The Development and Evaluation of the Subaxial Injury Classification Scoring System for Cervical Spine Trauma

Peter G. Whang MD, Alpesh A. Patel MD,
Alexander R. Vaccaro MD, PhD

Published online: 21 September 2010
© The Association of Bone and Joint Surgeons® 2010

Abstract

Background Fractures and dislocations of the subaxial cervical spine may give rise to devastating consequences. Previous algorithms for describing cervical trauma largely depend on retrospective reconstructions of injury mechanism and utilize nonspecific terminology which thus diminish their clinical relevance add to the difficulty of educating doctors and performing prospective research.

Questions/purposes We characterized the potential benefits of the Subaxial Injury Classification (SLIC) scale which considers three major variables that influence spinal stability: morphology, integrity of the discoligamentous complex, and neurologic status. Each category was assigned a certain number of points based on the severity of the injury which are added together to generate a total score; this value provides prognostic information and may

also be useful for directing subsequent management (ie, nonoperative treatment versus operative intervention).

Methods We examined the individual components that comprise the SLIC paradigm and reviewed the manner in which cervical injuries are scored and stratified. We also critically assessed the preliminary data comparing the SLIC scheme to preexisting classification systems.

Results The results of a preliminary analysis demonstrate that the intraclass coefficients (ICC) for the three primary components range between 0.49 and 0.90, suggesting that the overall reliability of the SLIC system appears to be at least as good as that of other conventional schemes for classifying subaxial cervical spine trauma (ICC between 0.41 and 0.53).

Conclusions This scheme will hopefully facilitate the development of evidence-based guidelines that may influence other aspects of the therapeutic decision-making process (eg, which operative approach is most appropriate for a particular injury). We anticipate its accuracy and reproducibility will increase over time as surgeons become more familiar with the protocol.

Each author certifies that he or she has no commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.

This work was performed at The Rothman Institute at Thomas Jefferson University.

P. G. Whang
Department of Orthopaedics and Rehabilitation, Yale University
School of Medicine, New Haven, CT, USA

A. A. Patel
Departments of Orthopaedic Surgery and Neurosurgery,
University of Utah, Salt Lake City, UT, USA

A. R. Vaccaro (✉)
Departments of Orthopaedic Surgery and Neurological Surgery,
Thomas Jefferson University and The Rothman Institute, 925
Chestnut Street, 5th Floor, Philadelphia, PA 19107, USA
e-mail: alexvaccaro3@aol.com

Introduction

Injuries to the spinal column are common, with more than 150,000 incidents reported in North America alone each year [11, 12]. Given its considerable mobility and its close proximity to the more rigid thoracic region, the subaxial cervical spine is particularly susceptible to traumatic disruption, which may often be accompanied by catastrophic neurologic insults as well. Injuries localizing to the subaxial cervical spine encompass a disparate collection of conditions ranging from ligamentous strains to fracture-dislocations, all of which may exhibit various degrees of

instability. Not surprisingly, there continues to be a lack of consensus regarding the ideal method for classifying subaxial cervical spine trauma.

Drawing from his experiences treating more than 2000 trauma patients, Sir Frank Holdsworth [9] published the seminal paradigm for categorizing spinal injuries in 1970, which was predicated upon the presumed mechanism of injury. Although this system did not differentiate between cervical conditions and those affecting the thoracolumbar spine, Holdsworth was the first to emphasize the importance of the posterior ligamentous complex for maintaining spinal stability. Allen et al. [1] subsequently proposed their mechanistic classification scheme for subaxial injuries, which was also based upon the findings of plain radiographs. According to their model, each group in this series was assigned a different numerical value, which supposedly reflected progressive instability of the spinal column. This approach was further modified by Harris et al. [8] who took into account the rotational vectors of the forces applied to the spine.

In these attempts to characterize subaxial trauma no single system has gained widespread acceptance. These systems share similar limitations. For example, these protocols require clinicians to retrospectively reconstruct the mechanism of injury suggested by plain radiographs, a process that is largely dependent upon subjective inferences rather than objective findings. By employing ill-defined descriptive terminology to segregate diverse fracture patterns into a wide range of arbitrary categories, these systems have proven to be cumbersome and impractical to use, contributing to their suboptimal validity and reproducibility [17]. Furthermore, none of these paradigms include other critical factors that influence spinal stability such as the status of the ligamentous structures evident on MRI studies or the neurologic status of the individual. As a result of these deficiencies, the classification of subaxial cervical spine injuries remains inconsistent between different institutions and practitioners alike. The lack of an accepted classification system adds complexity to the diagnosis and management of injured patients, which hampers scientific investigations and makes it more challenging to educate medical practitioners.

