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Variations in management of A3 and A4 cervical spine fractures as designated by the AO Spine Subaxial Injury Classification System

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OBJECTIVE Optimal management of A3 and A4 cervical spine fractures, as defined by the AO Spine Subaxial Injury Classification System, remains controversial. The objectives of this study were to determine whether significant management variations exist with respect to 1) fracture location across the upper, middle, and lower subaxial cervical spine and 2) geographic region, experience, or specialty.

METHODS A survey was internationally distributed to 272 AO Spine members across six geographic regions (North America, South America, Europe, Africa, Asia, and the Middle East). Participants' management of A3 and A4 subaxial cervical fractures across cervical regions was assessed in four clinical scenarios. Key characteristics considered in the vignettes included degree of neurological deficit, pain severity, cervical spine stability, presence of comorbidities, and fitness for surgery. Respondents were also directly asked about their preferences for operative management and misalignment acceptance across the subaxial cervical spine.

RESULTS In total, 155 (57.0%) participants completed the survey. Pooled analysis demonstrated that surgeons were more likely to offer operative intervention for both A3 ($p < 0.001$) and A4 ($p < 0.001$) fractures located at the cervicothoracic junction compared with fractures at the upper or middle subaxial cervical regions. There were no significant variations in management for junctional incomplete ($p = 0.116$) or complete ($p = 0.342$) burst fractures between geographic regions. Surgeons with more than 10 years of experience were more likely to operatively manage A3 ($p < 0.001$) and A4 ($p < 0.001$) fractures than their younger counterparts. Neurosurgeons were more likely to offer surgical stabilization of A3 ($p < 0.001$) and A4 ($p < 0.001$) fractures than their orthopedic colleagues. Clinicians from both specialties agreed regarding their preference for fixation of lower junctional A3 ($p = 0.866$) and A4 ($p = 0.368$) fractures. Overall, surgical fixation was recommended more often for A4 than A3 fractures in all four scenarios ($p < 0.001$).

CONCLUSIONS The subaxial cervical spine should not be considered a single unified entity. Both A3 and A4 fracture subtypes were more likely to be surgically managed at the cervicothoracic junction than the upper or middle subaxial cervical regions. The authors also determined that treatment strategies for A3 and A4 subaxial cervical spine fractures

ABBREVIATIONS SLIC = Subaxial Cervical Spine Injury Classification; VAS = visual analog scale.

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varied significantly, with the latter demonstrating a greater likelihood of operative management. These findings should be reflected in future subaxial cervical spine trauma algorithms.

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KEYWORDS burst; fracture; junctional; subaxial cervical spine; variation; trauma

Cervical spine fracture occurs in 2.4% of trauma patients and has the potential to cause devastating neurological sequelae.[1] The subaxial cervical spine is affected in more than 65% of patients. In particular, the lower junctional region, as the transitional point between the mobile lordotic cervical spine and rigid kyphotic thoracic spine, tends to be preferentially injured.[1,2] Indeed, fractures of the lower two cervical vertebrae (C6 and C7) constitute as many as 55% of all cervical fractures.[1–3] Despite this unequal distribution of injuries, which suggests that the junctional region is at greater risk for instability, the subaxial region is still perceived as a single entity by multiple contemporary classification systems.[4–6]

The current Subaxial Cervical Spine Injury Classification (SLIC) System recommends operative or nonoperative intervention on the basis of fracture pattern, integrity of the discoligamentous complex, and neurological state[8,9] but fails to differentiate different forms of burst fracture.[8,10] Conversely, the AO Spine Subaxial Injury Classification System does recognize incomplete (A3) and complete (A4) burst fracture morphologies and introduces fracture patterns to reflect their perceived stability in a gradated fashion. However, neither classification system takes into account the level of injury across the subaxial cervical spine.[8] To guide the formation of a novel subaxial cervical spine trauma algorithm, the international variations in management of A3 and A4 fractures were investigated.

The principal aim of our study was to determine whether worldwide management preferences of incomplete and complete cervical burst fractures differ across the upper, middle, and lower subaxial cervical regions. We hypothesized that surgeons would be more likely to recommend operative management for fractures of the lower subaxial cervical spine involving the cervicothoracic junction, as well as those of a complete burst fracture morphology. These would represent crucial findings in guiding future prospective trials and treatment algorithms given the paucity of high-quality evidence available. A universally applicable and accepted treatment algorithm has the potential to greatly streamline and improve the worldwide standard of spine trauma care.[7]

Methods

Data Collection

A 43-point survey was globally distributed to 272 AO Spine members across six distinct geographic regions. These 272 participants were volunteers from the approximately 6500 members of the AO Spine community who expressed interest in validating a new subaxial cervical spine trauma algorithm. Participant demographic characteristics, such as years of experience, specialty, and geographic region of practice, were collected. The survey assessed clinician management preferences for subaxial cervical fractures at different cervical regions, both directly with discrete questioning and indirectly through various clinical scenarios. Surgeons were presented with four clinical vignettes involving A3 or A4 subaxial cervical fracture (Fig. 1). The hypothetical patients sustained injury to either the upper subaxial region as represented by a C3 fracture, middle level as illustrated by a C5 fracture, or the lower cervicothoracic junctional area as characterized by a C7 fracture. Participants expressed their treatment plan across the subaxial cervical regions in the context of several variables, such as degree of pain as measured with the visual analog scale (VAS) and extent of medical comorbidities. Significant medical comorbidity was defined as American Society of Anesthesiologists physical status classification score 3 or higher.[12] Bias due to differing radiological interpretations of fracture morphologies was circumvented by the use of written clinical vignettes. The primary outcome was management preferences for surgery or rigid orthosis in the treatment of A3 and A4 cervical fractures across the upper, middle, and lower subaxial regions. Secondary outcome measures were variations in management according to experience, geographic region, and specialty.

