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

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Study Design. Global cross-sectional survey.

Objective. To validate the hierarchical nature of the AO Spine Upper Cervical Spine Injury Classification (UCIC) across AO geographical regions/practice experience.

Summary of Background Data. To create a universally validated scheme with prognostic value, AO Spine established an upper cervical spine injury classification involving three elements: injury morphology (region: I—occipital condyle and craniocervical junction; II—C1 ring and C1-2 joint; III—C2 and C2-3 joint), and (subtype: A—isolated bony injury; B—bony/ligamentous injury; C—displaced/translational injury), neurological status [N0—intact; N1—transient deficit; N2—radiculopathy; N3—incomplete spinal cord injury (SCI); N4—complete SCI, and NX—unable to examine], and case-specific modifiers (M1—injuries at risk of nonunion; M2—injuries at risk of instability; M3—patient specific factors; M4—vascular injury).

Materials and Methods. Totally, 151 AO Spine members (orthopaedic and neurosurgery) were surveyed globally regarding the severity (zero—low severity to 100—high severity) of each UCIC variable. Primary outcomes were differences in perceived injury severity score (ISS) over various geographic/practice settings, level of experience, and subspecialty.

Results. One hundred forty-eight responses were received. There was an increase in median perceived severity as each anatomic region (I–III) progressed from types A to B to C. Neurological status progressed similarly, except N1 and N2 were perceived similarly. Modifier M2 was perceived more severely than M3. There were no differences in ISS among levels of surgeon experience. There were small geographic differences with respondents from North and Central and South America perceiving types IC ($P = 0.003$), IIB ($P = 0.003$), and IIIB ($P = 0.003$) somewhat more severely than other regions. Neurosurgeons perceived types IB ($P = 0.002$) and IIIB ($P = 0.026$) as more severe than orthopaedic spine surgeons.

Conclusions. The AO Spine UCIC has overall excellent hierarchical progression in subtype ISS. These findings are consistent across geographic regions, spine subspecialty training and experience levels.

Key Words: upper cervical spine injury classification, AO Spine, validation, injury severity score, global, hierarchical

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Trauma to the upper cervical spine can result in devastating injuries—therefore rapid identification and optimal management is needed for successful outcomes. The upper cervical spine spans the occiput to the axis. Due

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to the substantial morphologic variation that exists at each level, there is a great diversity of fracture patterns that fall within this region. As a result, classification systems developed for the upper cervical spine have largely been descriptive and the majority have yet to reliably show utility in guiding treatment or prognosis.[1–8] One of the most cited upper cervical classifications is the Anderson and D'Alonzo classification for odontoid fractures. While this system has been shown to predict fracture types that may be treated with nonoperative intervention, there is still considerable debate about how well it can guide clinical decision-making in controversial type 2 patterns.[9] Further work by Grauer *et al*.[10] addressed this controversy by subclassifying Anderson and D'Alonzo type 2 fractures into three subtypes. Although this subclassification has shown promise in some smaller studies, further prospective work is needed.[11,12] Furthermore, these relatively well studied classification systems are germane only to the anatomy surrounding the odontoid process.

To address the need for a more unified and reliable system, the AO Spine Trauma Study Group developed the Upper Cervical Injury Classification (UCIC) system.[13] Along with incorporating the morphology of the injury, the UCIC includes the neurological status of the patient, as well as unique clinical modifiers. The goal of the classification is to produce an algorithm that can be used to guide management. To date, the UCIC has followed the validation pathway described by Audigé and colleagues and has been found to have excellent interobserver and intraobserver reliability of the UCIC, across a wide range of surgeon experience levels, geographic locations, and among both orthopedic and neurosurgical spine specialists.[13,14] Following this process of inter-rater correlation, successful scoring systems have been developed for previous AO Spine classification systems of other spine regions by evaluating the validity and reproducibility of the proposed hierarchy of each system.[15–17] This has historically been performed by allowing a wide variety of global spine experts to assign a perceived injury severity score to each step of the different components of the hierarchy to assess how the proposed hierarchy performs.[15,17,18] However, the hierarchical structure of the UCIC has yet to be validated in this manner, and thus a numeric scoring system for the UCIC has not been assigned. The goal of developing a scoring system is to create a treatment algorithm, which has been successfully performed by AO Spine for numerous other regions of the spine.[16,18–20] Thus, addressing this gap in the literature for the UCIC is critical to allow for not only broader adoption of the classification system, but also further standardization of treatment for a vulnerable patient population.

