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Adult Trauma Patients with Isolated Thoracolumbar Spinous and Transverse Process Fractures May be Managed Conservatively to Improve Emergency Department Throughput

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Purpose: Traumatic vertebral injuries have a prevalence of 4–5% at level I centers. Studies have demonstrated that isolated thoracolumbar transverse process fractures (iTPF) rarely require brace or surgical interventions. We hypothesized that similarly isolated thoracolumbar spinous process fractures (iSPF) would have less need for bracing and operative interventions than SPFs with associated vertebral body (VB) fractures (SPF+VB). We performed a similar analysis for iTPF compared to transverse process fractures associated with VB injury (TPF+VB).
Methods: In this single-center, retrospective study from 2012 to 2016, patients were classified into iSPF, SPF+VB, iTPF, and TPF+VB groups. Data including the fracture pattern, neurologic deficits, and operative intervention were obtained. The primary outcome studied was the need for bracing and/or surgery. A statistical analysis was conducted.
Results: Of 98 patients with spinous process fractures, 21 had iSPF and 77 had SPF+VB. No iSPF patients underwent surgery, whereas 24 (31.17%) SPF+VB patients did undergo surgery (p=0.012). In the iSPF group, three patients (15%) received braces only for comfort, whereas 37 (48.68%) of the SPF+VB group required bracing (p=0.058). Of 474 patients with transverse process fractures, 335 had iTPF and 139 had TPF+VB. No iTPF patients underwent surgery, whereas 28 (20.14%) TPF+VB patients did ($p\leq$ 0.001). Of the iTPF patients, six (1.86%) were recommended to receive braces only for comfort, while 68 (50.75%) of the TPF+VB patients required bracing (p<0.001).
Conclusions: No patients with iSPF or iTPF required surgical intervention, and bracing was recommended to patients in these groups for comfort only. It appears that these injures may be safely managed without interventions, calling into question the need for spine consultation.

Keywords: Spine; Surgery; Injury; Conservative treatment

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INTRODUCTION

Traumatic injuries involving the vertebral column are common, with a prevalence of approximately 4–5% in all trauma patients presenting to a level 1 trauma center [1]. The primary concern when treating spine fractures is determining whether the fracture is stable or unstable. In general, fractures involving two contiguous weight-bearing columns of the spine are unstable [1,2] and frequently require a spine consultation. However, the spinous and transverse processes are non-weight-bearing structures, serving as muscular and ligamentous attachment sites. Previous studies have demonstrated that isolated transverse process fractures (defined as transverse process fractures with no injury of the spinous process, vertebral body, or other spinal structure) do not require intervention or even a spine consultation [3-6].

With the widespread use of computed tomography (CT) scans for high-energy trauma mechanisms, our ability to detect injuries of spinal column structures has increased significantly [2-4,6]. The practice at University of California, Irvine and others has been to consult spine specialists for both isolated spinous and isolated transverse process fractures of the thoracolumbar spine even though the treatment of these injuries does not require any operative intervention or a brace outside of those prescribed for comfort [2-5]. This type of reflexive consultation can increase the length of time until spine clearance, which could be associated with an increase in adverse events including venous thromboembolism (VTE) and decubitus ulcer formation [3-5].

Recently, Akinpelu et al. [6] found that isolated transverse and spinous process fractures in a pediatric population could be treated symptomatically with no long-term sequelae related to these injuries. However, to our knowledge, no studies have evaluated the outcomes of isolated thoracolumbar spinous process fractures in adults. Based on our cumulative experience with these types of injuries, and the similarity of function between the spinous and transverse processes, we hypothesized that isolated thoracolumbar (defined as being between the first thoracic vertebra and the fifth lumbar vertebra) spinous process fractures can also be safely managed with no requirement for a brace or any spinal operative intervention, such as spinal fusion.

