Surgical Practice in Traumatic Spinal Fracture Treatment with Regard to the Subaxial Cervical Injury Classification and Severity and the Thoracolumbar Injury Classification and Severity Systems: A Review of 58 Patients at the University of Wisconsin

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OBJECTIVES: **Spine surgeons at a Level 1 Trauma Center have observed a high incidence of spine and spinal cord injuries owing to falls from tree stands. These injuries have been retrospectively reviewed in the context of the Thoracolumbar Injury Classification and Severity (TLICS) and the Subaxial Cervical Injury Classification and Severity (SLICS) classification systems to assess inter-user reliability and validity. We hypothesize that the inter-rater reliability will be similar between neuroradiology and neurosurgery raters and validity of the scoring system will be maintained at our institution.**

METHODS: **The University of Wisconsin Hospital and Clinics' trauma database was reviewed for tree stand–related injuries from 1999 to 2013, with a focus on patients suffering from spine and spinal cord injuries. The TLICS and SLICS scores were then independently determined for these injuries by a neurosurgeon and a neuroradiologist.**

RESULTS: **When cases were grouped by management recommendation (operative, equivocal, and nonoperative) reviewer agreement was 12/15 (80%) of SLICS and 38/52 (73%) of TLICS scores. Operative SLICS positive predictive value reached 100%, however, with a wide confidence interval. Conversely, the SLICS negative predictive value was poor at 54%–60%, with frequent operative treatment for patients assigned nonoperative scores. TLICS scores reached 77.8% and 93.3% positive predictive value per reviewer, whereas negative predictive values reached 93.9% and 89.2%, respectively.**

CONCLUSIONS: **The TLICS and SLICS systems provide good-to-excellent inter-rater reliability. SLICS validity was poor, whereas TLICS was reasonable for nonoperative cases and moderate for operative cases. Systems such as the TLICS and the SLICS may be best applied in the educational setting to confirm the fracture morphology and presence or absence of ligamentous injury between surgeons and radiologists.**

INTRODUCTION

Classification of spinal injuries to correspond with stability has evolved significantly since initial descriptions in the early 1900s.[1,2] As imaging capabilities improve, the characterization of spinal injury has become increasingly complex, making protocoled treatment algorithms difficult. A number of methods have been proposed over the last century, each prioritizing different aspects of the injury, including the mechanism, the fracture's anatomic appearance, or the consideration of instability.[1,3-7] Classification schemes may aim to simply describe a specific fracture type,[8] predict treatment plans,[3,9] or estimate outcomes and potential complications.[10]

Key words
- Spine fracture
- Spinal injury
- Spinal Injury Classification System
- Spinal surgery
- Tree stand fall

Abbreviations and Acronyms
CI: Confidence interval
ICC: Interclass correlation
NPV: Negative predictive value
PPV: Positive predictive value
SCI: Spinal cord injury
SLICS: Subaxial Cervical Injury Classification and Severity Score
TLICS: Thoracolumbar Injury Classification and Severity Score

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More recently, the Spine Trauma Study Group published algorithms for management of both subaxial cervical[11] and thoracolumbar[12] spine injuries. The Subaxial Cervical Injury Classification and Severity (SLICS) and the Thoracolumbar Injury Classification and Severity (TLICS) protocols incorporate the anatomic appearance of the osseous and ligamentous structures, as well as the presence or absence of a neurologic deficit. The scores are then used to identify patients who are likely to require surgical treatment.

Our department had previously reviewed the spinal injuries sustained in patients who fell from a tree stand while hunting in Wisconsin.[13] Here, we have investigated how our spinal injury treatment strategies for this specific patient population compare with those recommended by the SLICS and TLICS spinal injury classification systems.[11,12]

Specifically, we hypothesize that the inter-rater reliability will be similar between neuroradiology and neurosurgery raters, and validity of the scoring system will be maintained at our institution.

METHODS

This is a retrospective chart review, with focus on the management of spine and spinal cord injuries secondary to tree stand falls during the Wisconsin hunting season. The University of Wisconsin Hospital and Clinics' trauma registry database was used to identify patients whose injuries were related to falling from a tree stand. Beginning in 1999, the University of Wisconsin Hospital and Clinics' trauma database classified "tree stand fall" as a specific chief complaint. All such events between January 1, 1999 and February 19, 2013 were reviewed. All charts with this chief complaint were included in the study. The exclusion criteria for this study included fractures that were not located in the subaxial cervical or thoracolumbar spine (e.g., occipital condyle, sacrum) and fractures that are not considered to be unstable (e.g., transverse process and spinous process). Institutional review board exemption was granted for this study as a medical records review.

