED) is vital in ensuring patients receive optimized care. While suspected cord compression (CC) is a frequent indication for total spine MR imaging in the ED, the incidence of CC is low. Recently, our level 1 trauma center introduced a survey spine MR imaging protocol to evaluate for suspected CC while reducing examination time to avoid imaging overutilization. This study aims to evaluate the time savings, frequency of ordering patterns of the survey, and the symptoms and outcomes of patients undergoing the survey.

MATERIALS AND METHODS: This retrospective study examined patients who received a survey spine MR imaging in the ED at our institution between 2018 and 2022. All examinations were performed on a 1.5T GE Healthcare scanner by using our institutional CC survey protocol, which includes sagittal T2WI and STIR sequences through the cervical, thoracic, and lumbar spine. Examinations were read by a blinded, board-certified neuroradiologist.

RESULTS: A total of 2002 patients received a survey spine MR imaging protocol during the study period. Of these patients, 845 (42.2%, mean age 57 ± 19 years, 45% women) received survey spine MR imaging examinations for the suspicion of CC, and 120 patients (14.2% positivity rate) had radiographic CC. The survey spine MR imaging averaged 5 minutes and 50 seconds (79% faster than routine MR imaging). On multivariate analysis, trauma, back pain, lower extremity weakness, urinary or bowel incontinence, numbness, ataxia, and hyperreflexia were each independently associated with CC. Of the 120 patients with CC, 71 underwent emergent surgery, 20 underwent nonemergent surgery, and 29 were managed medically.

CONCLUSIONS: The survey spine protocol was positive for CC in 14% of patients in our cohort and acquired at a 79% faster rate compared with routine total spine. Understanding the positivity rate of CC, the clinical symptoms that are most associated with CC, and the subsequent care management for patients presenting with suspected cord compression who received the survey spine MR imaging may better inform the broad adoption and subsequent utilization of survey imaging protocols in emergency settings to increase throughput, improve allocation of resources, and provide efficient care for patients with suspected CC.

ABBREVIATIONS: CC = cord compression; ED = emergency department

Imaging stewardship in the emergency department (ED) is essential in ensuring patients receive high-quality, efficient care while avoiding unnecessary studies and their associated costs.[1-5] An area of focus is the increasing use of spine MR imaging in the ED.[6-12] Spine MRIs are commonly used to diagnose spinal injuries including cord compression (CC), which is a critical, time-sensitive diagnosis that often requires emergent surgery, radiation therapy, and/or medical management, given that untreated CC will result in permanent neurologic damage.[9-13]

Despite prior studies citing a low incidence rate for CC of 0.5% to 5%, total spine MR imaging examinations are the current standard of care for those suspected of possibly having an underlying correctable cause given the potentially devastating consequences.[6,14-18] Patients may present with a broad range of symptoms including back pain, radiculopathy, paresthesia, weakness, and urinary retention. The acquisition of a spine MR imaging provides unsurpassed insight into the diagnosis of CC by

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SUMMARY

PREVIOUS LITERATURE: Imaging stewardship is essential in ensuring patients receive high-quality, efficient care while avoiding unnecessary studies and their associated costs. An area of focus is the increasing use of spine MR imaging for the acute detection of CC. Despite the powerful diagnostic capabilities of MR imaging for CC, the long examination and image interpretation times hinder its broad application. Rapid MR imaging protocols have been posited as a solution to reduce imaging time while screening for specific indications. Our center developed a rapid survey spine MR imaging protocol to evaluate the total spine for the specific clinical indication of CC.

KEY FINDINGS: The survey spine protocol was positive for cord compression in 14% of patients in our cohort, acquired at a 79% faster rate compared with routine total spine, and 59% underwent emergent surgery. Presenting symptoms associated with CC included trauma, back pain, lower extremity weakness, urinary/bowel incontinence, numbness, ataxia, and hyperreflexia.

