

Evaluating the Long-Term Neurologic Sequelae Among Trauma Patients who Received Flexion-Extension Radiographs

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ABSTRACT

Introduction. This study evaluated the presence of neurologic sequelae among trauma patients after flexion-extension (F/E) radiographs.

Methods. Authors of the study conducted a retrospective review of patients (age ≥ 14 years) with a Glasgow Coma Score of 15 who sustained a blunt traumatic injury and received F/E radiographs. Radiographic scans were defined as positive, negative, inconclusive, or incomplete. The neurologic status of each patient was assessed before and after the F/E radiographs, and at discharge and follow-up.

Results. Of the 501 patients included in the analysis, 84.6% ($n = 424$) had negative F/E radiographs, and 3.2% ($n = 16$) had positive F/E radiographs. Ten percent ($n = 51$) of patients had incomplete F/E radiographs, and 2.0% ($n = 10$) were inconclusive due to the inability to rule out a ligamentous injury. Three patients (0.6%) had MRI-confirmed ligamentous injuries, all of which had initial incomplete F/E radiographs due to pain. No patient had a documented neurological deficit before or after the F/E exam. Three patients with an initial negative F/E radiograph returned to the clinic with symptoms of neurologic sequelae. Two of these patients had symptom resolution with no further issues at future follow-up appointments. The third patient was found to have chronic neurologic symptoms after further evaluation.

Conclusions. The inclusion of F/E exams in cervical spine clearance protocols did not demonstrate any new long-term iatrogenic neurologic injuries. Consideration should be given to performing MRIs on patients with incomplete F/E radiographs that cannot rule out a ligamentous injury. *Kans J Med* 2024;17:78-80

INTRODUCTION

Cervical collars can be clinically cleared in patients with a suspected cervical spine injury who are awake, neurologically intact, and without neck pain or tenderness.¹ Those with pain or tenderness, a neurologic deficit, altered mental status, or distracting injury should be further evaluated with radiographic imaging.¹ For patients who have continued neck pain despite negative computed tomography (CT) results, the Eastern Association for the Surgery of Trauma (EAST) guidelines recommend either continuing the cervical collar until follow-up or removing it after additional imaging with either magnetic resonance imaging (MRI) or flexion-extension (F/E) radiographs.¹

Cervical spine clearance protocols vary widely throughout the United States, with F/E examinations remaining a common method for

evaluation.² Several studies have evaluated the use of F/E radiographs among blunt trauma patients, but few have addressed any long-term neurologic sequelae resulting from the F/E examination.³⁻¹³ Therefore, this study evaluated the presence of neurologic sequelae among non-obtunded trauma patients who received F/E radiographs due to concern for a neck injury.

METHODS

After obtaining Institutional Review Board (IRB) approval, a retrospective chart review was conducted at an American College of Surgeons-verified Level I Trauma Center. Blunt trauma patients 14 years or older with a Glasgow Coma Scale (GCS) of 15 who received F/E radiographs and had a negative cervical spine CT between January 1, 2007, and March 1, 2022, were identified. Data collected included demographics, mechanism of injury, injury severity, hospitalization details, disposition, and outcomes. Exclusion criteria included the presence of neurologic deficits concerning cervical spine involvement before F/E imaging and altered mental status during the performance of F/E radiographs.

The official radiographic results were used to define patient F/E results as positive, negative, inconclusive, or incomplete. A result was categorized as inconclusive when the official report could not specify how much spinal motion was present and/or provide definitive guidance on whether the motion was pathological. Reasons for an incomplete F/E examination included the inability to perform flexion or extension to a sufficient degree, obscuration of necessary visualization due to body habitus or overlying structures, or failure to produce visualization down to the C7/T1 junction.

To determine the neurologic sequelae of each patient, charts were thoroughly reviewed, and the neurologic status of each patient was assessed before and after the F/E exam. Discharge summaries also were reviewed to identify any reports of changes in neurologic status. Patients who presented for follow-up with symptoms concerning new-onset neurologic deficits were identified and further evaluated by chart review.