In an effort to address the limitations of these preceding systems, the Spine Trauma Study Group (STSG) sought to develop a better method for assessing subaxial cervical injuries. This international organization is comprised of nearly 50 orthopaedic and neurologic surgeons renowned as leaders in the field of spinal trauma. In 2007, the members of the STSG introduced a novel algorithm for categorizing subaxial cervical spine trauma using several critical clinical and radiographic parameters derived from a thorough review of the literature, expert opinion, and their experiences devising a similar scheme for thoracolumbar injuries [3, 18]. Designated as the Subaxial Injury

Classification (SLIC) and Severity Scale, this paradigm was intended to enhance clinical care by standardizing the manner in which these injuries are described and providing prognostic information that may assist in the selection of the most appropriate therapeutic approach.

The SLIC model represents a substantial improvement over preexisting systems as it incorporates many objective characteristics such as fracture morphology, the integrity of the supporting soft tissue structures, advanced imaging modalities, spinal alignment, and neurologic function. Collectively, these criteria may more accurately convey the severity of a specific traumatic condition than an inferred mechanism of injury. Since it only utilizes a comparatively small number of anatomic descriptors, this scheme is reasonably easy to integrate into clinical practice but is sufficiently comprehensive so that atypical or more complex injury patterns are not excluded. Finally, the SLIC protocol facilitates communication between practitioners by creating a common nomenclature for stratifying these injuries. By doing so, it may function as a vital tool for completing prospective research studies and enhance the training of medical professionals.

The primary purposes of this investigation are to (1) review the various components of the SLIC system (morphology, integrity of the discoligamentous complex, and neurologic status); (2) demonstrate the application of this scoring protocol to a range of subaxial cervical spine injuries based on their severity including the presentation of relevant case examples; (3) review the existing data comparing the levels of agreement exhibited by practitioners using the SLIC scheme to those associated with conventional classification systems; (4) discuss the current limitations and ongoing development of the SLIC paradigm.

The SLIC Scoring System

The SLIC scoring system focuses on three essential variables that have previously been recognized as major independent predictors of prognosis following thoracolumbar trauma: (1) injury morphology; (2) status of the discoligamentous complex (DLC); and (3) neurologic examination; each of these components consists of additional subtypes graded according to their relative severity. This scale also records secondary features of the injury, including anatomic level, location of fractures, and other confounding factors (Table 1).

Morphology

Injury morphology is elucidated from the pattern of disruption exhibited by the spinal column on radiographic

Table 1. Classification of injuries involving the subaxial cervical spine using the SLIC algorithm (Reprinted with permission of Wolters Kluwer Health from Vaccaro AR, Hulbert RJ, Patel AA, Fisher C, Dvorak M, Lehman RA Jr, Anderson P, Harrop J, Oner FC, Arnold P, Fehlings M, Hedlund R, Madrazo I, Rechtine G, Aarabi B, Shainline M; Spine Trauma Study Group. The subaxial cervical spine injury classification system: a novel approach to recognize the importance of morphology, neurology, and integrity of the disco-ligamentous complex. *Spine*. 2007;32:2365–2374.)

Subcategory	Descriptor
1	Spinal level
2	Morphology (Table 2)
3	Description of bony injury
4	Integrity of discoligamentous complex with descriptors (Table 2)
5	Neurologic status (Table 2)
6	Confounding features

SLIC = Subaxial Injury Classification.

studies, which is defined by the structural relationships of the vertebral bodies with respect to neighboring segments and a detailed evaluation of the soft tissues, facet joints, and global alignment. Using a complete array of radiographic imaging techniques such as plain radiographs, CT, and MRI, injury morphology is subdivided into three groups: compression, distraction, and rotation/translation.

Compression is exemplified by visible loss of height through a portion (eg, the endplate) or the entire vertebra observed with standard compression and burst fractures, as well as those that propagate through the anterior column in the sagittal or coronal planes; flexion-compression or so-called “teardrop” injuries are also placed in this morphologic class. Concurrent fractures of the posterior elements may occur with more evenly distributed axial loads [2, 16]; likewise, lateral compressive forces may produce injuries involving the facet joints or lateral masses [1, 2], which are still assigned to this subcategory unless there is obvious intersegmental translation noted on imaging studies.