Data collected included patient demographics, medical history, traumatic injuries associated with their fall, and subsequent treatments. Two independent reviewers, a neuroradiology fellow (M.T.) and a neurosurgical spine fellow (D.J.), completed further analysis of the patients' radiographic images in the context of the SLICS and the TLICS classification systems. The radiography reviews were completed in a blinded fashion with regard to the treatment each patient received. Each reviewer independently assigned scores to both the cervical and the thoracolumbar injuries. Neurologic injury was accounted for within the appropriate regional score, given the level of neurologic deficit.

For purposes of definition, we define the "raw score" as the numerical score that is determined by each reviewer when evaluating the fracture pattern. The "treatment recommendation" is the category that the raw score falls under (e.g., operative, equivocal, and nonoperative).

The reviewers' raw scores and treatment recommendations were then compared for inter-rater reliability and the assigned versus actual patient treatment to establish validity. For inter-rater reliability, the treatment recommendation scores were determined to agree if the categories of operative or nonoperative were the same. For validity, the cases assigned equivocal scores were excluded because these scores could not be assigned to a treatment category. Then, agreement between operative or nonoperative assignment with the actual treatment was determined. The number of excluded equivocal cases were 2 for SLICS and 11 for TLICS. Statistical analysis was completed with the assistance of biostatisticians at our university with regard to inter-rater reliability and validity.

RESULTS

A total of 58 patients were identified with 1 or more spinal fractures, from C3 to L5. These patients were predominantly men (56 of the 58), with an average age of 45 (range 16–76) years. Neurologic dysfunction was noted in 33% (19/58) of patients with spinal fractures. Five patients suffered complete spinal cord injury (SCI), and an additional 5 patients experienced an incomplete SCI. Eight patients experienced focal radiculopathies, which were caused primarily by facet or compression fractures. Central cord syndrome was documented in 2 patients: 1 did not experience any acute cervical fracture. The other suffered multiple levels of cervical laminae fractures but also experienced a complete SCI associated with a thoracic burst fracture. Patients were assigned a single cervical score and a single thoracolumbar score, for a total of 67 scores assigned across the 58 patients.

Fifteen patients experienced cervical spine fractures and were assigned SLICS scores. Seven patients (47%) received surgical intervention for their fractures, whereas 8 (53%) were treated nonoperatively. Two of the nonoperative patients (25%) required surgery on a delayed basis and are analyzed here as operative cases.

Fifty-two patients suffered thoracolumbar spine fractures and were assigned TLICS scores. Of these, 17 patients (33%) were initially treated surgically, whereas 35 patients (67%) were treated nonoperatively. Of the nonoperative patients, 25 were braced and 10 required no treatment. One patient underwent delayed surgery and is analyzed as an operative patient.

Of the equivocal cases, 1 (50%) of the SLICS cases was nonoperative and 1 was operative. For the TLICS equivocal cases, 8 (72%) were nonoperative and 3 (27%) were deemed operative.

SLICS Evaluation

Inter-User Reliability. Fifteen cases were analyzed and scored by 2 reviewers. The raw SLICS scores were identical between reviewers in only 5 cases. However, the treatment recommendation assigned by each reviewer was consistent in 12 of 15 cases, whereas 2 cases were assigned equivocal scores by at least 1 of the reviewers. Statistical analysis of inter-rater agreement revealed an unweighted Cohen Kappa score of 0.591, with P value of 0.00381, which suggests that the frequency of agreement between raters is not random. The single case of reviewer disagreement in regard to overall management is described in the next paragraphs (Study ID #49). Statistical analysis of the interclass correlation (ICC) between the 2 reviewers confirms the observed frequent agreement between the radiologist and neurosurgeon (ICC = 0.852; P = 0.000226; confidence interval [CI], 0.525–0.952).