Statistical Analysis

All partial and complete responses to the survey were included in the analysis by using a simple random sampling scheme. Baseline continuous demographic characteristics were analyzed according to their mean, median,

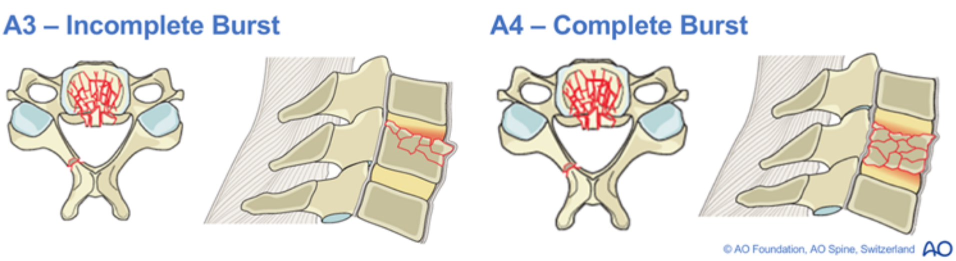

FIG. 1. A3 incomplete burst fracture involves a single endplate, whereas A4 complete burst fracture involves both endplates.[11] Copyright AO Spine, AO Foundation. Published with permission. Figure is available in color online only.

or interquartile range. Categorical data were analyzed according to absolute frequency and percentage of complete responses. The chi-square test or Fisher's exact test was used to analyze differences between categorical parameters, whereas the Cochran-Armitage test was used to assess for trends. Owing to underrepresentation of participants from the six different geographical regions, regions with a low number of participants were combined with their closest neighboring geographic region. The likelihood that a surgeon would offer operative intervention for A4 fracture compared with A3 fracture was also investigated by using ORs with 95% CIs. The statistical significance level was defined as $p < 0.05$. All statistical analysis was performed with SAS version 9.4 (SAS Institute Inc.).

Results

A total of 155 (57.0%) responses from specialists in six geographic regions were received. Baseline demographic characteristics are summarized in Table 1. Importantly, almost half the respondents worked in an academic center (49.7%), with a mean of 106.0 spine trauma patients treated per year.

TABLE 1. Demographic characteristics of the 155 AO Spine members who completed the internationally distributed survey

Characteristic	Value
Subspecialty	
Orthopedics	96 (61.9)
Neurosurgery	52 (33.5)
Other	7 (4.5)
Geographic region	
Europe	48 (31.0)
Latin & South America	40 (25.8)
Asia	29 (18.7)
North America	17 (11.0)
Middle East	13 (8.4)
Africa	8 (5.2)
Years in practice	
<5	27 (17.4)
5–10	52 (33.5)
11–20	50 (32.3)
>20	26 (16.8)
Work setting	
Academic	77 (49.7)
Hospital	54 (34.8)
Private practice	24 (15.5)
Treated spine trauma patients, no./yr	
Mean	106.0
Median	50.0 (20–100)
1–25	43 (27.7)
26–100	87 (56.1)
>100	25 (16.1)

Values are shown as number (percent) or median (interquartile range).

Management Preferences for A3 and A4 Subaxial Cervical Spine Fractures

When confronted with incomplete burst fractures consistent with the A3 subtype of the AO Spine Subaxial Injury Classification System, surgeons expressed a significantly increased preference for surgical management in all four scenarios if injuries were located at the lower cervicothoracic junction (Table 2). This was true for patients who were neurologically intact, otherwise medically fit, and had minimal pain ($p < 0.001$), and even for those who had significant comorbidities ($p = 0.002$). In the cohort of patients who had significant pain but were otherwise appropriate for surgical intervention, surgeons were again more likely to recommend operative management for inferior junctional fractures at the lower subaxial region than those located at the upper or middle subaxial cervical regions ($p = 0.004$). Patients with a notable degree of pain and comorbidities also demonstrated a significant trend toward undergoing operative intervention if their injuries were located at the lower junctional region ($p = 0.024$). Pooled analysis of all four scenarios was consistent with this tenet of preferential management of cervicothoracic junctional A3 fracture with surgical fixation rather than rigid orthosis ($p < 0.001$) compared with more superiorly located injuries.

A complete A4 burst fracture was also more likely to be managed operatively than its less severe A3 counterpart. Regardless of whether various key characteristics were altered, including degree of pain and presence of significant comorbidities, surgical intervention was preferred if the fracture was located at the cervicothoracic junction (Table 2). Although the individual scenarios failed to demonstrate a statistically significant difference in management of junctional A4 fractures, likely confounded by the overwhelming preference for surgical management of complete burst injuries in general, the pooled analysis confirmed that junctional complete burst fractures are preferentially treated with operative intervention compared with those fractures in the upper or middle cervical regions ($p < 0.001$).

Preferences According to Experience, Geographic Region, and Specialty

To determine whether degree of experience affected management of A3 and A4 fractures across the subaxial cervical spine, the cohort was dichotomized according to a threshold of 10 years of experience (Table 3). Interestingly, experienced surgeons tended to prefer surgery rather than rigid orthosis in comparison with their younger colleagues in the management of both incomplete burst (39.9% vs 28.0%, $p < 0.001$) and complete burst (75.9% vs 64.3%, $p < 0.001$) fractures across the entire subaxial cervical spine. Furthermore, there were no significant global differences in likelihood of offering operative intervention for single- or dual-endplate fractures across the individual four scenarios (Table 4). On pooled analysis, European surgeons were less inclined to favor operative management for A3 fracture compared with their American and Asian counterparts ($p = 0.019$). Overall, there was no significant regional variation in the management of A4 frac-

