Does preoperative magnetic resonance imaging alter the surgical plan in patients with acute traumatic cervical spinal cord injury?

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BACKGROUND: Whether magnetic resonance imaging (MRI) adds value to surgical planning for patients with acute traumatic cervical spinal cord injury (ATCSCI) remains controversial. In this study, we compared surgeons' operative planning decisions with and without preoperative MRI. We had two hypotheses: (1) the surgical plan for ATCSCI would not change substantially after the MRI and (2) intersurgeon agreement on the surgical plan would also not change substantially after the MRI.

METHODS: We performed a vignette-based survey study that included a retrospective review of all adult trauma patients who presented to our American College of Surgeons-verified level 1 trauma center from 2010 to 2019 with signs of acute quadriplegia and underwent computed tomography (CT), MRI, and subsequent cervical spine surgery within 48 hours of admission. We abstracted patient demographics, admission physiology, and injury details. Patient clinical scenarios were presented to three spine surgeons, first with only the CT and then, a minimum of 2 weeks later, with both the CT and MRI. At each presentation, the surgeons identified their surgical plan, which included timing (none, <8 , <24, >24 hours), approach (anterior, posterior, circumferential), and targeted vertebral levels. The outcomes were change in surgical plan and intersurgeon agreement. We used Fleiss' kappa (κ) to measure intersurgeon agreement.

RESULTS: Twenty-nine patients met the criteria and were included. Ninety-three percent of the surgical plans were changed after the MRI. Intersurgeon agreement was "slight" to "fair" both before the MRI (timing, $\kappa = 0.22$; approach, $\kappa = 0.35$; levels, $\kappa = 0.13$) and after the MRI (timing, $\kappa = 0.06$; approach, $\kappa = 0.27$; levels, $\kappa = 0.10$).

CONCLUSION: Surgical plans for ATCSCI changed substantially when the MRI was presented in addition to the CT; however, intersurgeon agreement regarding the surgical plan was low and not improved by the addition of the MRI. (*J Trauma Acute Care Surg*. 2021;90: 157–162.

LEVEL OF EVIDENCE: Diagnostic, level II.
KEY WORDS: Trauma; cervical; spine; MRI; surgery.

There are more than 200,000 people in the United States living with traumatic spinal cord injuries, and more than 16,000 new cases occur every year.[1] The most common anatomical region of injury is the cervical spine, constituting about half of all new cases.[1] Acute traumatic cervical spinal cord injuries (ATCSCIs) can have a devastating effect on a patient's physical and social well-being, and can impose substantial financial burdens on the patient, their family, and the community.[2,3] Optimal medical management is imperative to minimize these burdens, but there is substantial variability in diagnostic and treatment approach to ATCSCI.[4–11]

Upon arrival to the trauma bay, standard practice is to put patients at risk of an ATCSCI in spine motion restriction (e.g., a cervical collar) and perform a physical examination using the American Spinal Injury Association Impairment Scale to help guide diagnostics and treatment.[12–14] If further workup is indicated by the physical examination or if the patient is unexaminable, a diagnostic cervical spine computed tomography (CT) is then performed.[12] If the CT does not identify clinically significant injuries that are indications for cervical spine surgery, but the physical examination shows signs of ATCSCI (e.g., a focal neurological deficit), diagnostic cervical spine magnetic resonance imaging (MRI) is recommended.[15–18] Whether an MRI is useful if the CT and physical examination findings indicate a need for surgery is controversial. Currently, preoperative MRI for ATCSCI patients is relatively common, occurring in 73% of ATCSCI surgeries at our institution from 2010 to 2019. The MRI more effectively detects soft tissue injuries, but there are also significant costs and serious risks associated with the MRI in trauma patients.[18–20] There is a paucity of research assessing the usefulness of the MRI for surgical planning.