Validity of Treatment Assignment. Actual versus assigned management is shown in **Table 1**. Of the patients assigned operative scores, all underwent operative management (100% positive

Table 1. Actual Versus Assigned Cervical Spine Management

	Actual	
	Nonoperative	Operative
Assigned		
Nonoperative		
Radiology	6	5
Neurosurgery	5	4
Operative		
Radiology	0	3
Neurosurgery	0	5

predictive value [PPV] per reviewer; CI, 38.3–100 and 51.1–100; Table 2 and Figure 1). However, patients assigned nonoperative scores frequently proceeded to operative interventions, with a negative predictive value (NPV) of only 54.5% and 55.6% per reviewer (CI, 28–78.7 and 26.6–81.2).

There were 4 cases of disagreement between the assigned scores and actual management, and 1 case of outright disagreement between reviewers. Of these cases, all were assigned a nonoperative score by the SLICS system, but the patients eventually underwent operative management of their fractures. These cases are shown in Table 3 and described further here. In a complicated case (Study ID #49), the radiology reviewer assigned a score of 2 (1 point for compression fracture, 1 point for indeterminate injury of the discoligamentous complex or discoligamentous complex) to the patient suffering a fracture through a cervical anterior osteophyte. The neurosurgeon reviewer assigned a score of 6 (4 points for fracture morphology, 2 points for injury of the discoligamentous complex) to this same patient, classifying the fracture type as "rotational-translational," which incorporates an unstable 'tear drop' fracture. The patient was trialed in a cervical collar but found to be unstable on follow-up imaging, and underwent anterior cervical discectomy and fusion at 8-weeks postinjury. One patient (Study ID #96) was assigned a nonoperative score by both of the reviewers, however, the fracture involved the pedicle and facet, leading the spine surgeon involved in the patient's care to judge it as unstable and pursue an anterior cervical discectomy and fusion. The remaining 3 patients (Study ID #31, 64, and 100) were assigned nonoperative scores but underwent anterior cervical corpectomy and fusion because of associated radiculopathy. No patients assigned an operative score were managed conservatively.

TLICS Evaluation

Inter-User Reliability. Between the reviewers, the TLICS raw scores were identical in only 21 of 52 cases, or 40%. However, treatment recommendations were consistent in 38 cases (73%), with 11 additional cases assigned equivocal scores by 1 of the 2 reviewers; only 3 cases of outright disagreement between reviewers were identified. Statistical analysis of inter-rater agreement revealed an unweighted Cohen Kappa score of 0.521, with P value <0.001. ICC analysis between the 2 reviewers support the observed treatment agreement between the radiologist and neurosurgeon (ICC = 0.797; P < 0.001; CI, 0.671–0.879).

Validity of Treatment Assignment. Actual versus assigned management are displayed in Table 4. On individual score analysis by each reviewer, 18 and 15 patients were assigned operative scores; 14 of them underwent surgery, for respective PPVs of 77.8% and 93.3% (CI, 54.3–91.5 and 68.2–100; Table 5 and Figure 2). Nonoperative scores were given to 32 and 28 patients by respective reviewers, of which 3 and 4 patients actually pursued operative management. NPVs reached 93.8% and 89.3% (CI, 78.8–99.3 and 72–97.1).

Details of assigned versus actual treatment deviations are delineated in Table 6. One such patient (Study ID #37), with complete SCI owing to a distracting injury and multiple levels of compression fractures, originally underwent conservative management with a brace, but went on to surgical fusion nearly 1 year later due to multilevel nonunion. The patient's TLICS score was an 8, suggesting surgical intervention should be considered in the first place. Four patients were assigned TLICS scores in the operative range (>4) but underwent conservative management. These were predominately patients with a high-energy injury, but appropriate alignment and intact neurologic examinations. Four patients were assigned conservative treatment by 1 of the 2 reviewers, but operative intervention was actually pursued. Patients assigned equivocal scores were excluded from validity analysis.

DISCUSSION

We hypothesized that the inter-rater reliability would be similar between neuroradiology and neurosurgery raters and validity of the scoring system would be maintained at our institution.