All data were entered and managed using Research Electronic Data Capture (REDCap[®]).^{14,15} Continuous data are reported as the mean and standard deviation for normally distributed data and as the median with interquartile range for non-normally distributed data. Categorical data are presented as raw counts with percentages noted parenthetically. Data were collected, organized, and summarized using SAS 9.4 (SAS Institute).

RESULTS

During the study period, a total of 506 trauma patients received F/E radiographs. Five patients were excluded due to positive cervical fracture CT results, neurologic deficits concerning cervical-spine involvement before F/E imaging and altered mental status during the performance of F/E imaging. Most patients were White (85.6%, $n = 429$) males (58.9%, $n = 295$) with an average age of 48 ± 21 years

(Table 1). Motor vehicle crashes (MVC; 38.3%, n = 192) were the most common mechanisms of injury, and patients were minimally injured with a mean ISS of 7 ± 6.3.

Table 1. Patient demographics and injury characteristics.

| Characteristics | All Patients (N = 501) |
|----------------------------------|------------------------|
| Age, years, Mean (SD) | 48 ± 21 |
| Male sex, no. (%) | 295 (58.9%) |
| Caucasian, no. (%) | 429 (85.6%) |
| Mechanism of injury, no (%) | |
| Motor vehicle crash | 192 (38.3%) |
| Fall | 157 (31.3%) |
| Motorcycle crash | 52 (10.4%) |
| Vehicle versus pedestrian | 34 (6.8%) |
| Other | 66 (13.2%) |
| Injury Severity Score, Mean (SD) | 7 ± 6.3 |

SD = Standard deviation

Overall, 84.6% (n = 424) of F/E results were negative and 3.2% (n = 16) were positive (Table 2). Ten percent (10.2%, n = 51) of all patients were determined to have incomplete F/E results and 2.0% (n = 10) were inconclusive due to the lack of ability to rule out a ligamentous injury. Three patients (0.6%) had an MRI-confirmed ligamentous injury; all of which had an initial incomplete F/E exam due to pain restricting their range of motion.

Table 2. Patient diagnostic findings.

| Diagnostic Findings | All Patients (N = 501) |
|--------------------------------|------------------------|
| Negative flexion-extension | 424 (84.6%) |
| Incomplete flexion-extension | 51 (10.2%) |
| Cleared clinically | 23/51 (45.1%) |
| Interpreted as negative | 15/51 (29.4%) |
| Cleared with MRI | 6/51 (11.7%) |
| Discharged in collar | 4/51 (7.8%) |
| Positive MRI | 3/51 (5.9%) |
| Positive flexion-extension | 16 (3.2%) |
| Cleared with MRI | 14/16 (87.5%) |
| Cleared clinically | 1/16 (6.3%) |
| Discharged in collar | 1/16 (6.3%) |
| Inconclusive flexion-extension | 10 (2.0%) |
| Cleared with MRI | 4/10 (40.0%) |
| Discharged in collar | 3/10 (30.0%) |
| Interpreted as negative | 2/10 (20.0%) |
| Cleared clinically | 1/10 (10.0%) |

*Data are presented as the number (%)

Forty-one percent (n = 208) of patients required ICU admission, and 8% (n = 40) needed mechanical ventilation (Table 3). No patient had a documented neurologic sequela before or after the F/E exam. Most patients were discharged to home (77.8%, n = 390), and the mortality rate was 0.4% (n = 2). Of the 41.5% (n = 208) of patients who

returned for follow-up, three reported neurologic deficits that were not present before the F/E exam. None of these patients were found to have radiologic evidence of ligamentous injury, and all had an initial negative F/E radiograph.

Cases: Possible New Neurologic Deficit After F/E Radiographs

Four days after discharge, Patient #1, who was discharged in a C-collar, was cleared with an MRI but experienced symptoms of paresthesia. These symptoms persisted for two weeks, waxing and waning until they completely resolved. Patient #2 had an extensive stay in both the hospital and a rehabilitation facility due to significant polytrauma. Following discharge, the patient experienced symptoms of bilateral paresthesia in their hands and feet. However, these symptoms had fully resolved at a subsequent two-week follow-up appointment. Patient #3 reported chronic paresthesia prior to discharge and at a two-week follow-up, but did not return for subsequent appointments.

