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Establishing the Injury Severity of Subaxial Cervical Spine Trauma

Validating the Hierarchical Nature of the AO Spine Subaxial Cervical Spine Injury Classification System

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Study Design. Global cross-sectional survey.

Objective. The aim of this study was to validate the AO Spine Subaxial Cervical Spine Injury Classification by examining the perceived injury severity by surgeon across AO geographical regions and practice experience.

Summary of Background Data. Previous subaxial cervical spine injury classifications have been limited by subpar interobserver reliability and clinical applicability. In an attempt to create a universally validated scheme with prognostic value, AO Spine established a subaxial cervical spine injury classification involving four elements: injury morphology, facet injury involvement, neurologic status, and case-specific modifiers.

Methods. A survey was sent to 272 AO Spine members across all geographic regions and with a variety of practice experience. Respondents graded the severity of each variable of the classification system on a scale from zero (low severity) to 100 (high severity). Primary outcome was to assess differences in perceived injury severity for each injury type over geographic regions and level of practice experience.

Results. A total of 189 responses were received. Overall, the classification system exhibited a hierarchical progression in subtype injury severity scores. Only three subtypes showed a significant difference in injury severity score among geographic regions: F3 (floating lateral mass fracture, $P = 0.04$), N3 (incomplete spinal cord injury, $P = 0.03$), and M2 (critical disk herniation, $P = 0.04$). When stratified by surgeon experience, pairwise comparison showed only two morphological subtypes, B1 (bony posterior tension band injury, $P = 0.02$) and F2 (unstable facet fracture, $P = 0.03$), and one neurologic subtype (N3, $P = 0.02$) exhibited a significant difference in injury severity score.

Conclusion. The AO Spine Subaxial Cervical Spine Injury Classification System has shown to be reliable and suitable for proper patient management. The study shows this classification is substantially generalizable by geographic region and surgeon experience, and provides a consistent method of communication among physicians while covering the majority of subaxial cervical spine traumatic injuries.

Key words: AO spine subaxial cervical spine injury, cervical spine, classification system, injury severity score, trauma, validation.

Level of Evidence: 4

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Cervical spine trauma can be catastrophic, with timely identification and optimal treatment key to achieving successful outcomes. Efficient interprovider communication is essential in the management of

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cervical spine injuries. Classification systems are tools utilized by physicians to simplify communication, and are best when their use is simple and reproducible, while at the same time able to transmit comprehensive information from diagnosis to prognosis and clinical management.[1,2] The subaxial cervical spine is composed of all elements from C3 to C7, and various classification schemes have been developed over the years to describe traumatic injuries affecting this region of the spine.[3,4] Among the first systems established, Allen and Ferguson proposed a scheme based on radiographic findings and inferred mechanisms of injury, postulating six main categories each with a series of anatomic severity stages: flexion-compression, flexion-distraction, extension-compression, extension-distraction, vertical compression, and lateral flexion.[3–5] Harris *et al* expanded upon this scheme adding rotational components to the mechanisms considered.[4,6–8] Although this system and its modification were comprehensive, they lack reliability and clinical applicability.[4,7–9]

More recently, in an attempt to circumvent the shortcomings of the previous systems, the AO Spine Trauma Study Group developed the Subaxial Injury Classification System (SLIC).[8] In addition to considering the morphology of the injury, SLIC incorporated the neurological status of the patient, as well as the integrity of the disco-ligamentous complex, producing an algorithm that can be used to recommend conservative *versus* operative management.[2,8,10] Studies have shown the SLIC system to be valid and reliable.[8] Various reports have suggested it has good interobserver and intraobserver reliability when compared to older systems, with total score intraclass correlation coefficients ranging from 0.71 to 0.79 and 0.83 to 0.97, respectively.[9,11,12] Nevertheless, persistent provider disagreements on the morphological definitions postulated by SLIC are also suggested in the literature.[12]

To date, no single scheme has been fully accepted by experts as the ideal subaxial cervical spine classification system. In an effort to achieve widespread agreement, the AO Spine Subaxial Cervical Spine Injury Classification System was developed (Figure 1).[7] This system categorizes injuries based on four major criteria: injury morphology, facet injury involvement, neurological status, and case-specific modifiers.[7] First, morphology is divided into three major types: Type A (compression injuries), Type B (tension band injuries), and Type C (translational injuries in any axis). Types A and B, in turn, have subcategories. Type A0 for minor injury or no bony involvement; A1 for single endplate compression fractures with no posterior vertebral body involvement; A2 for pincer fractures of both endplates without posterior wall involvement; A3 for burst fractures of one endplate; and A4 for sagittal split fractures of both endplates. Type B1 describes a bony posterior tension band injury; B2 is a complete posterior tension band injury that includes soft tissue components; and B3 is an anterior tension band injury. Type C injuries do not have subcategories, but if there are associated injuries of the A or B types, it should be noted as a subtype after describing a Type C injury.[7]

