INTRODUCTION

Recent studies have reported that 0.6% of the cumulative risk of cancer to 75 years of age can be attributable to diagnostic X-rays and estimate that 0.4% of cancers in the United States are caused by CT scans.[2,3] Here, in an interest of limiting the number of postoperative X-rays, we analyzed how frequently patients with nonoperative cervical spine fractures underwent postoperative X-ray studies, along with their overall follow-up duration and time to orthosis removal.

MATERIALS AND METHODS

Clinical data

There were 69 patients included in this study (122 fractures) who averaged 58 years of age. The most common mechanism of injury was motor vehicle accidents ($n = 27$, 39%), followed by...
falls <1 m ($n=21$, 30%). Other variables studied included: patient demographics, average hospital length of stay, and the types of nonoperative cervical fractures treated [Table 1, Figures 1 and 2]. The Miami J was by far the most common orthotic used ($n=48$, 71%), followed by Miami J and CTO ($n=11$, 16%) [Figure 3]. Patients were cleared by an IRB committee and were selected utilizing multiple inclusion and exclusion criteria were used [Supplemental Table 1].

**RESULTS**

The study revealed that all patients had, on average, four follow-up visits occurred on average 28-, 66-, 94-, and 158-day post hospital discharge [Supplemental Table 2]. The average time between hospital discharge and clearance from an orthotic was 70 days [Table 2]. At 28 days, X-rays performed in 57 patients impacted clinical decision-making in four; two with vertebral body fractures, one with a facet fracture, and one with a compression fracture [Table 2]. However, at the second postoperative visit at 66 days, the third visit at 94 days, and the fourth visit at 158 days, repeat X-ray studies did not alter the clinical management of any patient [Table 2]. Of note, the average time between hospital discharge and removal of an orthotic device averaged 70 days [Table 2].

**DISCUSSION**

This analysis of the nonoperative management of 69 adults confirmed that only their initial postoperative X-rays

| Table 1: Patient data. |
|-------------------------|
| **Number of patients** | **Total (%)** |
| **Gender**              |               |
| Male                    | 57            | 82.6         |
| Female                  | 36            | 52.2         |
| **Race**                |               |
| Caucasian               | 57            | 82.6         |
| American Indian         | 5             | 7.2          |
| African American        | 5             | 7.2          |
| Other                   | 2             | 2.9          |
| **Age**                 |               |
| 17–40                   | 19            | 27.5         |
| 41–60                   | 17            | 24.6         |
| 61–80                   | 16            | 23.2         |
| 81–97                   | 17            | 24.6         |
| **Length of stay**      |               |
| 1–3                     | 37            | 53.6         |
| 4–7                     | 22            | 31.9         |
| 8–10                    | 5             | 7.2          |
| 11–20                   | 3             | 4.3          |
| 21–40                   | 2             | 2.9          |

**Figure 1**: Fracture type totals by cervical level.
obtained at an average of 28-day post discharge impacted their clinical management. All subsequent X-rays obtained at an average of 66-, 94-, and 158-day post discharge did not. Therefore, repeating postoperative X-rays and exposing patients to additional radiation with prolongation of the follow-up period were all unnecessary.

Success of conservative management of C1-C2 fractures

Kontautas et al. and Hadley et al. found that isolated C1 fractures heal well with a cervical collar alone (95% fusion rate). Type 1 fractures have been reported to achieve 100% union rates; however, Type 2 fractures are the most common and unfortunately present with high rates of pseudoarthrosis. For stable Type 3 fractures, conservative treatment is the standard of care due to high union rates. In our cohort, none the patients with isolated C1 fractures were followed beyond the second follow-up visit at 66-days, and further imaging never altered the clinical management. For isolated C2 fractures, our cohort consisted of 15 patients; managed with various orthoses with orthotic clearance on average 83-day post discharge. In our cohort, only two patients had a change in intervention from imaging performed during the first follow-up, and only three were followed beyond the second appointment. For the 12 patients with stable Type 3 fractures in our series, X-rays did not change management for any patient during follow-up period, with an average orthotic clearance of 89-day post discharge.

Conservative management of sub-axial fractures

Vedantam et al. reviewed 35 patients with sub-axial facet fractures managed non-operatively (cervical bracing alone) and 82.9% of patients fused successfully. Of our 56 patients with variable sub-axial fractures managed with various orthotics, Eighteen patients (32%) with sub-axial facet fractures were cleared from the orthotic on average 60-day post discharge, or at the second follow-up.
Optimal follow-up for nonsurgical cervical fractures

At present, there are few recommendations regarding the optimal number/types of imaging studies needed to follow patients with nonoperative cervical fractures and the optimal follow-up duration. Here, in 69 patients, we found that most will undergo a change in therapy/intervention based on X-ray studies obtained at the first follow-up visit, 28-day post discharge. Interestingly, no patients required additional alterations in management based on X-rays obtained on average 66-, 94-, and 158-day post discharge. Nonetheless, as patients typically had cervical orthoses removed an average of 70-day post discharge; the second follow-up visit was likely necessary.

