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Inter- and intra-observer agreement using the new AOSpine sacral fracture classification, with a comparison between spine and pelvic trauma surgeons ☆

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ABSTRACT

Background: Sacral fractures treatment frequently involves both spine and pelvic trauma surgeons; therefore, a consistent communication among surgical specialists is required. We independently assessed the new AOSpine sacral fracture classification's agreement from the perspective of spine and pelvic trauma surgeons.

Methods: Complete computerized tomography (CT) scans of 80 patients with sacral fractures were selected and classified using the new AOSpine sacral classification system by six spine surgeons and three pelvic trauma surgeons. After four weeks, the 80 cases were presented and reassessed by the same raters in a new random sequence. The Kappa coefficient (κ) was used to measure the inter-and intra-observer agreement.

Results: The inter-observer agreement considering the fracture severity types (A, B, or C) was substantial for spine surgeons (κ= 0.68 [0.63 - 0.72]) and pelvic trauma surgeons (κ= 0.74 (0.64 - 0.84). Regarding the subtypes, both groups achieved moderate agreement with κ= 0.52 (0.49 - 0.54) for spine surgeons and κ= 0.51 (0.45 - 0.57) for pelvic trauma surgeons. The intra-observer agreement considering the fracture types was substantial for spine surgeons (κ= 0.74 [0.63 - 0.75]) and almost perfect for pelvic trauma surgeons (κ= 0.84 [0.74 - 0.93]). Concerning the subtypes, both groups achieved substantial agreement with, κ= 0.61 (0.56 - 0.67) for spine surgeons and κ= 0.68 (0.62 - 0.74) for pelvic trauma surgeons.

Conclusion: This classification allows an adequate communication for spine surgeons and pelvic trauma surgeons at the fracture severity type, but the agreement is only moderate at the subtype level. Future prospective studies are required to evaluate whether this classification allows for treatment recommendations and establishing prognosis in patients with sacral fractures.

Introduction

Sacral fractures are relatively infrequent injuries, with heterogeneous patterns [1]. There have been several attempts to classify sacral injuries based on specific patterns, as in longitudinal [2] or transverse fractures [3]. These classifications were developed to allow communication among treating physicians, identify and group comparable cases, guide treatment, and standardize research concepts. However, previous sacral fracture classifications fail to in-

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clude the entire range of sacral fractures; also, they lack independent validations, and they have not been related to prognosis or treatment guidelines. Therefore, they have not achieved a universal use.

Recently, the AOSpine Knowledge Forum developed a new sacral injury classification system [4]; this is a morphology-based scheme that considers all the specific patterns of traumatic injuries involving the sacrum. Additionally, like other AOSpine classification schemes [5,6], this classification also evaluates the degree of neurologic deficit and the presence of specific modifiers (soft tissue damage, metabolic bone disease, anterior pelvic ring injury, and sacroiliac joint injury). The AOSpine sacral fracture classification was developed by a panel of spinal and orthopedic trauma surgeons. They obtained a moderate interobserver agreement using this classification (with substantial agreement assessing severity levels, i.e., A, B, or C, and substantial intra-observer agreement) [4].

The sacrum and coccyx are the most caudal segments of the spine, and spine surgeons usually treat their injuries. However, they can also occur as part of a pelvic ring injury, therefore pelvic trauma surgeons also need to be familiarized with this classification system. Recently, a group of spine surgeons published an independent validation of this fracture classification system, showing substantial inter-observer agreement at the fracture type level, and moderate agreement at the subtype level [7]. However, an independent validation by a panel of spine and pelvic trauma surgeons is yet to be performed.

In this study, we performed an independent inter-and intra-observer agreement evaluation of the AOSpine sacral fracture classification system, comparing the agreement obtained by spinal and pelvic trauma surgeons.

Patients and methods

Institutional review board approval was obtained to perform the study. One author (who did not participate in the cases' classification phase) retrospectively selected 80 cases with sacral fractures from two databases of patients treated from 2011 to 2020 in two tertiary care centers in Latin America. To performthis agreement study, that author included all ten subtypes of injuries defined by the AOSpine sacral classification system, but not all cases corresponded to consecutive patients.