Inter-Rater Reliability

Despite our reviewers infrequently assigning identical raw scores, their treatment recommendations agreed most of the time, 12/15

Table 2. Subaxial Cervical Injury Classification and Severity Score Positive and Negative Predictive Values

Rater	FN	FP	TN	TP	NPV	PPV
Neuroradiologist	5	0	6	3	54.5% CI: 28–78.7	100% CI: 38.3–100
Neurosurgery spine fellow	4	0	5	5	55.6% CI 26.6–81.2	100% CI: 51.1–100

FN, false negative (conservative score, operative management); FP, false positive (surgical score, conservative management); TN, true negative (conservative score, conservative management); TP, true positive (surgical score, surgical management); NPV, negative predictive value; PPV, positive predictive value.

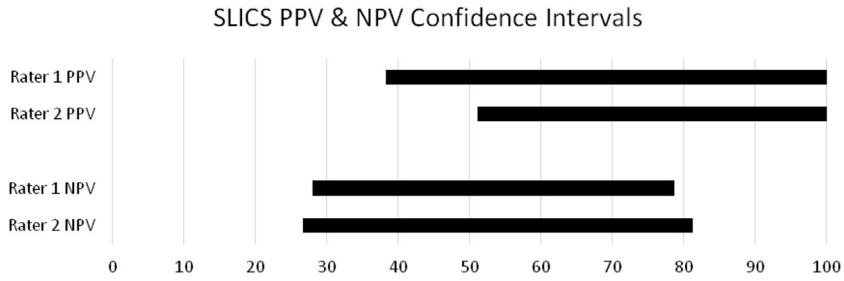

Figure 1. Confidence intervals for positive and negative predictive values of subaxial cervical injury classification and severity score.

(80%) of cervical and 38/52 (73%) of thoracolumbar scores. Reviewer disagreement on raw score was seen in all aspects of the scoring system, without any clear identifiable pattern in our group of 67 scores. Early studies of the intra- and inter-user reliability revealed inconsistencies in scoring the mechanism of injury category, which ultimately caused modifications of the original proposed system to include a morphology grade instead. Subsequent analysis has shown the greatest inconsistencies are with the evaluation of the posterior ligamentous complex.[14] Additionally, Raja Rampersaud et al.[15] found that reviewers agreed on raw scores in only 30% of cases but agreed on assigned treatment in nearly 75% of cases.[14]

When compared with previous classification systems, the inter-rater reliability of the TLICS and SLICS systems fairs much better.[16,17] As with all attempts to classify injuries, the greater detail included leads to limited clinical use for practical reasons, as well as increasing difficulty in reproducibility among users.[1,18]

Validity

The validity testing of the SLICS score in this cohort demonstrates that it did not reliably reflect management. The SLICS system identified those who need cervical surgery, with all patients assigned an operative score receiving an operative treatment. Despite the 100% PPV, CIs were large and ranged from 38.5–100 and 51.1–100 (Figure 1), meaning the true PPV is somewhere in that range. Our review identified a high rate of operative management in cases assigned nonoperative scores (Tables 1 and 3), reflecting the underestimation of surgical intervention by the SLICS score. Samuel et al.[19] found similar results with their retrospective review of cervical injuries at their level 1 trauma center; rates of agreement between assigned and actual treatments were higher in the assigned operative cohort than the assigned nonoperative cohort. In our series, patients with cervical body or facet injury with associated radiculopathy were most likely to undergo a surgical treatment despite a nonsurgical assigned SLICS score. Meanwhile, Joaquim et al.[20] prospectively applied the SLICS system to 48 cases of neurologically intact patients at their level 1 trauma center and found that no patients crossed over from an assigned nonoperative score to operative treatment. These observations may reflect a bias toward surgical intervention when neurologic deficit is present. Additionally, the "neurologic modifier" that accounts for ongoing compression of neural structures in the setting of a neurologic deficit is a single-point addition, which is unlikely to convert a nonoperative score to operative.

Table 3. Deviations in Management in the Cervical Spine

Study ID	Radiology SLICS Score	Neurosurgery SLICS Score	Assigned Treatment	Actual Treatment	Commentary
49	2	6	Reviewer disagreement	Nonoperative → Operative	Fracture through the body and anterior osteophyte. Failed brace trial, underwent ACDF at 8 weeks for instability.
96	1	2	Nonoperative	Operative	Vertebral body fracture with pedicle and facet involvement, judged to be unstable.
31	2	3	Nonoperative	Nonoperative → Operative	Facet fracture initially braced. Underwent ACDF at 6 weeks for persistent radiculopathy.
64	2	2	Nonoperative	Operative	Radiculopathy with lateral mass fracture at associated level.
100	2	2	Nonoperative	Operative	Radiculopathy with lateral mass fracture at associated level.