Additionally, this more comprehensive classification system incorporates facet injuries within the Type F category[7]: the F1 subtype for nondisplaced facet fractures, F2 for facet fractures with instability, F3 for floating lateral mass injuries, and F4 for pathologic subluxation or dislocated facet injuries. Moreover, the neurological status of the patient is described by the N descriptor, with N0 representing a neurologically intact patients, N1 for transient neurologic deficits that have resolved, N2 for radiculopathies, N3 for incomplete cord injuries, and N4 for complete cord injuries; note the NX descriptor is used for patients unable to be examined due to secondary causes.[7] Finally, the scheme incorporates case-specific modifiers to more thoroughly describe injuries. The M1 modifier describes partial disruption of the posterior soft tissue complex, whereas the M2 modifier depicts a critical disk herniation, and the M3 modifier signals the presence of an associated metabolic bone disorder. M4 describes the involvement of a vertebral artery.

This AO Spine subaxial cervical spine injury classification system has shown acceptable reliability, with various studies reporting kappa coefficients for overall interobserver reliability ranging from 0.57 to 0.64, and intraobserver reproducibility ranging from 0.54 to 0.95.[1,7,13–15] Nevertheless, there still exist differences among surgeons and countries on the management of subaxial cervical spine injuries, and the development of consistent and universal treatment strategies is desirable to achieve uniform outcomes.[16] The purpose of this study was to describe the severity of injury perceived by a surgeon as it relates to the scheme postulated by the AO Spine subaxial cervical spine injury classification, with the ultimate goal of developing a universally validated classification scheme.

METHODS

Data Collection

As previously established,[17] a survey (Supplemental Digital Content 1, http://links.lww.com/BRS/B694) was sent to the members of the AO Spine Cervical Classification Validation Group. The group is composed of spine surgeons located in six different geographic regions (North America, South America, Europe, Africa, Asia, and the Middle East). For each variable (including types and subtypes) of the AO Spine Subaxial Cervical Spine Injury Classification System, respondents were asked to provide a numerical severity grade, including the morphology of the injury, the neurological status, and the case-specific modifiers. A grade of zero was assigned to a minimally severe injury, whereas a grade of 100 belonged to injuries with the highest severity possible. Only questionnaires with at least one valid answer, in addition to the demographic information, were included in the final analysis. Note, years of practice experience was collected as <5 years, 5to 10 years, 11to 20 years, 20+ years.

Statistical Analysis

Based on previous studies,[17] surgeon responses were used to produce a perceived injury severity score (ISS) for each