We undertook this study to assess the added value of an MRI in patients requiring surgery for ATCSCI. We had two hypotheses: (1) the surgical plan for ATCSCI would not change substantially after the MRI, and (2) intersurgeon agreement on the surgical plan would also not change substantially after the MRI.

PATIENTS AND METHODS

We performed a vignette-based survey study, a validated research approach to assess clinician decision making.[21] The vignettes were developed from actual patient encounters that were identified through a retrospective review of all adult trauma patients (aged 18–89 years) who presented to our American College of Surgeons-verified level 1 trauma center from 2010 to 2019. The retrospective review identified 29 patients who presented with signs of quadriplegia and underwent a CT, MRI, and subsequent cervical spine surgery within 48 hours, all of whom were included in the study. We abstracted patient demographics, comorbidities, anticoagulation status, cause of injury, time delay until arrival, subjective patient complaints, physical examination findings, and radiology reports. This information was anonymized and compiled into the clinical vignettes.

The vignettes were presented in two phases to three neurosurgeons, who had 2, 10, and 13 years of experience performing spine surgery. In Phase 1, the clinical vignettes were presented along with only the corresponding CTs. In Phase 2, a minimum of 2 weeks later, the clinical vignettes were presented along with the corresponding CTs and MRIs. The neurosurgeons were allowed to see all digital planes of the imaging. In both phases, after reviewing each clinical vignette and corresponding imaging,

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This study was presented at the American College of Surgeons 106th Annual Clinical Congress, Scientific Forum, October 3, 2020, in Chicago, Illinois.
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TABLE 1. Neurosurgeon Survey

Survey Questions
1. Is a surgical intervention indicated? If yes, when?
a. No (not clinically indicated and/or potential benefit does not justify risk)
b. Not now, but reassess in a few weeks
c. Yes, within 8 hours
d. Yes, within 24 hours
e. Yes, but not acutely (i.e., beyond 24 hours)
2. Would/was an MRI (be) helpful for operation planning?
a. Yes
b. No
3. What surgical approach would you take?
a. Anterior alone
b. Anterior with instrumentation
c. Posterior fusion only
d. Posterior decompression only
e. Posterior decompression with fusion
f. Circumferential fusion without decompression
g. Circumferential fusion with decompression
h. Cannot determine surgical approach
4. What level of surgery should be performed (free text answer)?

the surgeons completed a survey in which they determined if surgery was indicated, as well as surgery timing, surgery approach, and the targeted cervical vertebral levels (Table 1). The neurosurgeons completed the surveys independently and were not allowed to discuss the study with one another.

The primary outcome of this study was change in surgical plan. We report the frequency with which each individual surgeon changed their plan—overall and for timing, approach, and levels separately, each with 95% confidence intervals. We also compared the frequency of changes among the three surgeons using χ^2. We used Fleiss' kappa (κ) to measure the secondary outcome of intersurgeon agreement, using the standards for interpretation suggested by Landis and Koch[22] (Table 2). Our institutional review board approved this study.

RESULTS

All 3 neurosurgeons completed all 29 vignettes with and without the MRI, for a total of 174 surgical plans (i.e., 87 without and 87 with the MRI). All three elements of the surgical plans chosen by the surgeons in our study were substantially changed after the MRI. The mean ± SD age of the 29 patients was 46 ± 19 years, 90% were male, and 79% were White, with 97% sustaining blunt trauma. On arrival to the emergency

TABLE 2. Fleiss' κ Interpretation

κ Statistic	Strength of Agreement
<0.00	Poor
0.00–0.20	Slight
0.21–0.40	Fair
0.41–0.60	Moderate
0.61–0.80	Substantial
0.81–1.00	Almost perfect

