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The Surgical Algorithm for the AO Spine Sacral Injury Classification System

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Study Design. Global cross-sectional survey.

Objective. To establish a surgical algorithm for sacral fractures based on the Arbeitsgemeinschaft für Osteosynthesefragen (AO) Spine Sacral Injury Classification System.

Summary of Background Data. Although the AO Spine Sacral Injury Classification has been validated across an international audience of surgeons, a consensus on a surgical algorithm for sacral fractures using the Sacral AO Spine Injury Score (Sacral AOSIS) has yet to be developed.

Methods. A survey was sent to general orthopedic surgeons, orthopedic spine surgeons, and neurosurgeons across the five AO spine regions of the world. Descriptions of controversial sacral injuries based on different fracture subtypes were given, and surgeons were asked whether the patient should undergo operative or nonoperative management. The results of the survey were used to create a surgical algorithm based on each subtype's sacral AOSIS.

Results. An international agreement of 70% was decided on by the AO Spine Knowledge Forum Trauma experts to indicate a recommendation of initial operative intervention. Using this, sacral fracture subtypes of AOSIS 5 or greater were considered operative, while those with AOSIS 4 or less were generally nonoperative. For subtypes with an AOSIS of 3 or 4, if the sacral fracture was associated with an anterior pelvic ring injury (M3 case-specific modifier), intervention should be left to the surgeons' discretion.

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Conclusion. The AO Spine Sacral Injury Classification System offers a validated hierarchical system to approach sacral injuries. Through multispecialty and global surgeon input, a surgical algorithm was developed to determine appropriate operative indications for sacral trauma. Further validation is required, but this algorithm provides surgeons across the world with the basis for discussion and the development of standards of care and treatment.

Key words: AO Spine, classification, validation, injury severity, injury score, spine trauma, sacral fracture, pelvic fracture

Level of Evidence. 4.

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Due to the anatomical location of the sacrum, which connects the lumbar spine to the pelvis, sacral fractures lie at the intersection of the fields of spine and trauma and often require a multidisciplinary team for treatment.[1,2] Although many sacral classification systems have been previously proposed, most are mainly descriptive and limited in their assessment of sacral and pelvic morphology, and none have been adopted as a universal standard.[3–6] Therefore, in 2020, the Arbeitsgemeinschaft für Osteosynthesefragen (AO) Knowledge Forum Trauma published the AO Spine Sacral Injury Classification System.[7] The goal of the classification was to design a comprehensive system that could be easily and consistently applied by practitioners across different specialties to guide the treatment of these complex injuries.

The AO Spine Sacral Injury Classification divides sacral fractures into three levels of fracture severity: type A (lower sacrococcygeal), type B (posterior pelvic), and type C (spinopelvic). These types were hierarchically stratified based on the potential disruption to the stability of the pelvis. Type A fractures, by definition, are injuries below the level of the sacroiliac joint that do not influence stability. Type B fractures involve unilateral vertical sacral fractures, which may disrupt the posterior pelvic ring but leave the contralateral sacroiliac joint and spinopelvic relationship intact. Type C fractures involve fractures that result in spinopelvic instability. Each type is then further differentiated into three to four subtypes for further morphologic analysis and supplemented with neurological and case-specific modifiers (Table 1).

Although there have been many sacral fracture classifications, none have offered a complete system addressing morphology, stability, and treatment options. The initial systems, including the hallmark classification by Denis *et al*,[3] focused on recognizing fracture morphologies and differentiating them by anatomical region.[8] Other classifications focused on specific fracture types, such as the description of transverse sacral fractures by Roy-Camille *et al*,[5] or on fracture shapes such as "U" or "H" morphologies of lower sacral injuries.[9] The relationship between sacral fractures and neurological injuries was addressed in Gibbons and colleagues, while Isler described sacral fractures in reference to pelvic ring injury and instability.[4,10] One classification by Lehman *et al*[11] used an algorithm to address clinical decision-making, but this was not widely adopted, possibly due to classification complexity, and no other classifications have offered treatment recommendations. Thus, the AO Spine Knowledge Forum Trauma attempted to combine aspects of previous sacral classifications to provide a simple, comprehensive system applicable to all sacral fractures, with the goal of developing treatment recommendations.