For these reasons, the purpose of the present study is to validate and establish a severity score for the hierarchical aspects of the UCIC through a survey of a wide variety of spine surgeons from around the world from a diverse range of practice settings and training backgrounds. The findings from this work will be used to further refine and validate the UCIC system, with the ultimate goal of creating a broadly applicable, quantitative scoring system and treatment algorithm.

MATERIALS AND METHODS

A Brief Description of the Classification

The UCIC system has been described previously and follows the well-validated structure of prior AO Spine injury classification schema (Fig. 1).[16,21–24] Given the unique morphology of the occiput and upper cervical spine, the UCIC begins with a description of the anatomic location of the injury. Region I includes the occipital condyle and craniocervical junction. Region II includes the C1 ring and C1-2 joint. Region III includes the C2 body, the odontoid process, and the C2-3 joint. The region is followed by a subtype designation (A, B, or C). Subtype A represents mostly bony injuries, which tend to have retained stability. Subtype B describes injuries with a bony and/or ligamentous component, but without translation of the vertebral body. These injuries can be stable or unstable, and typically are more fully characterized through advanced imaging such as flexion/extension radiographs or magnetic resonance imaging (MRI). Subtype C are injuries that involve translation of the cephalad and caudal aspects of the spinal column. These injuries are unstable and often require operative intervention. As for neurological status, modifiers account for a variety of presentations: N0—neurologically intact, N1—transient neurological deficit, N2—radicular symptoms, N3—incomplete spinal cord injury or any degree of cauda equina, N4—complete spinal cord injury, and NX—patients that cannot be examined due to secondary issues. Clinical modifiers that were included are M1—injuries at high risk of nonunion with nonoperative treatment, M2—injuries with significant potential for instability, M3—patient-specific factors affecting treatment, and M4—vascular injury or abnormality affecting treatment. Similar to prior AO Spine injury classifications, the UCIC is a hierarchical system where the A, B, and C subtypes and the N0-4 and M1-M4 modifiers are intended to reflect increased injury severity.[26]

Data Collection

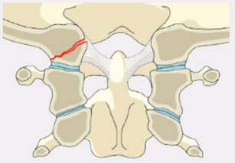
A survey was distributed to the members of the AO Spine Cervical Classification Validation Group (Supplemental File, Supplemental Digital Content 1, http://links.lww.com/BRS/C649). The group is composed of spine surgeons located in six different geographic regions (North America, South America, Europe, Africa, Asia, and the Middle East). Demographic information was gathered from each respondent including geographical region of practice, years of experience as a spine surgeon (<5, 5–10, 11–20, and >20 yr), subspecialty training background (neurosurgery, orthopedic spine or trauma surgery), and setting of work (private practice, hospital employed, or academic). For each variable (including anatomic regions and subtypes) of the AO Spine UCIC 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 mild injury not warranting surgery, whereas a grade of 100 belonged to injuries with the highest

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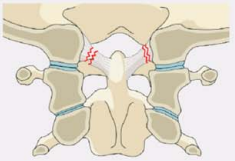
AO Spine Upper Cervical Injury Classification System

I. Occipital Condyle and Craniocervical junction

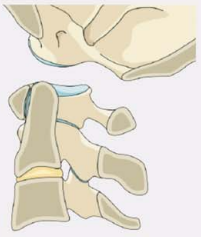
Type A Isolated bony injury (condyle)



Type B Non-displaced ligamentous injury (craniocervical)

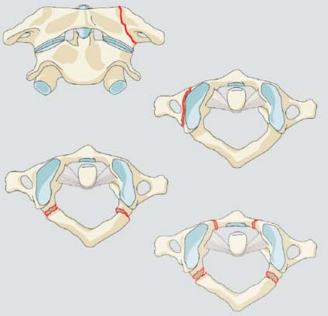


Type C Any injury with displacement on spinal imaging

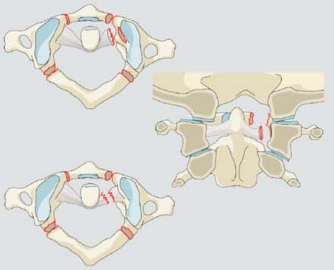


II. C1 Ring and C1-2 Joint

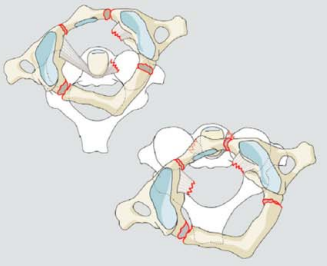
Type A Isolated bony only (arch)



