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ORIGINAL ARTICLE

Accuracy and reliability of the AO Spine subaxial cervical spine classification system grading subaxial cervical facet injury morphology

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Abstract

Purpose A classification system was recently developed by the international association AO Spine for assessing subaxial cervical spine fractures. Significant variability exists between users of the facet component, which consists of four morphological types (F1–F4). The primary aims of this study were to assess the diagnostic accuracy and reliability of this new system's facet injury morphological classifications.

Methods A survey consisting of 16 computed tomography (CT) scans of patients with cervical facet fractures was distributed to spine surgeon members of AO Spine Latin America. To provide a gold standard diagnosis for comparison, all 16 injuries had been classified previously by six co-authors and only were included after total consensus was achieved. Demographic and surgical practice characteristics of all respondents were analyzed, and diagnostic accuracy calculated. Inter- and intra-observer agreement rates were calculated across two survey rounds, conducted one month apart.

Results A total of 135 surgeons completed both surveys, among whom the mean age was 41.6 years (range 26–71), 130 (96.3%) were men, and 83 (61.5%) were orthopedic surgeons. The mean time in practice as a spine surgeon was 9.7 years (1–30). The overall diagnostic accuracy of all responses was 65.4%. Inter-observer and intra-observer agreement rates for F1/F2/F3/F4 were 55.4%/47.6%/64.0%/94.7% and 60.0%/49.1%/58.0%/93.0%, respectively.

Conclusion This study evaluates the AO Spine Classification System specifically for facet injuries involving the subaxial cervical spine in a large sample of spine surgeons. There was significant variability in diagnostic accuracy for F1 through F3-type fractures, whereas almost universal agreement was achieved for F4-type injuries.

Keywords Spine fracture · Facet joint · Observer variation · Classification · Subaxial cervical spine

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Introduction

Cervical spine injuries generally affect working-age and young adults [1], among whom subaxial facet fractures can occur as isolated injuries or be accompanied by other vertebral-body fractures and/or severe ligamentous injuries. By definition, a lateral mass fracture is a fracture of any portion of the lateral mass complex, including the articular processes and/or pedicle [2]. Attempts have been made to classify these injuries using proper terminology to improve communication among healthcare providers and aid in selecting better treatment options [3, 4].

The most recent subaxial spine injury classification system, developed by AO Spine [5], is widely used and accepted across the spine-surgery community. However, for this classification system to broadly influence management decisions when several treatment alternatives exist, a formalized reliability assessment is necessary [6–10].

Fortunately, computed tomography (CT) generates high-quality images that detect injuries not always visible on plain X-rays [11], allowing for early diagnosis and potentially improving a classification system's reliability. Knowing the correct morphological configuration of a facet fracture is paramount to avoiding progressive vertebral subluxation, radicular symptoms and other manifestations of early or late instability that could result from inappropriately applied nonoperative treatment [12].

Our two study aims were to assess the (1) diagnostic accuracy and (2) intra-rater reliability of the four grades of facet injury morphology listed in the AO Subaxial Cervical Spine Classification System.

Materials and Methods

Study design

A two-round, cross-sectional survey was performed during which questionnaires were sent to spine surgeons who were currently active members of AO Spine Latin America. Each survey included questions asking about respondent's demographic and surgical practice characteristics, followed by pairs of CT images for 16 patients with facet fractures, four for each grade of facet injury listed in the AO Spine classification criteria (F1—4). Each pair of images was accompanied by a question asking the respondent to classify the injury into one of the four AO Spine categories. Demographic and surgical practice variables for which data were collected included the surgeon's nationality, gender, age, specialty, years of experience, type of hospital where they worked (general, private, trauma, university), number of spine trauma surgeries performed annually and previous use of the AO Spine Classification System (AO-SCS) in daily practice.

Internal agreement and gold standard

The same 16 cases involving facet fractures of the subaxial cervical spine were included in each of the two survey rounds, four cases for each type of injury listed in the AO-SCS. Prior to survey distribution, all cases were independently evaluated by six of the co-authors, during which 100% consensus was achieved for 15 of 16 cases. The one case for which 100% consensus was not achievable was replaced with a different one, for which total agreement was achieved. The diagnostic categorizations of this internal validation process were considered the gold standard by which to evaluate diagnostic accuracy and variability among respondents.