Previous studies have validated the AO Spine Sacral Injury Classification, demonstrating that the classification is a reliable and reproducible system across an international audience of spine and trauma surgeons.[7,12] After the reliability of the classification was established, a numerical

TABLE 1. The AO Spine Sacral Injury Classification System and Associated AO Spine Injury Score (AOSIS)

AO spine sacral injury classification		AOSIS
Type A—lower sacrococcygeal injuries		
A1	Coccygeal or compression fractures vs. ligamentous avulsion fractures	0
A2	Nondisplaced transverse fractures below the sacroiliac joint	1
A3	Displaced transverse fractures below the sacroiliac joint	3
Type B—posterior pelvic injuries		
B1	Central fracture (involves spinal canal)	2
B2	Transalar fracture (does not involve foramina or spinal canal)	2
B3	Transforaminal fracture (involves foramina but not spinal canal)	3
Type C—Spinopelvic injuries		
C0	Nondisplaced sacral U-type variant	2
C1	Sacral U-type variant without posterior pelvic instability	3
C2	Bilateral complete type B injuries without transverse fracture	5
C3	Displaced U-type sacral fracture	6
N—neurological status		
N0	Neurology intact	0
N1	Transient neurological deficit	1
N2	Radicular symptoms	2
N3	Incomplete SCI or any degree of cauda equina injury	4
N4	Complete SCI	3
M—modifiers		
M1	Soft tissue injury	0
M2	Metabolic bone disease	0
M3	Anterior pelvic ring injury	1
M4	Sacroiliac joint injury	2

AO indicates Arbeitsgemeinschaft für Osteosynthesefragen; SCI, spinal cord injury.

value was then applied to each injury subtype to create the Sacral AO Spine Injury Score (Sacral AOSIS), which organized the classification into hierarchical order.[13] The current study now aims to provide an international consensus on surgical management for sacral fractures by using the Sacral AOSIS.

METHODS

The AO Spine Sacral Injury Classification System was developed and validated as previously described (Fig. 1).[7,12,14] The AO Spine Knowledge Forum Trauma designed a survey of cases based on the classification system and distributed it to orthopedic surgeons and