TABLE 2. Management preferences for A3 and A4 subaxial cervical spine fractures, stratified by upper, middle, and lower cervical regions

Subaxial Cervical Spine Level	A3 Fracture Management Strategy: Surgery (n [%])	A3 Fracture Management Strategy: Rigid Orthosis (n [%])	p Value	A4 Fracture Management Strategy: Surgery (n [%])	A4 Fracture Management Strategy: Rigid Orthosis (n [%])	p Value*
Scenario 1†						
Upper	34 (21.9)	121 (78.1)		104 (67.5)	50 (32.5)	
Middle	43 (27.9)	111 (72.1)	**<0.001**	111 (72.1)	43 (27.9)	0.165
Lower	61 (39.6)	93 (60.4)		115 (74.7)	39 (25.3)	
Scenario 2‡						
Upper	20 (13.0)	134 (87.0)		73 (47.4)	81 (52.6)	
Middle	22 (14.3)	132 (85.7)	**0.002**	87 (56.5)	67 (43.5)	**0.022**
Lower	41 (26.6)	113 (73.4)		93 (60.4)	61 (39.6)	
Scenario 3§						
Upper	66 (43.1)	87 (56.9)		123 (80.4)	30 (19.6)	
Middle	78 (51.0)	75 (49.0)	**0.004**	130 (85.0)	23 (15.0)	0.162
Lower	91 (59.5)	62 (40.5)		132 (86.3)	21 (13.7)	
Scenario 4¶						
Upper	49 (32.0)	104 (68.0)		97 (63.4)	56 (36.6)	
Middle	52 (34.0)	101 (66.0)	**0.024**	109 (71.2)	44 (28.8)	**0.018**
Lower	68 (44.4)	85 (55.6)		116 (75.8)	37 (24.2)	
Pooled analysis						
Upper	169 (27.5)	446 (72.5)		397 (64.7)	217 (35.3)	
Middle	195 (31.8)	419 (68.2)	**<0.001**	437 (71.2)	177 (28.8)	**<0.001**
Lower	261 (42.5)	353 (57.5)		456 (74.3)	158 (25.7)	

Boldface type indicates statistical significance ($p < 0.05$).
* Determined using the Cochran-Armitage trend test.
† Patient without neurological deficits, minimal cervical axial pain (VAS ≤ 4/10) on mobilization, stable cervical spine, and deemed fit for surgery.
‡ Patient without neurological deficits, minimal cervical axial pain (VAS ≤ 4/10) on mobilization, stable cervical spine, significant comorbidities, and deemed fit for surgery.
§ Patient without neurological deficits, significant cervical axial pain (VAS ≥ 5/10) on mobilization, stable cervical spine, and deemed fit for surgery.
¶ Patient without neurological deficits, significant cervical axial pain (VAS ≥ 5/10) on mobilization, stable cervical spine, significant comorbidities, and deemed fit for surgery.

tures, with the majority of clinicians opting to manage this fracture with surgical intervention rather than rigid orthosis ($p = 0.918$). On the other hand, pooled analysis of all four clinical scenarios revealed that neurosurgeons were more likely to offer operative intervention for A3 (39.9% vs 29.6%, $p < 0.001$) and A4 (76.3% vs 67.5%, $p < 0.001$) fractures compared with their orthopedic colleagues (Table 5). However, spine surgeons from both specialties exhibited similar preferences for operative management of lower junctional A3 (41.3% vs 42.1%, $p = 0.866$) and A4 (76.9% vs 73.5%, $p = 0.368$) fractures.

Misalignment Acceptance Rate

Clinicians accepted significantly different degrees of malalignment across the subaxial cervical spine in the management of A3 and A4 fractures sustained by medically fit, neurologically intact patients ($p = 0.040$). In particular, misalignment was less tolerated at the cervicothoracic junction (61.2% of participants) compared with the middle (47.4%) and upper (44.7%) subaxial cervical regions (Supplementary Table 1). There was no statistically significant difference with respect to the misalignment acceptance rate, and thus willingness to conservatively manage cervical burst fractures with rigid orthosis rather than surgical fixation, when stratified according to years of experience or geographic region of practice (Supplementary Tables 2 and 3). However, compared with their neurosurgical counterparts, orthopedic spine specialists indicated that they had a significantly lower tolerance of misalignment of A3 injuries compared with A4 injuries ($p = 0.046$). Despite this, there was no difference between the two specialties with respect to management of A3 or A4 fractures across the subaxial cervical spine (Supplementary Table 4).

AO Spine Subaxial Injury Classification System

This survey also provided unique insight into clinician management preferences for incomplete and complete burst fractures without radiological interpretation as a confounder. Surgeons overwhelmingly preferred operative fixation for the management of A4 fractures compared with A3 injuries in all four scenarios throughout the subaxial cervical spine (Table 6). This is consistent with the logical and gradated manner in which the AO Spine

TABLE 3. Participants who preferred surgical management for A3 and A4 subaxial cervical spine fractures, stratified by surgeon experience