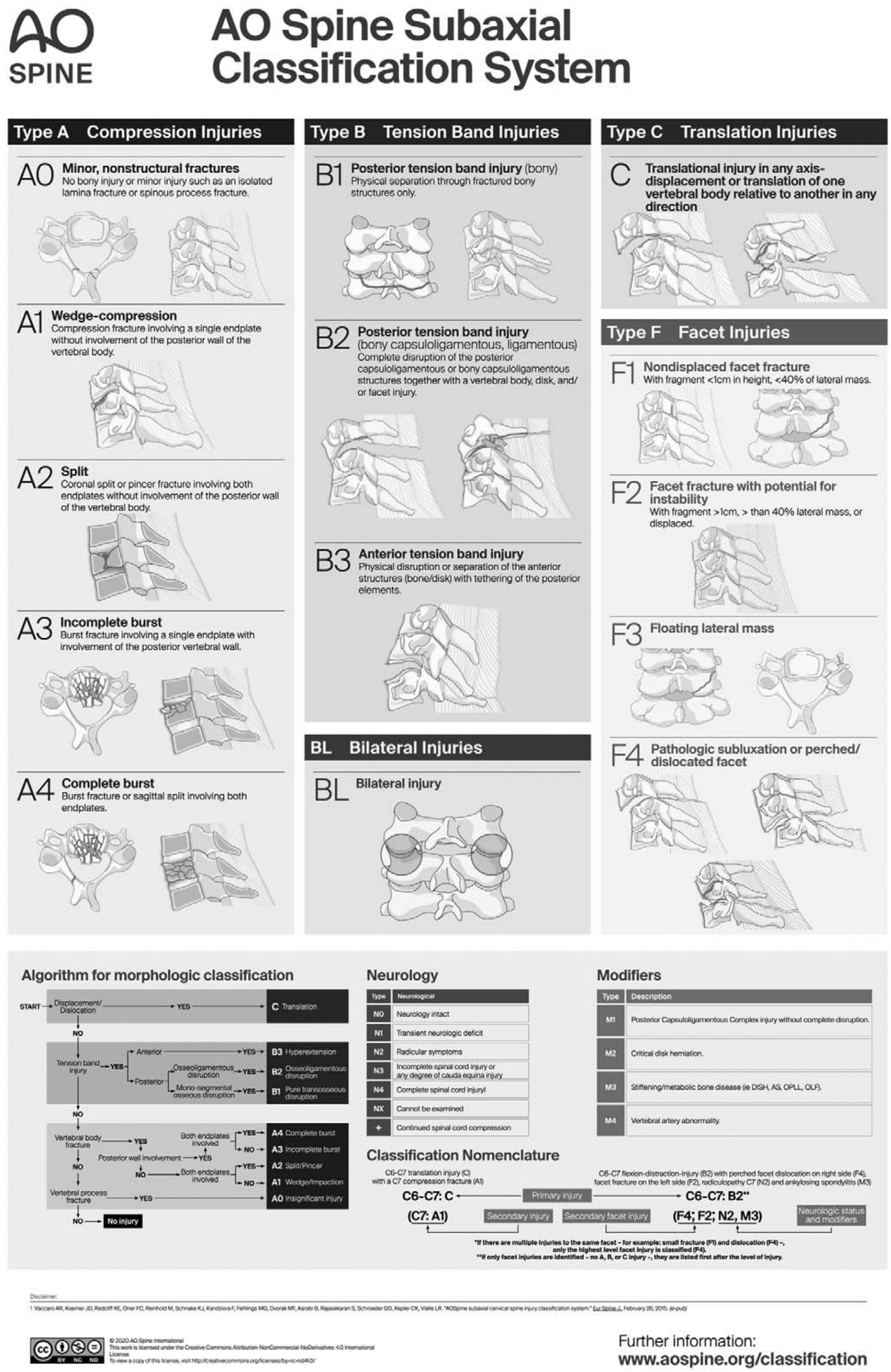

Figure 1. AO Spine Subaxial Cervical Spine Injury Classification.[1,7] Reprinted with permission from AO Spine International. © AO Foundation, Switzerland.

fracture type and subtype of the classification system, including neurological status and modifiers. ISS was generated for the total samples, as well as for subgroups according to geographical region and surgeon experience. A descriptive statistical analysis was performed for categorical and continuous data. For categorical data, frequencies were calculated based on the number of nonmissing replies. Continuous data were analyzed using the following descriptive statistics: mean, standard deviation, median, minimum, and maximum. Median ISS for the same fracture type, neurological status, and modifier were tested for equality across all geographic regions using a Kruskal-Wallis test. Years of surgeon experience was re-grouped ($\leq$10 years, $>$10 years), and fracture type, neurological status, and case-specific modifiers were tested for equality by a Wilcoxon rank sum test. Post-hoc analysis by geographic region of surgeons was done only for fracture types, neurological status, and modifiers which had an observed borderline significance ($P \leq 0.10$) upon Kruskal-Wallis testing. Regarding practice experience of surgeons, the post-hoc analysis was done for all fracture types, neurological status, and case-specific modifiers via pairwise comparison of injury severity scores utilizing a Tukey-Kramer adjustment. The significance level was defined at $\alpha = 0.05$. All analyses were performed using the statistical software SAS version 9.4 (SAS Institute Inc., Cary, NC).

RESULTS

A total of 195 out of 272 members of the AO Spine Cervical Classification Validation Group responded to the survey. Six surveys did not meet inclusion criteria and were excluded from analysis, for a total of 189 surveys considered in the final analysis. Respondent characteristics are summarized in Table 1. The overall injury severity score of each variable (including type/subtype) of the classification is presented in Table 2. The results show a hierarchical nature of the classification system, with only a B1 injury (bony posterior tension band, 60 [45.0, 70.0)]) being perceived slightly less severe than an A4 fracture (two endplate sagittal split, 60 [50,80]) based on interquartile range. All other injury types/subtypes were found to have increasing ISS based on median and interquartile range as the classification progressed.

