Cervical Spine Injury: A Clinical Decision Rule to Identify High-Risk Patients for Helical CT Screening

Julian A. Hanson[1]
C. Craig Blackmore[1,2]
Frederick A. Mann[1]
Anthony J. Wilson[1]

OBJECTIVE. We aimed to validate the routine use of a clinical decision rule to direct diagnostic imaging of adult blunt trauma patients at high risk for cervical spine injury.

MATERIALS AND METHODS. We previously developed and have since routinely used a prediction rule based on six clinical parameters to identify patients at greater than 5% risk of cervical spine injury to undergo screening helical CT of the cervical spine. During a 6-month period, 4285 screening imaging studies of the cervical spine were performed in adult blunt trauma patients. Six hundred one patients (398 males, 203 females; age range, 16–100 years; median age, 38 years) underwent helical CT, and the remainder underwent 3684 conventional radiographic examinations. Clinical and report data were extracted from the radiology department database, medical records, and the hospital trauma registry. Abnormal findings were independently confirmed by additional imaging studies, autopsy results, or clinical outcome.

RESULTS. The true-positive cervical spine injury rates in helical CT– and conventional radiography-screened patients who presented directly to our trauma center were 40 (8.7%) of 462 and seven (0.2%) of 3684, respectively. The cervical spine injury rate in patients who were transferred from outside institutions to our trauma center and who underwent helical CT was 37 (26.6%) of 139. This figure included 20 patients already known to have cervical spine fracture.

CONCLUSION. The clinical decision rule can distinguish patients at high and low risk of cervical spine injury, thus supporting its validity.

Spinal cord injury and paralysis are important health burdens in the United States, with an annual incidence of 40 per 1 million population. Most cases are caused by blunt force cervical spine trauma [1, 2]. Radiography, despite its recognized limitations [3], is the standard imaging technique for screening patients for suspected neck injury that may be clinically occult. A minimum standard examination comprises a lateral radiograph that completely shows C7 and anteroposterior and open-mouth odontoid views [4]. Recent interest has been shown in the technique of helical CT to screen for cervical spine injury [5]. Advantages of helical CT over radiography may include improved accuracy and faster diagnosis [6]. However, helical CT of the cervical spine is more expensive than conventional radiography, carries a higher radiation dose, and may be warranted only in high-risk patients. Recent work from our institution, using decision-tree analysis modeling and considering all long-term costs and outcomes, has shown that screening helical CT can be more cost-effective than conventional radiography, provided that contemporaneous head CT is performed and that the probability of cervical spine fracture in the screened population exceeds approximately 5% [7]. Thus, the optimal imaging strategy for a particular patient will depend on that individual's probability of injury.

Unfortunately, reliable predictors of cervical spine injury have proven difficult to identify, although several authors have proposed methods for stratifying patients into broad categories of risk [3, 8, 9]. We developed a clinical decision rule (Appendix), based on published and retrospective local institutional data, that was designed to select adult patients with blunt trauma who are at greater than 5% risk for cervical spine fracture to undergo screening helical CT [10]. Guidelines

Received July 2, 1999; accepted after revision August 31, 1999.

[1]Department of Radiology, Harborview Medical Center, University of Washington School of Medicine, 325 Ninth Ave, Seattle, WA 98104. Address correspondence to C. C. Blackmore.

[2]Department of Radiology, University of North Carolina, Manning Dr., Chapel Hill, NC 27599.

AJR 2000;174:713–717

0361–803X/00/1743–713

for clinical prediction rules call for their validation on study populations other than those from which they were derived [11, 12].

The objective of this study was to test whether clinical predictors of injury can be used to select high-risk patients for imaging. We evaluated a strategy of using a clinical decision rule to stratify patients to undergo either helical CT or conventional radiography for cervical spine screening. In this study we determined the yield (true-positive rate) for cervical spine injury for patients selected for helical CT and for those selected for radiography. In so doing, we validated the clinical decision rule.

Materials and Methods

In July 1997, we introduced a policy of using helical CT as the primary cervical spine imaging technique for high-risk adult blunt trauma patients. Screening helical CT of the cervical spine was to be performed only in combination with head CT and was to be preceded by emergent cross-table lateral cervical spine radiography performed in the resuscitation area. Patients were required to fulfill at least one of the six criteria that constituted the clinical decision rule (Appendix). The selection of these six clinical parameters was based on prior studies and local observations [10]. The parameters were chosen for being readily available to the clinician at the time of initial patient assessment. The requirement to undergo contemporaneous head CT was a condition of our previous cost-effectiveness analysis [7].