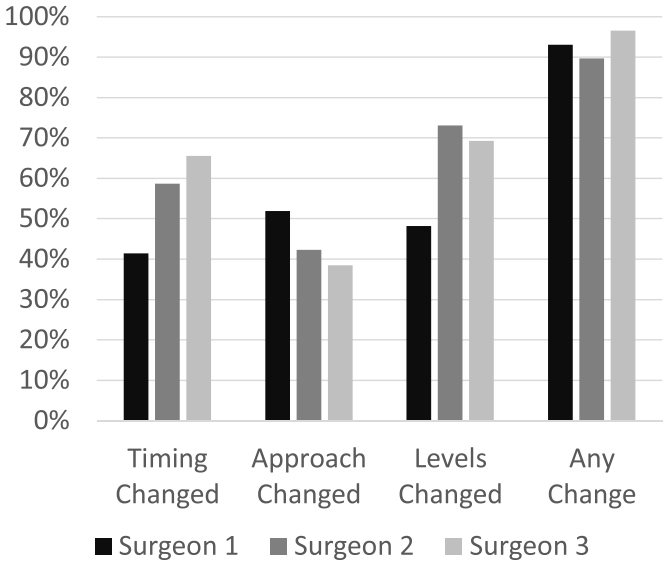

Figure 1. A graphic representation of the change in surgical timing, approach, and vertebral levels, as well as any change (i.e., timing and/or approach and/or vertebral levels) after the MRI, by surgeon. The percent represents the proportion of cases that changed after the MRI.

department, the patients had a heart rate of 83 ± 19 beats per minute, systolic blood pressure of 119 ± 35 mm Hg, a spine Abbreviated Injury Scale score of 5.0 ± 0.2, and an ISS of 34 ± 11. The patients were in the hospital for 20 ± 20 days, in the ICU for 12 ± 12 days, and on the ventilator for 10 ± 12 days and had a mortality of 14%.

Surgical timing was changed in 55% (confidence interval [CI], 44%–66%) of cases, approach in 44% (CI, 33%–55%) of cases, and targeted vertebral levels in 63% (CI, 52%–74%) of cases. When considering any change in the surgical plan (i.e., a change in timing and/or approach and/or levels), 93% (CI, 88%–98%) of surgical plans changed after the MRI. When comparing surgeons, the rate of changes in the surgical plan after the MRI was not dissimilar, as shown in Figure 1. The breakdown of changes in timing, approach, and vertebral levels after the MRI is shown in Figure 2.

Using Fleiss' κ, Table 3 shows the secondary outcome of intersurgeon agreement, which in our study is rated as "slight" to "fair" for all elements of the surgical plan, both before and after the MRI. κ marginally worsened for all elements of the surgical plan when the MRI was included with the vignettes.

DISCUSSION

The purpose of the study was to assess whether the addition of an MRI alters surgical planning for ATCSCI. We had two hypotheses: (1) the surgical plan for ATCSCI would not change substantially after the MRI, and (2) intersurgeon agreement on the surgical plan would also not change substantially after the MRI. Our study disproved the first hypothesis, as the surgical plan for ATCSCI was substantially changed after the MRI. Our study proved the second hypothesis, as intersurgeon agreement remained slight to fair both before and after the MRI.