TABLE 1. Surgeon Demographic Characteristics

Characteristics	Total Responders (n = 189)
Subspecialty*	
Orthopedic spine	131 (69.3)
Neurosurgery	58 (30.7)
Region*	
North America	18 (9.5)
Latin/South America	40 (21.2)
Europe	70 (37.0)
Africa	12 (6.3)
Asia	34 (18.0)
Middle East	15 (7.9)
No. of years in practice*	
<5	50 (26.5)
5–10	61 (32.3)
11–20	50 (26.5)
>20	28 (14.8)
Work setting*	
Academic	78 (41.3)
Hospital employed	88 (46.6)
Private practice	23 (12.2)
No. of spine trauma patients treated per year†	50 (20; 100)
Time to obtain an MRI at Home Institution*	
<2 h	52 (27.5)
2–12 h	62 (32.8)
12–24 h	28 (14.8)
>24 h	42 (22.2)
Cannot Obtain	5 (2.6)

MRI indicates magnetic resonance imaging.
*Proportions presented as: number of responders (%).
†Number presented as: median (interquartile range).

TABLE 2. Global Analysis of Injury Severity Score Based on Fracture Type, Neurologic Status, and Case-specific Modifier

Type	No. of Responders	Median (IQR)
A0	178	5.0 (0.0–10.0)
A1	179	20.0 (10.0–25.0)
A2	179	30.0 (20.0–50.0)
A3	179	50.0 (30.0–60.0)
A4	179	60.0 (50.0–80.0)
B1	179	60.0 (45.0–70.0)
B2	179	80.0 (70.0–85.0)
B3	179	80.0 (70.0–90.0)
C	178	100.0 (100.0–100.0)
F1	179	20.0 (10.0–30.0)
F2	179	40.0 (30.0–50.0)
F3	179	50.0 (40.0–70.0)
F4	179	100.0 (85.0–100.0)
N0	178	0.0 (0.0–0.0)
N1	178	20.0 (10.0–30.0)
N2	178	40.0 (30.0–50.0)
N3	178	80.0 (70.0–100.0)
N4	178	100.0 (85.0–100.0)
NX	178	80.0 (50.0–100.0)
M1	178	40.0 (30.0–60.0)
M2	178	70.0 (50.0–80.0)
M3	178	70.0 (60.0–80.0)
M4	178	60.0 (50.0–80.0)

IQR indicates interquartile range.

Subgroup analysis for classification morphology demonstrated that there were no statistically significant differences in ISS based on geographic region across fracture types/subtypes, with the exception of an F3 (floating lateral mass) fracture ($P = 0.04$) (Table 3). Additionally, no statistically significant difference based on region was found across neurological status grades, with the exception of the N3 (incomplete spinal cord injury) subtype ($P = 0.03$) (Table 3). Finally, in terms of case-specific modifier, only the M2 (critical disk herniation) subtype exhibited a statistically significant difference across geographical regions ($P = 0.04$) (Table 3). Further subgroup analysis with post-hoc pairwise comparison utilizing Tukey-Kramer adjustments showed that within the F3 subtype, there was a statistically significant difference in perceived severity between surgeons from Europe and Latin/South America ($P = 0.01$). Similarly, there was a significant difference in perceived severity

TABLE 3. Regional Analysis of Injury Severity Score Based on Fracture Type, Neurologic Status, and Case-specific Modifier