Type B Ligamentous injury (transverse atlantal ligament)

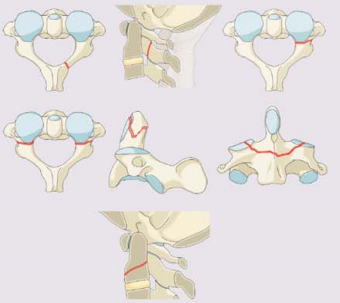


Type C Atlantoaxial instability / Translation in any plane

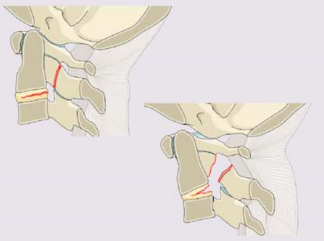


III. C2 and C2-3 Joint

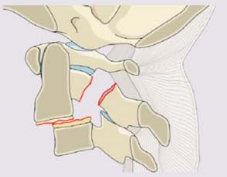
Type A Bony injury only without ligamentous, tension band, discal injury



Type B Tension band / Ligamentous injury with or without bony injury



Type C Any injury that leads to vertebral body translation in any directional plane



Upper Cervical Spine Fractures Overview

I. Occipital condyle and occipital cervical joint complex injuries	II. C1 ring and C1-2 joint complex injuries	III. C2 and C2-3 joint complex injuries

Type A — Bony injury only
- Without significant ligamentous, tension band, discal injury
- Stable injuries

Type B — Tension band/ ligamentous injury
- With or without bony injury
- No complete separation of anatomic integrity
- Stable or unstable depending on injury specifics

Type C — Translation injury
- Any injury with significant translation in any directional plane and separation of anatomic integrity
- Unstable injuries

Neurology

Type	Neurological
N0	Neurology intact
N1	Transient neurologic deficit
N2	Radicular symptoms
N3	Incomplete spinal cord injury or any degree of cauda equina injury
N4	Complete spinal cord injury
NX	Cannot be examined
+	Continued spinal cord compression

Modifiers

Type	Description
M1	Injuries at High Risk of Non-Union with Nonoperative Tx
M2	Injury with significant potential for instability
M3	Patient Specific Factors Affecting Tx
M4	Vascular Injury or Abnormality Affecting Tx

Classification Nomenclature

Atlanto-occipital dissociation with a complete spinal cord injury.

OC Type C, N4

Primary injury

Neurologic status and modifiers

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Further information:
www.aospine.org/classification

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Figure 1. Depiction of the AO Spine Upper Cervical spine injury classification system. Permission to use this figure was granted by AO Foundation, AO Spine, Switzerland.[25]

severity possible, requiring urgent surgical intervention. This same process has been used for prior AO Spine trauma classification systems in the thoracolumbar, sacral, and subaxial regions.[15,17,18] 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 were collected as < 5 years, 5 to 10 years, 11 to 20 years, and 20+ years.

Statistical Analysis

On the basis of previous studies, surgeon responses were used to produce a perceived injury severity score (ISS) for each fracture and subtype of the classification system, including the neurological status and modifiers.[15,18] 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, SD, median, first and third quartile, minimum, and maximum. To evaluate equality of median ISS for the same fracture subtype, neurological status, and modifier across all geographic regions, a Kruskal-Wallis test was performed. The same approach was taken for years of surgeon experience with an additional Wilcoxon rank sum test performed after regrouping years of experience into ≤ 10 *versus* > 10 years. Equality of median ISS for the same fracture subtype, neurological status, and modifier among neurosurgical *versus* orthopedic surgeons was performed using a Wilcoxon rank sum test as well. The threshold for statistical significance was defined at alpha = 0.05. All analyses were conducted using SAS statistical software version 9.4 (SAS Institute Inc., Cary, NC).