ID, identification; SLICS, Subaxial Cervical Injury Classification and Severity Score; ACDF, anterior cervical discectomy and fusion.

Table 4. Actual Versus Assigned Thoracolumbar Spine Management

	Actual	
	Nonoperative	Operative
Assigned		
Nonoperative		
Radiology	30	2
Neurosurgery	25	3
Operative		
Radiology	4	14
Neurosurgery	1	14

The TLICS system demonstrated reasonable validity with a good NPV and moderate PPV (Tables 5 and 6). The most significant discrepancy noted in regard to PPV involved 4 of the 18 patients assigned operative scores for high velocity injury, such as a bony chance fracture, which were managed conservatively due to preserved alignment. Additionally, our series revealed tendency for surgical management of thoracolumbar junction burst fractures despite assignment of scores for conservative management. This finding is consistent with previous reports by Dodwad et al.,[21] who reviewed injuries specific to the thoracolumbar junction and found greater validity of the TLICS system with regard to nonoperatively managed patients than those requiring surgical treatment. Congruent findings were also noted by Joaquim et al.,[18] with a 99% consistency for assigned and actual treatment methods for conservatively treated patients (expected TLICS $\leq$4), but only a 46% consistency for those patients who underwent surgical management (expected TLICS $\geq$4). All of the surgically managed TLICS deviations noted by Joaquim et al.[18] were thoracic burst fractures, which has previously been described as underscored by the TLICS system.[22,23]

Equivocal scores were excluded from analysis as they could not be assigned to a treatment category. The rate of equivocal scores were 13% for SLICS and 21% for TLICS. This raises an interesting discussion relating to the scoring system. An ideal scoring system would help spine care providers make consistent, reliable, and evidenced-based treatment decisions as often as possible. When a large percentage of the patients fall between treatment options, these decisions are left to the training bias and experience of a practitioner, although this does reflect the reality of traumatic spine care at this moment. Future work to improve these scoring systems should be employed to limit the number of equivocal cases and provide further clarity for the provider.

Patients with spinal fractures compose a diverse group of pathologies, and are therefore treated by a wide range of methods from observation to external bracing to surgical decompression and fixation. Approximately 50% of the spine fractures in our series required surgical intervention, some requiring assistance from general or vascular surgeons as well as the spine surgeon. Additionally, the surgeon must be prepared to evaluate all aspects of the patient's injuries. The assessment of spinal trauma must not only include the injury to the osseous components of the spine, but also the presence of neurologic deficits and any other associated injuries the patient has sustained. The disagreements seen between reviewers highlights the importance of interdisciplinary management of this traumatic injury patient population. When the surgical trainee's assessment of the injury disagrees significantly with that of the radiologist, further discussion is warranted to determine severity and stability of the injury. Use of the TLICS and SLICS systems could therefore be used as a teaching tool to initiate this conversation, improving both the care of the patient and the education of the trainee.

For nearly a century, surgeons have attempted to classify spinal injuries, in hopes of streamlining discussions of the injury morphology, stability, and severity.[24] Although many systems have been proposed with varying levels of complexity and reliability, no single system has been readily accepted and brought into universal use. To be useful, a classification system would need to address stability of the osseous and ligamentous elements, the neurologic status of the patient, and be a guide for treatment options.[5,9] The TLICS and SLICS systems aim to acknowledge these areas, while remaining limited enough for practical use. Notably, the scoring systems are specific to the anatomic regions, and scores are not cumulative when multiple fractures are present. Each region is assigned a single score to the most severe level of injury,[25] therefore, the total score may not accurately reflect the severity or instability of multilevel injuries. In the presence of multiple trauma, many patients may not be stable enough to undergo an operative intervention, particularly in the prone position. The TLICS and SLICS systems acknowledge the difficulty in extrapolation of their scoring to patient populations with multiple traumatic injuries, significant comorbidities, or osseous disease such as ankylosing spondylitis or diffuse idiopathic skeletal hyperostosis.[11,12] These individual factors should absolutely be considered when developing a treatment plan on a patient-to-patient basis.