CONCLUSION

When we studied 69 patients treated conservatively for nonoperative cervical spine fractures, we found that X-ray studies obtained on average 28-, 66-, 94-, and 158-day post discharge did not significantly alter patients' clinical management, but unnecessarily prolonged the follow-up duration.

Declaration of patient consent

Institutional Review Board (IRB) permission obtained for the study.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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SUPPLEMENTAL TABLES

Supplemental Table 1: Inclusion and exclusion criteria.

Inclusion and Exclusion Criteria

- One or more fractures involving the cervical spine
- One or more of the cervical fractures were managed nonoperatively
- Patients had sufficient follow‑up and radiographic information from outpatient clinic records
- For patients with comorbid operative and non‑operative fractures, only the nonoperative fracture and follow‑up information concerning nonoperative management was collected
- Alteration of the intervention by prolongation of orthotic clearance was determined by imaging results and/or surgeon dictation
- Physical examination findings, patient presentation, operatively managed fractures, or other patient related factors were excluded from this assessment
## Supplemental Table 2: Patient demographics, fracture, bracing, and follow-up data.

| Record ID | Age | Sex | Length of Stay (Days) | Discharge Destination | Bracing Device | Mechanism of Injury | Level of Injury | Type of Fracture | Days from Discharge to 1st FU | Imaging at 1st FU | Days from Discharge to 2nd FU | Imaging at 2nd FU | Changed Intervention? | Days from Discharge to 3rd FU | Imaging at 3rd FU | Changed Intervention? | Days from Discharge to 4th FU | Imaging at 4th FU | Changed Intervention? | Days from Discharge to Clearance |
|-----------|-----|-----|----------------------|-----------------------|-----------------|-------------------|------------------|----------------|-----------------------------|----------------|-----------------------------|----------------|--------------------------|-----------------------------|----------------|--------------------------|-----------------------------|----------------|--------------------------|-----------------------------|
| 2         | 20  | Male| 2                    | HOME                  | Miami J         | MVC               | C5, C7           | Facet, Lamina   | 42             | Y N                         | 60             | Y N                         | 92             | Y N                      | 92             | N                        | N                           | N                        | N                       | N                           |
| 9         | 79  | Female| 15                  | SNF                   | Miami J         | Fall < lm        | C1, C5           | SP, Lamina      | 39             | Y N                         | 57             | Y N                         | 99             | Y N                      | Unknown        | N                        | N                           | N                        | N                       | N                           |
| 11        | 83  | Female| 3                   | REHAB                 | Miami J         | Fall < lm        | C2               | Odontoid        | 15             | Y N                         | 50             | Y N                         | 99             | Y N                      | Unknown        | N                        | N                           | N                        | N                       | N                           |
| 12        | 31  | Female| 6                   | HOME                  | None            | MVC              | C6, C7           | TP              | 21             | N NA                        | 72             | Y N                         | 72             | Y N                      | Unknown        | N                        | N                           | N                        | N                       | N                           |
| 14        | 88  | Male | 4                   | SFN                   | Miami J         | Fall > lm        | C2, C6           | Odontoid, arch  | 8              | Y N                         | 50             | Y N                         | 99             | Y N                      | Unknown        | N                        | N                           | N                        | N                       | N                           |
| 17        | 17  | Female| 35                  | LTAC                  | Miami J         | MCV              | C2               | Lamina          | 13             | Y N                         | 41             | Y N                         | 41             | N                        | Unknown        | N                        | N                           | N                        | N                       | N                           |
| 18        | 46  | Male | 8                   | HOME                  | Miami J         | L-CTO            | ATV              | Facet, Lamina   | 16             | Y N                         | 72             | Y N                         | 72             | Y N                      | Unknown        | N                        | N                           | N                        | N                       | N                           |
| 22        | 53  | Female| 5                   | REHAB                 | Miami J         | MCV              | C5               | Facet           | 26             | Y Y                         | 82             | Y N                         | 82             | N                        | Unknown        | N                        | N                           | N                        | N                       | N                           |
| 23        | 19  | Female| 2                   | HOME                  | Miami J         | MVC              | Occiput, C7     | TP              | 20             | N NA                        | 30             | N N                         | 30             | N                        | Unknown        | N                        | N                           | N                        | N                       | N                           |
| 25        | 70  | Male | 2                   | HOME                  | Miami J         | Fall < lm        | C5, C6           | Facet, Lamina   | 30             | N N                         | 77             | N NA                        | 77             | N                        | Unknown        | N                        | N                           | N                        | N                       | N                           |
| 30        | 67  | Male | 1                   | HOME                  | None            | MVC              | C6               | LB              | 4              | Y N                         | 77             | N NA                        | 77             | N                        | Unknown        | N                        | N                           | N                        | N                       | N                           |
| 31        | 83  | Male | 5                   | REHAB                 | Miami J         | Fall > lm        | C3,46,6         | TP              | 35             | Y Y                         | 63             | Y N                         | 63             | Y N                      | Unknown        | N                        | N                           | N                        | N                       | N                           |