Data collection

For each case, the most representative axial and sagittal images of the CT scan were included, indicating the injured level and side. MRI images were not used, and all cases exclusively involved facet injuries from C3—C7.

Emails explaining the purpose of the study were sent to all registered members of AO Spine Latin America in May 2020, each email containing links to both a Portuguese and Spanish version of the survey. Also sent were descriptions of the facet component of the AO-SCS of subaxial cervical spine injuries and a picture of each type of fracture, as well as a link to allow respondents to review the AO-SCS.

All members who replied to the first open call were re-contacted one month later (July 2020) for a second round of the survey, during which the same 16 cases were presented in a different random order.

Facet injuries graded according to AO Spine subaxial cervical spine classification system [5]

The following descriptions detail the four classes of facet injury:

F1 = Non-displaced facet fracture (either superior or inferior facet): fragment < 1 cm, involving < 40% of the lateral mass.

F2 = Facet fracture with the potential for instability (either superior or inferior facet): fragment > 1 cm, with > 40% lateral mass transected or displaced.

F3 = Floating lateral mass: disruption of the pedicle and lamina resulting in disconnection of the superior and inferior articular processes at a given level or set of levels.

F4 = Pathologic subluxation or perched/dislocated facet: injury in which either the tip of the inferior articular process of the cephalad vertebrae rests upon the superior tip of the superior articular process of the caudal vertebrae, or in which the inferior facet of the cephalad vertebrae is translated over the superior articular surface of the caudal vertebrae and remains ventral to the superior facet of the caudal vertebral body.

Statistical analysis

Descriptive analysis was performed with all continuous variables summarized as means, standard errors and range, and tested for normal distribution using the Wilk-Shapiro test. All categorical variables were summarized as absolute values with percentages.

Diagnostic accuracy, by case, was calculated as the number of surgeons rating a case consistent with the confirmed diagnosis, divided by the number of respondents ($n = 135$ for all cases and all variables), multiplied by 100%. This was performed both for Round 1 and Round 2, and the two rounds compared by converting diagnostic accuracy into a binary variable (0 = not rated versus 1 = rated identical to the confirmed diagnosis) and mean accuracy, as a continuous variable from 0–1 compared between the two rounds by (a) Pearson $\chi 2$ analysis; and (b) to allow for the compiling of data from multiple cases (e.g., all F1 cases), both by paired t tests and by repeated measures analysis of variance (ANOVA) entering F level (F1-F4) and prior use of the AO Spine classification system (0 = no, 1 = yes) as covariates.

Univariate inter-group comparisons of overall diagnostic accuracy (e.g., by surgical specialty, age group, or past AO Spine criteria use) were conducted by generating a summation score from 0–16 for each round and from 0–32 for the two rounds, then comparing groups either with independent t-tests or ANOVA. Multivariable analysis then was performed to identify surgeon characteristics statistically associated with the overall diagnostic accuracy summation score by simple linear regression, with $p > 0.10$ the criterion for variable exclusion.

The percentage of intra-rater agreement was calculated for each case and each F level by generating a binary variable for each case (agreement/no agreement) and calculating percentages. The distribution of ratings at each level was calculated by creating a variable by subtracting the round 2 from round 1 rating and then calculating frequencies. Frequencies for each case then were summed across the eight cases (four per round) at each level.

Except for linear regression analysis, the criterion for statistical significance was $p \leq 0.05$ and all inferential tests were two-tailed.

Results

A total of 135 surgeons completed both rounds of the survey. They were predominantly from South America, mainly from Chile (25.2%), Argentina (22.2%) and Brazil (14.1%). The mean age of 41.6 years ranged from 26–71, and most respondents were male (96.3%) and orthopedists ($n = 83$). The mean time in practice as a spine surgeon was 9.7 years, ranging from 1 to 30 years. Mean number of trauma cases operated upon yearly was 31.6, ranging from 1 to 100 (Table 1).