Subaxial Cervical Spine Level	Preference for Surgery, Stratified by Experience		p Value
	≤10 yrs (n = 79)	>10 yrs (n = 76)	
Scenario 1*			
A3			
Upper	14 (17.7)	20 (26.3)	0.196
Middle	15 (19.2)	28 (36.8)	**0.015**
Lower	21 (26.9)	40 (52.6)	**0.001**
Overall	50 (21.1)	88 (38.6)	**<0.001**
A4			
Upper	49 (62.8)	55 (72.4)	0.206
Middle	52 (66.7)	59 (77.6)	0.129
Lower	52 (66.7)	63 (82.9)	**0.021**
Overall	153 (65.4)	177 (77.6)	**0.004**
Scenario 2†			
A3			
Upper	8 (10.3)	12 (15.8)	0.307
Middle	8 (10.3)	14 (18.4)	0.148
Lower	16 (20.5)	25 (32.9)	0.082
Overall	32 (13.7)	51 (22.4)	**0.015**
A4			
Upper	35 (44.9)	38 (50.0)	0.524
Middle	38 (48.7)	49 (64.5)	**0.049**
Lower	40 (51.3)	53 (69.7)	**0.019**
Overall	113 (48.3)	140 (61.4)	**0.005**
Scenario 3‡			
A3			
Upper	29 (37.7)	37 (48.7)	0.169
Middle	33 (42.9)	45 (59.2)	**0.043**
Lower	40 (51.9)	51 (67.1)	0.056
Overall	102 (44.2)	133 (58.3)	**0.002**
A4			
Upper	57 (74.0)	66 (86.8)	**0.046**
Middle	62 (80.5)	68 (89.5)	0.121
Lower	62 (80.5)	70 (92.1)	**0.037**
Overall	181 (78.4)	204 (89.5)	**0.001**
Scenario 4§			
A3			
Upper	23 (29.9)	26 (34.2)	0.565
Middle	23 (29.9)	29 (38.2)	0.279
Lower	31 (40.3)	37 (48.7)	0.294
Overall	77 (33.3)	92 (40.4)	0.119
A4			
Upper	47 (61.0)	50 (65.8)	0.542
Middle	50 (64.9)	59 (77.6)	0.083
Lower	54 (70.1)	62 (81.6)	0.098
Overall	151 (65.4)	171 (75.0)	**0.024**
Pooled analysis			
A3			
Upper	74 (23.8)	95 (31.3)	**0.038**
Middle	79 (25.5)	116 (38.2)	**<0.001**
Lower	108 (34.8)	153 (50.3)	**<0.001**
Overall	261 (28.0)	364 (39.9)	**<0.001**
A4			
Upper	188 (60.6)	209 (68.8)	**0.036**
Middle	202 (65.2)	235 (77.3)	**<0.001**
Lower	208 (67.1)	248 (81.6)	**<0.001**
Overall	598 (64.3)	692 (75.9)	**<0.001**

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TABLE 3. Participants who preferred surgical management for A3 and A4 subaxial cervical spine fractures, stratified by surgeon experience

Boldface type indicates statistical significance ($p < 0.05$). Values are shown as number (percent) unless indicated otherwise.

* Patient without neurological deficits, minimal cervical axial pain (VAS ≤ 4/10) on mobilization, stable cervical spine, and deemed fit for surgery.

† Patient without neurological deficits, minimal cervical axial pain (VAS ≤ 4/10) on mobilization, stable cervical spine, significant comorbidities, and deemed fit for surgery.

‡ Patient without neurological deficits, significant cervical axial pain (VAS ≥ 5/10) on mobilization, stable cervical spine, and deemed fit for surgery.

§ Patient without neurological deficits, significant cervical axial pain (VAS ≥ 5/10) on mobilization, stable cervical spine, significant comorbidities, and deemed fit for surgery.

Subaxial Injury Classification System introduces fracture patterns from least to most severe. In neurologically intact patients with minimal cervical pain (VAS ≤ 4/10) on mobilization who were deemed fit for surgery, A4 fractures were more likely to be treated with operative intervention than A3 fractures in the upper (OR 7.40, 95% CI 4.45–12.31, $p < 0.001$), middle (OR 6.66, 95% CI 4.05–10.96, $p < 0.001$), and lower (OR 4.50, 95% CI 2.77–7.31, $p < 0.001$) cervical regions.

Similar findings were also observed in patients with significant comorbidities. Complete burst fractures were again more likely to be managed surgically than incomplete burst fractures in the upper (OR 6.04, 95% CI 3.43–10.64, $p < 0.001$), middle (OR 7.79, 95% CI 4.48–13.54, $p < 0.001$), and lower (OR 4.20, 95% CI 2.60–6.80, $p < 0.001$) subaxial regions. Once again, patients with A3 junctional fractures in the lower subaxial spine were also more likely to be offered intervention than patients with similar fractures elsewhere. When significant pain (VAS ≥ 5/10) was introduced into preoperative decision-making, surgeons were again more likely to recommend surgical fixation for A4 fractures than A3 fractures across the upper (OR 5.40, 95% CI 3.24–9.01, $p < 0.001$), middle (OR 5.43, 95% CI 3.15–9.37, $p < 0.001$), and lower (OR 4.28, 95% CI 2.44–7.51, $p < 0.001$) subaxial regions. Consistent with previous scenarios, cervicothoracic junctional A3 fractures were

TABLE 4. Participants who preferred surgical management for A3 and A4 subaxial cervical spine fractures, stratified by geographic region