	North America		Latin/South America		Europe		Africa		Asia		Middle East		
Type	N	Median (IQR)	N	Median (IQR)	N	Median (IQR)	N	Median (IQR)	N	Median (IQR)	N	Median (IQR)	*P* *
A0	18	5.0 (1.0–10.0)	39	5.0 (0.0–10.0)	67	5.0 (0.0–10.0)	10	3.0 (0.0–10.0)	30	5.0 (1.0–10.0)	14	10.0 (0.0–10.0)	0.81
A1	18	12.5 (6.0–20.0)	39	15.0 (10.0–20.0)	68	20.0 (10.0–22.5)	10	20.0 (5.0–25.0)	30	20.0 (10.0–30.0)	14	20.0 (10.0–20.0)	0.27
A2	18	30.0 (20.0–50.0)	39	30.0 (20.0–45.0)	68	30.0 (20.0–40.0)	10	32.5 (30.0–50.0)	30	37.5 (25.0–60.0)	14	30.0 (25.0–50.0)	0.45
A3	18	50.0 (25.0–50.0)	39	45.0 (30.0–50.0)	68	40.0 (30.0–50.0)	10	50.0 (30.0–60.0)	30	50.0 (40.0–70.0)	14	45.0 (30.0–75.0)	0.53
A4	18	67.5 (50.0–75.0)	39	60.0 (50.0–70.0)	68	60.0 (45.0–70.0)	10	70.0 (50.0–90.0)	30	72.5 (50.0–90.0)	14	62.5 (50.0–90.0)	0.29
B1	18	50.0 (40.0–75.0)	39	55.0 (45.0–70.0)	68	60.0 (45.0–70.0)	10	55.0 (40.0–75.0)	30	60.0 (50.0–80.0)	14	60.0 (50.0–70.0)	0.97
B2	18	80.0 (70.0–90.0)	39	80.0 (70.0–80.0)	68	80.0 (67.5–80.0)	10	72.5 (70.0–80.0)	30	80.0 (60.0–90.0)	14	70.0 (60.0–85.0)	0.53
B3	18	80.0 (70.0–90.0)	39	80.0 (75.0–90.0)	68	80.0 (70.0–90.0)	10	87.5 (80.0–95.0)	30	80.0 (70.0–95.0)	14	80.0 (60.0–90.0)	0.43
C	17	100.0 (100.0–100.0)	39	100.0 (100.0–100.0)	68	100.0 (100.0–100.0)	10	100.0 (100.0–100.0)	30	100.0 (100.0–100.0)	14	100.0 (100.0–100.0)	0.61
F1	18	12.5 (10.0–25.0)	39	20.0 (10.0–30.0)	68	20.0 (10.0–25.0)	10	20.0 (10.0–30.0)	30	20.0 (10.0–30.0)	14	20.0 (15.0–20.0)	0.64
F2	18	41.0 (30.0–50.0)	39	40.0 (30.0–50.0)	68	30.0 (25.0–40.0)	10	50.0 (30.0–60.0)	30	40.0 (30.0–50.0)	14	40.0 (30.0–50.0)	0.06
F3	18	52.5 (40.0–70.0)	39	70.0 (40.0–75.0)	68	40.0 (40.0–60.0)	10	65.0 (50.0–75.0)	30	52.5 (40.0–60.0)	14	50.0 (40.0–60.0)	0.04
F4	18	100.0 (86.0–100.0)	39	100.0 (90.0–100.0)	68	100.0 (85.0–100.0)	10	100.0 (80.0–100.0)	30	97.5 (80.0–100.0)	14	95.0 (80.0–100.0)	0.89
N0	18	0.0 (0.0–1.0)	39	0.0 (0.0–0.0)	67	0.0 (0.0–0.0)	10	0.5 (0.0–10.0)	30	0.0 (0.0–0.0)	14	0.0 (0.0–0.0)	0.29
N1	18	20.0 (10.0–30.0)	39	20.0 (15.0–40.0)	67	20.0 (10.0–30.0)	10	20.0 (10.0–30.0)	30	20.0 (10.0–25.0)	14	20.0 (10.0–20.0)	0.63
N2	18	30.0 (20.0–50.0)	39	40.0 (30.0–60.0)	67	40.0 (25.0–50.0)	10	50.0 (40.0–55.0)	30	35.0 (25.0–50.0)	14	40.0 (30.0–40.0)	0.09
N3	18	99.5 (80.0–100.0)	39	90.0 (80.0–100.0)	67	80.0 (70.0–100.0)	10	77.5 (70.0–100.0)	30	80.0 (70.0–90.0)	14	75.0 (60.0–80.0)	0.03
N4	18	100.0 (99.0–100.0)	39	100.0 (90.0–100.0)	67	100.0 (90.0–100.0)	10	92.5 (75.0–100.0)	30	100.0 (80.0–100.0)	14	100.0 (80.0–100.0)	0.57
NX	18	87.5 (70.0–100.0)	39	80.0 (50.0–100.0)	67	70.0 (50.0–100.0)	10	100.0 (95.0–100.0)	30	80.0 (50.0–100.0)	14	87.5 (50.0–100.0)	0.21
M1	18	30.0 (25.0–70.0)	39	50.0 (40.0–60.0)	67	40.0 (20.0–50.0)	10	50.0 (25.0–75.0)	30	40.0 (30.0–60.0)	14	40.0 (20.0–60.0)	0.10
M2	18	77.5 (65.0–80.0)	39	80.0 (70.0–95.0)	67	70.0 (50.0–80.0)	10	60.0 (50.0–75.0)	30	70.0 (50.0–80.0)	14	72.5 (50.0–80.0)	0.04
M3	18	75.0 (60.0–90.0)	39	70.0 (50.0–80.0)	67	70.0 (50.0–80.0)	10	80.0 (75.0–80.0)	30	80.0 (60.0–90.0)	14	72.5 (60.0–80.0)	0.18
M4	18	60.0 (20.0–80.0)	39	70.0 (50.0–85.0)	67	60.0 (50.0–75.0)	10	85.0 (75.0–100.0)	30	65.0 (50.0–80.0)	14	70.0 (50.0–75.0)	0.07

Only questionnaires with at least one or more answers, in addition to demographic characteristics, were included. IQR indicates interquartile range.