Distraction injuries are less common than compressive lesions [2, 8, 9] and are distinguished by dissociation of the spinal column in the vertical axis. Because of the substantial forces required to overcome the extensive capsular and bony constraints of the facet articulations in flexion and the strong tensile properties of the anterior column in extension, any failure in distraction is usually indicative of more substantial trauma and greater instability of the spine [1, 2]. In most cases, a distractive mechanism of injury will also compromise the discoligamentous tissues and zygoapophyseal joints. In addition to facet subluxations or dislocations without fractures or rotation/translation, hyperextension injuries that give rise to a rift within the anterior longitudinal ligament, widening of the disk space, or posterior element fractures are also included in this

group. In the absence of any clear signs of distractive pathology (eg, frank dislocation or increase in the interspinous distance), MRI may be more sensitive for detecting subtle signs of injury to the DLC and the facet joints [6, 7, 10], which are the most important posterior structures responsible for maintaining spinal stability [15].

Rotation/translation entails the horizontal displacement of part of the subaxial spine with respect to another as demonstrated on either static or dynamic images that exceeds normal physiologic ranges; according to published data, the conventional threshold for rotational stability is a relative angulation of 11° and that for translational stability is less than 3.5 mm [20]. Examples of rotation/translation injuries are facet fracture-dislocations (unilateral or bilateral), “floating” lateral masses with vertebral subluxation, bilateral pedicle fractures resulting in a traumatic spondylolisthesis, and “teardrop” fractures of the body that extend into the posterior elements. Because these injuries imply both the anterior and posterior columns have been damaged, rotation/translation is considered the most severe of the three morphology patterns [19].

Integrity of the DLC

The DLC includes the myriad soft tissue structures that span each motion segment such as the anterior and posterior longitudinal ligaments, ligamentum flavum, interspinous and supraspinous ligaments, intervertebral disk, and facet capsules. Collectively, these anatomic restraints serve to withstand traumatic deformation while allowing normal movement of the subaxial cervical spine. Since the stability of the spinal column is intimately dependent upon the condition of the DLC, obtaining an accurate assessment of its competence is imperative for identifying the most suitable treatment for a particular injury. The integrity of the DLC is often ascertained indirectly by evaluating radiographic images for the presence of bony abnormalities, which may be visualized as widening of the disk space or interspinous distance, subluxation/dislocation of the facet joints (ie, articular apposition < 50% or diastasis > 2 mm), spondylolisthesis of the vertebral bodies, or a kyphotic deformity [2, 17, 20]. As such, distraction and rotation/translation morphologies are nearly always associated with some degree of DLC impairment. In some cases, there may be no signs of disruption or malalignment apparent on plain radiographs or CT, but T2-weighted MRI sequences may display high-intensity signal traversing the disc space or ligaments suggesting an injury to the DLC [7]. The importance of these isolated intrasubstance irregularities remains a matter of some debate because in this setting the resultant instability of the subaxial cervical spine cannot be quantified

any further at this time. Furthermore, the sensitivity and specificity of MRI for identifying injuries to the intervertebral disc and other ligamentous structures of the cervical spine are less than optimal when correlated with intraoperative findings [13]. Therefore, the SLIC system classifies any DLC pathology that is only evident on MRI studies as being “indeterminate” until sufficient data are available that may more definitively establish their clinical relevance.

Neurologic Status

The neurologic examination of a patient who has sustained trauma to the subaxial region reflects the severity of the injury to a large degree because any substantial deficits imply that the spinal column has been subjected to forces large enough to destabilize the rigid osteoligamentous arch that protects the neural elements. As such, the neurologic status is an influential factor that often impacts the operative decision-making process because some form of surgical intervention is routinely recommended for individuals with incomplete injuries whose cross-sectional imaging reveals persistent compression of either the spinal cord or nerve roots. It should be pointed out that there is still no Level 1 evidence confirming that these types of operations improve the degree of neurologic recovery [5]. Nevertheless, a prospective, multicenter cohort investigation (Surgical Treatment for Acute Spinal Cord Injury Study, STASCIS) designed to assess the effects of early decompression on the long-term neurologic recovery of patients with cervical trauma and concomitant spinal cord injuries is currently underway which will hopefully serve to elucidate the benefits of operative management relative to other treatment regimens [14].

