Is there a regional difference in morphology interpretation of A3 and A4 fractures among different cultures?

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OBJECTIVE The aim of this study was to determine if the ability of a surgeon to correctly classify A3 (burst fractures
with a single endplate involved) and A4 (burst fractures with both endplates involved) fractures is affected by either the
region or the experience of the surgeon.

METHODS A survey was sent to 100 AOSpine members from all 6 AO regions of the world (North America, South
America, Europe, Africa, Asia, and the Middle East) who had no prior knowledge of the new AOSpine Thoracolumbar
Spine Injury Classification System. Respondents were asked to classify 25 cases, including 6 thoracolumbar burst frac-
tures (A3 or A4). This study focuses on the effect of region and experience on surgeons’ ability to properly classify these
2 controversial fracture variants.

RESULTS All 100 surveyed surgeons completed the survey, and no significant regional (p > 0.50) or experiential (p >
0.21) variability in the ability to correctly classify burst fractures was identified; however, surgeons from all regions and
with all levels of experience were more likely to correctly classify A3 fractures than A4 fractures (p < 0.01). Further analy-
sis demonstrated that no region predisposed surgeons to increasing their assessment of severity of burst fractures.

CONCLUSIONS A3 and A4 fractures are the most difficult 2 fractures to correctly classify, but this is not affected by the
region or experience of the surgeon; therefore, regional variations in the treatment of thoracolumbar burst fractures (A3
and A4) is not due to differing radiographic interpretation of the fractures.

http://thejns.org/doi/abs/10.3171/2015.4.SPINE1584

KEY WORDS AOspine Thoracolumbar Spine Injury Classification System; regional treatment variation; regional
radiographic interpretation; thoracolumbar burst fractures; A3 fracture; A4 fracture; trauma

Over the last 3 decades, multiple thoracolumbar injury classifications, such as the Denis classification,5
the Magerl classification,11 and the Thoracolumbar Injury Classification Severity Score (TLICS),23 have been
designed to help guide treatment and facilitate clear communication between treating physicians, researchers, and
trainees. However due to limitations inherent to each classification system, none has been universally accepted, and
a globally recognized algorithm for the treatment of thoracolumbar trauma has yet to be established.11,13,23,24

The Magerl system is a morphologically based hierarchical classification system in which an increase in injury

ABBREVIATIONS PLC = posterior ligamentous complex; SIS = Spine Injury Score; TLICS = Thoracolumbar Injury Classification and Severity Score.
INCLUDE WHEN CITING Published online October 9, 2015; DOI: 10.3171/2015.4.SPINE1584.
severity, mechanical instability, and the risk of neurological injury is associated with an increased classification grade. However, with over 50 fracture subtypes, the system has only fair reproducibility and has been unable to be clinically validated. Furthermore, the system fails to formally consider the neurological status of the patient, which is often a critical determinant in the need for surgical treatment.

Recognizing the aforementioned limitations of the Magerl system, Vaccaro et al. designed the TLICS. Not only does the TLICS formally consider the neurological status of the patient, it also uses a simpler morphological grading system, and improved clinical reliability and validity has been reported. The TLICS recommends treatment based on the summation of numerical grades assigned to the fracture morphology, the integrity of the posterior ligamentous complex (PLC), and the neurological status of the patient. According to the TLICS system, a score of 5 points or more supports the decision in favor of operative treatment, while a score of 3 points or less would support nonoperative treatment. However, the most controversial fracture, a thoracolumbar burst fracture with a possible PLC disruption in a neurologically intact patient, is awarded 4 points, leaving no definitive treatment recommendation. Furthermore, while the overall reliability of the TLICS is high, the interobserver reliability of identifying an injury to the PLC, a crucial factor in the need for surgery in borderline cases, remains poor. The ability of TLICS to provide guidance for these patients has been criticized as the major flaw of the system as well as other contemporary classification systems.