KNOWLEDGE ADVANCEMENT: Our survey spine protocol detected CC at a 79% faster rate compared with routine total spine MRIs. Understanding the survey utilization and characteristics of the population receiving the survey may inform the adoption of rapid imaging protocols to decrease acquisition times and provide efficient care for patients with suspected CC.

allowing for visualization of the spinal cord to identify potential causes, such as extrinsic compression of the cord by tumors, traumatic injury, a herniated disc, spondylosis, infection and/or degenerative spine disease.[9-13,19] Furthermore, assessing the degree and localization of compression is critical to planning treatment and decision-making, especially regarding potentially emergent surgical decompression.[8,13,20,21]

Studies investigating the utility of imaging in the ED have suggested that as much as 22% of ED imaging studies may be unnecessary, resulting in increased health care costs, medical error, and potentially causing harm to patients.[22-24] Despite the powerful diagnostic capabilities of MR imaging for CC, the long examination and image interpretation times hinder the ease of broad application of MR imaging for emergent conditions.[25] Moreover, MR imaging scanners and the infrastructure needed to safely house them are expensive and labor-intensive, rendering them less accessible in the emergency setting.[26] Recently, rapid MR imaging protocols have been posited as a solution to long acquisition times associated with routine MR imaging. These protocols are focused on a specific clinical indication and have a reduced number of sequences and imaging time.[25,27-29]

Objective

Our level 1 trauma center implemented a rapid survey spine MR imaging protocol to reduce examination times while still maintaining the ability to detect the features associated with CC. The main difference between the cord compression survey and a routine total spine MR imaging is the lack of sagittal T1WI of the spine and complete axial imaging stacks. The core sequences of the cord compression survey are sagittal T2WI and STIR sequences for the assessment of canal compromise and potential cord signal abnormality. This study aims to evaluate the time savings, frequency of ordering patterns of the survey, and the symptoms and outcomes of patients undergoing the survey.

MATERIALS AND METHODS

Study Design, Setting, and Population

This is a retrospective, observational cohort study that was conducted at a large urban academic medical center with a level 1 trauma center from January 2018 to December 2022. All patients presenting to the ED who received a survey spine MR imaging protocol for the clinical suspicion of cord compression were included. The study was compliant with the Health Insurance Portability and Accountability Act and approved with exemption by our institutional review board.

Survey Spine MR Imaging Protocol

Our institution's survey spine MR imaging protocol included sagittal T2WI and STIR sequences through the cervical, thoracic, and lumbar spine. All survey MRIs were reviewed by a neuroradiology fellow or attending physician before the examination was completed, with axial T2WI sequences prescribed only at the discretion of the neuroradiologist if there was an area of concern on the sagittal views that the neuroradiologist wanted to view on axial for further evaluation. For instance, if the neuroradiologist suspected at least moderate spinal canal stenosis, moderate foraminal stenosis, or impingement of a nerve root based on the information from the sagittal examinations, axial slices were obtained. These cases could have near complete or complete effacement of the ventral or dorsal CSF spaces or any sort of disc extrusion or lateral protrusion that may have impinged on a nerve root or had foraminal extension present. All survey spine examinations were performed on a 1.5T scanner (GE Healthcare). Survey spine MR imaging sequence parameters are outlined in Table 1.

Variables

The primary outcome in this study was defined as the rate of CC-positive survey spine MR imaging examinations in all patients receiving a survey spine MR imaging and the time savings of the survey compared with routine total spine MR imaging. Secondary outcomes included the assessment of presenting symptoms in all patients receiving the survey and the outcomes for patients who received a positive study. A certified neuroradiologist (with more than 5 years of experience) read the radiographic images for the purposes of this study. The examinations were Certificate of Added Qualification– as 1 of 3 categories: 1) no radiographic findings, 2) chronic degenerative findings without severe spinal canal stenosis, and 3) severe spinal canal stenosis including

Table 1: Sequence parameters for the survey spine MR imaging protocol. Sequences are listed in the order of acquisition

Sequences	T2WI			Short Tau Inversion Recovery (STIR)		
	Cervical	Lumbar	Thoracic	Cervical	Lumbar	Thoracic
TR/TE (ms)	2782/85.1	2000/107.8	3864/108.2	5207/49.5	3856/48.3	4903/49.7
NEX	2	0.5	1.5	1.5	1.5	1.5
Flip angle	160	160	160	170	170	170
Matrix	288 × 220	288 × 256	288 × 224	288 × 192	288 × 192	288 × 192
FOV (mm^2)	210 × 210	280 × 280	340 × 340	200 × 200	280 × 280	350 × 350
Section thickness (mm)	3	3	4	3	4	3
Section spacing (mm)	3.5	3	5	3.5	4	3
Acquisition time	3 minutes, 31 seconds	3 minutes, 51 seconds	3 minutes, 48 seconds	1 minute, 38 seconds	2 minutes, 28 seconds	1 minute, 44 seconds