**Comparison using Kruskal-Wallis test with significance established at $P < 0.05$.*

between Middle Eastern and North American surgeons for N3 ($P = 0.03$), and European and Latin/South American surgeons for M2 ($P = 0.03$). No other regions exhibited significant differences via pairwise comparison.

Subgroup analysis of injury severity scores based on re-grouped years of surgeon experience (≤10 years and >10 years) revealed that five morphological subtypes, and the N3 ($P = 0.02$) neurological status subtype exhibited statistically significant differences (Table 4). For morphology, the A0 (minor injury), A1 (single endplate fracture), A2 (pincer fracture), B1 (bony posterior tension band injury), and F2 (unstable facet fractures) fracture subtypes showed significant differences with respect to surgeon experience ($P = 0.04$, 0.02, 0.02, 0.03, 0.04, respectively). Subgroup analysis, including all experience groups (<5 years, 5–10 years, 11–20 years, and 20+ years), with post-hoc comparison utilizing Tukey-Kramer adjustments showed a statistically significant difference within the B1 subtype in perceived severity by experience between surgeons with <5 years of practice and those with 20+ years of practice ($P = 0.02$). Furthermore, for the F2 and N3 subtypes, there was a significant difference in perceived severity between surgeons with <5 years of experience and those with 20+ years ($P = 0.03$), and between those with 5 to 10 years of experience and those with 11 to 20 years ($P = 0.02$), respectively. Post-hoc analysis did not exhibit statistically significant differences for A0, A1, or A2 subtypes.

DISCUSSION

The ultimate goal of a classification system for spine trauma is to be validated and uniformly utilized around the world. To date, no universally accepted spine trauma classification scheme exists, and the literature is awash with studies showing the variability in severity assessment and management of traumatic spine injuries.[17–25] The present study intended to describe the variations in injury severity perception by spine surgeons of the AO Spine Subaxial Cervical Spine Injury Classification System based on geographic region, as well as by a surgeon's experience in practice. Overall, the results show that the severity score of each variable within the classification system increases as the subtype increases, suggesting validity in the hierarchical progression of individual subtypes from A to C, and F1 to F4. Interestingly, there was only one instance in the entire classification scheme in which the score's hierarchical advancement was not consistent, the progression from an A4 (two endplate sagittal split) fracture to a B1 (bony posterior tension band injury, bony chance) fracture, with overall scores of 60.0 (50.0, 80.0) and 60.0 (45.0, 70.0), respectively. Although the results did not show a statistically significant difference in perceived injury severity across all geographic regions for either A4 or B1 fractures independently, it was not entirely surprising to find the transition from A4 to B1 to be inconsistent based on injury severity score. Cervical spine bony chance fractures are extremely rare, and surgeons may not be familiar with the

TABLE 4. Analysis of Injury Severity Score Based on Fracture Type, Neurologic Status, and Case-specific Modifier by Experience

