Spine Trauma

Surgical Techniques

Bearbeitet von
Vikas V. Patel, Evalina Burger, Courtney W. Brown

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2.1 Introduction

Clearing the cervical spine is among the highest priorities in the early assessment of trauma patients in emergency centers. Annually, more than ten million patients present to trauma centers in the USA, and in all of these patients, the possibility of cervical spine injury must be considered [34, 43, 60]. The actual incidence of cervical spine injury among blunt trauma patients is only 1–3% [77, 80, 81, 96]. Therefore, the need for a concise, yet thorough, approach to cervical spine clearance mandates that efficacious clearing guidelines are established and adhered to.

Traditionally, most physicians have considered imaging as the principal, if not the sole, method by which the cervical spine should be cleared. This opinion resulted in the tendency for many physicians to ignore the merits of the history and physical examination in the clearance process, and impeded the development of dependable clinical indicators of cervical injury. Subsequently, most initially developed cervical spine clearance protocols relied almost entirely on indiscriminate imaging [72]. The liberal use of imaging produces a large number of predominately normal or inadequate cervical spine X-rays, creates frequent delays in the patient’s emergency workup and subsequent treatment, and results in enormous costs for both personnel time and institutional resources [13, 86, 97].

Despite the numerous problems associated with indiscriminate cervical spine plain radiography in the trauma setting, this practice has been difficult to restrict. Although the history and physical examination are integral components of the cervical spine evaluation, there is no consensus among physicians on how to prioritize the impact of these clinical components on the diagnostic process. When cervical spine injury is missed and/or its treatment delayed, resultant patient morbidity can be devastating, and the cost to society is enormous. Finally, for many physicians, the potential liability of a missed cervical spine injury more than justifies routine X-ray imaging.

More than two decades ago, Jacobs and Schwartz [49] reported that the ability of emergency physician to clinically predict the presence of cervical spine injury in trauma patients was only 50%. However, the same physicians were able to successfully identify 94% of trauma patients without cervical spine injury. Inadvertently, this study not only emphasized the true focus of cervical spine clearance, that is, accurately determining the absence of cervical spine injury, but also affirmed that the clinical designation of absence of cervical spine injury was more feasible than the clinical detection on injury.

Because of the very low incidence of positive imaging findings, clearing the cervical spine solely dependent on imaging is extremely inefficient. In a retrospective series of 1,686 consecutive trauma patients subjected to cervical spine clearing, Lindsey et al. [57] questioned the efficacy of routine cervical spine imaging. These authors identified only 1.9% of patients with cervical spine injuries. Moreover, most of the detected cervical spine injuries were nonthreatening to the patient’s spinal stability or neurologic integrity. These findings suggest that the concept of a specific clinical protocol to better select patients who warrant imaging has enormous merit.
The objective of this chapter is to explore the complex issue of clearing the cervical spine in trauma patients. Among the topics addressed are: (1) defining cervical spine clearance, its rationale, and objectives; (2) identifying the trauma patient groups that determine the most appropriate clearing process; (3) establishing the clinical and imaging components of clearance; (4) reviewing the currently available guidelines for clearing the cervical spine; and (5) devising a new comprehensive algorithm for clearing of the cervical spine in the emergency setting.

### 2.2 Cervical Spine Clearance: Definition, Rationale, Objectives

The overwhelming majority of blunt trauma victims presenting to the emergency center do not have a cervical spine injury [42]. In order to reliably and effectively identify the patients who are injury-free, the term “clearance” of the cervical spine has recently been introduced to emergency medicine [59].

Cervical spine clearance in the trauma setting is defined as reliably ruling out the presence of cervical spine injury in a patient who indeed does not have a cervical spine injury. Contrary to the common misconception, cervical clearance is not intended to detect or classify an injury, or determine its most appropriate treatment. Clearance simply declares that injury is not present. The clearing process always requires a complete clinical evaluation, and occasionally warrants adjunctive imaging. Ideally, clearing should occur at the earliest point in the trauma assessment process so that it can be accomplished reliably. However, the clearance process does not place its major emphasis on how quickly it is accomplished, but on its accuracy.

The fundamental objective of cervical spine clearance is to improve the efficiency and accuracy of the entire trauma assessment process. When cervical spine injury can reliably be ruled out, neck immobilization precautions can be discontinued, additional neck diagnostic or therapeutic modalities are not warranted, and the trauma evaluation can focus on the other areas of the patient’s assessment. Considerable pressure may be placed on the emergency clinician to expeditiously clear, especially when the index of suspicion for injury is low. However, one must accept the reality that some patients simply cannot be cleared in the acute setting. If cervical spine injury cannot be reliably excluded, vigilant cervical spine precautions are maintained and efforts to establish a definitive position based on the status of the cervical spine must continue.