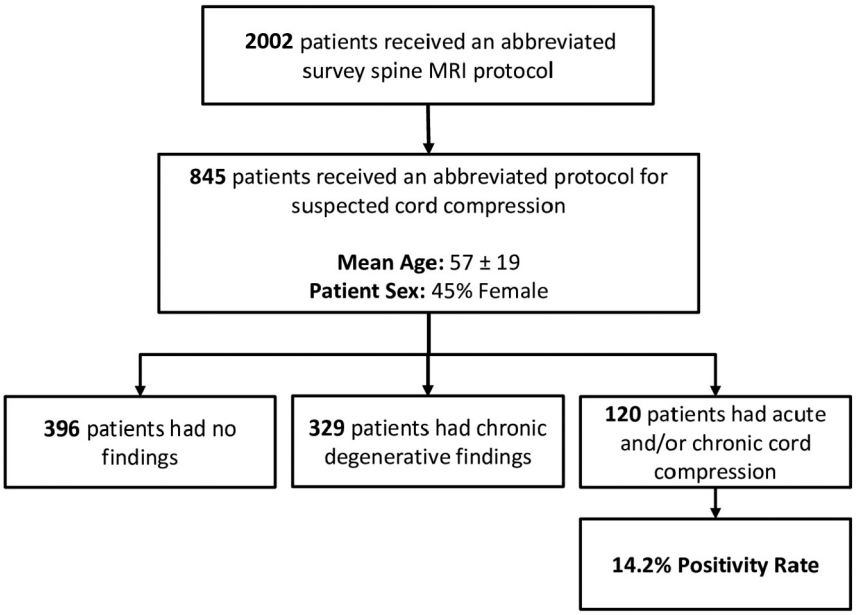

FIG 1. Overall 5-year positivity rate for study population.

acute and chronic cord compression. A positive examination was qualified as an examination resulting in severe spinal canal stenosis including acute and chronic cord compression. Demographic variables were also collected from the electronic medical record, including age, sex, and self-reported race.

Statistical Methods

Continuous data are presented as means and standard deviations or medians and interquartile ranges, as appropriate; categoric data are reported as counts and percentages. Univariate analysis was performed by using the χ^2 test. A multivariate logistic regression was performed with stepwise backward elimination where the variable with the largest P value was removed in a stepwise fashion in each iteration until all variables on the final model had a $P < .20$. Statistical significance was set at $P < .05$. All statistical computations were completed by using Stata version 18 (StataCorp).

RESULTS

Study Population and Demographics

A total of 845 patients (42.2%, mean age 57 ± 19 years, 45% women) received a survey spine MR imaging protocol for the suspicion of CC. Patient demographics and examination characteristics are compiled in the Online Supplemental Data.

Time Savings of Survey Spine MR Imaging

The survey spine MR imaging averaged 5 minutes and 50 seconds compared with an average time of 27 minutes and 13 seconds for routine total spine MR imaging during the same period, resulting in 22 minutes and 27 seconds saved per examination (79% faster compared with routine).

Positivity Rate of Cord Compression on Survey Spine MR Imaging

Of the 845 patients who received a protocol for CC, 396 patients (47%) had no radiographic findings, 329 patients (39%) had chronic degenerative findings without severe spinal canal stenosis, and 120 patients (overall positivity rate = 14.2%) had severe spinal canal stenosis including acute and chronic cord compression. Across the study period, positivity rate increased from 13.7% ($n = 25/183$) in 2018 to 16.4% ($n = 28/171$) in 2022, representing a 19.7% increase (Figs 1 and 2).

Patient Clinical Presentation

For patients who received a spine MR imaging for suspected CC, 55% had back pain, 29% had lower extremity weakness, 23% presented with trauma, 20% had numbness, 14% had neck pain, 14% had urinary incontinence, 7.3% had ataxia, 6.4% had hyperreflexia, 6.0% had bowel incontinence, and 5.7% had history of malignancy. On univariate analysis, trauma, back pain, numbness, ataxia, and hyperreflexia were associated with having evidence of cord compression on MR imaging (Table 2). In the multivariate model, trauma, back pain, lower extremity weakness, urinary or bowel incontinence, numbness, ataxia, and hyperreflexia were significantly associated with acute CC (Table 3).

Care Management for Patients with Cord Compression

Of the 120 patients with scans positive for CC, 71 (59%) underwent emergent spine surgery, and 20 (17%) underwent nonemergent surgery. Of the 29 nonoperative patients, 23 were referred for medical management, 3 were not surgical candidates because

of clinical instability, 1 required an emergent nonspine surgery, which superseded the need for emergent spine surgery, and 2 declined surgery or left against medical advice (Fig 3).