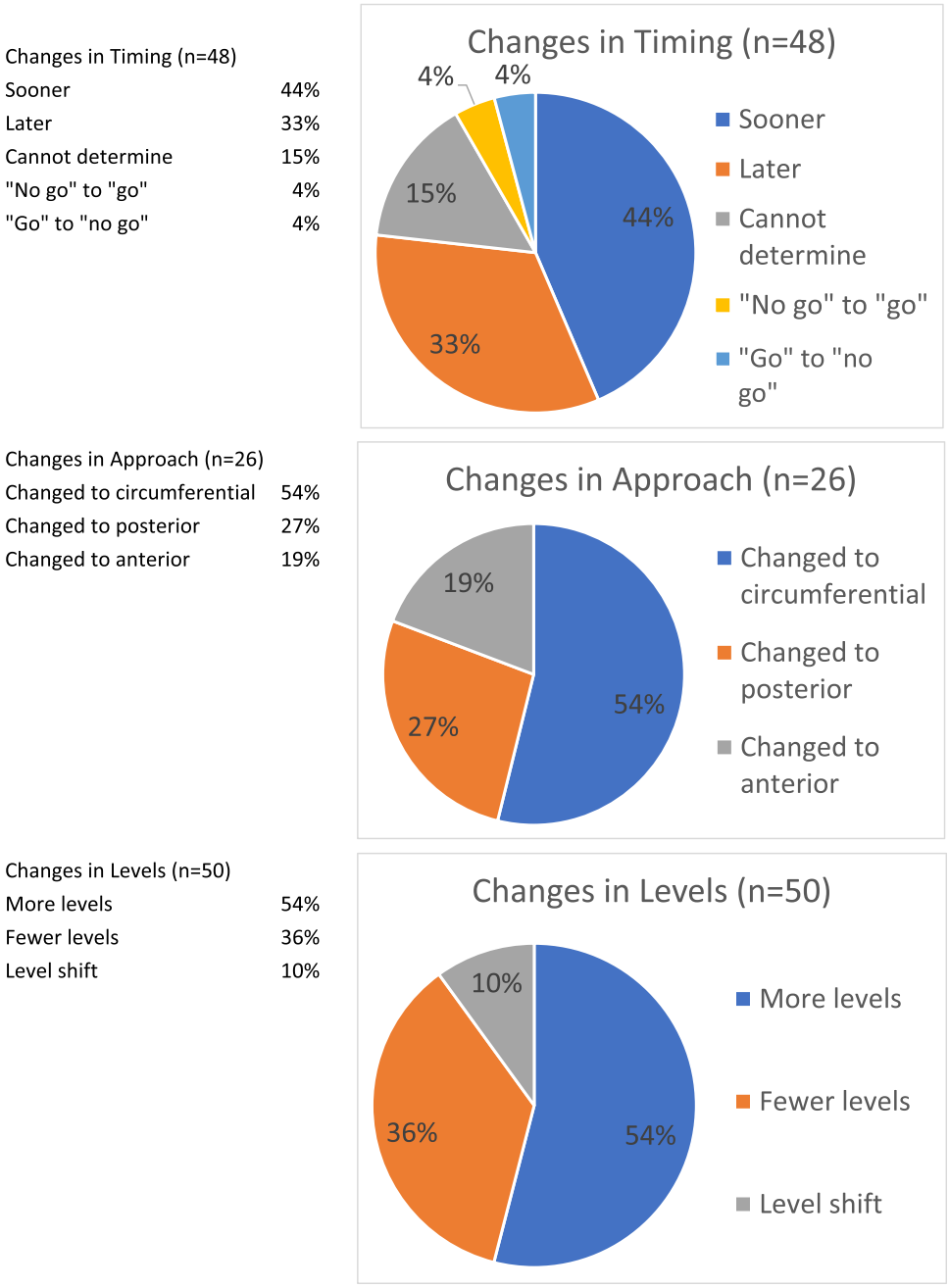

Figure 2. A graphic representation of the breakdown of the change in timing, approach, and vertebral levels after the MRI. The percent represents the proportion of cases that changed. Timing: *Sooner* means the surgeon chose to schedule the surgery for an earlier time. *Later* means the surgeon chose to schedule the surgery for a later time. *Cannot determine* means the surgeon was unable to determine the timing. *No go* to *go* means surgery was deemed unnecessary after the CT and necessary after the MRI. *Go* to *no go* means surgery was deemed necessary after the CT and unnecessary after the MRI. Approach: *Changed to circumferential* means the approach was changed from anterior or posterior to circumferential. *Changed to posterior* means the approach was changed from anterior or circumferential to posterior. *Changed to anterior* means the approach was changed from posterior or circumferential to anterior. Levels: *More levels* means the span of vertebral levels was expanded. *Fewer levels* means the span of vertebral levels was shrunken. *Level shift* means the span of vertebral levels did not change but was shifted up or down.