METHODS

Patients

This IRB-approved, single-center, retrospective study was conducted examining data from 2012 to 2016 (IRB No. HS# 2016-3183) The patients eligible for inclusion were all adult (age ≥18) trauma patients admitted to University of California, Irvine from January 2012 to October 2016 with isolated thoracolumbar spinous process fractures (iSPF) and spinous process fractures with associated vertebral body fracture (SPF+VB), as identified on CT scans. As a secondary objective, we also identified all adult (age ≥18) trauma patients in our database from 2012 to 2016 with isolated thoracolumbar transverse process fractures (iTPF) and transverse process fractures with associated vertebral body fracture (TPF+VB). Cervical spine and sacral fractures were not included in our analysis. Pregnant patients and prisoners were also excluded from this study.

Patients were grouped and compared as follows: iSPF versus SPF+VB, and iTPF versus TPF+VB. Chart review was conducted to determine baseline demographic information such as age and sex, as well as to obtain key outcome measures. The primary outcome assessed by this study was the need for a spine intervention, which was defined as bracing or an operative intervention. Secondary outcomes included the presence or absence of inpatient/post-discharge neurologic deficits, the development of morbidities associated with prolonged immobilization due to spine precautions such as venous thromboembolism or urinary retention, hospital and intensive care unit (ICU) length of stay (LOS), mortality, and need for outpatient follow-up. In addition, any available outpatient follow-up data were reported, including pain level (mild, moderate, or severe), need for further pain medication, and functional deficits.

Data was collected using the REDCap electronic data capture tool, which is a secure, web-based application designed to support data capture that provides 1) an intuitive interface for validated data entry, 2) audit trails for tracking data manipulation and export procedures, 3) au-

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tomated export procedures for seamless data downloads to common statistical packages, and 4) procedures for importing data from external sources [7]. The data were analyzed using the statistical computing software R [8,9].

The data were summarized as means with standard deviations, medians with interquartile ranges for continuous variables, or counts and percentages for categorical variables. The Fisher exact test was used to test the independence of the main outcomes of interest and the type of fracture for categorical outcomes. The Mann-Whitney-Wilcoxon test was used to test the independence of LOS and mortality. Statistical significance was set at the 5% level, and Holm's method for correction was used to guard against multiple comparisons.

RESULTS

Demographic data of spinous process fracture patients

A total of 572 patients from 2012 to 2016 were identified. Ninety-eight patients had spinous process fractures, of whom 21 (21.4%) had iSPF and 77 (78.6%) had SPF+VB. The mean age of the patients was similar between both groups (iSPF: 44.22 years vs. SPF+VB: 42.90 years). Men comprised the majority of patients in both groups. The mean Injury Severity Score (ISS) was lower in the iSPF group (16.38 vs. 18.89). The most common injury mechanism in both groups was pedestrian struck by vehicle (seven iSPF patients [33%] and 24 SPF+VB patients [31%]). The remaining demographic data and mechanisms of injury are summarized in Table 1.

Primary and key secondary outcomes in spinous process fracture patients

The primary outcome of an operative intervention occurred in 24 of the 77 patients in the SPF+VB group (31.17%) compared with none of the 24 patients in the iSPF group (0%) ($p<0.001$). Braces were given to 37 patients in the SPF+VB group (48.68%), compared to three in the iSPF group (15%) ($p=0.058$). However, the braces in the iSPF group were recommended for comfort only and not required for stabilization, while those in the SPF+VB group were required according to the consulting spine service.

There were no significant between-group differences in neurologic deficits, either on presentation (one iSPF patient [4.75%] vs. eight SPF+VB patients [10.39%], $p=0.679$), or on discharge (zero iSPF patients vs. seven SPF+VB patients [9.09%], $p=1.000$). Hospital LOS was shorter in the iSPF group (7.33 vs. 9.87 days), although this difference was not significant based on the Wilcoxon test ($p=0.057$). ICU LOS, however, was significantly shorter in the iSPF group (1.67 vs. 4.74 days) ($p=0.009$). Mortality was not significantly different between groups, with one death in each group (4.76% of iSPF patients vs. 1.32% SPF+VB patients, $p=1.000$). Of the 21 iSPF patients, only one (4.76%) received follow-up, compared to 30 patients (40.79%) in the SPF+VB group ($p=0.018$). This single patient in the iSPF group that received follow-up reported moderate pain, but did not require further pain medication and had no functional deficit (Table 2).