Table 1 Survey respondents demographic data ($n = 135$)

Variable	*N*	%
Region		
South America	111	82.2
Central America or Caribbean	24	17.8
Age		
≤ 35 years	44	32.6
30—50 years	67	49.6
> 50 years	24	17.8
Sex		
Male	130	96.3
Female	5	3.7
Speciality		
Orthopedic surgeon	83	61.5
Neurosurgeon	52	38.5
Type of center		
Private hospital	52	38.5
Trauma hospital	12	8.9
General hospital	41	30.4
University hospital	30	22.2
Time as a surgeon		
≤ 5 years	59	43.7
5—10 years	29	21.5
> 10 years	47	34.8
Number of spine trauma cases operated yearly		
≤ 15 cases	42	31.1
16–30 cases	45	33.3
31–50 cases	29	21.5
> 50 cases	19	14.1
Previous use of AO Spine Classification System?		
Yes	115	85.2
No	20	14.8

Diagnostic accuracy

Overall accuracy across all cases and both rounds was 65.4%, ranging from 47.6% for F2 cases to 94.7% for F4 cases. There was a significant improvement in accuracy between rounds 1 and 2, both for F1 (52.1 to 58.7%, $p=0.007$) and F2 (43.2 to 52.1%, $p=0.001$) cases. Little improvement was observed for F3 (63.5 to 64.5%, $p=0.72$) or F4 (93.7 to 95.8%, $p=0.16$). Overall improvement in accuracy between the two rounds was from 63.1 to 67.7% ($p<0.001$). Comparative accuracies by F type are summarized in Fig. 1.

Univariate comparison of diagnostic accuracy performed in different respondent groups identified greater accuracy among South versus Central American/Caribbean surgeons (66.6% vs. 59.9%, $p=0.039$), in neurosurgeons versus orthopedists (68.5% vs. 63.5%, $p=0.049$), and among surgeons with 5–10 years of experience versus those with < 5 or > 10 years of experience (72.2% vs. 61.2% and 66.5%, $p=0.003$) (Table 2).

On multivariate analysis to identify surgeon characteristics predictive of overall diagnostic accuracy, only region (South America) and hospital type remained significant (Table 3).

Inter-observer and Intra-observer agreement

Overall inter-observer agreement was 65.4%, while intra-observer agreement was 65.0%. The lowest levels of inter and intra-observer agreement were observed for F2-grade fractures, while the highest were for F4, for which inter-observer and intra-observer agreement were 94.7% and 93.0%, respectively (Table 4). Both ratings for F4 were statistically greater than for the other three fracture grades,

Table 2 Overall diagnostic accuracy in different respondent groups

Respondent group	N	Accuracy (%)	*p* Value
Region			
South America	111	66.6	0.039
Central America or Caribbean	24	59.9	
Age			
≤ 35 years	44	64.1	0.77
30—50 years	67	65.9	
> 50 years	24	66.3	
Sex			
Male	130	66.3	0.30
Female	5	58.8	
Speciality			
Orthopedic surgeon	83	63.5	0.049
Neurosurgeon	52	68.5	
Type of center			
Private hospital	52	68.6	0.39
Trauma hospital	12	63.3	
General hospital	41	62.7	
University hospital	30	64.5	
Experience			
≤ 5 years	59	61.2	0.003
5—10 years	29	72.2	
> 10 years	47	66.5	
Number of spine trauma cases operated yearly			
≤ 15 cases	42	62.7	0.32
16–30 cases	45	65.6	
31–50 cases	29	66.1	
> 50 cases	19	70.1	
Previous use of AO Spine Classification System?			
Yes	115	65.7	0.86
No	20	63.8	