Previous studies assessing the utility of the MRI in ATCSCI patients have mostly focused on screening for ATCSCI on arrival at the hospital.[12,13,16] Substantial evidence has accumulated from these studies showing that an MRI is necessary for ATCSCI screening in certain circumstances (e.g., signs of cord compression on physical examination).[7–10,23] However, there is a paucity of research on the value of an MRI for surgical planning. A vignette-based survey study performed by Grassner et al.[9] in

TABLE 3. Intersurgeon Agreement

	CT Only		CT and MRI	
	% Agreement	κ	% Agreement	κ
Timing	50.6%	0.22	42.5%	0.06
Approach	59.8%	0.35	69.0%	0.27
Levels	17.2%	0.13	20.7%	0.10

2019 found the MRI had a substantial impact on the surgical plan, with a 41% change in timing, 48% change in approach, and 57% change in levels. Our study found similar changes in timing, approach, and levels, but we also looked at the surgical plan as a whole and found that 93% of plans changed in some way. The vast majority of cases in our study had clear indications for surgery based on the clinical examination and CT; the three neurosurgeons chose surgery for 94% of the vignettes after seeing the CT alone (i.e., Phase 1 of our study). While current neurosurgery and radiology society guidelines somewhat vaguely recommend an MRI in suspected ATCSCI cases, we hope this study will add to the body of literature and further clarify the role of the MRI for ATCSCI surgical planning.[24,25] Given the effect size seen in our study, we recommend performing both a CT and MRI on all ATCSCI patients for whom an operation is deemed necessary.

Despite the value of the MRI in some ATCSCI patients, it does have risks. A cervical spine MRI takes about 30 minutes at our institution, in addition to the delay between when the MRI is ordered and performed. Patients with unstable ATCSCI are at risk during this time. While in the MRI machine, certain patient monitoring capabilities may be limited or inconsistent.[19] Furthermore, patients undergoing MRI have been shown to be at higher risk of hypoxia, hypotension, intracranial hypertension, seizures, and ventilator acquired pneumonia.[20] Acute traumatic cervical spinal cord injury patients with unstable injuries may also be at risk of ATCSCI exacerbation before and during the scan, as evidenced by two patients included in our study (Fig. 3). These risks must be weighed against the potential benefit of an MRI in each clinical scenario. Although an MRI has risks and financial costs, our study adds weight to the contention that the MRI plays a key role in ATCSCI surgical planning and should, therefore, be used whenever feasible.

The low intersurgeon agreement in our study after the CT was expected. A lack of level 1 evidence has resulted in society guidelines that are vague and often optional regarding ATCSCI diagnostics and surgical planning.[24,25] For example, timing of ATCSCI surgical intervention remains a controversial topic, with older studies suggesting that early intervention is hazardous and newer studies suggesting that it improves outcomes.[8,26] As a result, there is substantial variability between surgeons and no clear criterion standard regarding the best diagnostic and treatment approach for ATCSCI.[4–11] This variability made the low intersurgeon agreement after the CT predictable; however, we did not expect the intersurgeon agreement to worsen after the MRI in all areas of the surgical plan. We anticipated that increasing the amount of objective information about ATCSCI cases would lead to greater alignment among surgeons, but that was not the case. A vignette-based survey study performed by Grauer et al.[6] in 2009 looking at cases of bilateral facet dislocation also found low intersurgeon agreement, but intersurgeon agreement did improve somewhat when the MRI was available for planning (from "poor" to "slight"). One possible explanation for the worsening of intersurgeon agreement after the MRI in our study is variability in surgical training and imaging interpretation. Another possibility is that there was insufficient physical examination data in the clinical vignettes, as many lacked American Spinal Injury Association scale data because of imperfect documentation in the electronic health record. Lastly, the worsening of the intersurgeon agreement after the MRI also raises the possibility that the large effect size seen in our study was not due to the influence of the MRI, but rather to inherent surgeon variability or study flaws. One way to resolve this issue would be to conduct the study again with the same neurosurgeons and vignettes after a period of time and compare answers between the two studies; however, given the time required for the neurosurgeons to complete these vignettes, that is not feasible. Further research is warranted to disentangle these effects and further clarify the usefulness of the MRI in ATCSCI surgical planning.