It may be difficult to detect more subtle findings such as radicular deficits in patients who are obtunded, sedated, or distracted by other associated injuries. In these instances, the neurologic status should be considered “indeterminate” and a value is not able to be assigned to this category until the patient is fully responsive and can cooperate with the physical examination. At this point, the fracture may be more appropriately assessed and the total score may be used to guide subsequent management according to this protocol.

SLIC Scoring Protocol

With the SLIC algorithm, a traumatic lesion of the subaxial cervical spine is classified using the three major variables (ie, morphology, integrity of the DLC, neurologic status) and several other descriptive terms (Table 1). For each of the primary categories, the injury is graded according to its

Table 2. Scoring protocol for the SLIC algorithm (Reprinted with permission of Wolters Kluwer Health from Vaccaro AR, Hulbert RJ, Patel AA, Fisher C, Dvorak M, Lehman RA Jr, Anderson P, Harrop J, Oner FC, Arnold P, Fehlings M, Hedlund R, Madrazo I, Rechtine G, Aarabi B, Shainline M; Spine Trauma Study Group. The subaxial cervical spine injury classification system: a novel approach to recognize the importance of morphology, neurology, and integrity of the disco-ligamentous complex. *Spine*. 2007;32:2365–2374.)

Subcategory	Points
Morphology	
No abnormality	0
Compression	1
Burst	+1 (2)
Distraction	3
Rotation/translation	4
Integrity of the discoligamentous complex	
Intact	0
Indeterminate	1
Disrupted	2
Neurologic status	
Intact	0
Root injury	1
Complete spinal cord injury	2
Incomplete spinal cord injury	3
Continuous cord compression in setting of neurologic deficit	+1

SLIC = Subaxial Injury Classification.

For each of these primary categories, an injury is graded according to its severity. These three values are added together to generate a total score that may be useful for guiding subsequent treatment; specifically, a value of 4 has been proposed as the threshold for surgery (≤ 3 , nonoperative management; ≥ 5 , realignment/stabilization with decompression if warranted; 4, equivocal).

severity such that the patterns that yield poorer outcomes or necessitate operative care are assigned more points (Table 2). These three sets of numbers are summed to generate an overall score which may be useful for guiding the treatment of these patients; specifically, a value of 4 has been proposed as the threshold for surgery (≤ 3 , nonoperative management; ≥ 5 , realignment/stabilization with decompression if warranted; 4, equivocal). In an initial assessment of this scoring protocol completed by the Spine Trauma Study Group, raters agreed with the treatment recommendation advocated by the SLIC scale in 91.8% of cases [17]. Besides differentiating between injuries that may be best managed with or without an operation, this total may also provide information that may be helpful for resolving which surgical approach is most appropriate [4]. Nevertheless, it is important to emphasize that the current data supporting the use of this numerical score as a method for determining the optimal treatment or type of surgical approach represents Level 4 evidence and there continues

to be a paucity of prospective, randomized, controlled studies addressing the utility of the SLIC system.

The injury classification is further modified by appending supplementary terms to acknowledge fractures or dislocations of various osseous structures, including the endplates, pedicles, transverse processes, facet joints, articular processes, laminae, lateral masses, and spinous processes. Any confounding pathologic conditions that may conceivably alter the manner in which a particular injury is addressed is also documented, such as ankylosing spondylitis, diffuse idiopathic skeletal hyperostosis, osteoporosis, advanced spondylosis, or a history of previous cervical spine surgery.

When several levels of the subaxial cervical spine are damaged, the affected vertebrae are considered independently and separate SLIC values are calculated for each injury, which are not added together. Conversely, a spinal segment that exhibits multiple injury patterns should only be assessed for its most severe characteristics in terms of morphology, DLC, and neurologic status; the more benign features may be referred to using other descriptors but are not incorporated into the final score because they are likely to have little bearing on prognosis or the type of treatment that is ultimately implemented.