Table 5. Thoracolumbar Injury Classification and Severity Score Positive and Negative Predictive Values

Rater	FN	FP	TN	TP	NPV	PPV
Neuroradiologist	2	4	30	14	93.8% CI: 78.8–99.3	77.8% CI: 54.3–91.5
Neurosurgery spine fellow	3	1	25	14	89.3% CI: 72–97.1	93.3% CI: 68.2–100

FN, false negative (conservative score, operative management); FP, false positive (surgical score, conservative management); TN, true negative (conservative score, conservative management); TP, true positive (surgical score, surgical management); NPV, negative predictive value; PPV, positive predictive value.

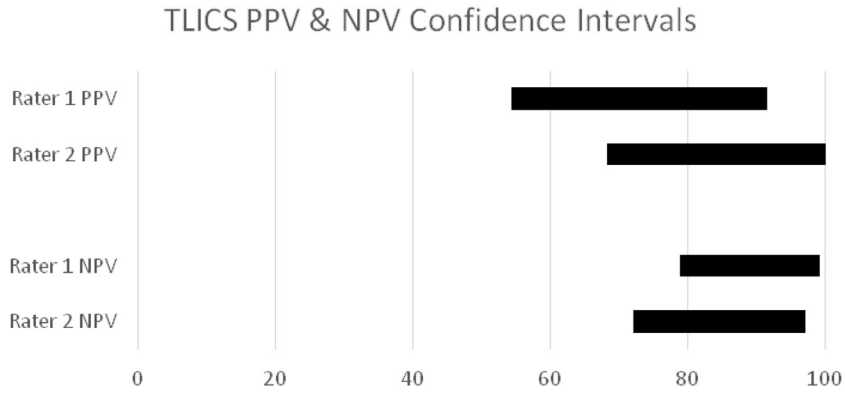

Figure 2. Confidence intervals for positive and negative predictive values of thoracolumbar injury classification and severity score.

Limitations of our study include the retrospective nature, lack of a power analysis, as well as the small number of patients and reviewers.

CONCLUSIONS

The SLICS and TLICS classification systems proposed by Vaccaro et al.[11,12] provided moderate inter-rater reliability between radiology and neurosurgical providers. The SLICS score did not demonstrate good validity. The TLICS score showed reasonable validity, better for nonoperative management than operative. Classification systems should be used with caution in the setting of multiple trauma, as the patient's injuries may be more complex than suggested by the SLICS or TLICS score. Additionally, these scoring systems may be best applied in the educational setting to confirm the fracture morphology and presence or absence of

Table 6. Deviations in Management in the Thoracolumbar Spine

Study ID	Radiology TLICS Score	Neurosurgery TLICS Score	Assigned Treatment	Actual Treatment	Commentary
21	10	8	Operative	Nonoperative	Completed spinal cord injury; bony chance fracture with appropriate alignment, braced.
37	9	7	Operative	Nonoperative → Operative	Multiple compression fractures above and below the T5 fracture dislocation. Underwent fusion at 10 months postinjury owing to nonunion (C7-T12 fusion).
92	7	4	Operative	Nonoperative	Bony chance fracture with appropriate alignment. Limited follow-up due to VA transfer.
126	7	4	Operative	Nonoperative	Flexion distraction injury with intact examination and appropriate alignment, braced.
107	5	4	Operative	Nonoperative	Burst fracture with intact examination, braced.
74	7	1	Reviewer disagreement	Operative	Treated as a distraction injury. Open reduction with T11-L1 posterior fusion.
106	6	1	Nonoperative	Operative	Bilateral perched facets. Open reduction with T11-L1 posterior fusion.
123	2	5	Nonoperative	Operative	Burst fracture with adjacent level facet fractures. T4 corpectomy with T2-6 fusion.
93	2	2	Nonoperative	Operative	Comminuted burst fracture with canal compromise. L1 corpectomy with T12-L2 fusion.

ID, identification; TLICS, Thoracolumbar Injury Classification and Severity Score; VA, Veteran's Affairs Hospital.

ligamentous injury between surgeons and radiologists. Further study could assess reliability among more users, whether neurosurgeons, orthopedic surgeons, or radiologists, each at varying levels of postgraduate training and careers. The grading systems would also benefit from further work to identify diagnostic criteria to narrow the range of the equivocal treatment category to improve the consistency of patient management.

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