Subaxial Cervical Spine Level	Preference for Surgery, Stratified by Region			
	North, Latin, & South America (n = 57)	Europe (n = 48)	Africa, Asia, & the Middle East (n = 50)	p Value
Scenario 1*				
A3				
Upper	14 (24.6)	9 (18.8)	11 (22.0)	0.773
Middle	17 (29.8)	10 (20.8)	16 (32.7)	0.397
Lower	23 (40.4)	17 (35.4)	21 (42.9)	0.748
Overall	54 (31.6)	36 (25.0)	48 (32.4)	0.311
A4				
Upper	38 (66.7)	35 (72.9)	31 (63.3)	0.588
Middle	38 (66.7)	38 (79.2)	35 (71.4)	0.361
Lower	42 (73.7)	39 (81.3)	34 (69.4)	0.396
Overall	118 (69.0)	112 (77.8)	100 (68.0)	0.124
Scenario 2†				
A3				
Upper	10 (17.5)	5 (10.4)	5 (10.2)	0.435
Middle	11 (19.3)	4 (8.3)	7 (14.3)	0.278
Lower	19 (33.3)	9 (18.8)	13 (26.5)	0.242
Overall	40 (23.4)	18 (12.5)	25 (17.0)	**0.040**
A4				
Upper	30 (52.6)	23 (47.9)	20 (40.8)	0.477
Middle	32 (56.1)	27 (56.3)	28 (57.1)	0.994
Lower	36 (63.2)	31 (64.6)	26 (53.1)	0.441
Overall	98 (57.3)	81 (56.3)	74 (50.3)	0.420
Scenario 3‡				
A3				
Upper	25 (43.9)	20 (41.7)	21 (43.8)	0.970
Middle	27 (47.4)	24 (50.0)	27 (56.3)	0.654
Lower	35 (61.4)	28 (58.3)	28 (58.3)	0.933
Overall	87 (50.9)	72 (50.0)	76 (52.8)	0.890
A4				
Upper	46 (80.7)	36 (75.0)	41 (85.4)	0.437
Middle	47 (82.5)	40 (83.3)	43 (89.6)	0.554
Lower	51 (89.5)	41 (85.4)	40 (83.3)	0.646
Overall	144 (84.2)	117 (81.3)	124 (86.1)	0.527
Scenario 4§				
A3				
Upper	20 (35.1)	14 (29.2)	15 (31.3)	0.803
Middle	20 (35.1)	13 (27.1)	19 (39.6)	0.423
Lower	28 (49.1)	16 (33.3)	24 (50.0)	0.173
Overall	68 (39.8)	43 (29.9)	58 (40.3)	0.112
A4				
Upper	38 (66.7)	29 (60.4)	30 (62.5)	0.181
Middle	38 (66.7)	32 (66.7)	39 (81.3)	0.181
Lower	46 (80.7)	33 (68.8)	37 (77.1)	0.352
Overall	122 (71.3)	94 (65.3)	106 (73.6)	0.276

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TABLE 4. Participants who preferred surgical management for A3 and A4 subaxial cervical spine fractures, stratified by geographic region

Subaxial Cervical Spine Level	Preference for Surgery, Stratified by Region			
	North, Latin, & South America (n = 57)	Europe (n = 48)	Africa, Asia, & the Middle East (n = 50)	p Value
Pooled analysis				
A3				
Upper	69 (30.3)	48 (25.0)	52 (26.7)	0.462
Middle	75 (32.9)	51 (26.6)	69 (35.6)	0.148
Lower	105 (46.1)	70 (36.5)	86 (44.3)	0.116
Overall	249 (36.4)	169 (29.3)	207 (35.5)	**0.019**
A4				
Upper	152 (66.7)	123 (64.1)	122 (62.9)	0.705
Middle	155 (68.0)	137 (71.4)	145 (74.7)	0.311
Lower	175 (76.8)	144 (75.0)	137 (70.6)	0.342
Overall	482 (70.5)	404 (70.1)	404 (69.4)	0.918

Boldface type indicates statistical significance ($p < 0.05$). Values are shown as number (percent) unless indicated otherwise.

* Patient without neurological deficits, minimal cervical axial pain (VAS ≤ 4/10) on mobilization, stable cervical spine, and deemed fit for surgery.

† Patient without neurological deficits, minimal cervical axial pain (VAS ≤ 4/10) on mobilization, stable cervical spine, significant comorbidities, and deemed fit for surgery.

‡ Patient without neurological deficits, significant cervical axial pain (VAS ≥ 5/10) on mobilization, stable cervical spine, and deemed fit for surgery.

§ Patient without neurological deficits, significant cervical axial pain (VAS ≥ 5/10) on mobilization, stable cervical spine, significant comorbidities, and deemed fit for surgery.

also more likely to be operatively managed than those located elsewhere.

Finally, complex surgical decision-making was interrogated with challenging clinical vignettes in which perioperative risk of comorbidities needed to be weighed against the benefits of operative intervention such as spinal stability and analgesic effect. In this instance, the AO Spine Subaxial Injury Classification System held true, with A4 fractures more likely to be deemed suitable for operative management at every cervical region. Importantly, there was less management variation at C3 (OR 3.68, 95% CI 2.29–5.90, p < 0.001) and C7 (OR 3.92, 95% CI 2.40–6.39, p < 0.001) than for fractures located in the middle location (OR 4.81, 2.96–7.81, p < 0.001). In other words, this scenario indirectly demonstrates that surgeons were more likely to surgically manage A3 fractures at the lower cervicothoracic junction than those at the upper or middle subaxial regions.

Discussion

Traumatic spine injury in the cervical region results in the highest rate of complete motor and sensory neurological deficit.[13] Although the considerable range of motion afforded by the cervical's spine reliance upon ligamentous structures rather than bony stability is a functional advantage, it simultaneously confers a particular susceptibility to injury and instability.[14–16] In turn, this leads to a significant risk of morbidity and mortality given the potential for high spinal cord injury and permanent neurological deficit.[14–16] As such, there are ongoing international efforts to formulate both a universal classification system and accepted treatment algorithm.[8,17–19] Our survey addresses both these subjects. We determined that junctional subaxial cervical region fractures are more likely to be operatively managed, and also that the AO Spine Subaxial Injury Classification System represents a logical progression of injury morphology because A4 fractures were more likely to be surgically stabilized than A3 fractures.[20]

There is an unequal distribution of dislocations and fractures across the subaxial cervical spine, with as many as 90% of fractures occurring in the middle and lower regions.[1,21] As the transitional point between the comparatively mobile lordotic cervical spine and the more rigid kyphotic thoracic spine, the cervicothoracic junction is especially vulnerable to mechanical instability and disruption.[22,23] Fractures affecting the lower two cervical vertebra (C6 and C7) have been estimated to constitute between 39% and 55% of all cervical fractures.[1–3] More specifically, the C6–7 level is the most commonly fractured level of the subaxial cervical spine (21.2%).[24] This is closely followed by fracture of C7 or dislocation at the C7/T1 junction, which account for 17% of all injuries.[25] Quarrington et al. also found that the C6–7 level was the most commonly involved level for facet dislocation.[26] This pattern of fractures and dislocations that preferentially occur in the lower subaxial spine reflects this region's increased vulnerability to injury. The results of our worldwide survey are consistent with this tenet.