Reliability and Validity of the SLIC Algorithm

Before any classification scheme may be accepted into clinical practice, it must be scrutinized to ensure it is both reproducible and capable of achieving all of its intended goals. In a recent multicenter investigation, the reliability and validity of the SLIC paradigm were quantified and compared to those associated with other existing systems for categorizing subaxial cervical spine trauma [17]. According to this analysis, the intraclass correlation coefficients (ICC) for the three principal components, total injury severity score, and management recommendations ranged from as low as 0.49 for competence of the DLC to as high as 0.90 for neurologic status. In this same study, the experts of the STSG concurred with the therapeutic strategy (ie, operative versus nonoperative management) advocated by the SLIC system in more than 90% of cases. While relatively high levels of agreement are not the only criteria used to determine the utility of a classification scheme, the overall reliability of the SLIC scheme appears to be at least as good as that exemplified by the systems of Allen et al. [1] and Harris et al. [8] for classifying injuries of the subaxial cervical spine (ICC of 0.53 and 0.41, respectively). The reproducibility of the SLIC paradigm may continue to improve as surgeons become more familiar with its organization and gain more experience applying this model to injuries they encounter in clinical practice.

Case Examples

Case 1

A 32-year-old man presented with isolated axial neck pain after a 10-foot fall off scaffolding at a construction site. The patient complained of some tenderness to palpation over his posterior cervical spine and reported some discomfort with ROM of his neck, but he was otherwise neurologically intact. Imaging studies revealed fractures of the C4 vertebral body and left lamina but no substantial retropulsion of cortical fragments or any evidence of damage to the DLC (Fig. 1). Using the SLIC scale, this injury is classified as a C4 burst fracture (1 + 1 points) with involvement of the left lamina and an intact DLC (0 points) in a patient with no neurologic deficits (0 points), giving rise to a total score of 2 points.

Case 2

A 57-year-old female driver was evaluated for cervical symptoms as a result of a motor vehicle collision. Aside from neck pain radiating to her left shoulder, the patient was not noted to have any obvious sensory changes or motor weakness. A CT scan demonstrated a unilateral, left-sided C3–C4 facet dislocation with an associated lamina fracture and approximately 7 mm of listhesis; a subsequent MRI displayed subtle signal changes within the C3–C4 disc space and posterior soft tissues but no substantial central or foraminal stenosis (Fig. 2). According to the SLIC protocol, this individual's condition is described as a C3–C4 rotation/translation injury (4 points) with a left lamina fracture and an indeterminate DLC (1 point) with no compression of the spinal cord or nerve roots (0 points) which yielded a total score of 5 points.

Case 3

A 46-year-old man sustained trauma to his cervical spine after being struck by an automobile while crossing the street. On physical examination, the patient did not exhibit any meaningful motor or sensory function below the level of his shoulders, which was considered consistent with a complete spinal cord injury (ie, ASIA A). CT and MRI modalities confirmed the diagnosis of a C5 flexion “tear-drop” injury with fractures of his left lamina and right inferior articular facet, an obvious defect in the posterior ligamentous structures, and considerable impingement on the spinal cord (Fig. 3). The SLIC paradigm defines this traumatic pathology as a rotation/translation injury (4 points) with multiple fractures of the posterior elements,

Fig. 1A–D (A) Sagittal, (B) coronal, and (C) axial CT images of the cervical spine demonstrate a C4 burst fracture (D) with involvement of the left lamina with no disruption of the DLC evident or retropulsion of bony fragments evident on T2-weighted MRI.

clear disruption of the DLC (2 points), and a complete spinal cord injury with ongoing compression (2 + 1 points); based on these criteria, the patient was assigned a total score of 9 points.

Discussion

Fractures or dislocations localizing to the subaxial cervical spine may subject patients to substantial morbidity and give rise to any number of catastrophic consequences including neurologic deterioration or even death. As a result, it is essential that these injuries be diagnosed in an accurate and expedient fashion so the appropriate treatment strategies may be implemented. While multiple classification systems have previously been introduced, none of these protocols have proven ideal for stratifying subaxial cervical trauma because they utilize vague terminology, require

practitioners to retrospectively recreate the injury mechanism, and fail to consider other essential variables that may contribute to the stability of the spinal column. The Spine Trauma Study group recently elaborated the Subaxial Injury Classification (SLIC) scale which is designed to overcome the shortcomings of these other schemes and provide a more clinically relevant framework for approaching these types of traumatic conditions. The purpose of this review was to describe the different elements of the SLIC paradigm and demonstrate how they are employed to generate a numerical value for a particular fracture that may be useful for assessing the severity of this injury based upon its overall stability. In addition to presenting the findings of a preliminary analysis comparing the levels of agreement calculated for the SLIC method to those of other systems, we also reported the apparent limitations of this scheme which may hopefully be addressed over time by incorporating further changes to its structure and organization.