Additionally, there were no morbidities associated with prolonged immobilization in the iSPF group (0%), com-

Table 1. Summary of patients' demographic characteristics and injury mechanisms by type of spinous process fracture: isolated (iSPF) versus associated (SPF+VB)

Characteristic	SPF+VB (n=77)	iSPF (n=21)
Age (years)	44.22 (18.56)	42.90 (21.12)
Gender		
Female	17 (22)	3 (14)
Male	60 (78)	18 (86)
Mechanism of Injury		
Fall from height	6 (7.8)	5 (24)
GLF	21 (27)	1 (4.8)
Penetrating	1 (1.3)	2 (9.5)
MCC	6 (7.8)	0 (0)
MVC	11 (14)	3 (14)
Pedestrian struck	24 (31)	7 (33)
Other/unknown	8 (10)	3 (14)
ISS	18.89 (10.31)	16.38 (12.27)
ISS	17.00 (12.50–25.50)	10.00 (8.00–22.00)

Values are presented as number (%) or median (interquartile range).
iSPF: isolated thoracolumbar spinous process fractures, SPF+VB: spinous process fractures with associated vertebral body fracture, GLF: ground level fall, MCC: motor vehicle collision, MVC: motorcycle collision, ISS: Injury Severity Score.

pared to eight patients in the SPF+VB group (10.38%) (p=0.195). While there was a case of organ-space surgical site infection noted in the iSPF group, this was from an unassociated (non-spine) procedure. The remaining morbidities for these groups are summarized in Table 3.

Demographic data of transverse process fracture patients

Of the 474 patients with transverse process fractures, 335 (70.7%) had iTPF and 139 (29.3%) had TPF+VB. The mean age of the iTPF group was 46.37 years compared to 49.45 in the TPF+VB group. The majority of both groups were men, and the mean ISS was lower in the iTPF group than in the TPF+VB group (16.76 vs. 18.02). The most common injury mechanism in both groups was motor vehicle collisions (142 iTPF patients [42%] vs. 40 TPF+VB patients [29%]) (Table 4).

Primary and key secondary outcomes of transverse process fracture patients

An operative intervention was required in 28 of the 139 TPF+VB patients (20.14%), and none of the iTPF patients (0%) (p<0.0001). Braces were issued in 68 patients in the TPF+VB group (50.75%) versus six patients in the iTPF group (1.86%) (p<0.0001). Similar to the iSPF group, the iTPF group received braces only for comfort. There was no significant difference in mortality between groups, with two deaths in each group (0.60% of iTPF patients vs.

Table 3. Summary of patients' spine-related and other morbidities by type of spinous process fracture: isolated (iSPF) versus associated (SPF+VB)

Characteristic	SPF+VB (n=77)	iSPF (n=21)	*p*-value (naïve)
DVT	2 (2.60)	0 (0.00)	1
Pulmonary embolism	4 (5.19)	0 (0.00)	0.574
Urinary retention	2 (2.60)	0 (0.00)	1
Total spine related morbidity	8 (10.38)	0 (0.00)	0.195
UTI	1 (1.30)	0 (0.00)	1
Myocardial infarction	0 (0.00)	0 (0.00)	NA
Organ space SSI	1 (1.30)	1 (4.76)	0.384
Acute kidney injury	1 (1.30)	0 (0.00)	1
Pneumonia	5 (6.49)	0 (0.00)	0.581
Catheter related infection	0 (0.00)	0 (0.00)	NA
Unplanned return to the OR	0 (0.00)	0 (0.00)	NA
No other morbidity	68 (88.31)	20 (95.24)	0.684

Values are presented as number (%).
iSPF: isolated thoracolumbar spinous process fractures, SPF+VB: spinous process fractures with associated vertebral body fracture, DVT: deep vein thrombosis, UTI: urinary tract infection, SSI: surgical site infection, OR: operating room, NA: non-available.