TABLE 5. Participants who preferred surgical management for A3 and A4 subaxial cervical spine fractures, stratified by surgical specialty

Subaxial Cervical Spine Level	Preference for Surgery, Stratified by Specialty: Orthopedics (n = 96)	Neurosurgery (n = 52)	p Value
Scenario 1*			
A3			
Upper	17 (17.7)	14 (26.9)	0.189
Middle	22 (23.2)	19 (36.5)	0.084
Lower	40 (42.1)	17 (32.7)	0.263
Overall	79 (27.6)	50 (32.1)	0.328
A4			
Upper	62 (65.3)	39 (75.0)	0.224
Middle	67 (70.5)	41 (78.8)	0.275
Lower	70 (73.7)	41 (78.8)	0.487
Overall	199 (69.8)	121 (77.6)	0.082
Scenario 2†			
A3			
Upper	10 (10.5)	8 (15.4)	0.390
Middle	10 (10.5)	10 (19.2)	0.141
Lower	26 (27.4)	12 (23.1)	0.570
Overall	46 (16.1)	30 (19.2)	0.411
A4			
Upper	40 (42.1)	30 (57.7)	0.070
Middle	49 (51.6)	35 (67.3)	0.065
Lower	58 (61.1)	32 (61.5)	0.954
Overall	147 (51.6)	97 (62.2)	**0.032**
Scenario 3‡			
A3			
Upper	32 (34.0)	29 (55.8)	**0.011**
Middle	40 (42.6)	34 (65.4)	**0.008**
Lower	53 (56.4)	32 (61.5)	0.545
Overall	125 (44.3)	95 (60.9)	**<0.001**
A4			
Upper	73 (77.7)	45 (86.5)	0.192
Middle	79 (84.0)	46 (88.5)	0.466
Lower	80 (85.1)	46 (88.5)	0.572
Overall	232 (82.3)	137 (87.8)	0.127
Scenario 4§			
A3			
Upper	22 (23.4)	24 (46.2)	**0.005**
Middle	24 (25.5)	25 (48.1)	**0.006**
Lower	40 (42.6)	25 (48.1)	0.520
Overall	86 (30.5)	74 (47.4)	**<0.001**
A4			
Upper	53 (56.4)	39 (75.0)	**0.026**
Middle	64 (68.1)	41 (78.8)	0.167
Lower	70 (74.5)	41 (78.8)	0.553
Overall	187 (66.3)	121 (77.6)	**0.014**
Pooled analysis			
A3			
Upper	81 (21.4)	75 (36.1)	**<0.001**
Middle	96 (25.4)	88 (42.3)	**<0.001**
Lower	159 (42.1)	86 (41.3)	0.866
Overall	336 (29.6)	249 (39.9)	**<0.001**
A4			
Upper	228 (60.3)	153 (73.6)	**0.001**
Middle	259 (68.5)	163 (78.4)	**0.011**
Lower	278 (73.5)	160 (76.9)	0.368
Overall	765 (67.5)	476 (76.3)	**<0.001**

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TABLE 5. Participants who preferred surgical management for A3 and A4 subaxial cervical spine fractures, stratified by surgical specialty

Boldface type indicates statistical significance ($p < 0.05$). Values are shown as number (percent) unless indicated otherwise.

* Patient without neurological deficits, minimal cervical axial pain (VAS ≤ 4/10) on mobilization, stable cervical spine, and deemed fit for surgery.

† Patient without neurological deficits, minimal cervical axial pain (VAS ≤ 4/10) on mobilization, stable cervical spine, significant comorbidities, and deemed fit for surgery.

‡ Patient without neurological deficits, significant cervical axial pain (VAS ≥ 5/10) on mobilization, stable cervical spine, and deemed fit for surgery.

§ Patient without neurological deficits, significant cervical axial pain (VAS ≥ 5/10) on mobilization, stable cervical spine, significant comorbidities, and deemed fit for surgery.

Indeed, we determined that junctional fractures of both the A3 ($p < 0.001$) and A4 ($p < 0.001$) subtypes are more likely to be managed with operative intervention than injuries located elsewhere. Furthermore, the current AO Spine Subaxial Injury Classification System differentiates between incomplete and complete burst fracture morphologies, but it does not take into account the subaxial spine level as a formal discrete category or modifier.[8] Similarly, the Spine Section of the German Society for Orthopedics and Trauma (DGOU) advocates surgical fixation for complete burst fractures of the subaxial cervical spine, while suggesting that rigid orthosis and close observation may be considered for neurologically intact patients with incomplete burst fracture.[27] However, the level of the subaxial cervical fracture is not taken into account by the DGOU algorithm.[27] Our novel finding of a consistent global preference for operative intervention for fractures located at the cervicothoracic region, compared with fractures at the upper and middle regional cervical regions, was evident even in patients with significant comorbidities ($p = 0.002$). As such, we advocate for consideration of inclusion of the level of subaxial cervical spine injury in future classification and treatment algorithms.