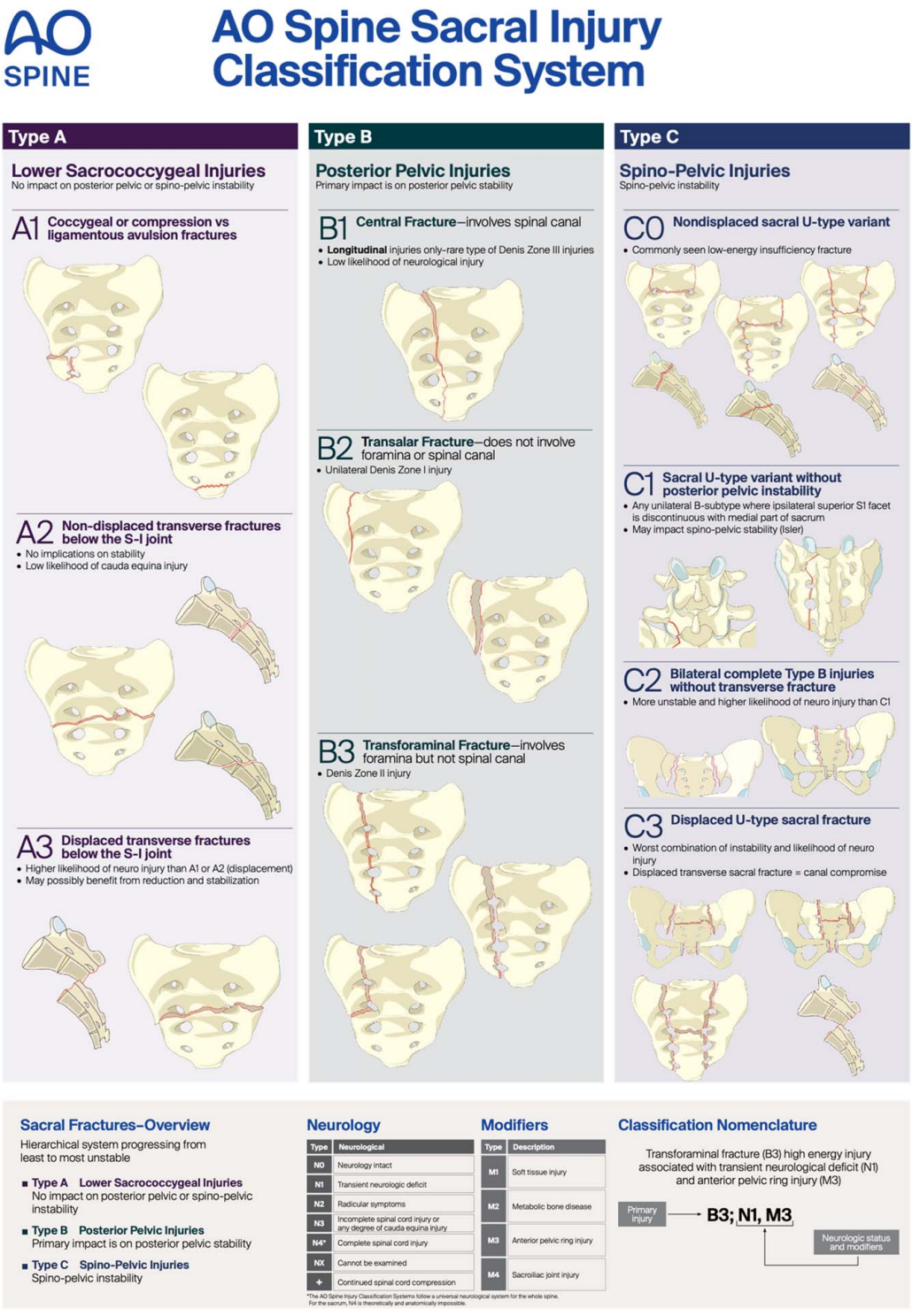

Figure 1. The Arbeitsgemeinschaft für Osteosynthesefragen (AO) Spine Sacral Classification System. Permission to use this figure was granted by the AO Foundation, AO Spine, Switzerland. Copyright AO Foundation, AO Spine, Switzerland, Davos, Switzerland. All permission requests for this image should be made to the copyright holder.

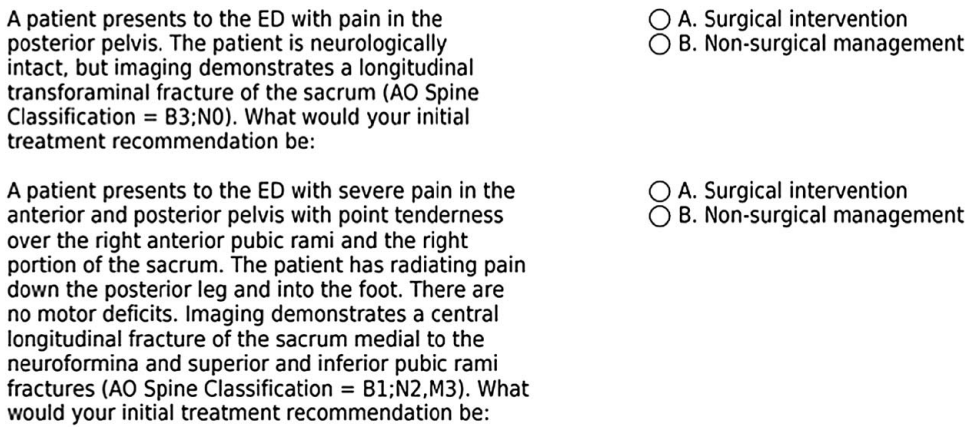

Figure 2. Two examples of survey questions from the Arbeitsgemeinschaft für Osteosynthesefragen (AO) Spine Knowledge Forum Trauma. For all cases, a short descriptive paragraph without images was presented to the surgeons, who were then asked to choose whether the preferred initial treatment was operative or nonoperative. To avoid any issues with the interpretation of images, only text was distributed. ED indicates Emergency Department.

neurosurgeons across the following regions: North America, South America, Europe, Africa, the Middle East, and Asia. Examples of survey questions can be seen in Figure 2. The survey covered all injuries with historically controversial treatment, including A3 (A3N0 and A3N1) and all type B fractures with and without anterior pelvic ring injury (ie, B1N0 and B1N0M3) for the neurological modifiers N0, N1, and N2. For type C injuries, C0 fractures were examined with and without metabolic bone disease as well as concomitant anterior pelvic ring injury (ie, C0N0, C0N0M2, and C0N0M2M3) for the same neurological modifiers as above. C1 injuries were examined with and without anterior pelvic ring injury (ie, C1N0 and C1N0M3) for the same neurological modifiers. Type A fractures were not given case-specific modifiers as they, by definition, do not confer pelvic ring instability. Unstable fractures (such as C2 and C3) were excluded from the study as they are widely considered to be operative. Similarly, N3 and N4 modifiers were not included as an incomplete or complete spinal cord injury is an accepted indication for operative management. In all cases, a short descriptive paragraph without images was presented to the surgeons, who were then asked to choose whether the preferred initial treatment was operative or nonoperative. To avoid any issues with the interpretation of images, only text was distributed.