In 2013, Vaccaro et al. published the new AO spine Thoracolumbar Spine Injury Classification System, which incorporates the strengths of the previous Magerl/AO system and the TLICS. The AO spine Thoracolumbar Spine Injury Classification System first categorizes fractures by morphological type. Type A injuries are compression injuries; Type B injuries indicate a disruption of the anterior or posterior tension band without evidence of translation; and Type C injuries are all injuries associated with translation of the vertebral bodies. Type A and B injuries can then be classified into 5 and 3 subtypes, respectively. The classification also formally accounts for the neurological status of the patient. N0 is used in neurologically intact patients; N1 identifies patients who had a transient neurological deficit; N2 is used to identify a patient with a nerve root injury; N3 is used to identify a patient with an incomplete spinal cord injury or cauda equina injury; N4 is used to identify a patient with a complete spinal cord injury; and NX indicates that a reliable exam cannot be obtained. Finally, patient-specific modifications that may affect the treatment algorithm can be added: M1 is used if there is a possible ligamentous injury to the tension band, and M2 indicates that the patient has morbidities such as ankylosing spondylitis or other significant medical comorbidities that may alter the recommended treatment.

While this classification has been described in detail previously, the treatment algorithm associated with the classification is still being developed. Ongoing studies have been designed to establish the foundations for the development of a Spine Injury Score (SIS). Similar to the TLICS score, this SIS will guide the treatment for each subgroup of the AO spine Thoracolumbar Spine Injury Classification System.

Specifically, an increased understanding in the regional variability of the treatment of thoracolumbar burst fractures (AO spine Thoracolumbar Spine Injury Classification System subtype A3—a burst fracture with a single endplate involved [Fig. 1]; subtype A4—a burst fracture with both endplates involved [Fig. 2]) is necessary. Contemporary studies from North and South America report successful results with nonoperative treatment of these fractures with or without a brace, while current European publications report excellent outcomes from treating similar fractures with 360° fusion. Prior to establishing the SIS and the globally applicable algorithm for the treatment of thoracolumbar trauma, an improved understanding of why this variability exists is desirable.

In an effort to better understand the regional variation in treatment, Schroeder et al. investigated the perception of severity of each subclassification of the AO spine Thoracolumbar Spine Injury Classification System. They found that the perceived severity of each fracture is independent of region and experience. These findings indicated that regional perception of severity was not primarily driving treatment variations, but rather other variables such as cultural preferences for immediate stability, local education and training, or possibly regional differences in the radiographic interpretation of thoracolumbar burst fractures.

Kepler et al. reported moderate interobserver reliability (k = 0.56) of the AO spineThoracolumbar Spine Injury Classification System in 100 surgeons from all regions of the world, but the interobserver reliability was only 0.42 for A3 fractures and 0.19 for A4 fractures. This finding indicates that regional variation in the treatment of these particular thoracolumbar burst fracture variants may be due to divergent regional interpretation of their inherent fracture morphologies. The aim of this study is to explore the potential influence of regional variations in the classification of burst fractures with a single (A3) or both endplates involved (A4). Identification of regional variations that affect treatment recommendations would allow for globally applicable treatment recommendations for each subgroup of the AO spine Thoracolumbar Spine Injury Classification System.

Methods
A survey was sent to 100 AO spine members from all 6 AO regions of the world (North America, South America, Europe, Africa, Asia, and the Middle East) who had no prior knowledge of the new AO spine Thoracolumbar Spine Injury Classification System. Initially a video introduction, written descriptions, and iconic depictions with drawings and clinical images of the new classification system were presented to the surgeons (http://www.aovideo.ch/external/AOSCT7). After the introduction, the subjects were presented with high quality CT images and clinical information for 25 thoracolumbar trauma cases and asked to classify each one. Overall inter- and intraobserver reliability of this cohort has been previously reported. The current analysis focuses on 6 cases involving A3 and A4 type fractures. Based on a unanimous agreement among 3 members of the AO spine Trauma Knowledge Group, each
case had a “correct” answer, and the appropriate classification for 3 of these cases was A3 and an additional three cases was A4. The ability of surgeons to correctly categorize A3 and A4 fractures was determined.