	≤5 y		5–10 y		11–20 y		≥ 20 y		≤10 *vs.* ≥10 y
Type	N	Median (IQR)	N	Median (IQR)	N	Median (IQR)	N	Median (IQR)	P*
A0	44	5.0 (1.0–10.0)	59	5.0 (1.0–10.0)	48	1.5 (0.0–10.0)	27	5.0 (1.0–10.0)	0.04
A1	44	20.0 (10.0–27.5)	59	20.0 (10.0–30.0)	49	10.0 (10.0–20.0)	27	20.0 (10.0–20.0)	0.02
A2	44	30.0 (30.0–50.0)	59	40.0 (25.0–50.0)	49	30.0 (20.0–35.0)	27	30.0 (20.0–50.0)	0.02
A3	44	40.0 (30.0–50.0)	59	50.0 (35.0–60.0)	49	50.0 (30.0–60.0)	27	40.0 (30.0–55.0)	0.80
A4	44	60.0 (50.0–70.0)	59	65.0 (50.0–80.0)	49	60.0 (50.0–80.0)	27	60.0 (45.0–80.0)	0.63
B1	44	67.5 (50.0–75.0)	59	60.0 (50.0–70.0)	49	55.0 (50.0–60.0)	27	50.0 (30.0–60.0)	0.03
B2	44	80.0 (70.0–82.5)	59	80.0 (70.0–90.0)	49	80.0 (70.0–90.0)	27	70.0 (60.0–80.0)	0.79
B3	44	80.0 (72.5–90.0)	59	80.0 (70.0–90.0)	49	80.0 (70.0–95.0)	27	75.0 (65.0–85.0)	0.99
C	44	100.0 (100.0–100.0)	58	100.0 (100.0–100.0)	49	100.0 (100.0–100.0)	27	100.0 (100.0–100.0)	0.53
F1	44	20.0 (12.5–30.0)	59	20.0 (10.0–30.0)	49	20.0 (10.0–30.0)	27	20.0 (10.0–20.0)	0.77
F2	44	40.0 (30.0–52.5)	59	40.0 (30.0–50.0)	49	30.0 (30.0–50.0)	27	30.0 (20.0–40.0)	0.04
F3	44	52.5 (40.0–70.0)	59	60.0 (40.0–70.0)	49	50.0 (40.0–70.0)	27	50.0 (40.0–60.0)	0.18
F4	44	100.0 (90.0–100.0)	59	100.0 (80.0–100.0)	49	100.0 (90.0–100.0)	27	90.0 (80.0–100.0)	0.84
N0	44	0.0 (0.0–0.0)	59	0.0 (0.0–0.0)	49	0.0 (0.0–0.0)	26	0.0 (0.0–0.0)	0.89
N1	44	20.0 (12.5–25.0)	59	20.0 (10.0–25.0)	49	20.0 (10.0–40.0)	26	20.0 (10.0–30.0)	0.29
N2	44	40.0 (30.0–50.0)	59	40.0 (25.0–50.0)	49	40.0 (20.0–60.0)	26	40.0 (20.0–50.0)	0.58
N3	44	80.0 (72.5–100.0)	59	80.0 (70.0–90.0)	49	90.0 (80.0–100.0)	26	80.0 (70.0–100.0)	0.02
N4	44	100.0 (80.0–100.0)	59	100.0 (90.0–100.0)	49	100.0 (90.0–100.0)	26	100.0 (90.0–100.0)	0.15
NX	44	90.0 (50.0–100.0)	59	80.0 (50.0–100.0)	49	80.0 (50.0–100.0)	26	90.0 (50.0–100.0)	0.34
M1	44	47.5 (25.0–60.0)	59	40.0 (25.0–60.0)	49	50.0 (30.0–60.0)	26	40.0 (30.0–50.0)	0.61
M2	44	70.0 (50.0–90.0)	59	70.0 (50.0–80.0)	49	75.0 (60.0–80.0)	26	70.0 (50.0–80.0)	0.47
M3	44	75.0 (55.0–80.0)	59	70.0 (50.0–80.0)	49	70.0 (60.0–90.0)	26	72.5 (60.0–80.0)	0.51
M4	44	70.0 (50.0–90.0)	59	60.0 (40.0–75.0)	49	60.0 (50.0–80.0)	26	70.0 (50.0–80.0)	0.94

Only questionnaires with at least one or more answers, in addition to demographic characteristics, were included. IQR indicates interquartile range.

**Comparison using Wilcoxon rank sum test with significance established at $P < 0.05$.*

management of said injuries.[26] This fact is supported by our finding that a surgeon's years of experience did show a statistically significant difference in terms of perceived injury severity of B1 fractures, with surgeons having <5 years of practice experience giving a B1 fracture an average score of 67.5 (50.0, 75.0), and injury severity scores progressively decreasing as a surgeon's years of experience advanced, with surgeons having ≥20 years of experience averaging a B1 injury severity score of 50.0 (30.0, 60.0). In fact, subgroup analysis via pairwise comparison revealed a statistically significant difference in perceived injury severity for B1 subtypes only between the aforementioned groups <5 years and 20+ years ($P = 0.02$). Although commonly observed in the thoracolumbar spine transition between T10-L2, bony chance fractures involving the cervical spine are generally most often seen in the setting of ankylosing spondylitis,[26–31] and the lack of experience with this type of injury leads to the observed inconsistent scoring. Furthermore, even in the more common thoracolumbar burst fracture, Schroeder *et al*[17] reported that AO Spine thoracolumbar B1 fractures are considered less severe than A4 fractures, highlighting the observation that within both, the cervical spine and thoracolumbar spine, there is no clear perceived severity difference between A4 and B1 fracture subtypes.