Table 3. Patient hospital outcomes.

| Hospital Outcomes | All Patients (N = 501) |
|--|------------------------|
| Intensive Care Unit (ICU) admit, no. (%) | 208 (41.5%) |
| ICU length of stay, Mean (SD) | 1.2 ± 1.2 |
| Mechanical ventilation, no. (%) | 40 (8.0%) |
| Vent days, Mean (SD) | 2.6 ± 2.5 |
| Hospital length of stay, Mean (SD) | 3.4 ± 5.0 |
| Discharge disposition, no. (%) | |
| Home or self-care | 390 (77.8%) |
| Rehab, acute care, skilled nursing | 88 (17.6%) |
| Mortality, no. (%) | 2 (0.4%) |
| Neurologic symptoms, no. (%) | 3 (0.6%) |
| Before flexion-extension exam | 0 (0.0%) |
| After flexion-extension exam | 0 (0.0%) |
| At discharge | 1 (0.2%) |
| At follow-up | 3 (0.6%) |
| Returned for follow-up, no. (%) | 208 (41.5%) |

SD = Standard deviation

DISCUSSION

Although there has been research as to whether F/E radiographs add clear benefit to patient care^{4,9} and whether their performance and interpretation can be provider-dependent,^{10,11} there are few studies evaluating the safety of performing F/E radiographs in the setting of trauma.^{3,4} A secondary analysis of the NEXUS database noted that no harm was identified in the 10.5% of patients who obtained F/E radiographs.⁴ An additional study by Brady et al.³ investigated F/E radiograph utilization among 451 adult trauma patients and demonstrated that, despite F/E radiographs being performed without direct medical supervision, no patients had complications. However, these studies only noted that no complications or harm were identified in their study population and no patient follow-up was performed.

The current study adds to this literature as it is the first to investigate the neurologic status of each patient before and after an F/E exam, at discharge, and during follow-up. Study results identified three patients during the follow-up period who had symptoms of neurologic deficits after the F/E exam. Although the cause of the neurologic symptoms in these patients at follow-up is not fully understood, two patients had

complete resolution of symptoms within two to four weeks, and one patient was deemed to have chronic neurologic symptoms after further interview.

In the current study, three patients (0.6%) were found to have confirmed ligamentous injury on MRI. Interestingly, all three of these patients had incomplete F/E exams due to pain restricting their ability to perform the necessary movements. None of these patients required surgical intervention, and none suffered permanent neurologic sequelae. While this is a very small subset, it raises a concern about increasing the index of suspicion for ligamentous injury when significant discomfort is noted during the F/E examination.

Of the available clearance options by the EAST guidelines, F/E radiographs seem to provide a balance between safety and cost-effectiveness. Aside from F/E radiographs, other options include the patient being discharged with a cervical collar or being cleared by MRI.¹ Remaining in a cervical collar and returning for follow-up is often an inconvenient, costly, and unfollowed request of many patients. While MRIs provide the highest sensitivity for ligamentous injury, their routine use is costly, time-consuming, and likely impractical.

Limitations. This study had several limitations most notably that the data were collected retrospectively and from a single institution. Due to its retrospective nature, the authors were unable to accurately determine the cause of the two cases of new neurologic symptoms among the study population; however, as stated above, these symptoms resolved at follow-up. Also, the small size of our study may limit the generalizability of the results. There is also no standard protocol for the use of F/E exams, which are provider-dependent, and use varies among trauma physicians. Finally, there is a lack of long-term follow-up in a large portion of the included participants, however, it is assumed that these patients did not develop neurologic symptoms requiring a post-hospital visit.

CONCLUSIONS

The inclusion of F/E exams in cervical spine clearance protocols did not demonstrate any new, long-term iatrogenic neurologic injuries in this study. F/E exams are a readily accessible and cost-effective method for evaluating cervical spine ligamentous injury, while also satisfying EAST guidelines. Consideration for MRI should be given to trauma patients with inconclusive F/E exams, particularly if they experience pain or discomfort during the F/E exam.

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