The AO Spine Trauma Knowledge Forum decided by consensus to consider a 70% agreement among surgeons to be the cutoff for the recommendation of operative management. This was meant to be consistent with the previous cutoff of 70% used for the AO Spine Thoracolumbar Injury Classification System.[15] Using this cutoff, fracture types with a given AOSIS score would be evaluated, and those that were found to consistently reach consensus for surgery would be recommended to undergo operative intervention. Alternatively, fracture types that did not meet this 70% cutoff would generally be recommended for an initial trial of nonoperative management.

Statistical Analysis

Frequencies and percentages were recorded for participating surgeons regarding the region, experience, practice setting, subspecialty, and number of sacral fractures treated per year. Due to the small absolute response

TABLE 2. Demographics of Survey Participants

	N = 111, N (%)
AO region	
North America	14 (12.6)
Latin and South America	23 (20.7)
Europe	41 (36.9)
Africa and Middle East	14 (12.6)
Asia	19 (17.1)
Experience (y)	
< 5	23 (20.7)
5-10	22 (19.8)
11-20	38 (34.2)
> 20	27 (24.3)
Practice setting	
Academic	53 (47.7)
Hospital employed	46 (41.4)
Private practice	12 (10.8)
Sacral fractures treated per year	
0-5	35 (31.5)
6-10	32 (28.8)
11-20	19 (17.1)
> 20	18 (16.2)
Not reported	7 (6.3)
Subspecialty	
Orthopedics	87 (78.4)
General	14 (12.6)
Orthopedic spine	73 (65.8)
Neurosurgeon	24 (21.6)

AO indicates Arbeitsgemeinschaft für Osteosynthesefragen.

TABLE 3. Number of Surgeons by Region Who Would Recommend Surgical Treatment for Controversial Sacral Fractures