| 32        | 83  | Male | 2                   | REHAB                 | Miami J         | Fall > lm        | C3,46,6         | TP              | 35             | Y Y                         | 105            | Y N                         | 105            | Y N                      | Unknown        | N                        | N                           | N                        | N                       | N                           |
| 34        | 53  | Male | 6                   | HOME                  | Aspen            | MCV              | C5               | Lamina         | 14             | Y N                         | 98             | Y N                         | 98             | Y N                      | Unknown        | N                        | N                           | N                        | N                       | N                           |
| 35        | 70  | Female| 7                   | SNF                   | Miami J         | Fall > lm        | C7               | Other           | 18             | N NA                        | 38             | N NA                        | 38             | N NA                     | Unknown        | N                        | N                           | N                        | N                       | N                           |
| 36        | 17  | Female| 1                   | HOME                  | Miami J         | MCV              | C7               | TP              | 5              | N NA                        | 171            | Y N                         | 171            | Y N                      | Unknown        | N                        | N                           | N                        | N                       | N                           |
| 37        | 38  | Male | 15                  | REHAB                 | Miami J         | ATV              | C6               | Facet           | 73             | Y N                         | 106            | Y N                         | 106            | Y N                      | Unknown        | N                        | N                           | N                        | N                       | N                           |
| 39        | 86  | Female| 4                   | REHAB                 | Miami J         | Fall < lm        | C2               | Odontoid        | 19             | N NA                        | 64             | Y N                         | 64             | Y N                      | Unknown        | N                        | N                           | N                        | N                       | N                           |
| 40        | 65  | Male | 1                   | HOME w/ supervision   | Miami J         | Fall < lm        | C6, C7           | Facet           | 19             | Y Y                         | 68             | Y N                         | 68             | Y N                      | 110            | Y N                      | 110            | N                        | 110            | N                        | N                           | N                        | N                       | N                           |
| 41        | 85  | Female| 5                   | REHAB                 | Miami J         | Fall < lm        | C1               | Arch            | 29             | Y N                         | 53             | N NA                        | 53             | N NA                     | Unknown        | N                        | N                           | N                        | N                       | N                           |
| 42        | 82  | Male | 1                   | HOME                  | None            | MVC              | C6               | LB              | 34             | Y N                         | 37             | Y N                         | 37             | Y N                      | Unknown        | N                        | N                           | N                        | N                       | N                           |
| 43        | 88  | Female| 2                   | HOME w/ supervision   | Miami J         | Fall < lm        | C2               | Odontoid        | 11             | N NA                        | 9              | N NA                        | 9              | N NA                     | Unknown        | N                        | N                           | N                        | N                       | N                           |
| 49        | 63  | Female| 1                   | HOME                  | Miami J         | MCV              | C2, C5           | Facet           | 11             | N NA                        | 37             | Y N                         | 37             | Y N                      | Unknown        | N                        | N                           | N                        | N                       | N                           |
| 50        | 59  | Female| 5                   | REHAB                 | Miami J         | ATV              | C6               | Facet, Lamina   | 9              | N NA                        | 53             | N NA                        | 53             | N NA                     | Unknown        | N                        | N                           | N                        | N                       | N                           |
| 54        | 20  | Female| 30                  | REHAB                 | Miami J         | MCV              | C2               | Odontoid        | 47             | Y N                         | 124            | N NA                        | 124            | N NA                     | Unknown        | N                        | N                           | N                        | N                       | N                           |
| 56        | 36  | Female| 5                   | HOME                  | Miami J         | MCV              | C2               | Endplate        | 14             | Y N                         | 42             | Y N                         | 42             | Y N                      | Unknown        | N                        | N                           | N                        | N                       | N                           |
| Age | Sex | Site of Injury | Onset | Destination | Device | Level of Intervention | Days from Onset | Days from Discharge to FU | Days from 2nd FU Discharge | Days from Imaging | Changed |
|-----|-----|----------------|-------|-------------|--------|----------------------|-----------------|--------------------------|--------------------------|-----------------|---------|
| 22  | Female | HOME | I-CTO | Occiput | C1, C2 | C1, C2, C3 | 57 | 60 | Y | N | 57 | N | 56 | N | 56 | N |
| 88  | Female | HOME | Lower back | Occiput | C1, C2 | C1, C2, C3 | 60 | 60 | Y | N | 30 | N | 30 | Y | 30 | N |
| 27  | Male | HOME | Lower back | Occiput | C1, C2 | C1, C2, C3 | 64 | 60 | Y | N | 30 | N | 30 | N | 30 | N |
| 91  | Male | HOME | Lower back | Occiput | C1, C2 | C1, C2, C3 | 70 | 70 | Y | N | 30 | N | 30 | Y | 30 | N |
| 26  | Male | HOME | Lower back | Occiput | C1, C2 | C1, C2, C3 | 72 | 68 | Y | N | 30 | N | 30 | N | 30 | N |
| 34  | Male | HOME | Lower back | Occiput | C1, C2 | C1, C2, C3 | 89 | 75 | Y | N | 30 | N | 30 | N | 30 | N |