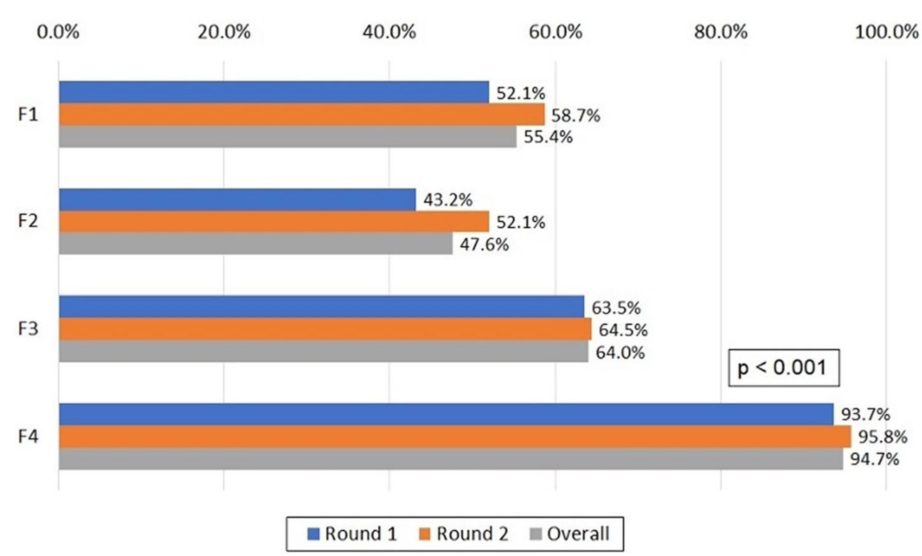

Fig. 1 Comparing diagnostic accuracy by F type

Table 3 Results of multivariate analysis to identify surgeon characteristics predictive of overall diagnostic accuracy

Variables	*p* Value
Region	0.095
Age group	0.693
Gender	0.473
Specialty	0.136
Hospital type	0.033
Experience level	0.191
Spine trauma experience	0.133
AO Spine classification use	0.223

Table 4 Inter-observer and intra-observer agreement

F Type	Inter-observer agreement (%)	Intra-observer agreement* (%)
F1	55.4	60.0
F2	47.6	49.1
F3	64.0	58.0
F4	94.7**	93.0**
Overall	65.0	65.4

*Agreement on correct diagnosis; **F4 different than F1, F2 and F3 at $p < 0.001$

among which there was no statistically significant difference (Fig. 2).

The levels of inter-observer agreement, in both rounds, were compared between surgeons who had used and those who had not used the AO-SCS in daily practice, and no significant differences were observed for any F type of injury. Overall agreement in Round 1 for those surgeons who had previously used the classification system was 63.1% versus 62.5% among those who had not ($p = 0.86$); in Round 2, corresponding levels of agreement were 68.1% and 65.0% ($p = 0.44$) (Table 5).

Discussion

There is variability in both the classification and therapeutic approaches selected for subaxial cervical spine injuries, particularly when different injury subtypes are compared [2, 13]. Many attempts have been made to improve the quality of existing classification systems for subaxial cervical spine injuries [3–5]. Recently, studies assessing the level of diagnostic agreement for cervical fractures using the latest classification systems developed by AO Spine and others have been published [14–17]. However, none of these studies focused specifically on facet injuries.