Fig. 2A–D (A) Sagittal, (B) left parasagittal, and (C) axial CT images reveal a left-sided C3–C4 facet dislocation with an associated lamina fracture and approximately 7 mm of listhesis. (D) T2-weighted MRI displays subtle signal changes within the C3–C4 disc space and posterior ligamentous structures without any substantial impingement of the neural elements.

Despite its promise as a novel classification system for subaxial cervical spine trauma, there are still certain limitations to the SLIC model. First, the components comprising the SLIC score are still susceptible to variations in individual interpretations. These variations are most problematic when grading the integrity of the DLC [13, 17], a deficiency reflected by its ICC of 0.49, which is the lowest of the three primary categories. The challenges associated with evaluating the status of the DLC are likely related to the tremendous sensitivity of MRI for detecting abnormalities within these soft tissue structures. Second, the clinical implications of these signal changes in the absence of any obvious signs of bony or ligamentous disruption on plain radiographs or CT images remain unknown. For this reason, in these situations the STSG committee that originally developed this system recommends that the DLC should be designated as being “indeterminate” to avoid assigning too much importance to these MRI findings [17]; nevertheless, further investigations imparting a more thorough understanding of the DLC should only enhance the utility of the SLIC scheme for classifying injuries of the subaxial cervical spine.

Perhaps most importantly, although the SLIC protocol addresses many of the inadequacies inherent to previous methods for stratifying subaxial cervical spine trauma, the clinical relevance of this scoring scale must still be definitively established through additional prospective studies to corroborate its diagnostic reliability and evaluate its prognostic capacity.

In many instances, the optimal method of treatment for injuries of the subaxial cervical spine is still controversial and the decision-making process is limited by the lack of a prevailing classification scheme and standardized nomenclature. A majority of previous research endeavors have proven overly dependent upon local biases and subjective judgments because of a lack of consistent techniques for categorizing subaxial cervical spine injuries. The SLIC scoring protocol represents a reproducible and valid system that not only facilitates the assessment of this pathology but also has the potential to guide medical decision making. While the SLIC score in its present form conveys whether a certain injury may be stable enough for nonoperative measures or necessitates surgical intervention, it has been suggested that this system may also be useful for

Fig. 3A–C (A) Sagittal and (B) axial CT images depict a C5 flexion “teardrop” injury with fractures of the left lamina and right inferior articular facet. (C) T2-weighted MRI confirmed the presence of an obvious defect in the DLC with ongoing compression of the spinal cord.

preoperative planning as well [4]. The STSG recently translated the objective criteria incorporated by the SLIC protocol into an evidence-based algorithm intended to determine the most effective surgical approach (ie, anterior, posterior, or circumferential) for a given subaxial cervical spine injury [3]. Thus, the information derived from the SLIC paradigm may assist practitioners as they attempt to answer two fundamental questions: whether an operation is required, and if so, which techniques should be employed.

In the future, it is anticipated that the SLIC system may also serve as the basis for developing evidence-based treatment algorithms directing the management of these injuries. By utilizing such a treatment protocol, any wide variations in the treatment of subaxial trauma should be diminished. This standardization may not only improve patient outcomes but also promote medical education and facilitate multicenter research in this field.

Acknowledgments We thank the other members of the Spine Trauma Study Group for their previous contributions to the development of this classification system.

References

1. Allen BL Jr, Ferguson RL, Lehmann T. A mechanistic classification of closed, indirect fractures and dislocations of the lower cervical spine. *Spine (Phila Pa 1976)*. 1982;7:1–27.
2. Bono CM, Carreras E. Cervical spine fractures and dislocations. In: Bucholz RW, Heckman JD, Court-Brown CM, Tornetta P, eds. *Rockwood and Green's Fractures in Adults*. 7th Ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2009:1312–1376.
3. Bono CM, Vaccaro AR, Fehlings M, Fisher C, Dvorak M, Ludwig S, Harrop J. Measurement techniques for lower cervical spine injuries: consensus statement of the Spine Trauma Study Group. *Spine (Phila Pa 1976)*. 2006;31:603–609.
4. Dvorak MF, Fisher CG, Fehlings MG, Rampersaud R, Oner FC, Aarabi B, Vaccaro AR. The surgical approach to subaxial cervical spine injuries: an evidence-based algorithm based on the SLIC classification system. *Spine (Phila Pa 1976)*. 2007;32:2620–2629.
5. Fehlings MG, Perrin RG. The timing of surgical intervention in the treatment of spinal cord injury: a systematic review of recent clinical evidence. *Spine (Phila Pa 1976)*. 2006;31:S28–S35.
6. Goldberg AL, Rothfus WE, Deeb ZL, Daffner RH, Lupetin AR, Wilberger JE, Prostko ER. The impact of magnetic resonance on the diagnostic evaluation of acute cervicothoracic spinal trauma. *Skeletal Radiol*. 1988;17:89–95.
7. Halliday AL, Henderson BR, Hart BL, Benzel EC. The management of unilateral lateral mass/facet fractures of the subaxial cervical spine: the use of magnetic resonance imaging to predict instability. *Spine (Phila Pa 1976)*. 1997;22:2614–2621.
8. Harris JH, Edeiken-Monroe B, Kopaniky DR. A practical classification of acute cervical spine injuries. *Orthop Clin North Am*. 1986;1:15–30.
9. Holdsworth F. Fractures, dislocations, and fracture-dislocations of the spine. *J Bone Joint Surg Am*. 1970;52:1534–1551.
10. Katzberg RW, Benedetti PF, Drake CM, Ivanovic M, Levine RA, Beatty CS, Nemzek WR, McFall RA, Ontell FK, Bishop DM,