In the 6-month period from January 1 through June 30, 1998, 4285 adult trauma patients who presented to our high-volume urban trauma center underwent an imaging screening study of the cervical spine. Indications for cervical spine imaging are based on the injury mechanism and include all motor vehicle, pedestrian, and other traffic accidents; falls; and serious assaults. Six hundred one of these 4285 patients (398 males, 203 females; age range 16–100 years; median age, 38) underwent helical CT of the cervical spine. Once we established our imaging policy and high-risk criteria, the ultimate choice of imaging technique was at the discretion of the clinical trauma service. In the helical CT group, the median patient Injury Severity Score was 15, with a range of 1–75 (data available in 530 [88%] of 601 cases). The Injury Severity Score is a summary statistic for grading anatomic severity of injury and predicting outcome for polytrauma patients. Individual injuries are given a score of 1 (minor) to 6 (lethal) on the basis of tables from the International Classification of Diseases [13]. The Injury Severity Score is the sum of the squares of the three highest injury scores for the face, head and neck, chest, abdomen and pelvic contents, extremities and pelvic girdle, and integument.

The screening helical CT technique involved 3-mm collimation helical scanning at a pitch of 1.5 from T4 to the occiput, performed in two acquisitions (Fig. 1A). The upper thoracic region was included in the scanning protocol to visualize this frequently obscured zone and thus to hasten radiographic spine clearance. Peak kilovoltages of 140 and 120 with milliampere-seconds of 280 and 170 were used for the upper thoracic and cervical spine segments, respectively. Axial images were reconstructed with the bone algorithm at 1.5-mm intervals with sagittal (Fig. 1B) and coronal reformations. Reporting was based on alternate images recorded on hard-copy film, with the full set of images available for review at a workstation when necessary.

Report data were obtained from the radiology department database (IDXrad Radiology Information System; IDX Systems, Burlington, VT). Scan findings were classified into four groups on the basis of original reports: definite or possible cervical spine fracture or ligament injury; other fractures involving the upper thoracic spine, proximal ribs, mandible, or skull base; no acute traumatic abnormalities; and technically inadequate. CT criteria used to suggest possible ligamentous injury were based on sagittal and coronal reformations and included abnormal widening of articulations at the craniocervical junction, focal kyphosis with splaying of spinolaminar distances, and widening or subluxation of facet joints. Contemporaneous cervical spine and cranial CT imaging studies were identified.

Definite or possible cervical spine injuries were independently confirmed using a combination of additional imaging (dedicated axial 1-mm collimation CT, cervical spine MR imaging, or supplementary conventional radiography), surgical findings, or postmortem results. Possible ligamentous injuries were refuted in alert patients by results of flexion and extension radiographs and normal clinical examination. Patients with obtusion underwent MR imaging.

Patients' clinical data were extracted from the hospital trauma registry (a general database of all hospital trauma admissions), the regional spine trauma database (maintained jointly by the departments of neurosurgery, orthopedics, and rehabilitation medicine, and covering local admissions and regional referrals), and the medical record database (an on-line compilation of patient data including transcripts of discharge summaries and outpatient notes). In each case the appropriateness of cervical spine screening CT was retrospectively assessed from information contained in the discharge summary and outpatient records; unless fulfillment of at least one of the decision rule parameters was recorded, it was assumed that the patient had not satisfied screening CT criteria. One hundred thirty-nine (23%) of 601 patients who were transferred to our trauma center from outside institutions underwent helical CT and were analyzed as a separate group.

Results

Four hundred sixty-two (77%) of 601 patients presented directly to our trauma center and underwent screening helical CT, with a true-positive yield for cervical spine injury of 40 (9%) of 462 (Fig. 2). Thirty-seven (93%) of these 40 injuries were fractures. After exclusion of patients with isolated transverse and spinous process fractures ($n = 10$), the screening injury yield was 30 (7%) of 462. One hundred seven (23%) of the 462 patients were retrospectively judged not to fulfill criteria for screening helical CT, either because a full conventional radiography cervical spine series had been initially performed, the patient had not undergone contemporaneous cranial CT, or the trauma mechanism did not meet the clinical decision rule specifications. In the remaining 355 of 462 patients, the true-positive injury detection rate was 35 (10%) of 355 (Fig. 2).