TABLE 1. General Demographic Information of Participating Surgeons Who Completed the Survey

Characteristic	n (%)
Geographical region of origin	148
North America	10 (6.8)
Central and South America	22 (14.9)
Europe	61 (41.2)
Africa	3 (2.0)
Asia	26 (17.6)
Middle East	8 (5.4)
Unknown	18 (12.2)
Practical experience of surgeon (yr)	148
< 5	42 (28.4)
5–10	30 (20.3)
11–20	47 (31.8)
> 20	29 (19.6)
Subspeciality	148
Neurosurgery	54 (36.5)
Orthopedic spine surgery	93 (62.8)
Orthopedic trauma surgery	1 (0.7)
Setting of work	148
Private practice	18 (12.2)
Hospital employed	59 (39.9)
Academic	71 (48.0)

RESULTS

Evaluation of Perceived Severity

A total of 148 of 151 members (98%) of the AO Spine Cervical Classification Validation Group responded to the survey. Characteristics of respondents are summarized in Table 1. Table 2 displays the number of responders per injury classification, and the median ISS and interquartile range assigned for each injury morphology, subtype, neurological status modifier, and clinical modifier. Overall, the results show a hierarchical nature of the classification system. There was an increase in median perceived severity as each anatomic region (I–III) progressed from types A to B to C. Within this progression, there was no overlap in the interval defined by the first and third quartiles for perceived ISS as subtype increased within the anatomic regions. A similar trend was seen regarding neurological status. However, N1 (transient neurological symptoms) and N2 (radicular symptoms) modifiers demonstrated equivalent median ISS (30.0), and there was slight overlap of the interval defined by the first and third quartiles between N3 and N4 modifiers. NX was perceived as more severe than N2, but less severe than N3. Among clinical modifiers, there was generally a hierarchical progression, except that the ISS of M2 modifier [injury with significant potential instability, 75.0 (60.0–80.0)] was perceived as more severe than an M3 modifier [patient-specific factors affecting treatment, 60 (50.0–75.0)].

Table 3 demonstrates geographic subanalysis of variations in ISS perception. Respondents from Africa

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

Type	No. of responders	Median (IQR)
I Type A	148	20.0 (10.0–30.0)
I Type B	147	40.0 (30.0–60.0)
I Type C	148	100 (90.0–100.0)
II Type A	147	25.0 (20.0–30.0)
II Type B	148	72.5 (60.0–88.0)
II Type C	147	90.0 (80.0–100.0)
III Type A	148	30.0 (20.0–50.0)
III Type B	148	70.0 (50.0–80.0)
III Type C	148	90.0 (80.0–100.0)
N0	148	0.0 (0.0–10.0)
N1	148	30.0 (20.0–60.0)
N2	148	30.0 (25.0–50.0)
N3	148	87.5 (75.0–99.5)
N4	148	100.0 (80.0–100.0)
NX	148	80.0 (50.0–100.0)
M1	148	60.0 (50.0–75.0)
M2	148	75.0 (60.0–80.0)
M3	148	60.0 (50.0–70.0)
M4	148	80.0 (60.0–92.5)

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and the Middle East were pooled to have adequate statistical power. The median perceived fracture severity was higher for IC in both North America (NA) and Central and South America (CSA) compared with the rest of the world ($P = 0.003$). Similar findings were noted between the median severities reported from NA and CSA compared with the rest of the world for IIB ($P = 0.003$), and IIIB ($P = 0.003$). All other comparisons were similar among the different geographic groups.

Table 4 demonstrates the perceived ISS subdivided by surgeon experience. There were no significant differences among levels of experience. Table 5 demonstrates the perceived ISS subdivided by subspecialty training background (neurosurgery *vs.* orthopedic spine surgery). Notably, type IB ($P = 0.002$) and type IIIB ($P = 0.026$) were perceived as more severe for neurosurgeons than for orthopedic spine surgeons. Similarly, N1 ($P = 0.005$) was perceived as more severe for neurosurgeons than for orthopedic spine surgeons.

DISCUSSION

Validation of a spine trauma classification system is critical to promote broad utilization and to standardize care. Unfortunately, there is not currently a single, comprehensive spine trauma classification system, and prior studies have demonstrated substantial variation in the assessment of injury severity and management of spine trauma.[27–35] The AO Spine UCIC system was first described in 2018 and has been shown to have globally excellent interobserver and intraobserver reliability.[13,14,23,36] The UCIC fills a substantial need in terms of description, prognostication, and standardization of treatment of upper cervical spine injuries, which can often involve devastating sequelae if not managed properly. To date, the hierarchical nature of the UCIC has not been validated. The purpose of the present study is to assess the differences in perception of injury severity across the proposed hierarchy of the AO Spine UCIC System. The current findings demonstrate complete agreement between the proposed hierarchy of the UCIC A through C subtypes for each anatomic region and the globally pooled ISS responses provided by the survey respondents. Notably, survey response rate was excellent (98%) compared with prior data on physician survey response rate.[37] In addition, these data represent a wide range of spine surgeons in terms of geographic practice location, experience level, and subspecialty training background. Taken in the aggregate, these findings suggest validity of the stepwise progression of the UCIC subtypes.