	North America, n (%)	Latin and South America, n (%)	Europe, n (%)	Africa and Middle East, n (%)	Asia, n (%)	Global, n (%)	*P*	AOSIS
A3N0	1 (7.1)	8 (34.8)	14 (34.1)	7 (50.0)	7 (36.8)	37 (33.3)	0.158‡	3
A3N1	6 (42.9)	10 (45.5)	17 (42.5)	8 (61.5)	9 (47.4)	50 (46.3)	0.822‡	4
B1N0	7 (50)	4 (18.2)	3 (7.7)	3 (23.1)	5 (26.3)	22 (20.6)	0.017*‡	2
B1N0M3	10 (71.4)	10 (47.6)	22 (56.4)	10 (76.9)	14 (73.7)	66 (62.3)	0.265†	3
B1N1	8 (57.1)	5 (22.7)	7 (17.5)	2 (15.4)	5 (26.3)	27 (25.0)	0.071‡	3
B1N1M3	11 (78.6)	12 (54.5)	28 (70.0)	8 (57.1)	12 (63.2)	71 (65.1)	0.559‡	4
B1N2	9 (64.3)	9 (40.9)	14 (35.0)	3 (23.1)	8 (42.1)	43 (39.8)	0.243‡	4
B1N2M3	12 (85.7)	18 (81.8)	33 (84.6)	9 (69.2)	16 (84.2)	88 (82.2)	0.780‡	5
B2N0	6 (42.9)	2 (9.1)	4 (10.3)	2 (15.4)	4 (21.1)	18 (16.8)	0.076‡	2
B2N0M3	11 (78.6)	15 (68.2)	26 (66.7)	11 (84.6)	15 (78.9)	78 (72.9)	0.690‡	3
B2N1	9 (64.3)	3 (13.6)	13 (33.3)	5 (38.5)	8 (42.1)	38 (35.5)	0.035*‡	3
B2N1M3	12 (85.7)	18 (81.8)	33 (84.6)	11 (84.6)	18 (94.7)	92 (86.0)	0.789‡	4
B2N2	10 (71.4)	10 (45.5)	23 (59.0)	5 (38.5)	11 (57.9)	59 (55.1)	0.394†	4
B2N2M3	12 (85.7)	17 (73.9)	33 (80.5)	11 (78.6)	15 (78.9)	88 (79.3)	0.965‡	5
B3N0	8 (57.1)	6 (27.3)	10 (25.6)	5 (38.5)	9 (47.4)	38 (35.5)	0.175‡	3
B3N0M3	11 (78.6)	17 (77.3)	25 (64.1)	11 (84.6)	14 (73.7)	78 (72.9)	0.638‡	4
B3N1	10 (71.4)	9 (42.9)	21 (53.8)	7 (53.8)	15 (78.9)	62 (58.5)	0.146†	4
B3N1M3	12 (85.7)	19 (86.4)	35 (89.7)	11 (84.6)	16 (84.2)	93 (86.9)	0.937‡	5
B3N2	11 (78.6)	15 (71.4)	27 (69.2)	9 (69.2)	12 (63.2)	74 (69.8)	0.931‡	5
B3N2M3	13 (92.9)	19 (86.4)	36 (92.3)	11 (84.6)	18 (94.7)	97 (90.7)	0.804‡	6
C0N0	7 (50.0)	3 (14.3)	3 (7.7)	4 (30.8)	3 (15.8)	20 (18.9)	0.010*‡	2
C0N0M2	9 (64.3)	7 (31.8)	9 (23.1)	5 (38.5)	4 (21.1)	34 (31.8)	0.061‡	2
C0N0M2M3	9 (64.3)	14 (66.7)	22 (56.4)	6 (46.2)	11 (57.9)	62 (58.5)	0.798†	3
C0N1	9 (64.3)	6 (27.3)	11 (28.2)	5 (38.5)	7 (36.8)	38 (35.5)	0.170‡	3
C0N1M2	9 (64.3)	6 (28.6)	11 (28.2)	4 (30.8)	6 (31.6)	36 (34.0)	0.180‡	3
C0N1M2M3	10 (71.4)	15 (71.4)	20 (51.3)	7 (53.8)	7 (36.8)	59 (55.7)	0.160†	4
C0N2	8 (57.1)	8 (38.1)	12 (30.8)	4 (30.8)	8 (42.1)	40 (37.7)	0.482†	4
C0N2M2	9 (64.3)	9 (42.9)	15 (38.5)	5 (35.7)	8 (42.1)	46 (43.0)	0.521†	4
C0N2M2M3	11 (78.6)	15 (71.4)	22 (56.4)	7 (50.0)	12 (63.2)	67 (62.6)	0.432†	5
C1N0	10 (71.4)	9 (42.9)	9 (23.1)	8 (61.5)	6 (31.6)	42 (39.6)	0.009*†	3
C1N0M3	12 (85.7)	17 (77.3)	29 (74.4)	12 (92.3)	13 (68.4)	83 (77.6)	0.546‡	4
C1N1	12 (85.7)	10 (45.5)	18 (46.2)	11 (84.6)	10 (52.6)	61 (57.0)	0.018*†	4
C1N1M3	13 (92.9)	15 (71.4)	31 (79.5)	10 (71.4)	13 (68.4)	82 (76.6)	0.461‡	5
C1N2	13 (92.9)	14 (66.7)	24 (61.5)	10 (76.9)	15 (78.9)	76 (71.7)	0.201‡	5
C1N2M3	14 (100.0)	17 (81.0)	31 (79.5)	12 (92.3)	15 (78.9)	89 (84.0)	0.347‡	6

**Indicates statistically significant regional treatment variability.*
†χ^2 test.
‡Fisher's exact test.
AOSIS indicates Arbeitsgemeinschaft für Osteosynthesefragen Spine Injury Score.

number from two global regions, responses from Africa and the Middle East were combined. Descriptive analyses were then performed to find possible associations between regions, experience, work setting, and subspecialty, as well as the likelihood of those characteristics leading to the surgeon defining the sacral injury as operative using χ^2 and the Fisher exact tests as appropriate. Since the variable on years of experience was an ordinal one, its association with the likelihood of leading to the surgeon defining the sacral injury as operative was assessed using a

TABLE 4. Subspecialty of Surgeons Who Would Recommend Surgical Treatment for Controversial Sacral Fractures