One hundred thirty-nine (23%) of 601 patients were transferred to our trauma center from outside institutions and underwent screening CT. In 20 patients already known to have a fracture, helical CT evaluation of the complete cervical spine revealed an additional 12 fractures or dislocations in nine cases (45%). All but one of these additional fractures occurred at levels contiguous with the known injury. Cervical fractures were detected in 17 (14%) of the remaining 119 transferred patients.

Thus, of the 84 patients in whom a cervical spine injury was confirmed, 57 (68%) were diagnosed on screening helical CT and seven (8%) on conventional radiographs, and 20 (24%) were initially identified from prior imaging at referring hospitals. The overall true-positive detection rates for cervical spine injury in helical CT– and radiography-screened patients were 77 (13%) of 601 and seven (0.2%) of 3684, respectively (Fig. 2). The most common abnormalities identified on helical CT were fractures or subluxations involving the C3–C7 pedicles, facets, or laminae (Table 1).

Furthermore, 54 (9%) of 601 patients were found to have fractures of the upper thoracic spine, proximal ribs, mandible, or skull base (Table 2). Eleven (2%) of 601 patients had fractures of the upper thoracic vertebrae, seven of which involved the body or bony neural arch.

Discussion

Little published data exist on helical screening CT of the complete cervical spine. Its use was first described in 1994 by Nunez et al. [6], who reported the results of screening cervical spine CT in 800 high-risk blunt trauma patients (defined as those with a revised trauma score of 3 or less who required CT evaluation as part of the initial trauma im-