For inclusion in this study, all patients were required to have complete computerized tomography (CT) scans, including axial, coronal, and sagittal images with a section thickness of 1 mm. The CT scans were reviewed using the Impax Web3000 program (Agfa-Gevaert, Mortsel, Belgium) by six spine surgeons and three pelvic trauma surgeons from six different centers in three different countries in Latin America. With this proportion, we intended to emulate the study describing the classification, which used fourteen spine surgeons and four trauma surgeons[5]. The age of the raters varied from 36 to 56 (median= 41) years old. All the evaluators were trained in this new classification before performing their assessments. They were provided with the original article by Vaccaro et al[5]. to resolve any doubt at the assessment time. The raters were unaware of the patients' identification or the treatments they received.

The nine evaluators classified the fractures according to the AOSpine sacral classification into types A, B, or C injuries (Fig. 1) and subtypes. The case-specific modifiers and neurological modifiers were not included because no clinical information was provided.

The level of inter-observer agreement was determined by comparing the initial responses of the nine raters; the raters had four weeks to complete this first phase of assessments. The intra-observer agreement was established by comparing the same raters' responses between two assessments of the same cases, separated by a four-week interval and presented in a new random sequence to avoid recall bias. The assessors also had four weeks to complete the second evaluation; therefore, the assessment phase was completed in 12 weeks.

R (The R Project for Statistical Computing, Vienna, Austria) was used to determine the sample size. As reported by Rotondi et al. [8], and considering the data from Vaccaro et al.[5], a confidence interval to sampling size estimation for inter-observer agreement studies with multiple raters was used. For an expected substantial reliability, with a lower limit of 0.6 and an upper limit of 0.8, with a 95% confidence interval, we determined a minimum of 65 cases as the required sample. However, considering that some subtypes are less frequent than others, we increased the number of cases to 80 patients to ensure enough cases of each subtype.

We used SPSS version 17 (SPSS, Chicago, IL, USA) to conduct the statistical analysis, and used the Kappa coefficient (κ) to determine the interobserver and intra-observer agreement of the classification; κ values were expressed with a 95% confidence interval (CI). The agreement was first measured by type level (A, B, or C type), and then at the subtype level. Levels of agreement for κ were determined as proposed by Landis et al. [9] with κ values 0.00–0.20 considered slight agreement; 0.21–0.40, fair agreement; 0.41–0.60, moderate agreement; 0.61–0.80, substantial agreement; and 0.81–1.00, almost perfect agreement.

Results

All three major fracture severity patterns (A, B, and C) were identified by at least one evaluator, as well as all the ten different subtypes of injuries (A1 through C3).

Of the 720 first assessments, 85 (11.8%) were described as type A fractures, 456 (63.3%), as type B injuries, and 179 (24.9%) as type C lesions (Table 1).

Inter-observer agreement

When assessing severity type (A, B, or C), we observed a substantial agreement both among spine surgeons (κ= 0.68 [95% CI: 0.63 - 0.72]) and pelvis surgeons (κ= 0.74 [95% CI: 0.64 to 0.84]). The detailed κ values for each fracture type in both groups are shown in Table 2.

Table 1
Distribution of sacral fractures.

Type/Subtype	N	% (subtype)	% (type)
A1	24	3.3	11.8
A2	51	7.1	
A3	10	1.4	
B1	15	2.1	63.3
B2	301	41.8	
B3	140	19.4	
C0	53	7.4	24.9
C1	35	4.9	
C2	29	4.0	
C3	62	8.6	
Total	720	100	100

Table 2
Interobserver Agreement (κ) by type.