Statistical Analysis

The absolute numbers and frequencies of fracture types A3 and A4 according to the agreed-upon “gold standard,” AO region, and experience were presented. Chi-square tests were used to investigate possible associations between misclassifications and AO region and experience. Subsequently, the absolute numbers and frequencies of surgeons who misclassified burst fractures to fractures of an increased severity (using the previously established injury rating for each fracture) was calculated. Due to the limited number of frequencies, Fisher’s exact test was used to compare those frequency distributions across categories of AO region. The statistical significance was set at 0.05. The analysis was performed using the statistical software STATA version 12 (Stata Corporation).

Results

All 100 surgeons completed the survey (Table 1), and their responses were analyzed. In light of a solitary response from Africa, this region was excluded from the regional evaluation. Globally, surgeons were significantly more likely to correctly classify A3 fractures than A4 fractures (59.3% vs 30.0%, respectively, p < 0.0001), and this difference was significant (p < 0.01) for every region. While all surgeons were more likely to correctly classify A3 fractures compared with A4 fractures, no regional variability in the ability to correctly classify A3 (p = 0.87), A4 (p = 0.50), or combined A3 and A4 (p = 0.49) fractures was identified (Table 2). Further analysis was performed to determine if any region was more likely to misclassify fractures to fractures of an increased severity.

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>AO region</td>
<td></td>
</tr>
<tr>
<td>Europe</td>
<td>19</td>
</tr>
<tr>
<td>Asia Pacific</td>
<td>29</td>
</tr>
<tr>
<td>Latin America</td>
<td>21</td>
</tr>
<tr>
<td>Middle East</td>
<td>15</td>
</tr>
<tr>
<td>North America</td>
<td>15</td>
</tr>
<tr>
<td>Africa</td>
<td>1</td>
</tr>
<tr>
<td>Experience in years</td>
<td>30</td>
</tr>
<tr>
<td>1–10</td>
<td>30</td>
</tr>
<tr>
<td>11–20</td>
<td>44</td>
</tr>
<tr>
<td>≥21</td>
<td>26</td>
</tr>
</tbody>
</table>
the fracture as one of increased severity (Table 3), but, similarly, no regional predilection toward increasing the severity of fractures was identified. Lastly, an analysis was performed to determine the effect experience had on the ability to correctly classify A3 and A4 fractures. Similar to region, surgeons of all experience levels were more likely to correctly classify A3 than A4 fractures (p < 0.01), but there was no difference between surgeons of different experience levels in the ability to correctly classify A3 (p = 0.47), A4 (p = 0.55), or combined A3 and A4 (p = 0.34) fractures (Table 4).

**Discussion**

The aim of this study was to identify if region or experience affect spinal surgeons’ ability to accurately classify A3 and A4 fractures. Determining this is important in laying the intellectual foundation for the development of globally accepted treatment recommendations to accompany the recently described AOSpine Thoracolumbar Spine Injury Classification System Spine Injury Score.10 While the current study identified that A3 fractures are more easily classified than A4 fractures, no regional or experiential

**TABLE 2. Regional analysis of the actual number and frequencies of respondents who correctly classified thoracolumbar A3 and A4 fractures**

<table>
<thead>
<tr>
<th>Respondents</th>
<th>Europe</th>
<th>Asia Pacific</th>
<th>Latin America</th>
<th>Middle East</th>
<th>North America</th>
<th>Africa†</th>
<th>Total</th>
<th>p Value‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correctly classified A3 fractures</td>
<td>34 (59.6)</td>
<td>55 (63.2)</td>
<td>37 (58.7)</td>
<td>24 (53.3)</td>
<td>27 (60.0)</td>
<td>1 (33.3)</td>
<td>178 (59.3)</td>
<td>0.87</td>
</tr>
<tr>
<td>Correctly classified A4 fractures</td>
<td>18 (31.6)</td>
<td>32 (36.8)</td>
<td>15 (23.8)</td>
<td>12 (26.7)</td>
<td>13 (28.9)</td>
<td>0 (0.0)</td>
<td>90 (30.0)</td>
<td>0.50</td>
</tr>
<tr>
<td>Correctly classified A3 &amp; A4 fractures</td>
<td>52 (45.6)</td>
<td>87 (50.0)</td>
<td>52 (41.3)</td>
<td>36 (40.0)</td>
<td>40 (44.4)</td>
<td>1 (16.7)</td>
<td>268 (44.7)</td>
<td>0.49</td>
</tr>
</tbody>
</table>