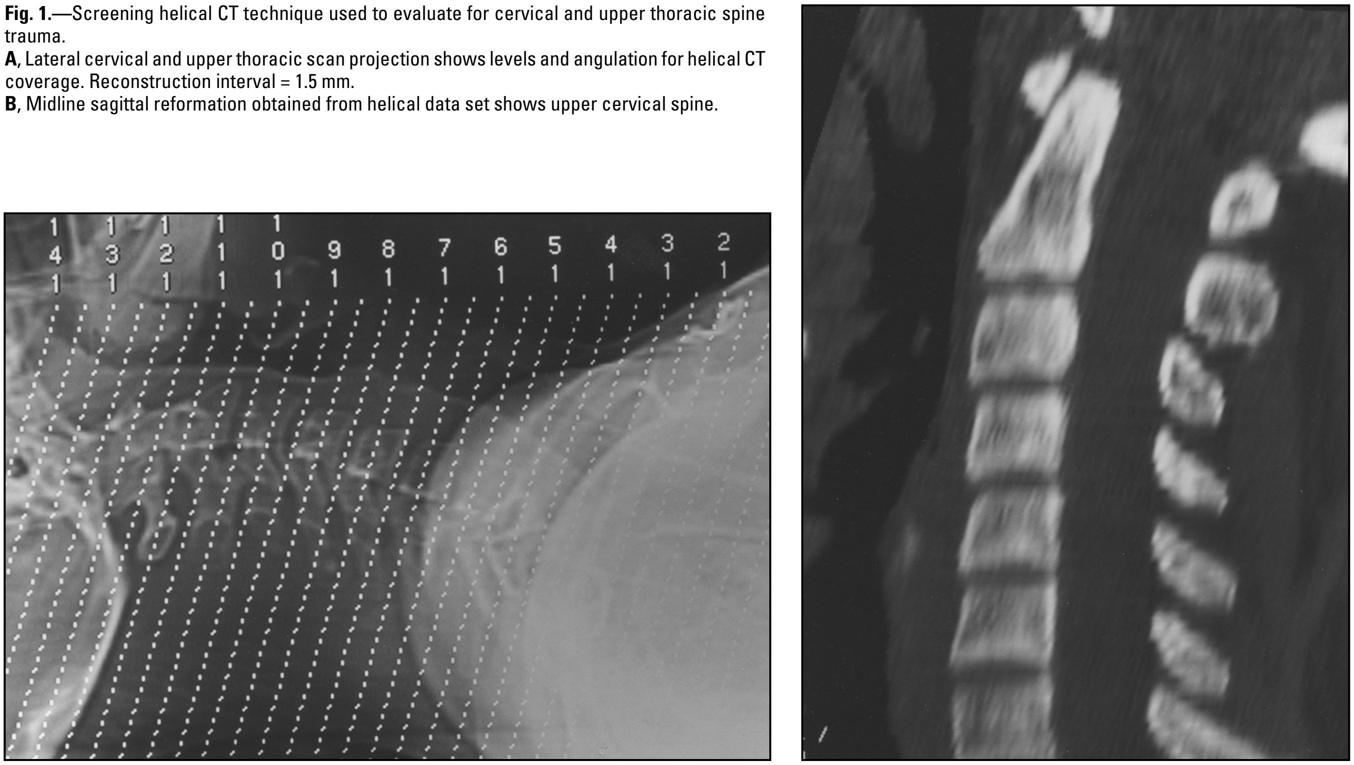

Fig. 1.—Screening helical CT technique used to evaluate for cervical and upper thoracic spine trauma.
A, Lateral cervical and upper thoracic scan projection shows levels and angulation for helical CT coverage. Reconstruction interval = 1.5 mm.
B, Midline sagittal reformation obtained from helical data set shows upper cervical spine.

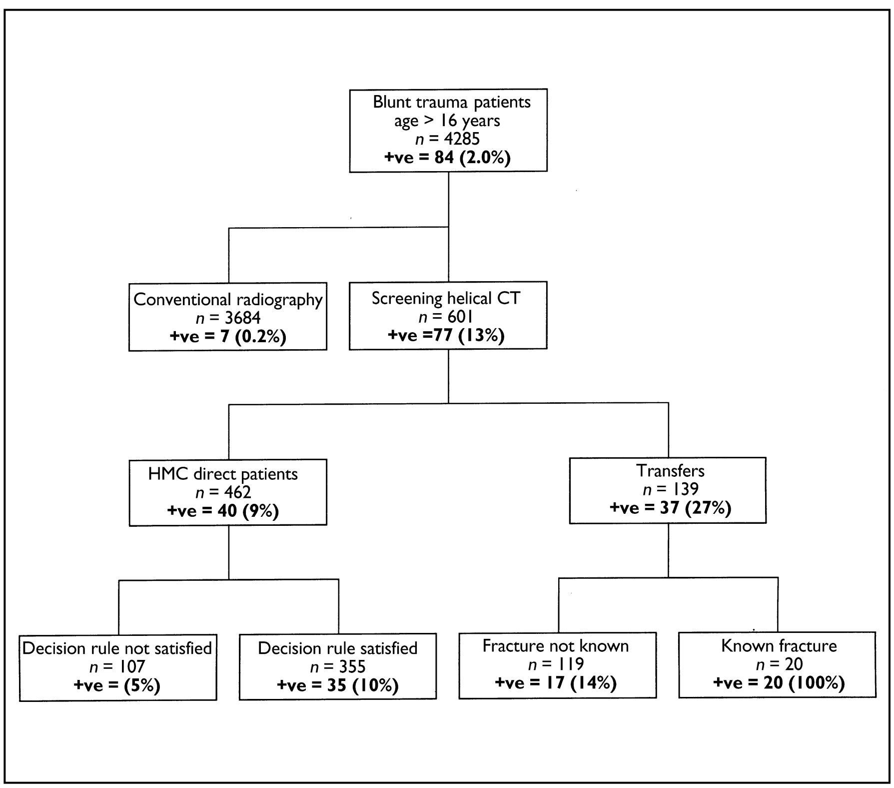

Fig. 2.—Decision tree shows radiologic screening yields according to imaging technique and patient subset (direct admission to Harborview Medical Center [HMC] or transfer). +ve = true-positive study for cervical spine injury.

aging workup. (The revised trauma score is a physiologic measure of injury severity that is based on respiratory rate, the Glasgow Coma scale, and systolic blood pressure). In the study by Nunez et al., the researchers found 68 fractures in 46 (5.8%) of the 800 patients studied. Thirty-nine (57%) of these 68 fractures were detected on CT but not on standard radiography. These authors observed that the introduction of a CT screening policy was associated with a reduction in the time required for patient imaging evaluation in their emergency department.