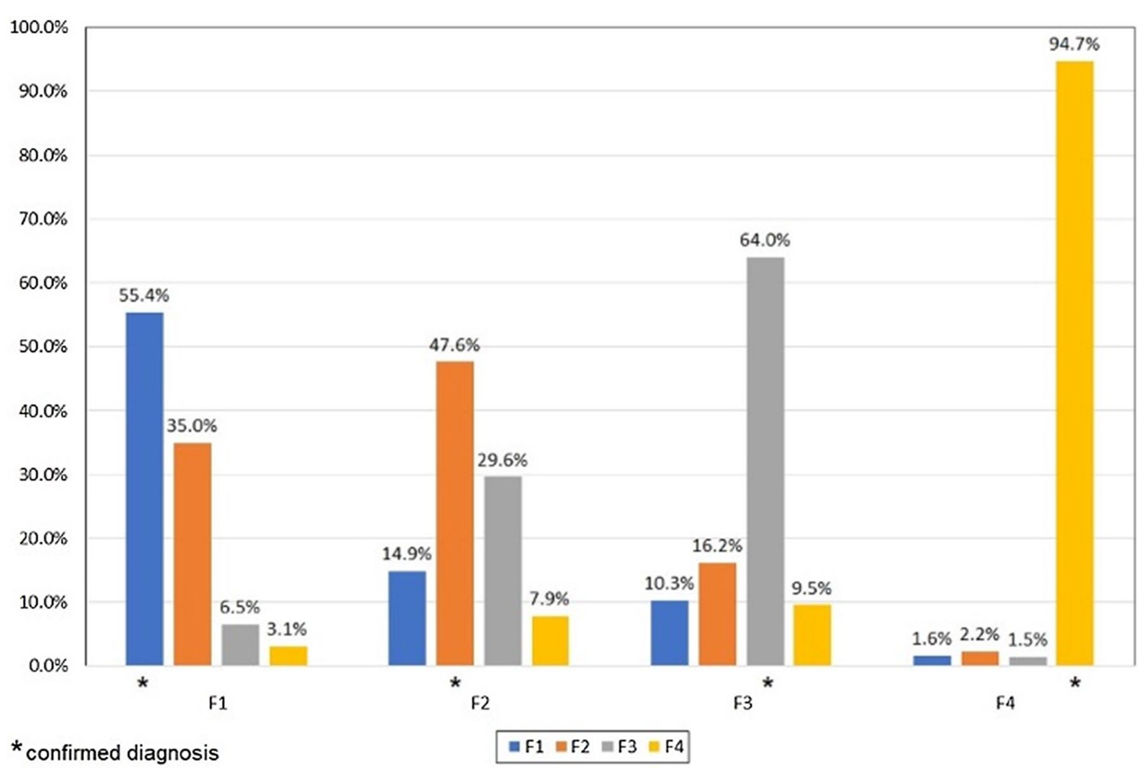

Fig. 2 Distribution of F type ratings for each confirmed F injury

Table 5 Inter-observer agreement according to previous use of the AO spine classification system in daily practice (Yes/No)

F Type	Round 1			Round 2		
	Yes (%) ($N=115$)	No (%) ($N=20$)	p Value	Yes (%) ($N=115$)	No (%) ($N=20$)	p Value
F1	51.5	55.0	0.61	57.6	65.0	0.28
F2	42.3	45.0	0.77	53.3	45.0	0.22
F3	64.8	56.3	0.053	65.0	61.3	0.58
F4	93.7	93.8	0.99	97.0	88.8	0.18
Overall	63.1	62.5	0.86	68.2	65.0	0.44

In addition, morphology criteria in the Subaxial Cervical Spine Injury Classification (SLIC) system exhibited only a low degree of inter-rater agreement (kappa = 0.29) in a validation study in which 12 raters assessed 51 random cases [17]. In the same study, the level of inter-rater agreement for treatment was lower when based upon the total SLIC injury severity score than each surgeon's personal preference ($k=0.55$ vs. $k=0.63$). The AO-SCS has an advantage over the SLIC, in that it considers the facet complex separately, thereby facilitating decision-making [10] and guiding the timing of surgical treatment for facet-specific injuries [18].

Validation studies have been performed evaluating the entire AO Spine Subaxial Cervical Spine Classification System, wherein facet type is one component, by Da Silva et al. using five observers [16], Urrutia et al. employing six observers with different levels of expertise [14], and Vaccaro et al. with 10 observers [5]. Unfortunately, in the study of Vaccaro, F1 and F4 type injuries exhibited less reliability given the low frequency of cases analyzed, despite considering facet injury types separately. To our knowledge, the current study is one of the largest surveys to assess diagnostic accuracy and reliability using the AO-SCS, specifically facet fractures involving the subaxial cervical spine. Moreover, given our sample of 135 spine surgeons from across Latin America, our two-round study is likely a more accurate representation of the real-time application of this system.

As expected, we found more severe and unstable facet injury morphologies to be more accurately diagnosed by spine surgeons. In fact, for F4 type injuries, 94.7% agreement was observed, compared to only 55.4% and 47.6% for type F1 and F2 injuries, respectively. There was a statistically significant, albeit still small degree of improvement in accuracy between Rounds 1 and 2 overall, and specifically for F types 1 and 2, suggesting that practice using these criteria might improve surgeons' diagnostic accuracy. The most commonly confused morphologies were F1 and F2, and F2 and F3. Jenjitranant et al. [19] have attempted to identify characteristics that differentiate between F1 and F2 morphologies, and found that transverse process involvement and comminution were both associated with F2-type fractures. Confusion between type F1 and F2 facet injuries could bias decision-making, potentially leading surgeons to less-than-optimal treatment.