Table 2. Summary of patient outcomes by type of spinous process fracture: isolated (iSPF) versus associated (SPF+VB). Crude and adjusted *p*-values are included. The Fisher exact test was used to test the independence of each categorical outcome with spinous process fracture type. The Mann-Whitney-Wilcoxon nonparametric test was used for hospital and ICU LOS. Corrected *p*-values were calculated using the Holm method for multiple comparisons

Characteristic	SPF+VB (n=77)	iSPF (n=21)	*p*-value	Corrected *p*-value
Neurologic deficit	8 (10.39)	1 (4.76)	0.679	1.000
Need for operation	24 (31.17)	0 (0.00)	0.001	0.012
Brace issued	37 (48.68)	3 (15.00)	0.010	0.058
Mortality	1 (1.32)	1 (4.76)	0.388	1.000
Hospital LOS	7.00 (4.00–13.00)	3.00 (2.00–5.00)		0.057
ICU LOS	2.00 (0.00–6.00)	0.00 (0.00–3.00)		0.009
Spine follow-up after discharge	31 (40.79%)	1 (5.00%)	0.003	0.018

Values are presented as number (%) or median (interquartile range).
MWW test was used here due to the highly non-normal distribution of these variables.
iSPF: isolated thoracolumbar spinous process fractures, SPF+VB: spinous process fractures with associated vertebral body fracture, LOS: length of stay, SD: standard deviation, IQR: interquartile range, ICU: intensive care unit, MWW: Mann-Whitney-Wilcoxon.

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Table 4. Summary of patients' demographic characteristics and injury mechanisms by type of transverse process fracture: isolated (iTPF) versus associated (TPF+VB)

Characteristic	TPF+VB (n=139)	iTPF (n=335)
Age (years)	49.45 (18.80)	46.37 (34.63)
Gender		
Female	27 (19)	104 (31)
Male	112 (81)	231 (69)
Mechanism of injury		
Assault	2 (1.4)	9 (2.7)
Auto vs. bike	8 (5.8)	16 (4.8)
Fall from height	36 (26)	43 (13)
GLF	5 (3.6)	8 (2.4)
Penetrating	24 (17.3)	7 (2.1)
MCC	17 (12)	47 (14)
MVC	40 (29)	142 (42)
Pedestrian struck	20 (14)	52 (16)
Other/unknown/missing	5 (3.6)	11 (3.2)
ISS	18.02 (9.99)	16.76 (10.52)
ISS	17.00 (12.00–22.00)	14.00 (9.00–22.00)

Values are presented as mean±standard deviation or number (%) or median (interquartile range).
iSPF: isolated thoracolumbar spinous process fractures, SPF+VB: spinous process fractures with associated vertebral body fracture, GLF: ground level fall, MCC: motor vehicle collision, MVC: motorcycle collision, ISS: Injury Severity Score, SD: standard deviation, IQR: interquartile range.

1.45% of TPF+VB patients, p=0.584); however, none of these deaths were spine-related. Only 21 of 335 (7.83%) iTPF patients presented for follow-up, compared to 44 of 139 (32.35%) patients with TPF+VB (p<0.001). Furthermore, none of the iTPF patients reported the presence of a functional deficit, compared to five patients (3.59%) in the TPF+VB group (p=0.057). (Table 5). Like the spinous process groups, there were no significant differences between the groups in neurologic deficits, either on presentation (10 iTPF patients vs. eight TPF+VB patients, p=0.456) or on discharge (two iTPF patients vs. three TPF+VB patients, p=0.456). Hospital LOS was shorter for iTPF patients than for TPF+VB patients (7.19 vs. 8.56 days) (p=0.002). ICU LOS was also similarly shorter for iTPF patients (2.51 vs. 4.07 days) (p=0.004) (Table 4). There were nine morbidities associated with immobilization in the iTPF group (2.68%) and nine in the TPF+VB group (6.47%) (p=0.083). VTE was the most common immobility-related complication (eight iTPF patients [2.38%] and seven TPF+VB patients [5.03%], p=0.459). The remaining morbidities are summarized in Table 6.