Unfortunately, there is a distinct paucity of prospective data that directly compare surgical outcomes after operative and nonoperative management of subaxial cervical

TABLE 6. Management strategies for A3 versus A4 subaxial cervical spine fractures

Subaxial Cervical Spine Level	Management Strategy		OR (95% CI)*	p Value
	Surgery	Rigid Orthosis		
Scenario 1†				
Upper				
A3	34 (21.9)	121 (78.1)	7.40 (4.45–12.31)	**<0.001**
A4	104 (67.5)	50 (32.5)		
Middle				
A3	43 (27.9)	111 (72.1)	6.66 (4.05–10.96)	**<0.001**
A4	111 (72.1)	43 (27.9)		
Lower				
A3	61 (39.6)	93 (60.4)	4.50 (2.77–7.31)	**<0.001**
A4	115 (74.7)	39 (25.3)		
Scenario 2‡				
Upper				
A3	20 (13.0)	134 (87.0)	6.04 (3.43–10.64)	**<0.001**
A4	73 (47.4)	81 (52.6)		
Middle				
A3	22 (14.3)	132 (85.7)	7.79 (4.48–13.54)	**<0.001**
A4	87 (56.5)	67 (43.5)		
Lower				
A3	41 (26.6)	113 (73.4)	4.20 (2.60–6.80)	**<0.001**
A4	93 (60.4)	61 (39.6)		
Scenario 3§				
Upper				
A3	66 (43.1)	87 (56.9)	5.40 (3.24–9.01)	**<0.001**
A4	123 (80.4)	30 (19.6)		
Middle				
A3	78 (51.0)	75 (49.0)	5.43 (3.15–9.37)	**<0.001**
A4	130 (85.0)	23 (15.0)		
Lower				
A3	91 (59.5)	62 (40.5)	4.28 (2.44–7.51)	**<0.001**
A4	132 (86.3)	21 (13.7)		
Scenario 4¶				
Upper				
A3	49 (32.0)	104 (68.0)	3.68 (2.29–5.90)	**<0.001**
A4	97 (63.4)	56 (36.6)		
Middle				
A3	52 (34.0)	101 (66.0)	4.81 (2.96–7.81)	**<0.001**
A4	109 (71.2)	44 (28.8)		
Lower				
A3	68 (44.4)	85 (55.6)	3.92 (2.40–6.39)	**<0.001**
A4	116 (75.8)	37 (24.2)		

Boldface type indicates statistical significance ($p < 0.05$). Values are shown as number (percent) unless indicated otherwise.

* Indicates the likelihood of surgical intervention for A4 fracture compared with A3 fracture.

† Patient without neurological deficits, minimal cervical axial pain (VAS ≤ 4/10) on mobilization, stable cervical spine, and deemed fit for surgery.

‡ Patient without neurological deficits, minimal cervical axial pain (VAS ≤ 4/10) on mobilization, stable cervical spine, significant comorbidities, and deemed fit for surgery.

§ Patient without neurological deficits, significant cervical axial pain (VAS ≥ 5/10) on mobilization, stable cervical spine, and deemed fit for surgery.

¶ Patient without neurological deficits, significant cervical axial pain (VAS ≥ 5/10) on mobilization, stable cervical spine, significant comorbidities, and deemed fit for surgery.

spine fractures stratified by level of injury. Koivikko et al. examined 69 neurologically intact patients with burst or teardrop fractures who underwent either surgical decompression and stabilization or skull traction and halo bracing.[21] The operative cohort experienced superior outcomes with respect to improved Frankel grade of neurological status, reduced spinal canal narrowing, and less kyphotic deformity compared with the nonoperative group.[21] Importantly, 67 of 69 patients had middle and lower cervical fractures (C5–7). Toh et al. and Fisher et al. concurred with the role of surgical intervention for fractures of the middle and lower cervical spine, and they advocated for an anterior rather than posterior or conservative approach owing to superior decompression and overall outcome.[28,29] Overall, these studies favored operative intervention for the management of lower cervical fracture, which is consistent with the preferences expressed in our global survey. Nonetheless, there is still a need for randomized trials to confirm this apparent treatment benefit.

Numerous treatment algorithms, with varying degrees of usability and reliability, have been proposed to guide clinical decision-making for the management of subaxial cervical spine fracture. The Allen and Ferguson system attempted to classify injuries according to six main mechanisms of injury but is based on findings on plain radiography, which Song et al. argued makes it less applicable today.[6,30] Likewise, the Harris classification divides subaxial cervical spine injuries into five categories on the basis of mechanism.[5] On the other hand, the pioneering AO Spine Subaxial Injury Classification System introduced by Vaccaro et al. in 2016 divides injuries into three main categories: type A (compression), type B (distraction), and type C (translation). Each category introduces fracture patterns in a logical gradated manner of increasing severity.[8] This methodological classification has shown serviceable intraobserver and interobserver reliability for all categories.[8] Our study provided original compelling evidence that type A4 complete burst fracture is overwhelmingly believed to be more severe than A3 incomplete burst fracture, and thus more likely to be operatively managed irrespective of patient comorbidity status ($p < 0.001$).