We implemented a cervical spine trauma screening policy using a modified CT protocol with narrower collimation and more extensive spinal coverage. We designed a clinical decision rule to particularly focus on cervical trauma risk factors. In the group of patients who directly presented to our trauma center and who were selected to undergo screening helical CT on the basis of this decision rule, the cervical spine injury rate was 8.7%. Recent work has suggested that helical CT could be a cost-effective strategy in populations with fracture risk exceeding approximately 5% [7]. Thus, the clinical decision rule was sufficiently useful to serve as a tool when selecting patients for screening helical CT. In

TABLE 1 Cervical Spine Injuries Revealed on Helical CT in 77 Patients

Injury	HMC Patients[a]	Transferred Patients
Occipital, atlantal, or axial fracture or subluxation	3	2
C1 fracture	0	6
C2 fracture	9	15
C3–C7 body fracture	4	10
C3–C7 facet, pedicle, or lamina fracture or subluxation	16	15
C3–C7 transverse or spinous process fracture	13	8
Total	45	56

[a] Patients admitted directly to Harborview Medical Center.

TABLE 2 Additional Injuries Revealed on Helical CT in 54 Patients

Injury	No.
Upper thoracic spine fracture	11
Proximal rib fracture	32
Skull base fracture	12
Mandible fracture	3
Hyoid fracture	1
Total	59

addition, we observed a very low incidence (0.2%) of cervical spine injury in the large group of 3684 patients who underwent conventional cervical radiography and who did not satisfy high-risk criteria.

Helical CT imaging revealed a substantial number of additional injuries remote from the cervical spine. Of particular importance were 11 cases of vertebral fracture in the upper thorax, a segment of the spine often difficult to visualize on conventional radiographs. This consideration had prompted the inclusion of the upper four thoracic vertebrae in the design of the screening CT protocol.

The cost-effectiveness of the screening CT strategy is based on preventing delayed cases of paralysis by improved detection of unstable injuries [7]. The risk of preventable paralysis is estimated from conventional radiographic studies of misdiagnosed fractures. Extrapolation of the same risk to CT data requires caution. Although helical CT may be more sensitive than conventional radiography for cervical spine fracture in general, it is the diagnostic yield for unstable injuries that determines the rate of avoidable neurologic deficit and thereby the justification for CT screening. The clinical significance of some screening CT–detected abnormalities remains unclear. CT reveals minimally symptomatic and asymptomatic nondisplaced spinous and transverse process fractures that may have no risk for neurologic injury and that may have been previously overlooked in conventional radiographic series that relied on clinical presentation with fracture as the diagnostic gold standard. Although these injuries might be insignificant in terms of the need for surgical stabilization, their presence reflects substantial absorbed energy, and it may be important to detect them as markers for more severe ligamentous, disk, brachial plexus, or vertebral artery injury [14].

In this study, the most common types of injury revealed on CT were C3–C7 articular mass, pedicle, and lamina fractures or subluxations. Thirty-one such injuries were found in 27 (4.5%) of 601 patients. Seventeen of these 27 patients required stabilization with surgical instrumentation or halo fixation, or died. The remaining 10 patients had minimally displaced or nondisplaced fractures or subluxations that were stable on serial radiographic studies and that were treated with cervical brace or collar immobilization for up to 12 weeks. Isolated transverse or spinous process fractures were detected in 15 (2.5%) of 601 patients, and the screening helical CT injury yield remained high even after exclusion of these cases.

We observed “dilution” of the indications for screening CT, with 107 (23%) of 462 patients directly presenting to our trauma center judged in retrospect not to have satisfied selection criteria. This indication drift, or deviation from the standard protocol, may be due to presumptions that screening CT is a more accurate, faster, and more convenient technique. Requesting trauma physicians may exercise clinical judgment on factors not included in the original prediction rule. For example, falls were all grouped together in the original prediction rule because we had insufficient data to separate them. Intuitively, however, one would expect falls from great heights to be greater injury risk factors than falls from standing, and one might assign greater weight to a fall from some height than that mandated by the prediction rule. Clinical judgments of this nature may contribute to the cases in which the protocol was not strictly followed. Some indication drift is probably inevitable in an effectiveness study such as this one. This bias to include nonprotocol patients could reduce the overall injury detection rate in the screened population. Despite this effect, the positive scan rate (8.7%) was sufficiently high for the imaging strategy to be cost-effective, as predicted by modeling. Indeed, a higher positive scan rate of 9.9% was found in the 355 patients who were retrospectively thought to satisfy the decision rule.

The retrospective extraction of clinical data from the medical record, as performed in this study, is subject to limitations. The presence or absence of individual decision rule criteria was not routinely recorded, so it was not possible to correlate the association between individual parameters and fracture risk, or to further refine the decision rule. Furthermore, it may not be appropriate to use information compiled after the event (i.e., medical records) to justify patient selection for helical CT, a decision that must be made in the immediate evaluation period.