* Values are n (%). Percentages were calculated as the number of respondents who correctly classified thoracolumbar A3, A4, and combined A3 and A4 fractures within each AO region, divided by the total number of respondents of this region.
† Since only one respondent was from Africa, this region was not included in the calculation of p value.
‡ Derived from chi-square test and represents the regional variability in the ability to correctly classify A3, A4, or A3 and A4 fractures.

**TABLE 3. Regional analysis of the actual number and frequencies of respondents who misclassified thoracolumbar A3 and A4 fractures as more severe fractures**

<table>
<thead>
<tr>
<th>Respondents</th>
<th>Europe</th>
<th>Asia Pacific</th>
<th>Latin America†</th>
<th>Middle East</th>
<th>North America</th>
<th>Africa‡</th>
<th>Total</th>
<th>p Value§</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classified A3 fractures as a more severe injury</td>
<td>4 (17.4)</td>
<td>5 (15.6)</td>
<td>5 (20.0)</td>
<td>1 (4.8)</td>
<td>1 (5.6)</td>
<td>0 (0.0)</td>
<td>16 (13.2)</td>
<td>0.47</td>
</tr>
<tr>
<td>Classified A4 fractures as a more severe injury</td>
<td>5 (12.8)</td>
<td>4 (7.3)</td>
<td>2 (4.2)</td>
<td>2 (6.1)</td>
<td>1 (3.1)</td>
<td>0 (0.0)</td>
<td>14 (6.7)</td>
<td>0.55</td>
</tr>
<tr>
<td>Classified A3 &amp; A4 fractures as a more severe injury</td>
<td>9 (14.5)</td>
<td>9 (10.3)</td>
<td>7 (9.6)</td>
<td>3 (5.6)</td>
<td>2 (4.0)</td>
<td>0 (0.0)</td>
<td>30 (9.1)</td>
<td>0.34</td>
</tr>
</tbody>
</table>

* Values are n (%). Percentages were calculated as the number of respondents who correctly classified thoracolumbar A3, A4, and combined A3 and A4 fractures within each AO region, divided by the total number of respondents of this region.
† The classification of 1 case was missing for 1 respondent from Latin America; therefore, it was not applicable to evaluate whether there was an increase in the severity.
‡ Since only 1 respondent was from Africa, Africa region was not included in the calculation of p value.
§ Derived from Fisher’s exact test and represents the experiential variability in the ability to correctly classify A3, A4, or A3 and A4 fractures.

**TABLE 4. Experiential analysis of the actual number and frequencies of respondents who correctly classified thoracolumbar A3 and A4 fractures**

<table>
<thead>
<tr>
<th>Respondents</th>
<th>Years of Experience</th>
<th>p Value†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correctly classified A3 fractures</td>
<td>1–10</td>
<td>11–20</td>
</tr>
<tr>
<td>Correctly classified A4 fractures</td>
<td>32 (35.6)</td>
<td>40 (30.3)</td>
</tr>
<tr>
<td>Correctly classified A3 &amp; A4 fractures</td>
<td>88 (48.9)</td>
<td>115 (43.6)</td>
</tr>
</tbody>
</table>

* Values are n (%). Percentages were calculated as the number of respondents who correctly classified thoracolumbar A3, A4, and combined A3 and A4 fractures within each experience group, divided by the total number of respondents of this group.
† Derived from chi-square test.
differences in the ability of surgeons to correctly classify A3 and A4 fractures was identified. Furthermore, region was not a significant predictor of surgeons who upgraded A3 and A4 fractures to more severe fracture grades. These findings are critical because they indicate that the development of a single worldwide surgical algorithm may be possible. Combined with the previously established substantial reliability and injury severity score, the current study indicates that the AOSpine Thoracolumbar Spine Injury Classification System provides a suitable cornerstone for the establishment of a global evidence-based algorithm for the treatment of thoracolumbar trauma, and that regional interpretation of the classification is not needed.