In our survey, a higher percentage of respondents from South America, neurosurgeons, and surgeons with from 5 to 10 years of surgical experience were diagnostically accurate than among Central America/Caribbean and orthopedists, and those with either < 5 or > 10 years of experience. However, on multivariate analysis, only two surgeon characteristics (geographic region and hospital type) remained as significant predictors of overall diagnostic accuracy. The highest levels of inter- and intra-observer agreement were observed for F4-type injuries.

The AO-SCS bases its diagnosis on the CT scan [3], without taking into account the MRI or other radiological studies. The inclusion of other studies could increase the accuracy of the diagnosis. In addition, studies such as MRI, vascular studies and dynamic radiographs are part of the armamentarium to complement the assessment of structural integrity and, therefore, are influencing the decision-making [20]. However, the tomographic basis of the Classification allows greater reproducibility in any trauma center and a shortening in the time to define management. A possible line of improvement in accuracy will be to perform CT scan of 1 mm or less slice thickness and the inclusion of 3D surface reconstruction as recommended [10] rather than any change in the Classification itself, in fact the Classification was created to facilitate the analysis of subaxial cervical and facet injury morphologies [5].

Another interesting finding was that surgeons who had not used the AO-SCS in daily practice before taking the survey were no different in their diagnostic accuracy than surgeons who had. We infer from this that spine surgeons with different levels of expertise are able to apply the AO-SCS, irrespective of their familiarity with it [4]. Furthermore, in a recent two-part study [21, 22] in which 37 raters in a first assessment and 24 in a second 1.5 months apart compared the reliability of different classification systems including the AO-SCS in 64 consecutive patients, fair to moderate agreement was observed in the two rounds despite different degrees of expertise. The 18 raters who used the AO-SCS either routinely ($n = 9$) or occasionally ($n = 9$) exhibited greater within-rater reproducibility than those who had not.

Facet fractures of the subaxial cervical spine are often associated with other vertebral fractures or disco-ligament disruptions, depending on the degree of instability. Assessing stability to guide treatment decisions (surgical versus non-surgical) relies on many factors, among which fracture morphology plays a large role, along with the patient's neurological status and overall clinical condition. Despite its importance, the grading of facet fracture morphology in the subaxial cervical spine is highly variable among spine surgeons, especially for F1-3 type injuries, as is the treatment of facet dislocation in different geographic regions [13].

Undoubtedly, the currently reported survey has limitations. Among its strengths are that the sample included 135 surgeons from 15 countries across Latin America; respondents were highly heterogeneous in terms of their clinical practice; both neurosurgeons and orthopedists were surveyed; and, in terms of using the AO Spine criteria, surgeons ranged from initial to advanced stages of the learning curve. Among its limitations are that the cases were preselected for unanimous agreement, which means that our results cannot be generalized to less diagnostically clear lesions. Second, we exclusively evaluated unilateral and not bilateral facet injuries of the subaxial cervical spine, further limiting the generalizability of results. Third, to optimize treatment decisions, subaxial facet fractures always must be considered simultaneously to other associated injuries and the patient's neurological status, neither of which our study addressed. Finally, our conclusions might not be applicable to surgeons outside of Latin America or those without AO Spine membership.

Conclusions

This study is one of the largest specifically assessing diagnostic accuracies and reliability of facet injury classification in the subaxial cervical spine employing the recently published AO Spine Subaxial Cervical Spine Classification System. As a consequence of its tomographic basis, considerable variability was observed in the diagnostic accuracy of all but F4-type facet injuries, for which there was approximately 95% consensus. Other radiological studies can complement this assessment improving the diagnosis accuracy of all facet injuries. Similar studies in other geographic regions are indicated, as are studies assessing the impact of the AO Spine classification system on treatment outcomes.

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Declarations

Conflicts of interest The authors have nothing to disclose.

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