DISCUSSION

Patients presenting with symptoms for CC are common in the emergency setting. Our level 1 trauma center developed a survey spine MR imaging protocol to reduce examination times while still maintaining the ability to detect the features associated with CC. We report on its utilization in a pilot study conducted over a 5-year period and the characteristics of the patient population. In addition, we report on the presenting symptoms associated with CC and the outcomes of patients found to have CC to inform triage of utilizing the survey protocol and improve resource allocation. The results of this study demonstrate that a survey spine protocol results in time savings and may inform the potential adoption of rapid survey spine MR imaging protocols for CC screening at other institutions.

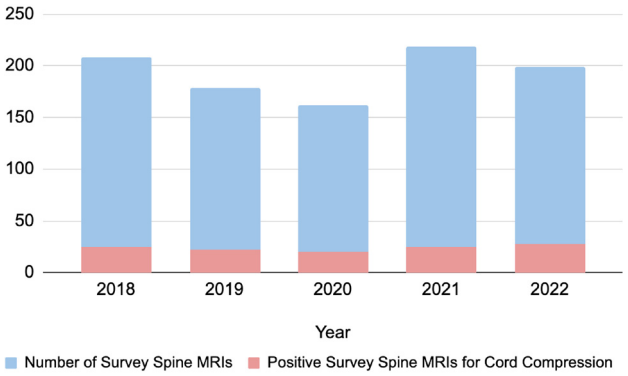

FIG 2. Relative utilization of a survey spine MR imaging protocol and its positivity rate for cord compression over a 5-year duration.

Imaging stewardship is a core tenet in radiology that guides the efficient use of imaging modalities. In the current paradigm, MR imaging is the reference standard for imaging of patients with suspected spinal CC as it is noninvasive and has been demonstrated to have high sensitivity and specificity in diagnosing spinal CC.[9-13,19,22] Acute spinal CC can lead to devastating neurologic impairment. Therefore, timely and accurate diagnosis is paramount.[30-33] Since multiple levels in the spinal cord can be involved in patients with metastatic CC, it is recommended that the entirety of the spine be surveyed for epidural and spinal lesions.[33] However, the presenting symptoms of CC are myriad, and the incidence rate of CC is low.[19] Therefore, screening for CC in the emergency setting presents multiple challenges due to the inherent pressures of maintaining an expeditious throughput of patients, resource constraints, and the high number of patients with back and neck pain, of whom the overwhelming majority have benign etiologies.[25,27,32] In addition, MR imaging scanners are expensive, and examinations require time to complete, rendering them challenging to access in the emergency setting.[25,26] The ability to reduce acquisition time while maintaining the capacity to detect the features of CC would afford more efficient patient turnaround and care management in the ED setting.

The use of rapid MR imaging protocols has been posited as a solution to reduce imaging time while screening for specific indications.[25,27-29] These protocols have shown promise in abdominal screening;[34] in identifying hydrocephalus in pediatric populations;[35-41] and for evaluating traumatic brain injuries, seizures, tumors, and vascular malformations, among others.[42-47] Prior studies have reported on the development of a rapid protocol including sagittal T1WI and T2WI fat-saturated sequences of the lumbar spine only to detect acute fracture, infection, and malignancy.[29] Others have developed rapid protocols for total spine evaluation. One group developed a 20-minute "FAST" spine MR imaging protocol including sagittal T1WI and STIR sequences in all spinal regions.[25] Another group developed a rapid total spine protocol comprising sagittal STIR and axial T2WI sequences and demonstrated it is noninferior to standard MR imaging for emergent findings.[27]

Table 2: Univariate analysis of factors associated with positive versus negative MR imaging for acute cord compression

Predictor	MR Imaging Negative for CC ($n = 725$)	MR Imaging Positive for CC ($n = 120$)	*P* Value
Age	57.4 ± 19.4	59.3 ± 17.0	.31
Men	381 (52.6%)	82 (68.3%)	.001
Trauma presentation	3139 (19.2%)	56 (46.7%)	<.001
Back pain	382 (52.7%)	86 (71.7%)	<.001
Lower extremity weakness	163 (22.5%)	79 (65.8%)	<.001
Malignancy history	39 (5.4%)	9 (7.5%)	.35
Urinary incontinence	77 (10.6%)	42 (35.0%)	<.001
Bowel incontinence	29 (4.0%)	22 (18.3%)	<.001
Neck pain	98 (13.5%)	22 (18.3%)	.11
Sensory paresthesia	91 (12.6%)	77 (64.2%)	<.001
Ataxia	16 (2.2%)	46 (38.3%)	<.001
Hyperreflexia	7 (1.0%)	47 (39.2%)	<.001