While the main goal of this study was to identify regional or experiential differences in the classification of A3 and A4 fractures, one of the unexpected findings was that surgeons are significantly more accurate at classifying A3 (Fig. 3) fractures compared with A4 fractures (Fig. 4). It is possible that the relatively poor classification of A4 fractures may be due to subtle ambiguity regarding the

**FIG. 3.** Sagittal (A) and axial (B) CT images showing an A3 fracture.

**FIG. 4.** CT images demonstrating the variability of A4 fractures. A: Sagittal CT image showing an A4 fracture with significant comminution and obvious involvement of both endplates. B1 and B2: Sagittal (B1) and coronal (B2) CT images of an A4 fracture. In the sagittal image, involvement of the inferior endplate is not apparent, but the coronal image shows clear involvement of the inferior endplate. C: Sagittal CT image showing a burst fracture with significant superior comminution and only a single fracture line extending into the inferior endplate. Figure is available in color online only.
degree of involvement of the second (commonly inferior) endplate in the fracture. Any involvement of the second endplate results in the fracture being classified as A4; even a sagittal split that appears relatively undisplaced will qualify a fracture for the A4 designation. This distinction was deemed necessary when the classification was designed, because it is believed the risk of a progressive kyphotic deformity may differ between A3 and A4 fractures. The need for separating these fractures has since been substantiated, as a worldwide survey showed that the perceived severity of A4 fractures was found to be significantly worse than that of A3 fractures. However, even though surgeons had a more difficult time classifying A4 compared with A3 fractures, the overall correct classification of A3 fractures was still only 59%. When an A3 fracture was misclassified, 87% of the time these fractures were classified as a less severe injury (A1 or A2), so it is clear that the difficulty with classifying these fractures was in identifying a disruption of the posterior cortex. Further training is needed to help surgeons to distinguish an A3 fracture from an A1 or A2 fracture.

There is well-established regional variation in the treatment of thoracolumbar burst fractures, with recommendations ranging from no treatment to extensive and invasive fusion procedures. Reinhold et al. published on the operative treatment of 733 patients with thoracolumbar trauma in Germany and Austria, including 365 neurologically intact patients with a compression or burst fracture. Similarly, Schnake and colleagues have described excellent results after treatment of neurologically intact patients with burst fractures using 360° fusion. In contrast, Bailey et al. performed a multicenter trial in Canada regarding the treatment of burst fractures with and without a brace, reporting excellent clinical outcomes without surgery and only a rare need for delayed surgical intervention. Divergent regional treatment biases may be the primary reason that a high-quality comparative study has never been performed. The results of the current study support the theory that regional differences in thoracolumbar burst fracture management cannot be explained by variations in the radiographic interpretation of A3 and A4 fractures. Combining the results of the current study with another study demonstrating no regional difference in the perceived severity of fractures, we believe that cultural and regional variables including willingness to perform/undergo invasive procedures, decreased cost associated with conservative care, and access to health care and surgeons are likely the key factors driving the regional patterns in the treatment of A3 and A4 fractures.

Some aspects of the cultural and regional differences which impact the treatment of burst fractures in neurologically intact patients are unlikely to quickly change. Patient acceptance of limitations associated with nonoperative management of injuries, patient access to health care, and the resources available to surgeons treating these patients are complex issues that will not be easily influenced by research studies or classification systems. Nonetheless, it is important to recognize that medical equipoise does exist to some degree within the treatment of neurologically intact patients with burst fractures and likely represents over- or undertreatment of some of these patients. Regional variation in early iterations of treatment algorithms to accompany the AOSpine Thoracolumbar Spine Injury Classification System is expected in recognition of current practices to encourage widespread adoption of the classification system. Recognition of current practices does not dampen the need for more robust guidance regarding treatment of these patients, which will likely be derived from global prospective outcome studies and should eventually allow convergence of treatment algorithms.