Slight deviations from a perfect match between the overall UCIC hierarchy and the perceived ISS of respondents include equivalence between the ISS for neurological status modifiers N1 (transient neurological deficit) and N2 (radicular symptoms). This discrepancy may be secondary to the relatively low incidence of traumatic, as opposed to degenerative, cervical radiculopathy, and the somewhat broad range of potential interpretations of how cervical radiculopathy may present.[38] Cervical radiculopathy can manifest as a static or progressive clinical picture of any combination of radicular pain, sensory deficits, motor deficits, or diminished reflexes correlated to the anatomic course of a cervical nerve root, with different degrees of severity.[14] Similarly, transient neurological deficit is also somewhat broad and may conjure a wide range of different levels of impairment. Finally, radiculopathy/neuropathic pain in the upper cervical (C0-C2) region may be difficult to distinguish from fracture-related pain. This is because the C2 nerve root has

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

	Median (IQR)					
	North America, N = 10	**Central and South America, N = 22**	**Europe, N = 61**	**Africa and Middle East, N = 11**	**Asia, N = 26**	***P***
I Type A	20.0 (10.0; 25.0)	20.0 (10.0; 20.0)	20.0 (10.0; 30.0)	20.0 (20.0; 30.0)	20.0 (10.0; 30.0)	0.452
I Type B	55.0 (30.0; 80.0)	50.0 (30.0; 75.0)	40.0 (30.0; 60.0)	35.0 (25.0; 50.0)	40.0 (20.0; 50.0)	0.130
I Type C	100.0 (95.0; 100.0)	100.0 (100.0; 100.0)	100.0 (95.0; 100.0)	100.0 (90.0; 100.0)	90.0 (80.0; 100.0)	**0.003**
II Type A	25.0 (10.0; 30.0)	30.0 (10.0; 40.0)	25.0 (20.0; 30.0)	27.5 (20.0; 30.0)	20.0 (20.0; 30.0)	0.973
II Type B	80.0 (70.0; 80.0)	90.0 (70.0; 100.0)	70.0 (60.0; 80.0)	60.0 (50.0; 75.0)	70.0 (50.0; 80.0)	**0.003**
II Type C	100.0 (90.0; 100.0)	100.0 (90.0; 100.0)	95.0 (85.0; 100.0)	85.0 (80.0; 100.0)	90.0 (80.0; 100.0)	0.076
III Type A	37.5 (20.0; 50.0)	27.5 (20.0; 40.0)	30.0 (20.0; 50.0)	40.0 (30.0; 50.0)	40.0 (20.0; 50.0)	0.276
III Type B	75.0 (60.0; 80.0)	75.0 (60.0; 80.0)	70.0 (50.0; 80.0)	70.0 (50.0; 80.0)	60.0 (50.0; 65.0)	**0.003**
III Type C	95.0 (90.0; 100.0)	99.0 (90.0; 100.0)	90.0 (80.0; 100.0)	85.0 (70.0; 100.0)	85.0 (80.0; 90.0)	0.094
N0	0.0 (0.0; 10.0)	0.0 (0.0; 20.0)	0.0 (0.0; 10.0)	0.0 (0.0; 20.0)	0.0 (0.0; 10.0)	0.834
N1	32.5 (20.0; 60.0)	40.0 (30.0; 60.0)	30.0 (20.0; 60.0)	30.0 (20.0; 50.0)	30.0 (20.0; 50.0)	0.808
N2	40.0 (25.0; 70.0)	30.0 (20.0; 50.0)	40.0 (30.0; 50.0)	40.0 (15.0; 60.0)	30.0 (20.0; 40.0)	0.643
N3	90.0 (75.0; 100.0)	90.0 (80.0; 100.0)	80.0 (75.0; 100.0)	95.0 (75.0; 100.0)	80.0 (70.0; 90.0)	0.439
N4	90.0 (90.0; 100.0)	100.0 (89.0; 100.0)	100.0 (80.0; 100.0)	100.0 (80.0; 100.0)	100.0 (90.0; 100.0)	0.857
NX	72.5 (50.0; 90.0)	85.0 (60.0; 100.0)	80.0 (50.0; 100.0)	50.0 (50.0; 80.0)	77.5 (50.0; 90.0)	0.403
M1	60.0 (50.0; 75.0)	80.0 (50.0; 80.0)	60.0 (50.0; 75.0)	60.0 (50.0; 70.0)	57.5 (50.0; 75.0)	0.189
M2	75.0 (70.0; 80.0)	55.0 (40.0; 90.0)	80.0 (70.0; 80.0)	85.0 (70.0; 90.0)	70.0 (60.0; 80.0)	0.284
M3	55.0 (50.0; 80.0)	60.0 (50.0; 70.0)	50.0 (50.0; 70.0)	50.0 (50.0; 75.0)	60.0 (50.0; 70.0)	0.982
M4	77.5 (60.0; 90.0)	85.0 (50.0; 100.0)	80.0 (60.0; 85.0)	80.0 (50.0; 90.0)	90.0 (70.0; 100.0)	0.180