- Poirier VC, Chong BW. Acute cervical spine injuries: prospective MR imaging assessment at a level 1 trauma center. *Radiology*. 1999;213:203–212.
11. Kwon BK, Vaccaro AR, Grauer JN, Fisher CG, Dvorak MF. Subaxial cervical spine trauma. *J Am Acad Orthop Surg*. 2006;14:78–89.
 12. Lowery DW, Wald MM, Browne BJ, Tigges, S, Hoffman JR, Mower WR; NEXUS Group. Epidemiology of cervical spine injury victims. *Ann Emerg Med*. 2001;38:12–16.
 13. Malham GM, Ackland HM, Varma DK, Williamson OD. Traumatic cervical discoligamentous injuries: correlation of magnetic resonance imaging and operative findings. *Spine (Phila Pa 1976)*. 2009;34:2754–2759.
 14. Ng WP, Fehlings MG, Cuddy B, Dickman C, Fazl M, Green B, Hitchon P, Northrup B, Sonntag V, Wagner F, Tator CH. Surgical treatment for acute spinal cord injury pilot study #2: evaluation of protocol for decompressive surgery within 8 hours of injury. *Neurosurg Focus*. 1999;6:e3.
 15. Pitzen T, Lane C, Goertzen D, Dvorak M, Fisher C, Barbier D, Steudel WI, Oxland T. Anterior cervical plate fixation: biomechanical effectiveness as a function of posterior element injury. *J Neurosurg*. 2003;99(Suppl 1):84–90.
 16. Torg JS, Pavlov H, O'Neill MJ, Nichols CE Jr, Sennett B. The axial load teardrop fracture. A biomechanical, clinical, and roentgenographic analysis. *Am J Sports Med*. 1991;19:355–364.
 17. Vaccaro AR, Hurlbert RJ, Patel AA, Fisher C, Dvorak M, Lehman RA Jr, Anderson P, Harrop J, Oner FC, Arnold P, Fehlings M, Hedlund R, Madrazo I, Rechtine G, Aarabi B, Shainline; Spine Trauma Study Group. The subaxial cervical spine injury classification system: a novel approach to recognize the importance of morphology, neurology, and integrity of the disco-ligamentous complex. *Spine (Phila Pa 1976)*. 2007;32:2365–2374.
 18. Vaccaro AR, Lehman RA Jr, Hurlbert RJ, Anderson PA, Harris M, Hedlund R, Harrop J, Dvorak M, Wood K, Fehlings MG, Fisher C, Zeiller SC, Anderson DG, Bono CM, Stock GH, Brown AK, Kuklo T, Oner FC. A new classification of thoracolumbar injuries: the importance of injury morphology, the integrity of the posterior ligamentous complex, and neurologic status. *Spine (Phila Pa 1976)*. 2005;20:2325–2333.
 19. Vaccaro AR, Madigan L, Schweitzer ME, Flanders AE, Hilibrand AS, Albert TJ. Magnetic resonance imaging analysis of soft tissue disruption after flexion-distraction injuries of the subaxial cervical spine. *Spine (Phila Pa 1976)*. 2001;26:1866–1872.
 20. White AA III, Panjabi MM. Update on the evaluation of instability of the lower cervical spine. *Instr Course Lect*. 1987;36:513–520.