It is important to acknowledge that a number of significant limitations to this study exist, including the fact that this is a survey-based study. While significant care was taken by a workgroup of AOSpine (AOSpine Classifica-
of this study cannot be extrapolated to Africa. Lastly, it is possible that the years of experience do not mirror clinical experience treating thoracolumbar burst fractures, so while the current study found no difference in the ability to classify fractures based on years of experience, it is possible that if a more specific thoracolumbar trauma experience metric was used (such as the total number of thoracolumbar trauma cases a physician has treated) our study may have yielded a different result.

Conclusions

While A3 and A4 fractures are the most difficult fractures to correctly classify, the ability of surgeons to correctly classify A3 and A4 fractures is independent of region and experience. In conjunction with another study, this finding suggests that the establishment of a globally accepted algorithm for the treatment of thoracolumbar trauma based on the AOSpine Thoracolumbar Spine Injury Classification System is feasible; however, educational efforts centered on correctly classifying A4 fractures may be needed.

References

the AOSpine Thoracolumbar Spine Injury Classification System. Global Spine J [in press], 2015


25. Wood KB, Khanna G, Vaccaro AR, Arnold PM, Harris MB, Mehboob AA: Assessment of two thoracolumbar fracture class-

### Disclosure

This manuscript was supported by AOSpine. AOSpine is a clinical division of the AO Foundation—an independent medically guided, not-for-profit organization. The AO has strong financial independence, thanks to the foundation’s endowment. The annual operating activities are financed through three pillars: collaboration and support agreements with DePuy Synthes and other industrial partners, return on own financial assets, and other third party income (e.g., participant fees, R&D projects, memberships). The AOSpine Knowledge Forums are pathology-focused working groups acting on behalf of AOSpine in their domain of scientific expertise. Each forum consists of a steering committee of up to 10 international spine experts who meet biannually to discuss research, assess the best evidence for current practices, and formulate clinical trials to advance their field of spine expertise. Authors are compensated for their travel and accommodation costs. Study support is provided directly through AOSpine’s research department and AO’s Clinical Investigation and Documentation unit. There are no other institutional subsidies, corporate affiliations, or funding sources supporting this work unless clearly documented and disclosed.

Dr. Schroeder reports receiving travel grants to attend meetings of the CSRS and SRS from Medtronic. Dr. Dvorak reports being a consultant for and holding a patent with Medtronic. Dr. Schnake reports receiving clinical or research support for the study described from AOSpine. Dr. Vaccaro reports being a board member with Innovative Surgical Design, AOSpine, Association of Collaborative Spine Research, and Spinility: being a consultant for Medtronic, Stryker Spine, Global Spinal Medical, Gerson Lehrman Group, Guidepoint Global, Medacorp, Innovative Surgical Design, and Orbital bullets; receiving an institutional/educational grant from CureMed; receiving royalties from Spine Surgery; Stryker Spine, Stryker Spine, Biomet, Thieme, Jaypee, Elsevier, and Taylor Francis; having direct stock ownership in Replication Medica, Global Paradigm Spine, Stout Medical, Spine Medica, Computational Biodynamics, Progressive Spinal Technologies, Spinology, and Small Bone Innovations, Cross Current, Syndicom, In Vivo, Flagship Surgical, Advanced Spinal Intellectual Properties, Cytonics, Bonovo Orthopaedics, Electrocure, Gamma Spine, Location Based Intelligence, FlowPharma, R.S.I., Rothman Institute and related properties.

### Author Contributions

Conception and design: Schroeder, Kepler, Koerner, Chapman, Bellabarba, Oner, Reinhold, Dvorak, Araabi, Vialle, Rajasekaran, Kandziora, Schnake, Vaccaro. Acquisition of data: Fehlings. Analysis and interpretation of data: Schnake. Drafting the article: Schroeder, Kepler, Koerner, Oner, Vaccaro. Critically revising the article: Schroeder, Kepler, Koerner, Chapman, Bellabarba, Oner, Reinhold, Dvorak, Araabi, Vialle, Fehlings, Rajasekaran, Kandziora, Vaccaro. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Schroeder.

### Supplemental Information

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