	General orthopedics, N = 14, n (%)	Orthopedic spine surgery, N = 73, n (%)	Neurosurgery, N = 24, n (%)	Total, N = 111, n (%)	*P*	AOSIS
A3N0	4 (28.6)	25 (34.2)	8 (33.3)	37 (33.3)	0.918†	3
A3N1	7 (50.0)	35 (48.6)	8 (36.4)	50 (46.3)	0.575†	4
B1N0	3 (21.4)	17 (23.9)	2 (9.1)	22 (20.6)	0.347‡	2
B1N0M3	9 (64.3)	46 (65.7)	11 (50.0)	66 (62.3)	0.409†	3
B1N1	4 (28.6)	19 (26.4)	4 (18.2)	27 (25.0)	0.700†	3
B1N1M3	10 (71.4)	50 (70.4)	11 (45.8)	71 (65.1)	0.080†	4
B1N2	9 (64.3)	29 (40.3)	5 (22.7)	43 (39.8)	**0.045***†	4
B1N2M3	12 (85.7)	61 (85.9)	15 (68.2)	88 (82.2)	0.204‡	5
B2N0	2 (14.3)	14 (19.7)	2 (9.1)	18 (16.8)	0.587‡	2
B2N0M3	11 (78.6)	54 (76.1)	13 (59.1)	78 (72.9)	0.258†	3
B2N1	6 (42.9)	27 (38.0)	5 (22.7)	38 (35.5)	0.351†	3
B2N1M3	12 (85.7)	62 (87.3)	18 (81.8)	92 (86.0)	0.770‡	4
B2N2	9 (64.3)	40 (56.3)	10 (45.5)	59 (55.1)	0.509†	4
B2N2M3	11 (78.6)	61 (83.6)	16 (66.7)	88 (79.3)	0.198‡	5
B3N0	5 (35.7)	26 (36.6)	7 (31.8)	38 (35.5)	0.919†	3
B3N0M3	11 (78.6)	54 (76.1)	13 (59.1)	78 (72.9)	0.258†	4
B3N1	10 (71.4)	45 (64.3)	7 (31.8)	62 (58.5)	**0.015***†	4
B3N1M3	12 (85.7)	63 (88.7)	18 (81.8)	93 (86.9)	0.622‡	5
B3N2	11 (78.6)	54 (77.1)	9 (40.9)	74 (69.8)	**0.004**†	5
B3N2M3	13 (92.9)	64 (90.1)	20 (90.9)	97 (90.7)	1.000‡	6
C0N0	4 (28.6)	15 (21.4)	1 (4.5)	20 (18.9)	0.111‡	2
C0N0M2	9 (64.3)	19 (26.8)	6 (27.3)	34 (31.8)	**0.020***†	2
C0N0M2M3	12 (85.7)	37 (52.9)	13 (59.1)	62 (58.5)	0.075†	3
C0N1	7 (50.0)	25 (35.2)	6 (27.3)	38 (35.5)	0.379†	3
C0N1M2	9 (64.3)	19 (27.1)	8 (36.4)	36 (34.0)	**0.027***†	3
C0N1M2M3	9 (64.3)	35 (50.0)	15 (68.2)	59 (55.7)	0.256†	4
C0N2	8 (57.1)	25 (35.7)	7 (31.8)	40 (37.7)	0.260†	4
C0N2M2	11 (78.6)	25 (35.7)	10 (43.5)	46 (43.0)	**0.013***†	4
C0N2M2M3	12 (85.7)	41 (58.6)	14 (60.9)	67 (62.6)	0.156†	5
C1N0	6 (42.9)	31 (44.3)	5 (22.7)	42 (39.6)	0.190†	3
C1N0M3	13 (92.9)	54 (76.1)	16 (72.7)	83 (77.6)	0.345‡	4
C1N1	10 (71.4)	42 (59.2)	9 (40.9)	61 (57.0)	0.161†	4
C1N1M3	12 (85.7)	53 (75.7)	17 (73.9)	82 (76.6)	0.679†	5
C1N2	13 (92.9)	51 (72.9)	12 (54.5)	76 (71.7)	**0.042***†	5
C1N2M3	14 (100.0)	58 (82.9)	17 (77.3)	89 (84.0)	0.177‡	6

Bold values indicate statistical significance P value < 0.05.

**Indicates statistically significant regional treatment variability.*

‡Fisher's exact test.

†χ^2 test.

AOSIS indicates Arbeitsgemeinschaft für Osteosynthesefragen Spine Injury Score.

Cochran-Armitage test for trend. Statistical significance was set at 0.05. The analysis was performed using SAS version 9.2 (SAS Institute, Cary, NC).

RESULTS

One hundred and eleven surgeons completed the survey, with representation from different regions. The experience of the participants varied from <5 to >20 years, and most were employed in an academic (47.4%) or hospital practice setting (41.4%). The majority (60.4%) reported treating 0 to 10 sacral fractures a year. In terms of subspecialities, 12.6% of participants were general orthopedists, 65.8% were orthopedic spine surgeons, and 21.6% were neurosurgeons (Table 2).