Table 3: Multivariate logistic regression of predictors associated with MR imaging findings suggestive of acute cord compression among patients undergoing spine MR imaging for suspected cord compression in the emergency department

Predictor	Odds Ratio	95% Confidence Interval	*P* Value
Age	1.01	1.00–1.03	.08
Men	1.81	1.01–3.23	.045
Trauma presentation	4.71	2.56–8.68	<.001
Back pain	4.45	2.40–8.28	<.001
Lower extremity weakness	2.86	1.58–5.16	.001
Urinary incontinence	2.92	1.45–5.90	.003
Neck pain	1.86	0.81–4.28	.15
Sensory paresthesia	3.30	1.74–6.24	<.001
Ataxia	8.49	3.18–22.64	<.001
Hyperreflexia	15.31	5.19–45.13	<.001

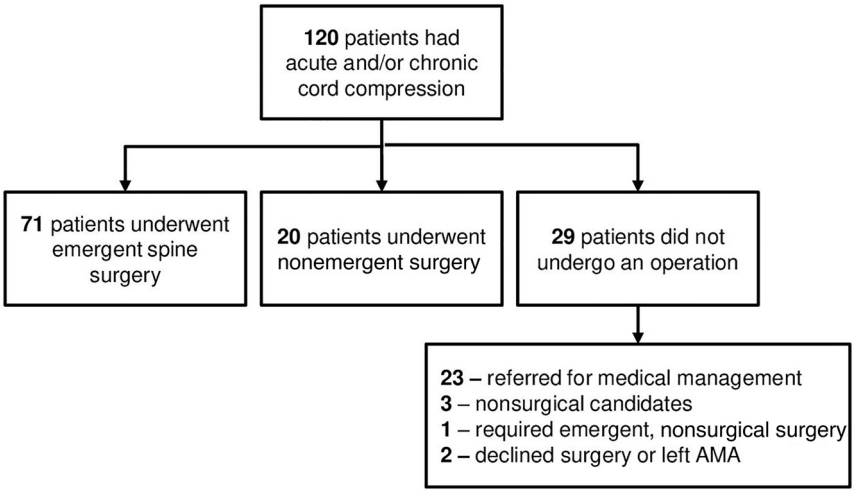

FIG 3. Care management for patients with cord compression.

Our center developed a rapid survey spine MR imaging protocol to evaluate the total spine for the specific clinical indication of CC. The survey is unique in that it is 5 minutes and 50 seconds and comprises sagittal T2WI and STIR sequences, with the ability to add axial T2WI sequence at the discretion of the neuroradiologist. The impetus for developing the survey spine MR imaging protocol for cord compression was multifactorial. Foremost, we wanted to provide a high-quality and rapid MR evaluation of multiple segments of the spine to expedite a diagnosis of acute cord compression. Second, this reduced scan time expedites imaging turnaround times with the goal of decreasing ED disposition (either admission to a hospital floor or discharge to home). Moreover, patients who would otherwise be unable to tolerate a long scan acquisition may be more likely to obtain a diagnostic scan. The main difference between the survey spine MR imaging and conventional total spine MR imaging is the lack of sagittal T1WI of the spine and the lack of complete axial imaging stacks. The protocol for the spine survey was chosen utilizing T2WI/STIR sequences as this yields higher soft tissue–to-fluid contrast compared with T1WIs. This enables the ability to assess the degree of effacement of the ventral and dorsal CSF spaces surrounding the cord to evaluate the degree of spinal canal stenosis. Similarly, in instances where there is compression of the cord with intramedullary edema, we are able to easily visualize the intramedullary edema on T2WI/STIR sequences. This is not as easily apparent on T1WIs.

Using the survey protocol, we identified findings positive for CC in 120 (14.2%) patients who received the survey spine protocol for CC. The general incidence rates of cord compression have been previously cited as 2.5%–5% in patients with cancer[48,49] while other studies cite an incidence of 24.4% for CC in the cervical spine in their population.[50] The findings in our study are higher than the general incidence rates of cord compression given that our cohort is solely derived from patients who presented with suspected CC, and thus our findings are not generalizable to the broader population. Our CC survey was specifically designed to be utilized in patients with suspected CC, and thus, patients who received it were more likely to have CC. Additionally, our center is a major tertiary care hospital with a large referral network, which may further contribute to our higher reported rates of CC. It is also important to note that 86% of patients overall who received the survey spine MR imaging protocol in our cohort did not have findings positive for CC requiring emergent intervention. While the positivity rate increased by 20% across the study period, demonstrating improved utilization, there is still room for improvement in decreasing the ordering frequency of imaging for patients with suspected CC.