DISCUSSION

In this single-center study of 572 patients, we demonstrat-

Table 5. Summary of patient outcomes by type of transverse process fracture: isolated (iTPF) versus associated (TPF+VB). Crude and adjusted *p*-values are included. The Fisher exact test was used to test the independence of each categorical outcome with spinous process fracture type. The Mann-Whitney-Wilcoxon nonparametric test was used for hospital and ICU length of stay. Corrected *p*-values were calculated using the Holm method for multiple comparisons

Characteristic	TPF+VB (n=139)	iTPF (n=335)	*p*-value	Corrected *p*-value
Neurologic deficit	8 (5.80)	10 (2.99)	0.185	0.456
Need for OPERATION	28 (20.14)	0 (0.00)	<0.0001	<0.0001
Brace ISSUED	68 (50.75)	6 (1.86)	<0.0001	<0.0001
Mortality	2 (1.45)	2 (0.60)	0.584	0.584
Hospital LOS	6.00 (3.00–10.00)	5.00 (2.00–7.00)		0.002
ICU LOS	2.00 (0.00–4.00)	0.00 (0.00–3.00)		0.004
Spine follow-up after discharge	44 (32.35)	26 (7.83)	<0.0001	<0.0001

Values are presented as number (%) or median (interquartile range).
MWW test was used here due to the highly non-normal distribution of these variables.
iSPF: isolated thoracolumbar spinous process fractures, SPF+VB: spinous process fractures with associated vertebral body fracture, LOS: length of stay, SD: standard deviation, IQR: interquartile range, ICU: intensive care unit, MWW: Mann-Whitney-Wilcoxon.

Table 6. Summaries of patients' spine-related and other morbidities by type of transverse process fracture: isolated (iTPF) versus associated (TPF+VB). The mean (SD) is reported for continuous variables, and counts and percentages for categorical variables

Characteristic	TPF+VB (n=139)	iTPF (n=335)	*p*-value (naïve)
DVT	3 (2.16)	3 (0.90)	0.365
Pulmonary embolism	4 (2.88)	5 (1.49)	0.459
Urinary retention	2 (1.44)	1 (0.30)	0.207
Total spine related morbidity	9 (6.47)	9 (2.68)	0.083
UTI	3 (2.16)	6 (1.79)	0.725
Myocardial infarction	1 (0.72)	0 (0.00)	0.293
Organ space SSI	2 (1.44)	3 (0.90)	0.633
Acute kidney injury	3 (2.16)	5 (1.49)	0.697
Pneumonia	11 (7.91)	15 (4.48)	0.581
Catheter related infection	0 (0.00)	1 (0.30)	1
Unplanned return to the OR	1 (0.72)	0 (0.00)	0.293
No other morbidity	119 (85.61)	311 (92.84)	0.057

Values are presented as number (%).
iSPF: isolated thoracolumbar spinous process fractures, SPF+VB: spinous process fractures with associated vertebral body fracture, SD: standard deviation, DVT: deep vein thrombosis, UTI: urinary tract infection, SSI: surgical site infection, OR: operating room.

ed that no patients with iTPF or iSPF required operative interventions, thus confirming our hypothesis. Bracing was statistically significantly different among the groups in the unadjusted analysis, but statistical significance did not remain after adjustment. Furthermore, no patients in either the iSPF or iTPF group required bracing for stabilization; instead, the braces were merely issued for comfort. Together, these findings support the proposal that management of patients with iSPF or iTPF may be performed safely without consultation of a spine specialist.

Our finding that no iTPF patient required bracing or operation is concordant with previous publications on transverse process fractures [3-5]. In a 2008 study, Bradley et al. [3] compared iTPF to TPF with an associated injury and found that there was no need for specialist interventions (operation or bracing) in the iTPF group, and no long-term neurologic sequelae were observed in this group. In a 2016 retrospective analysis of 306 patients, Boulter et al. [5] likewise found that no iTPF patients required operative interventions or bracing. As in our study, braces were only issued for comfort.