Type	Spine surgeons		Pelvic trauma surgeons	
	κ	95% CI	K	95% CI
A	0.79	0.73 - 0.85	0.84	0.72 - 0.97
B	0.65	0.59 - 0.71	0.75	0.62 - 0.87
C	0.64	0.59 - 0.70	0.67	0.55 - 0.80

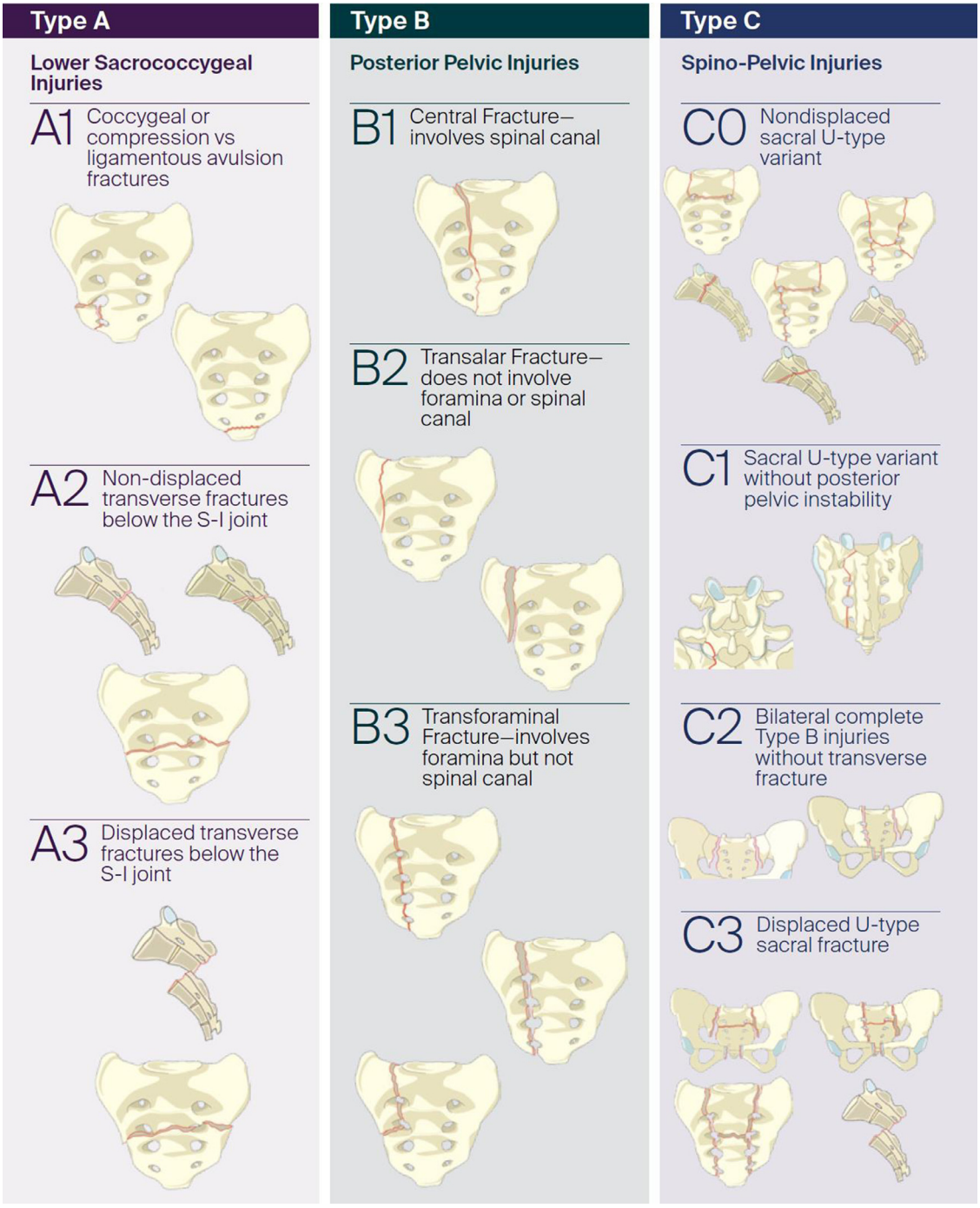

Fig. 1. Main characteristics of injury types and sub-types of the AO classification of sacral fractures. Acknowledgement of Copyright – AO Foundation.