The AO Spine Trauma Knowledge Forum decided by consensus to consider a 70% agreement among surgeons to be the cutoff for the recommendation of operative management. Using this cutoff, fracture types of AOSIS 5 or more were found to consistently reach consensus for surgery. This consisted of B1N2M3 (82.2% agreement), B2N2M3 (79.3%), B3N1M3 (86.9%), B3N2 (69.8%), B3N2M3 (90.7%), C1N1M3 (76.6%), C1N2 (71.7%), and C1N2M3 (84.0%). The only one that did not reach 70% consensus was C0N2M2M3, which had a high percentage of agreement at 62.6%. Thus, an injury type with an AOSIS of 5 or 6 are recommended to undergo operative intervention.

The geographic variability in the percentage of surgeons that would recommend surgical management is demonstrated in Table 3. Of the 35 controversial sacral fracture types, there was agreement on 30 types. The five injury subtypes that showed regional differences were B1N0, B2N1, C0N0, C1N0, and C1N1. North America had the highest rates of operative fixation as initial management in all these subtypes, while Europe had the lowest rates of B1N0, C0N0, and C1N0. Latin and South America had the lowest rates in B2N1 and C1N1. The decision for surgical management was then examined based on the surgeon's subspecialty to compare trends in their initial recommendation of operative or conservative care (Table 4). There was disagreement in 7 of the 35 fracture types, namely B1N2, B3N1, B3N2, C0N0M2, C0N1M2, C0N2M2, and C1N2. In all these types, general orthopedists recommended operative treatment more frequently than neurosurgeons, while orthopedic spine surgeons' recommendations were more variable. When assessing surgeons based on years of experience, there were no significant differences in initial management preference (Supplemental Table 1, Supplemental Digital Content 1, http://links.lww.com/BRS/C326).

Among fracture types that were AOSIS 4 or lower, there were 4 of 26 that reached the cutoff for operative management: B2N0M3 (72.9% agreement), B2N1M3 (86.0%), B3N0M3 (72.9%), and C1N0M3 (77.6%). Although these were both AOSIS 3 and 4 score types, these cases were likely considered operative due to the M3 modifier, namely anterior pelvic ring injury. And in fact, the other AOSIS 3 and 4 types with M3 modifiers were found to have relatively higher agreement scores, namely B1N0M3 (62.3%), B1N1M3 (65.1%), C0N0M2M3 (58.5%), and C0N1M2M3 (55.7%). From this, the consensus recommendation was updated to consider patients for nonoperative or operative management if fractures had an AOSIS score of 3 or 4 with a M3 modifier. Otherwise, an initial trial of nonoperative management was recommended for all other types (AOSIS 2 as well as AOSIS 3 or 4 without M3 modifiers).

DISCUSSION

Using the AO Spine Sacral Injury Classification System and associated AOSIS, the AO Spine Trauma Knowledge Forum has created an algorithm for the treatment of sacral fractures. We recommend that fractures with AOSIS 1 or 2 should be treated nonoperatively, while those with AOSIS 5 or greater should be treated operatively. For fractures with an AOSIS score of 3 and 4, an initial trial of nonoperative management is recommended unless the fracture has a concomitant anterior pelvic ring injury (an M3 modifier), whereby initial operative management may be appropriate and should be determined based on the individual surgeon's treatment preference.

Regional differences in operative indications for spinal trauma have previously been identified in the literature. International surgeons, mainly from Europe and Asia, have demonstrated a general preference to operate on spinal trauma more frequently than their North American peers.[16,17] Moreover, when determining the surgical algorithm for the AO Spine Thoracolumbar Injury Classification System, significant regional variability was seen in 15 of the 19 controversial fracture types, with more surgeons from Europe recommending operative treatment.[15] This has not always held true for all fracture types; however, members from the Americas were more likely to recommend surgery after unilateral cervical facet fractures.[18] In the present study, we found regional differences in 5 of the 35 types of sacral fractures, which exemplify some of the overarching regional differences seen in our study. In three of the five cases (B1N0, B2N1, and C0N0), although there were regional differences, none reached 70% agreement on operative management, indicating that all the regions would independently have agreed on nonoperative management when using a 70% cutoff. In the case of C1N0, 71.4% of North American surgeons recommended surgery, while no other regions reached 70%. And in the remaining case of C1N1, North America was again the highest at 85.7%. Of the other regions, only the combined region of Africa and the Middle East reached 70%, while the other three regions did not. Similarly, surgeons from North America were the ones most likely to recommend surgical treatment for 25 of the 35 reviewed sacral fracture types. This may be due to a confluence of factors, including the fact that there may have been more general orthopedic surgeons in the North American group.