However, while there is a growing body of literature demonstrating that there is no need for intervention for transverse process fractures, to our knowledge, this is the first study to present this type of analysis for spinous process fractures in adults. In a 2016 study on pediatric patients, Akinpelu et al. [6] found that none of the 82 pediatric patients required operation for isolated thoracolumbar spinous process fractures, and there were no observed neurologic sequelae at follow-up.

Our study indicates that similarly to iTPF, iSPF can be managed without requirement for braces or operative interventions. From a biomechanical perspective, this makes sense, as the axial load placed on the spinal column is carried primarily by the anterior and middle columns. Conversely, the posterior column, where the spinous and transverse processes are located, is the site of multiple ligamentous and muscular attachments [10]. This allows for continued stability even in the setting of fractures to these structures. Additionally, these structures are farther away from the spinal cord than structures in either the anterior or middle column, making an associated spinal cord injury less likely. This is reflected in our data, where, although not statistically significant, a higher percentage of neurologic deficits were present in the patients with vertebral body fractures (SPF+VB and TPF+VB) than in those with isolated spinous and transverse process fractures (iSPF and iTPF). The single patient in the iSPF group who presented with neurologic deficits had negative findings on magnetic resonance imaging (MRI), and since a neurologic deficit is a clear indication for MRI, the choice to obtain MRI in this setting can be made by the trauma provider with no need for additional consultation.

Homnick et al. [4] previously demonstrated significant increases in the LOS for patients with isolated transverse process fractures while they awaited the availability of a specialist to clear their spine precautions, with patients in their study remaining in logroll precautions for as long as 29±32 hours until seen by a specialist. Prolonged immobilization is a well-known risk factor for the development of VTE. Patients who are whole-body immobilized (such as those with logroll precautions) have been shown to be up

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to 1.76 times as likely to develop VTE than those who are not similarly immobilized [11]. Our study found a 2.38% rate of VTE in the iTPF group. Given that such immobilization is completely unnecessary for these patients, VTE is a potentially avoidable morbidity in this population. The potential cost savings resulting from the decreased number of consultations should also be kept in mind, since a single level 4 consultation (the most commonly used code) may cost up to $178.00 per consultation per patient [12-14]. Future multicenter prospective studies should be conducted to determine the safety of not consulting spine surgeons for patients with iTPF and/or iSPF and should evaluate whether avoiding spine consultations in these patients leads to reductions in morbidity and LOS, as well as overall healthcare savings.

Our study is subject to some limitations. This is a retrospective study, and therefore subject to the limitations inherent in such a study design. Additionally, all data came from a single level 1 trauma center, raising the question of the generalizability of these results to other hospitals. The most significant limitation is the small sample size in the spinous process group, which may have hindered the ability to evaluate secondary endpoints such as neurologic deficits. Furthermore, MRI tests were only ordered for neurologic symptoms; thus, this study may have underestimated the incidence of ligamentous injury. In addition, our study did not investigate cervical spinous process or transverse process fractures. The results of the hospital and ICU LOS in both groups should be interpreted with caution. Both variables had highly skewed, non-normal distributions with different variances, thereby potentially violating the assumptions of the statistical tests used. Also of note, our outpatient follow-up data are limited, for which a possible explanation may be that the iSPF patients who were recommended follow-up as needed by a spine specialist did not actually require follow-up.

However, we cannot be sure that delayed complications or adverse outcomes did not occur (although no record of re-presentation to either the emergency department or the patient's primary care physician was found in our electronic records). Thus, future prospective studies with long-term outpatient data are needed. Finally, data on the time of the spine consultation and the time until clearance of spine precautions were not available in our chart records, precluding the possibility of drawing any conclusions on this matter.

CONCLUSION

In support of our hypothesis, we demonstrated that no patients with iSPF or iTPF required a brace or underwent an operative intervention. Our findings provide a rationale for the feasibility of safely managing these patients without a spine consultation, which may lead to decreased time to spine precaution clearance, reduced morbidity, and/or healthcare savings. Future prospective multicenter studies appear warranted to determine the safety of managing thoracolumbar iSPF and iTPF without spine consultation and to evaluate whether significant benefits can be achieved from this shift in management.

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