To further reduce imaging and better guide the triage of patients who may be good candidates to receive survey protocols to improve resource allocation, we evaluated the presenting symptoms of all patients and the outcomes of patients who received a positive study. Prior studies cite that the most common and often first symptom of CC is back pain.[11,14,18] Similarly, in our cohort, 55.3% of patients presented with back pain. Additional common presenting symptoms in patients with CC have been cited as neck pain, difficulty ambulating, and weakness.[32] However, patient presentations are varied given the broad etiologies of CC ranging from vertebral fracture to spinal epidural abscess and hematoma to disc herniation and metastatic or primary spine tumors, among others.[11,32] In our study, we found that trauma, back pain, numbness, ataxia, and hyperreflexia were symptoms significantly associated with CC in both univariate and multivariate models, and lower extremity weakness and urinary or bowel incontinence were significantly associated with CC in the multivariate model. It is important to note that while certain presenting symptoms (eg, back pain) were associated with studies positive for CC, 1 symptom in isolation is likely not a marker that is specific enough for CC. Rather, these symptoms combined may be more highly associated with cord compression. Nonetheless, evaluating the symptoms commonly associated with the clinical presentation of CC can inform which patients may be more likely to have CC and thereby require emergent imaging to rule in acute CC and pursue subsequent work-up.

Urgent evaluation for acute spinal CC is necessary because, untreated, it has the potential to cause progressive and devastating neurologic impairment. Previous studies have shown that neurologic function at the time of treatment is an important predictor of final outcome, and if diagnosis is missed or delayed, patients may have further neurologic deterioration.[31] The workup for acute CC often requires emergent decompressive surgery. For these reasons, we further investigated the subsequent care management of the 120 patients with CC in our cohort. We found that 71 underwent emergent spine surgery, 20 underwent nonemergent surgery, and 29 did not receive surgery. Of those that did not receive any form of intervention, medical management, lack of surgical candidacy, and decline of procedure were the most common reasons. There are some considerations to

help eliminate imaging use in patients positive for CC who never underwent surgery: medical management, patient surgical candidacy, and desire for surgery could all be addressed before ordering imaging to ensure imaging is adding value and guidance for subsequent management.

The goal of the rapid MR imaging protocols is to reduce acquisition time and allow for more efficient triage.[7,8,25,27-29] At our institution, our survey spine MR imaging is 22 minutes and 27 seconds faster than routine spine MR imaging, operating at a 79% faster rate. Eliminating extraneous scan time further could lead to cost savings and more efficient patient care in the emergency setting, especially in certain imaging studies such as MR imaging.[6] Thus, the use of survey protocols for common indications such as CC in the emergency setting may lead to efficient and cost-saving patient management.

Limitations

This study has several limitations. First, this retrospective study is susceptible to patient and outcome selection bias. We relied exclusively on documentation present in each patient's medical record, and therefore, our data are subject to the possibility of being confounded by unmeasured variables. All patients in this study were evaluated at a single center, which houses dedicated 24/7/365 subspecialized neuroradiology coverage that includes the ability for neuroradiologists to evaluate scans as they are being performed, which could limit the generalizability of the results to other locations with different demographics, disease patterns or subspecialty coverage. Additionally, our center is a major tertiary care hospital with a large referral network, which may contribute to our higher reported rates of CC. Future studies should evaluate the use of the survey spine MR imaging protocol at their sites to best understand its potential broad adoption into clinical care. It may be difficult to achieve time savings at institutions that are unable to provide around-the-clock neuroradiology coverage to check and modify the scans in real-time.

CONCLUSIONS

Our level 1 trauma center developed a survey spine MR imaging protocol to screen for CC in the emergency setting. We found that the survey spine protocol was positive for CC in 14.2% of patients with suspected CC and was acquired at a 79% faster rate compared with routine total spine. Understanding the positivity rate of CC, the clinical symptoms that are most associated with CC, and the subsequent care management for patients presenting with suspected cord compression who received the survey spine MR imaging may better inform the broad adoption and subsequent utilization of survey imaging protocols in emergency settings to increase throughput, improve allocation of resources, and provide efficient care for patients with suspected CC.

Disclosure forms provided by the authors are available with the full text and PDF of this article at www.ajnr.org.

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