When evaluating at the subtype level, we observed a moderate agreement among spine surgeons (κ= 0.52 [95% CI: 0.49 - 0.54]) and pelvic surgeons (κ= 0.51 [95% CI: 0.45 to 0.57]). The detailed inter-rater agreement by subtype level in both groups is shown in Table 3.

The evaluators' age did not influence the inter-observer agreement; we observed a substantial agreement both among the four surgeons older than 50 years old (κ= 0.67 [95% CI: 0.55 - 0.79]) and the five surgeons younger than 50 years old (κ= 0.71 [95% CI: 0.62 to 0.82]) evaluating the types level.

Intra-observer agreement

In the second evaluation four weeks after the first assessment, at the type level, we observed a substantial agreement among spine surgeons (κ= 0.74 [95% CI: 0.63 - 0.75]), and an almost perfect agreement among pelvic surgeons (κ= 0.84 [95% CI: 0.74 to 0.93]). However, there was no statistical difference in the agreement comparing the two groups. The detailed intra-observer agreement in both groups by type level is shown in Table 4.

Table 3
Interobserver Agreement (κ) by subtype.

Type/Subtype	Spine surgeons		Pelvic trauma surgeons	
	κ	95% CI	K	95% CI
A1	0.33	0.27 - 0.38	0.35	0.23- 0.48
A2	0.56	0.5 - 0.62	0.54	0.42 - 0.67
A3	0.19	0.13 - 0.24	0.50	0.37 - 0.62
B1	'−0.008	'- 0.07 - 0.0	0.05	'- 0.08 - 0.17
B2	0.7	0.64 - 0.75	0.67	0.54 - 0.80
B3	0.49	0.43 - 0.55	0.38	0.25 - 0.50
C0	0.42	0.36 - 0.47	0.66	0.53 - 0.78
C1	0.24	0.18 - 0.29	0.08	'- 0.50 - 0.20
C2	0.33	0.28 - 0.39	0.15	0.02 - 0.27
C3	0.56	0.5 - 0.61	0.75	0.62 - 0.88

Table 4
Intraobserver Agreement (κ) by type.

Type/Subtype	Spine surgeons		Pelvic trauma surgeons	
	κ	95% CI	κ	95% CI
A	0.71	0.62 - 0.80	0.9	0.77 - 1.03
B	0.67	0.58 - 0.76	0.83	0.71 - 0.96
C	0.7	0.61 - 0.79	0.80	0.67 - 0.93

Table 5
Intraobserver Agreement (κ) by subtype.

Type/Subtype	Spine surgeons		Pelvic trauma surgeons	
	κ	95% CI	κ	95% CI
A1	0.43	0.34 - 0.52	0.56	0.43 - 0.69
A2	0.54	0.45 - 0.62	0.66	0.53 - 0.79
A3	0.53	0.44 - 0.62	0.49	0.37 - 0.62
B1	0.28	0.19 - 0.37	0.52	0.40 - 0.65
B2	0.7	0.61 - 0.79	0.78	0.65 - 0.90
B3	0.6	0.51 - 0.69	0.56	0.43 - 0.68
C0	0.62	0.53 - 0.71	0.75	0.62 - 0.88
C1	0.46	0.38 - 0.55	0.54	0.41 - 0.67
C2	0.48	0.39 - 0.57	0.35	0.22 - 0.48
C3	0.74	0.65 - 0.83	0.87	0.74 - 0.99

At the subtype level, we observed a substantial agreement both for spine surgeons (κ= 0.61 [95% CI: 0.56 - 0.67]) and pelvic surgeons (κ= 0.68 [95% CI: 0.62 to 0.74].

The detailed intra-observer agreement in both groups by subtype level is shown in Table 5.

The evaluators' age did not influence the intra-observer agreement either; we noted a substantial agreement both among the surgeons older than 50 years old (κ= 0.80 [95% CI: 0.73 - 0.86]) and the surgeons younger than 50 years old (κ= 0.73 [95% CI: 0.66 to 0.79]) at the main types level.