When looking at surgical recommendations based on surgeon subspecialities, general orthopedists were more likely to recommend surgery than orthopedic spine surgeons or neurosurgeons. Significantly different operative rates were found when comparing the three subspecialties in 7 of 35 sacral fracture subtypes (B1N2, B3N1, B3N2, C0N0M2, C0N1M2, C0N2M2, and C1N2). In three of these cases (B1N2, C0N0M2, and C0N1M2), none of the groups reached 70% agreement on surgical treatment, supporting the recommendation for nonoperative management. All four other cases showed a higher than 70% operative rate by general orthopedists, with a concomitant operative rate ranging from 31.8% to 54.5% by the neurosurgeon group. The recommendation of the orthopedic spine surgeons was more split, with only two of the four subtypes (B3N2 and C1N2) reaching 70%. In both of these cases, the AOSIS was

5, ultimately recommending these fracture types for operative intervention.

Unfortunately, there is sparse literature on the differences between surgical subspecialties in the management of sacral fractures. Lindtner *et al*[19] offered both the orthopedic traumatologist and orthopedic spine surgeon viewpoints on the treatment of sacral fractures. As sacral fractures are often accompanied by pelvic ring injuries, soft tissue injuries, and possibly life-threatening injuries, the traumatologists may be better equipped to manage these polytrauma patients, as well as anatomically reduce and percutaneously fix pelvic fractures. Meanwhile, if there are cauda equina or sacral nerve root compression symptoms, spine surgeons are often more experienced at performing nerve root decompressions. Moreover, in the case of fractures with lumbosacral instability, such as vertically unstable or complex bilateral sacral fractures, lumbopelvic fixation has become more prevalent, and this may require a multidisciplinary approach.[20,21]

The current study found that years of surgeon experience did not significantly affect the operative indication for sacral fractures. This is similar to the thoracolumbar fracture literature, in which surgeon experience was not found to impact the operative indication of thoracolumbar fracture subtypes.[22] Interestingly, this is in contrast to findings demonstrating that experienced attendings have more misclassifications when using the AO Spine Injury Classification System. For the AO Spine Sacral Injury Classification, Karamian *et al*[12] found that surgeons with >20 years of experience were less reliable in classifying fracture subtype and morphology than those with 11 to 20 years of experience. Meanwhile, for the AO Spine Thoracolumbar Injury Classification, Rajasekaran *et al*[22] and Sadiqi *et al*[23] similarly showed that more experienced surgeons were found to have more misclassifications. However, these differences were not substantial, and when given the scenario of a classification, surgeons of all experience groups appear to have similar recommendations on operative indication.

Our study does have significant limitations. One of the main limitations derives from the fact that surgeons were basing their decisions off injury descriptions rather than images. This was a conscious choice when designing this study, as we wanted to eliminate any confounding factors related to imaging interpretation. Although we did not find many significant regional differences, regions that had more representation in the survey could have skewed the total global percentage and shifted our algorithm toward a more aggressive initial treatment approach. Similarly, we had a larger group of orthopedic spine surgeons who responded to the survey than general orthopedists or neurosurgeons, possibly leading to heavier weight being placed on the recommendations from orthopedic spine surgeons. Although our algorithm suggests an initial trial of operative or nonoperative management for a variety of sacral injury subtypes, this classification does not recommend specific operative approaches since sacral injuries can be managed through different techniques. The efficacy of each surgical approach is likely based on a surgeon's proficiency and experience employing that technique; thus, recommending open versus minimally invasive techniques to a global population composed of varying surgical subspecialties would not have been appropriate.

CONCLUSION

By arranging sacral fractures into a hierarchical system, the AO Spine Sacral Injury Classification was able to create a treatment algorithm based on injury morphology and severity. In this study, we present the algorithm, which is based on an international and multispecialty survey and can help guide the treatment of controversial sacral fractures. As previous sacral fracture classifications have often been more descriptive in manner or limited in scope, this simple injury classification will help elucidate initial consensus global treatment standards for a variety of sacral injuries.

➢ Key Points

- ❑ Using a cutoff of 70% agreement, fractures with AOSIS 1 or 2 were treated nonoperatively, while those with AOSIS 5 or greater were treated operatively.
- ❑ For fractures with an AOSIS score of 3 and 4, an initial trial of nonoperative management is recommended unless the fracture has a concomitant anterior pelvic ring injury (an M3 modifier), whereby initial operative management may be appropriate and should be determined based on the individual surgeon's treatment preference.
- ❑ When given the scenario of an AO Spine Sacral Injury Classification, surgeons of all experience groups appear to have similar recommendations on operative indication.

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