Bolded values indicate statistical significance.

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

	Median (IQR)				*P*	*P*
	≤5 yr	5–10 yr	11–20 yr	≥20 yr	*P*	≤10 *vs.* >10 yr
I Type A	20.0 (15.0; 30.0)	20.0 (10.0; 30.0)	20.0 (10.0; 30.0)	20.0 (10.0; 20.0)	0.117	0.248
I Type B	40.0 (30.0; 60.0)	40.0 (30.0; 60.0)	50.0 (30.0; 60.0)	40.0 (30.0; 50.0)	0.053	0.828
I Type C	100.0 (90.0; 100.0)	100.0 (90.0; 100.0)	100.0 (90.0; 100.0)	100.0 (98.0; 100.0)	0.333	0.233
II Type A	30.0 (20.0; 40.0)	20.0 (10.0; 30.0)	25.0 (20.0; 30.0)	20.0 (10.0; 30.0)	0.616	0.0.205
II Type B	70.0 (60.0; 90.0)	80.0 (60.0; 90.0)	70.0 (60.0; 80.0)	70.0 (60.0; 90.0)	0.570	0.0.212
II Type C	90.0 (80.0; 100.0)	95.0 (90.0; 100.0)	90.0 (80.0; 100.0)	100.0 (90.0; 100.0)	0.775	0.785
III Type A	35.0 (20.0; 50.0)	35.0 (20.0; 50.0)	35.0 (20.0; 50.0)	30.0 (20.0; 40.0)	0.495	0.628
III Type B	70.0 (60.0; 80.0)	65.0 (50.0; 90.0)	65.0 (50.0; 75.0)	70.0 (50.0; 75.0)	0.186	0.298
III Type C	90.0 (80.0; 100.0)	92.5 (90.0; 100.0)	90.0 (80.0; 100.0)	90.0 (80.0; 100.0)	0.557	0.252
N0	0.0 (0.0; 10.0)	0.0 (0.0; 20.0)	0.0 (0.0; 10.0)	0.0 (0.0; 10.0)	0.844	0.965
N1	30.0 (20.0; 60.0)	55.0 (20.0; 75.0)	30.0 (20.0; 50.0)	25.0 (20.0; 50.0)	0.477	0.302
N2	30.0 (20.0; 60.0)	35.0 (25.0; 50.0)	40.0 (30.0; 50.0)	30.0 (25.0; 40.0)	0.800	0.801
N3	90.0 (80.0; 100.0)	82.5 (75.0; 90.0)	90.0 (80.0; 100.0)	75.0 (70.0; 90.0)	**0.011**	0.276
N4	95.0 (80.0; 100.0)	100.0 (90.0; 100.0)	100.0 (80.0; 100.0)	100.0 (80.0; 100.0)	0.470	0.658
NX	80.0 (50.0; 100.0)	75.0 (50.0; 100.0)	75.0 (50.0; 100.0)	80.0 (50.0; 100.0)	0.478	0.919
M1	65.0 (50.0; 80.0)	60.0 (50.0; 75.0)	60.0 (50.0; 80.0)	50.0 (40.0; 70.0)	0.334	0.586
M2	70.0 (50.0; 80.0)	77.5 (70.0; 80.0)	80.0 (60.0; 90.0)	70.0 (50.0; 80.0)	0.333	0.918
M3	50.0 (50.0; 70.0)	50.0 (50.0; 70.0)	60.0 (50.0; 75.0)	50.0 (50.0; 60.0)	0.336	0.499
M4	80.0 (70.0; 95.0)	80.0 (60.0; 90.0)	80.0 (70.0; 90.0)	75.0 (50.0; 100.0)	0.508	0.317