In terms of subgroup variations, with the exception of an F3 fracture ($P = 0.04$), the current results did not show any significant difference in morphology-based injury severity score based on a surgeon's geographical area. Given the complex nature of the F3 subtypes, it was unsurprising to find regional variations in perceived injury severity. Floating lateral mass fractures (F3) are relatively rare, unstable injuries, difficult to diagnose and generally resulting from high-energy mechanisms.[32–34] Various studies in spine trauma discuss the persistently controversial management of cervical facet fractures, with F3 injuries generally requiring surgical intervention for instability.[32–34] In a recent case series, Manoso *et al*[32] identified 60 consecutive cases of floating lateral mass cervical facet fractures between C3-C7, and found that all patients treated nonoperatively developed instability, whereas all patients treated with two-level fusions did not show evidence of radiographic failure and maintained alignment. Comparatively, Vedantam *et al*[33] retrospectively reviewed 35 patients with subaxial cervical facet fractures, six of whom had F3 injuries. Even though two of six patients failed conservative management, the authors advocate that nondisplaced injuries warrant a trial of nonoperative interventions. Regarding other AO Spine classification subtypes with notable differences across geographical regions, only N3 injuries ($P = 0.03$) and an M2 modifier ($P = 0.04$) showed a statistically significant difference across geographic areas. Again, this was foreseeable, given the continually contentious diagnostic and management recommendations of patients with incomplete spinal cord injuries and critical disc herniations in the setting of facet dislocations.[35] Overall, with limited exceptions, our observations suggest that the AO Spine Subaxial Cervical Spine Injury Classification System is geographically generalizable, similar to our group's findings regarding the AO Spine Thoracolumbar Spine Injury Classification scheme.[17]

When considering a surgeon's years of practice experience, after subgroup analysis adjustments, only morphology-related injury subtypes B1 and F2 appeared to exhibit a significant difference in injury severity scores. As previously discussed, B1 injuries are relatively rare and case experience is likely to play a factor in perceived injury severity. For facet fractures with instability (F2), similar inferences can be made given the controversial nature of facet fracture management particularly when unstable.[32–34] Additionally, for other variables in the classification, only the N3 ($P = 0.02$) neurological grade showed significant variation across surgeon experience, with variability noted in mid-career surgeons, likely secondary to the aforementioned controversies in the management of incomplete spinal cord injuries.

As seen in equivalent analysis of the AO Spine Thoracolumbar Spine Injury Classification, this study's findings suggest that regional and experiential variations observed in cervical trauma management are possibly influenced by factors outside of the interpretation of an injury's perceived severity, such as cultural differences, health care infrastructure, and costs.[17] This is the reason behind basing the classification system on morphological features and not treatment algorithms.[7] In terms of subspecialty training, although there is a higher proportion of orthopedic spine surgeons compared to neurosurgeons in our study, previous reports highlight high agreement on primary management decisions among spine specialists.[36,37] Although further studies with proportional subspecialty respondents will be helpful, perceived severity scores are unlikely to change.

The present study is not without limitations. First, the survey study design provides a small sample of surgeons with uneven numbers across geographical regions and subspecialty training. Moreover, the questionnaire administration followed the preestablished order of the classification scheme, leaving open the possibility of bias when surgeons assigned perceived injury severity scores to each ascending type/subtype in the scheme. Additionally, this report does not establish guidelines for the surgical *versus* nonsurgical management of fracture types/subtypes within the classification, instead it establishes their perceived severity of injury.[17] Finally, all respondents of the survey had affiliations with academic institutions, which is unlikely to represent all spine surgeons practicing in a specific geographical region where community hospitals may be more numerous.

Based on our findings, and the system's considerable interobserver and intraobserver reliability, the AO Spine Subaxial Cervical Spine Injury Classification System is a sound foundation for the development of a universally accepted treatment algorithm for subaxial cervical spine trauma. With few exceptions within controversial injury subtypes, this classification system is considerably generalizable by geographic region and surgeon experience.

Key Points

- The AO Spine Subaxial Cervical Spine Injury Classification System exhibited a hierarchical progression in subtype injury severity scores.
- Only F3, N3 and M3 classification subtypes showed a significant difference in injury severity score among AO geographic regions.
- When stratified by surgeon experience, only B1, F2 and N3 subtypes exhibited a significant difference in injury severity score.
- With few exceptions, the perceived injury severity scores of the classification system subtypes are independent of geographic region and surgeon experience.

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