Discussion

Our study demonstrated substantial inter-observer agreement at the fracture type-level among spinal surgeons and pelvic surgeons using the new AOSpine sacral fracture classification system, without differences comparing the two groups. Likewise, there was moderate agreement at the subtype level in both groups (κ= 0.52 and 0.51, respectively).

A sacral fracture classification scheme should include all the sacrum's different injury patterns and demonstrate adequate inter- and intra-observer agreement applying it. Some previous classification systems have assessed sacral fractures as part of a pelvic injury [3,10,11], while others have focused more on the sacral fracture's specific patterns [2,12–14]. Nevertheless, none of those classifications have included all types of sacral injuries, none of them has been evaluated with an inter- and intra-observer agreement study, and they are not a hierarchical system. Consequently, they are not universally accepted as they do not propose treatment options.

The AOSpine sacral classification provides a possible answer to this problem, as it proposes a hierarchical system based on an increasing grade of posterior pelvic and spino-pelvic instability. In this scheme, type-A fractures do not present posterior pelvic or spino-pelvic instability, type-B fractures are vertical patterns with posterior pelvic instability but not spino-pelvic instability, and type C injuries are those presenting with spinopelvic instability.

Our study found a substantial inter-observer agreement at the fracture severity level in independent groups of six spine surgeons and three pelvic trauma surgeons. This agreement was not different among the two groups and is comparable to the agreement observed by the panel describing the classification, who reported a κ= 0.75 between fourteen spine surgeons and four trauma surgeons [4]. Similarly, both groups achieved a moderate agreement at the fracture subtype level, which is equivalent to the agreement observed in the study performed by Vaccaro et al. (κ= 0.58).

Like the study from Vaccaro et al. [4], the highest inter-observer agreement by severity level was observed in type A fractures in both spinal and pelvic surgeons, achieving an almost perfect agreement. Regarding subtypes, we found a higher agreement in B2 fractures (which were also the most frequently observed) and the lowest agreement rating in A3, B1, C1, and C2 fractures. Vaccaro et al. had their highest and lowest agreement rating in A2 and A1 injuries, respectively. We believe that the low agreement achieved in these particular subtypes could result from the low number of cases classified in each one since the subtype's prevalence strongly influences κ values. Nonetheless, the inter-observer agreement for type B and type C fractures was substantial in both groups.

The validation of a new classification should undergo three steps [15]: a) A definition of categories by experts, b) A multicenter agreement evaluation carried out by future users of the classification, and c) A prospective clinical study to evaluate its clinical utility. Our study contributes to this classification's validation process with a multicenter, agreement assessment performed independently by spinal and pelvic trauma surgeons. This approach is important because sacral fractures are frequently part of a pelvic ring injury and therefore are commonly treated by both groups of specialists.

Our results clinical connotation is that the inter- and intra-observer agreement obtained indicates that this classification allows adequate communication between spinal and between pelvic trauma surgeons; thus, it may be used in clinical practice. However, we observed only a moderate inter-observer agreement at the subtype level with some subtypes achieving only a slight agreement. This could represent a limitation of this classification scheme since various evaluators will classify an important proportion of injuries differently, resulting in differences in treatment in patients presenting the same injury. However, these results are alike other validations of AOSpine classifications, including the thoracolumbar spine classification (κ= 0.62 for the main types and κ= 0.55 for subtype) and subaxial cervical spine scheme (κ= 0.61 for the main types and κ= 0.57 for subtypes) [16–18].

One strength of our study is that the evaluators assessed the entire imaging files on each patient, which reproduces a more real clinical practice. However, this can decrease the agreement in more complex fracture patterns because each evaluator has to choose the images they consider the most representative of the injury pattern. In addition, this is a multicentric study, in which each evaluator has a different expertise level and surgical volume, adding variability in their surgical and clinical background, which increases its applicability.

From a research perspective, our study's results should allow clinical studies to use this system with confidence regarding its reliability. However, prospective studies are still required to establish

whether this classification system could facilitate treatment decisions in patients with sacral fractures and its prognostic value.

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