a difficult to test dermatomal distribution of the back of the scalp, which would likely have substantial overlap with any neck pain the patient may be experiencing.[39] In addition, the C2 nerve root is responsible for innervating only small paraspinal muscles including the rectus capitis anterior and lateralis, and thus is difficult to test on motor exam.[39] Similarly, the C1 nerve root typically has only a rudimentary dorsal root ganglion with minimal sensory function. Its motor functions relate predominantly to paraspinal and anterior neck musculature that are not routinely tested.[40] In contrast, N3 (incomplete spinal cord injury) and N4 (complete spinal cord injury) are themselves associated with robust and validated, quantitative classification systems and a body of literature supporting their respective prognoses.[41,42] Thus, assigning an ISS for these modifiers is likely more straightforward.

In addition, the clinical modifier M2 (injury with significant potential instability) was perceived as more severe than the clinical modifier M3 (patient-specific factors affecting treatment). Similar to the neurological modifier discrepancy discussed earlier, the mismatch between perceived ISS progression and the UCIC proposed hierarchy for clinical modifiers is likely secondary to the slight ambiguity suggested by M3.

A critical aspect of a universal spine trauma classification system is its ability to be easily applicable by not only highly experienced spine surgeons, but also younger attendings and ideally even trainees such as fellows and residents. Notably, there were no differences in ISS responses among any of the surgeon experience level categories for any of the UCIC subtypes, or modifiers. In contrast, geographic subanalysis showed some small variations in perceived ISS among the different global regions. Respondents from NA and CSA perceived B subtype (ligamentous injury) in both the II (C1 ring and C1-2 joint) and III (C2 and C2-3 joint) regions as more severe than the other global regions. The subtype C (translation) in the I (occipital condyle and craniocervical junction) region was also perceived as more severe among the NA and CSA respondents. Despite these small regional variations noted on subgroup analysis, the overall findings suggest a high degree of validity and robust applicability for the UCIC. Importantly, these findings also suggest that external factors such as cultural variations, and health care infrastructure and cost concerns are not playing a substantial role in clinical decision-making. These external issues have been raised on prior validation efforts for other AO spine classification systems due to their global nature.[18,27]

Finally, subspecialty training was found to play a minor role in terms of influencing ISS assignments from survey respondents. Type IB and type IIIB injuries were both perceived as somewhat more severe by neurosurgeons than by orthopedic spine surgeons. Depending on differences in practice structure and division of spine trauma call duty between orthopedic and neurosurgical spine surgeons at each institution, there may be variations in the familiarity of surgeons with these specific injury patterns. In addition, a small body of prior work has noted that neurosurgeons tend to order preoperative MRI more frequently than orthopedic surgeons for cervical trauma.[43,44] A recent study by Sedighim *et al*.[44] reported on 630 vertebral fracture patients, and concluded that neurosurgeons are more likely to offer surgery compared with orthopedic spine surgeons (13.2% vs. 7.4%, $P = 0.0016$, despite similar fracture number and severity). Thus, it is possible that neurosurgical training involves a slightly higher index of severity regarding cervical trauma, which is being detected by this study's results. However, it is beyond the scope of the current work to comment more definitively on the reasons for differences in ISS between neurosurgeons and orthopedic spine surgeons. Also, it is important to note that prior work has indicated both that differences in clinical decision-making between providers within the same specialty tend to outpace differences

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TABLE 5. Analysis of Injury Severity Score Based on Fracture Type, Neurological Status, and Case-Specific Modifier by Subspecialty