This is not to state that the algorithm is beyond refinement. Indeed, others have challenged the reliability of the AO Spine Subaxial Injury Classification System. Silva et al. astutely noted that B type and facet injuries are often poorly distinguished.[18] Only the extremes of injuries, whether minor or severe, were reliably rated while the use of facet modifiers was relatively imprecise and difficult to assess.[18] Hitti et al. also attempted to modify the system by incorporating comorbidities, such as osteoporosis, in an attempt to predict failure of nonoperative treatment.[19] The significance of using modifiers to address additional determinants of stability was addressed by Divi et al., who incorporated important conditions such as ankylosing spondylitis or diffuse idiopathic skeletal hyperostosis into the system.[31] It is evident that treatment algorithms are continuously evolving. We propose, much like Schleicher et al., that not only does fracture morphology carry importance but also the level of the affected subaxial cervical region.[32] Indeed, fracture location at a junctional region has already been incorporated into the validated Spine Instability Neoplastic Score as contributing additional points toward instability.[33]

The rationale behind developing a subaxial cervical spine algorithm is the sizable morbidity and mortality rate attributed to these devastating fractures. Sokolowski et al. found that the overall acute mortality rate for all patients with cervical spine injury was 5.92%.[16] On subgroup analysis, the elderly population age 65 years or older had an astonishingly high acute mortality rate of 18%.[34] Overall, 86% of elderly patients age 65 years and older survived, compared with 96.1% of their younger counterparts. When Lenoir et al. exclusively evaluated patients with unstable fracture of the cervicothoracic junction, they found an even higher mortality rate of 23%. This observed variability in overall survival rate across the subaxial cervical spine was reflected in our international study, which demonstrated that statistically significant variations in management do indeed exist according to the subaxial cervical region affected.[35]

A criticism that may be leveled against any spine fracture treatment algorithm is its applicability and generalizability. Management preferences may vary according to region and surgeon experience, as well as between surgical specialties. We investigated all of these factors in our global survey. Generally, there were no significant discrepancies in management preferences across the three stratified regions of the Americas, Europe, and finally the combined region of Africa, Asia, and the Middle East. The only noteworthy finding was that European spinal specialists were less inclined to offer surgical management for A3 fractures than their American and Asian colleagues ($p = 0.019$). Misalignment acceptance rates were also similar across geographic regions. This is a testament to the universality of the AO Spine Subaxial Injury Classification System.

From an experiential standpoint, surgeons with more than 10 years of experience were more likely to operatively manage incomplete ($p < 0.001$) and complete ($p < 0.001$) burst fractures than their younger colleagues. It could be argued that there is evidence in the overall surgical population that experienced surgeons may have lower postoperative complication and mortality rates than younger surgeons and therefore we should defer to their experience.[36] Alternatively, these better outcomes could be attributed to other factors, such as the experienced surgeon's skillset rather than their decision-making. This is an intriguing finding with potential for further investigations to evaluate postoperative outcomes in this particular population according to surgeon experience.

Finally, neurosurgeons preferred operative intervention for the management of traumatic A3 ($p < 0.001$) and A4 ($p < 0.001$) fractures in comparison with their orthopedic colleagues on pooled analysis. However, it is telling that both groups agreed regarding the management of both A3 ($p = 0.866$) and A4 ($p = 0.368$) junctional fractures in the lower subaxial cervical region, despite offering different treatment strategies for fractures in the upper and middle regions. It has been suggested that neurosurgeons perform a higher overall volume of spinal procedures during their training than orthopedic surgeons, but they do have a reduced focus on spinal deformity surgery.[37] The purpose of highlighting potential intrinsic specialty bias regarding management preferences is to raise self-awareness among spinal surgeons and encourage multidisciplinary discussion.

Another consideration for our survey was the potential for nuances in radiological interpretation and classification of fracture types to act as confounders of variations in treatment strategy. Fortunately, Schroeder et al. already demonstrated that the interpretation of A3 and A4 fractures, as incomplete and complete burst fractures in the thoracolumbar spine, is not affected by region or experience.[38] However, this has yet to be definitively shown for the subaxial cervical spine. Our didactic survey circumvented this potential for radiological bias by evaluating preferences for surgical or nonoperative management with predefined incomplete and complete subaxial fractures.

A major strength of our study was the global nature of our survey, spanning six distinct geographic regions. Participants had varying levels of experience, backgrounds, and specialties. We also assessed clinician surgical strategy directly with questions as well as indirectly with several clinical vignettes. The fact that our study eliminated radiological interpretation of fracture subtype as a potential confounder of management preference was also an advantage. However, our study was not without limitations. Rather than being based on prospective randomized clinical data, our conclusions were drawn from international clinician opinions. Although we achieved statistical significance for our primary and secondary outcomes, only 57% of addressed participants responded and the majority of our participants were from academic spine centers. This may lend a degree of confidence that we gathered data from involved experts working in leading tertiary institutions, but this may also mean that the results carry less external validity given the potential for volunteer bias. As with any survey, there is also a potential for nonresponder bias. However, we attempted to counteract this by using a simple random sampling scheme. Our subgroup analysis was also limited by the fact that some geographic areas were underrepresented, such as Asia and North America, and therefore had to be combined with their nearest neighboring geographic region. It is evident that there is still a need for large high-quality prospective trials to elucidate the optimal management strategy for fractures across the subaxial cervical spine.

As Joaquim et al. and Cruz et al. previously posited, accurate decision-making guided by an algorithm may not only lead to patients undergoing operative intervention in a timely fashion, but also decrease the number of patients who undergo an operation, and are therefore exposed to its associated risks, that may not necessarily be indicated.[18,39,40] Our international survey is the first to encapsulate the current management preferences for incomplete and complete burst fractures of the subaxial cervical spine. This is especially important given the current dearth of clinical patient data relating to patient outcomes after these potentially devastating neurological injuries.

Conclusions

The subaxial cervical spine should not be considered a single unified entity. Fractures of both the A3 and A4 subtypes were more likely to be surgically managed if they occurred at the cervicothoracic junction compared with those at the upper or middle subaxial regions. There was significant management variation between A3 and A4 injuries across the subaxial cervical spine, with surgeons displaying a greater preponderance to operatively manage the latter fracture morphology subtype. These findings warrant further investigation in multicenter randomized trials prior to incorporation into future algorithms for the treatment of subaxial cervical spine trauma.

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Appendix

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Disclosures

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Supplemental Information

Online-Only Content

Supplemental material is available with the online version of the article.

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