In 20 patients with known cervical spine fractures (based on prior conventional radiographs), the helical CT study was used to screen for a second injury. Almost 50% of this group (9/20) had at least one additional unsuspected fracture. However, the clinical impact of these additional detected injuries was limited because they were generally contiguous with the known injury level and would therefore have been diagnosed using a conventional targeted CT examination.

We noted a higher incidence of fracture in the transferred (14.3%) than in the directly presenting (8.7%) patients. The transferred patients were a selected group with more severe injuries, which was reflected by higher injury severity scores than those of the direct admission patients (median [range]: 17 [5–45] compared with 14 [1–75], respectively; $p < 0.05$, Mann-Whitney statistical analysis).

In summary, this report supports the assertion that simple clinical parameters can be used to stratify patients on the basis of the probability of cervical spine injury. Such stratification can be used to select appropriate patients for more cost-effective screening for cervical spine injury using helical CT.

References

1. Bracken MB, Freeman DH, Hellenbrand K. Incidence of acute traumatic hospitalized spinal cord injury in the United States, 1970–1977. *Am J Epidemiol* **1981**;113:615–622
2. DeVivo MJ, Rutt RD, Black KJ, Go BK, Stover SL. Trends in spinal cord injury demographics and treatment outcomes between 1973 and 1986. *Arch Phys Med Rehabil* **1992**;73:424–430
3. Vandemark RM. Radiology of the cervical spine in trauma patients: practice pitfalls and recommendations for improving efficiency and communication. *AJR* **1990**;155:465–472
4. American College of Radiology. *Appropriateness criteria for imaging and treatment decisions.* Reston, VA: American College of Radiology, **1995**
5. Nuñez DB Jr, Quencer RM. The role of helical CT in the assessment of cervical spine injuries. *AJR* **1998**; 171:951–957
6. Nunez DB, Ahmad AA, Coin CG, et al. Clearing the cervical spine in multiple trauma victims: a time-effective protocol using helical computed tomography. *Emerg Radiol* **1994**;1:273–278
7. Blackmore CC, Ramsey SD, Mann FA, Deyo RA. Cervical spine screening with computed tomography in trauma patients: a cost-effectiveness analysis. *Radiology* **1999**;212:117–125
8. Jacobs LM, Schwartz R. Prospective analysis of acute cervical spine injury: a methodology to predict injury. *Ann Emerg Med* **1988**;15:44–49
9. Ross SE, Schwab CW, David ET, Delong WG, Born CT. Clearing the cervical spine: initial radiologic evaluation. *J Trauma* **1978**;27:1055–1060
10. Blackmore CC, Emerson SS, Mann FA, Koepsell TD. Cervical spine imaging in patients with trauma: determination of fracture risk to optimize use. *Radiology* **1999**;211:759–765
11. Laupacis A, Seklar N, Stiell IG. Clinical prediction rules: a review and suggested modifications of methodological standards. *JAMA* **1997**;277:488–494
12. Sackett DL, Haynes RB, Guyatt GH, Tugwell P. *Clinical epidemiology: a basic science for clinical medicine.* Boston: Little, Brown, **1991**:183–184
13. Mackenzie EJ, Steinwachs DM, Shankar B. Classifying trauma severity based on hospital discharge diagnoses: validation of an ICD-9CM to AIS-85 conversion table. *Med Care* **1989**;27:412–420
14. Woodring JH, Lee C, Duncan V. Transverse process fractures of the cervical vertebrae: are they significant? *J Trauma* **1993**;34:797–802

APPENDIX: Clinical Decision Rule to Select High-Risk Patients to Undergo Helical CT of the Cervical Spine: Six Injury Mechanisms or Clinical Parameters

Injury mechanism parameters based on initial report of emergency transportation personnel, patient, or witnesses:

1. High-speed (≥35 mph [56 kmph] combined impact) motor vehicle accident
2. Crash with death at scene of motor vehicle accident
3. Fall from height (≥10 ft [3 m])

Clinical parameters based on primary patient survey:

4. Significant closed head injury (or intracranial hemorrhage seen on CT)
5. Neurologic symptoms or signs referred to the cervical spine
6. Pelvic or multiple extremity fractures

The presence of any one parameter places the patient in the high-risk category (>5% risk of cervical spine fracture) and indicates that the patient should undergo helical CT. It is assumed that CT of the head will be performed contemporaneously.