	Median (IQR)		
	Neurosurgery, N = 54	Orthopedic surgery, N = 93	*P*
I Type A	20.0 (10.0; 30.0)	20.0 (10.0; 30.0)	0.186
I Type B	50.0 (30.0; 70.0)	40.0 (27.5; 50.0)	**0.002**
I Type C	100.0 (90.0; 100.0)	100.0 (90.0; 100.0)	0.326
II Type A	30.0 (20.0; 40.0)	22.5 (17.5; 30.0)	0.338
II Type B	75.0 (60.0; 90.0)	70.0 (60.0; 86.0)	0.398
II Type C	95.0 (90.0; 100.0)	90.0 (80.0; 100.0)	0.209
III Type A	35.0 (20.0; 50.0)	30.0 (20.0; 50.0)	0.712
III Type B	70.0 (60.0; 80.0)	60.0 (50.0; 75.0)	**0.026**
III Type C	90.0 (80.0; 100.0)	90.0 (80.0; 100.0)	0.784
N0	0.0 (0.0; 20.0)	0.0 (0.0; 10.0)	0.054
N1	50.0 (25.0; 60.0)	30.0 (20.0; 50.0)	**0.005**
N2	30.0 (25.0; 50.0)	40.0 (25.0; 50.0)	0.640
N3	90.0 (80.0; 100.0)	80.0 (75.0; 95.0)	0.206
N4	100.0 (90.0; 100.0)	100.0 (80.0; 100.0)	0.146
NX	77.5 (50.0; 100.0)	80.0 (50.0; 100.0)	0.515
M1	60.0 (50.0; 75.0)	60.0 (50.0; 75.0)	0.929
M2	72.5 (60.0; 80.0)	75.0 (60.0; 85.0)	0.318
M3	60.0 (50.0; 70.0)	50.0 (50.0; 70.0)	0.280
M4	80.0 (65.0; 90.0)	80.0 (60.0; 95.0)	0.768

Bolded values indicate statistical significance.

between orthopedic and neurosurgery spine providers, and that clinical outcomes are similar between the two training disciplines.[43,45] Similarly, N1 was perceived as more severe for neurosurgeons than for orthopedic spine surgeons. In general, however, there is an impressive degree of agreement between surgeons in terms of subspecialty training background. This is concordant with prior work that has highlighted the generally high degree of agreement between orthopedic spine surgeons and neurosurgeons on management decision-making in the setting of spine trauma.[46,47]

There are a number of limitations inherent to this work. First, surgeons are not evenly distributed among geographic areas, and the overall number of respondents is relatively limited for a global survey. This limitation is somewhat ameliorated by an excellent response rate (98%) from the AO Spine Cervical Classification Validation Group, which helps to bolster numbers and decreases the chance for nonresponse bias. Second, all respondents were drawn from the same study group, and survey options were delivered in ascending order of injury subtype. These factors entail the risk of biasing the respondent due to likely prior exposure to AO Spine Classification schema, affiliation with an academic rather than a community spine center, as well as possibly implying a hierarchy due to survey question order. This is evidenced by the majority of respondents being affiliated with academic institutions. These issues are countered by the wide variety of subspecialty training backgrounds, experience levels, and geographic distribution of respondents—all of which contribute to the pretest variability of possible responses. Third, because of the highly variable anatomy in the upper cervical spine, certain specific fracture types such as Anderson and D'Alonzo Type 2 odontoid fractures may be somewhat difficult to assess with as much granularity as more anatomically delimited classification systems. The goal of the UCIC system was to provide a structured, and universally applicable schema for the entire upper cervical region—for these reasons, it is by design less anatomically specialized to describe individual fracture types. It is hoped that, through the use of UCIC's modifiers such as M1 (high risk of nonunion), or M2 (significant potential for instability), the clinically important variables can be adequately captured to still guide treatment. This possibility will be assessed by applying the injury severity scores evaluated in this work to create a treatment algorithm, a study which is forthcoming. Notably, given that the M2 modifier was perceived as more severe than M3 in this system, it is a possible consideration to slightly re-order the modifiers in the treatment algorithm study. Finally, although there was overall excellent agreement between ISS answers and the hierarchy proposed by the UCIC system, ultimately the survey responses are only able to comment on the perceived severity of injury, rather than commenting directly on operative *versus* nonoperative treatment.

CONCLUSION

The findings from the present work, in combination with prior literature suggesting excellent interobserver and intraobserver reliability, suggest that the AO Spine UCIC System is a reliable and robust classification schema with a high degree of agreement between the ISS suggested by spine surgeons and the hierarchy proposed by the system itself. These findings appear to be durable across a wide range of geographic practice regions, spine subspecialty training backgrounds, and experience levels.

➢ Key Points

- ❑ There was an increase in median perceived severity as each anatomic region (I–III) progressed from types A to B to C.
- ❑ There was an increase in perceived severity of neurological status as scores progressed, except N1 and N2 were perceived similarly.
- ❑ There were no differences in perceived injury severity score among levels of surgeon experience.
- ❑ There were small geographic differences with respondents from North and Central and South America perceiving types IC, IIB, and IIIB somewhat more severely than other regions.

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