Several limitations of this study can be attributed to our approach of building the vignettes based on retrospective chart reviews. We relied on the accuracy of the electronic health record and the trauma registry. We would have liked to capture more physical examination data. Our study also included only three neurosurgeons; one of the neurosurgeons that participated

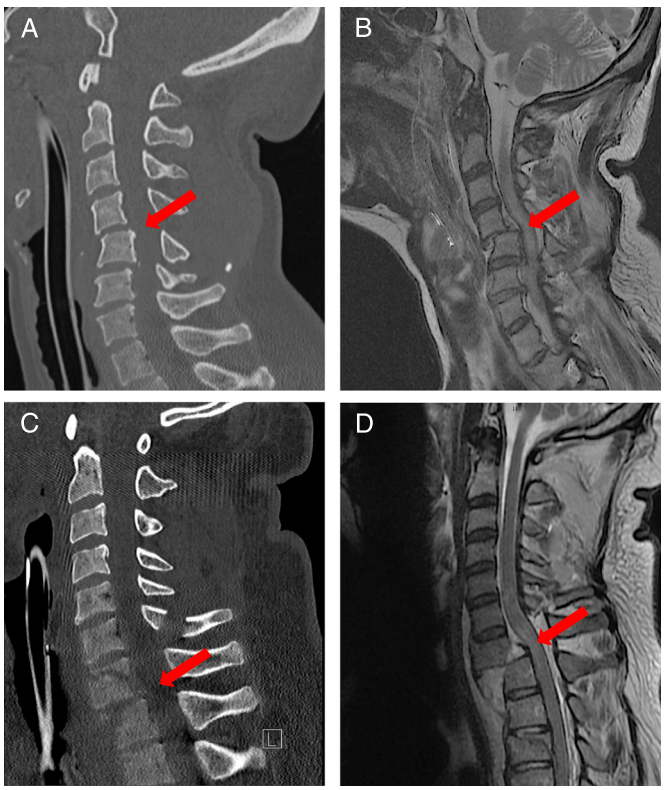

Figure 3. Representative images showing the risks of an MRI for patients with an unstable ATCSCI. (*A*) and (*B*) are sagittal CT and MRI images, respectively, of the same patient taken 6 hours apart, the MRI after the CT. (*C*) and (*D*) are sagittal CT and MRI images, respectively, of the same patient taken 2 hours apart, the MRI after the CT. In both patients, the ATCSCI evolved into cord compression between the two scans.

in the study had performed three of the cases included in the study in reality, but it had been over a year since those surgeries. Our design did not include repeated evaluations of the same scenarios that would allow us to estimate the consistency of surgeon operative planning; therefore, we cannot know whether the differences between the surgeons' plans in the CT only versus CT and MRI scenarios represent an influence of the MRI or simply inherent inconsistency in surgeons' approach to individual cases. There is also no established criterion standard against which to compare the accuracy of the surgeons' operative plans.

In conclusion, surgical plans for ATCSCI changed substantially when the MRI was presented in addition to the CT; however, intersurgeon agreement regarding the surgical plans was low and not improved by the addition of the MRI. Further research is needed to quantify the impact of the MRI on ATCSCI surgical planning and to account for the low intersurgeon agreement.

AUTHORSHIP

F.R.B., V.Y.W., J.P.A., J.R.O.-B., L.H.B., P.G.T., J.D.A., E.L., S.A., and C.V.R.B. performed the literature search, study design, data collection, data analysis, data interpretation, writing, and critical revision.

DISCLOSURE

The authors declare no conflicts of interest.

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