(Contd...)
Supplemental Table 2: (Continued)

| Record ID | Age | Sex | Length of Stay (Days) | Discharge Destination | Bracing Device | Mechanism of Injury | Level of Injury | Type of Fracture | Days from Discharge to 1st FU | Imaging at 1st FU | Changed Intervention? | Days from Discharge to 2nd FU | Imaging at 2nd FU | Changed Intervention? | Days from Discharge to 3rd FU | Imaging at 3rd FU | Changed Intervention? | Days from Discharge to 4th FU | Imaging at 4th FU | Changed Intervention? | Days from Discharge to Brace Clearance | Service |
|-----------|-----|-----|-----------------------|-----------------------|----------------|---------------------|-----------------|-----------------|---------------------------|----------------|---------------------|---------------------------|----------------|---------------------|---------------------------|----------------|---------------------|---------------------------|----------------|---------------------|----------------------------|---------|
| 144       | 77  | Female | 1                     | HOME                  | Miami J        | Fall <1m           | C1              | Other           | 27                        | Y              | Y                   | 30                        | Y              | Y                   | 85                        | Y              | Y                   | 14                        | Unknown | NES                 |
| 149       | 57  | Female | 3                     | HOME                  | Miami J        | Assault            | C2, C6          | Lateral Mass, Pedicle, Facet, Compression | 50                        | Y              | N                   | 85                        | Y              | Y                   | 8                        | Unknown | NES                 |
| 154       | 55  | Male   | 2                     | HOME                  | Miami J        | MVC                | C6, C7          | Other           | 32                        | Y              | N                   | 68                        | Y              | Y                   | 8                        | Unknown | NES                 |
| 158       | 94  | Female | 1                     | HOME w/ home health  | Miami J        | Fall <1m           | C3              | Other           | 4                         | Y              | N                   | 53                        | N              | NA                  | Unknown                   | Ortho   |
| 161       | 49  | Female | 6                     | HOME                  | Miami J        | MVC                | C5, C6, C7      | Lateral Mass, Facet, Compression, Transverse Foramen | 7                         | N              | Y                   | 84                        | Y              | Y                   | Unknown                   | Ortho   |
| 166       | 81  | Female | 3                     | HOME                  | Miami J        | Fall <1m           | C1, C4          | Other           | 14                        | Y              | N                   | 28                        | N              | NA                  | 70                        | Y              | Y                   | 70                        | Ortho   |
| 170       | 51  | Male   | 1                     | HOME                  | Miami J        | MVC                | C7              | Facet, VB       | 8                         | Y              | N                   | Unknown                   | Ortho   |
| 172       | 32  | Male   | 1                     | HOME                  | Miami J        | MVC                | C3              | Arch            | 40                        | Y              | N                   | Unknown                   | Ortho   |
| 174       | 48  | Male   | 2                     | HOME                  | Miami J        | ATV                | C4              | Facet           | 41                        | Y              | N                   | 76                        | Y              | Y                   | 71                        | Y              | N                   | 71                        | NES     |
| 182       | 35  | Female | 4                     | REHAB                 | Miami J        | MVC                | C4              | TP, Lamina, Pedicle                                  | 36                        | Y              | N                   | 71                        | Y              | Y                   | 71                        | Y              | N                   | 71                        | NES     |
| 183       | 27  | Female | 5                     | HOME                  | Miami J        | Fall >1m           | C6, C7          | TP, VB          | 13                        | Y              | N                   | 41                        | Y              | N                   | 90                        | Y              | N                   | 90                        | Ortho   |
| 189       | 29  | Male   | 1                     | HOME                  | Miami J        | MVC                | C6, C7          | Facet           | 14                        | Y              | N                   | Unknown                   | Ortho   |
| 196       | 65  | Female | 4                     | HOME                  | Miami J        | Fall <1m           | C5, C6          | Compression, Other                                   | 37                        | Y              | Y                   | 77                        | Y              | N                   | 77                        | NES     |

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