### 2.3 Cervical Spine Clearance: Patient Groups

Two basic principles are applied to all blunt trauma patients in regard to the cervical spine clearance process. First, a meaningful clinical examination is imperative before cervical spine clearance can be considered. The fundamental requirement is a lucid patient. Therefore, the initial step in the clearance process is to determine the patient’s level of alertness (Tables 2.1 and 2.2). Although all patients should be thoroughly evaluated, only fully alert patients (Ransohoff Class 1, Glasgow Coma Scale >14) are capable of undergoing a dependable physical examination, and constitute the only type of patients in whom cervical injury can reliably be ruled out, with or without supplemental imaging. Secondarily, alert, oriented patients should be assessed in respect to the presence or absence of symptoms that can either be attributed to or possibly mask cervical spine injury. These include intoxication and distracting injuries. On the basis of these principles, all blunt trauma patients can be acutely categorized into three cervical spine patient clearance groups [59] (Table 2.3).

#### Table 2.1 Ransohoff classification of consciousness levels

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Alert; responds immediately to questions; may be disoriented and confused; follows complex commands</td>
</tr>
<tr>
<td>2</td>
<td>Drowsy, confused, uninterested; does not lapse into sleep when undisturbed; follows simple commands only</td>
</tr>
<tr>
<td>3</td>
<td>Stuporous; sleeps when not disturbed; responds briskly and appropriately to noxious stimuli</td>
</tr>
<tr>
<td>4</td>
<td>Deep stupor; responds defensively to prolonged noxious stimuli</td>
</tr>
<tr>
<td>5</td>
<td>Coma; no appropriate response to any stimuli; includes decorticate and decerebrate responses</td>
</tr>
<tr>
<td>6</td>
<td>Deep coma; flaccidity; no response to any stimuli</td>
</tr>
</tbody>
</table>

Adapted from Ransohoff and Fleischer [75]
2 Clearing the Cervical Spine

2.3.1 Group I (Asymptomatic)

Patients who can be reliably cleared by clinical examination alone without imaging (i.e., no plain radiography, computed tomography (CT), magnetic resonance imaging (MRI), etc.) constitute Group I. Patients in this group must satisfy all of the following five criteria [44]: (1) full alertness; (2) no intoxication; (3) no midline tenderness; (4) no focal neurologic deficit, and (5) no distracting painful injury (Table 2.4). A randomized, prospective study of 34,069 patients by the National Emergency X-Radiography Utilization Study (NEXUS) group [42] demonstrated that significant cervical spine injury could be reliably excluded by physical examination alone when applying these criteria. The reliability of cervical spine clearance by physical examination of the alert patient has been corroborated by other studies [4, 27, 57]. Successfully clinically cleared patients do not require further diagnostic measures, and cervical spine precautions can be discontinued.

2.3.2 Group II (Symptomatic)

Fully oriented and alert patients who demonstrate symptoms of neck pain, tenderness, neurologic deficit, and decreased mobility on physical examination require additional diagnostic assessment to effectively clear the cervical spine comprise Group II. This group also includes patients with a distracting injury or past history of cervical spine pathology. Additional diagnostic studies typically consist of three-view radiography (anteroposterior, lateral, open-mouth odontoid) and may also require adjunctive CT or MRI [59]. Voluntary lateral flexion–extension radiography is indicated only after symptomatic treatment has failed over a brief period of time (typically 2 weeks), and is not generally recommended in the acute setting. An alert patient who presents with a partial or complete neurologic deficit is assumed to have a spine injury, and thereby always requires imaging. Whether the deficit is due to spinal cord, spinal root, or peripheral nerve injury, an exhaustive diagnostic effort must be made to rule out spine instability and/or injury. Throughout this process, the physician must strictly adhere to all precautionary spine immobilization techniques, even if the initial examination suggests a complete neurologic deficit. Plain radiography and/or sophisticated imaging are always indicated.

### Table 2.2 Glasgow coma scale

<table>
<thead>
<tr>
<th>Feature</th>
<th>Response</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eye opening</td>
<td>Spontaneous</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>To speech</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>To pain</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>1</td>
</tr>
<tr>
<td>Verbal response</td>
<td>Oriented</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Confused conversation</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Words inappropriate</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Sounds incomprehensible</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>1</td>
</tr>
<tr>
<td>Best motor response</td>
<td>Obey commands</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Localizes pain</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Flexion normal</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Flexion abnormal</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Extended</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total coma score</strong></td>
<td></td>
<td>3–15</td>
</tr>
</tbody>
</table>

### Table 2.3 Cervical spine clearance patient group designation

<table>
<thead>
<tr>
<th>Group</th>
<th>Designation</th>
<th>Patient characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Asymptomatic</td>
<td>Awake, alert</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No neck pain/tenderness</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Normal neurologic function</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No intoxication</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No distracting injuries</td>
</tr>
<tr>
<td>II</td>
<td>Symptomatic</td>
<td>Neck pain and/or tenderness</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neurologic deficits</td>
</tr>
<tr>
<td>III</td>
<td>Nonevaluable</td>
<td>Intoxicated (alcohol, drugs)</td>
</tr>
<tr>
<td></td>
<td>Temporarily</td>
<td>Presence of distracting injury</td>
</tr>
<tr>
<td></td>
<td>Indefinitely</td>
<td>Obtunded (brain injury)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Intubated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pharmacological coma</td>
</tr>
</tbody>
</table>
to diagnose and categorize the injury. Prophylactic treatment modalities such as high dose steroids administration, when indicated, must be instituted emergently. Serial examinations to document neurologic progression or improvement, ideally performed by the same physician, are recommended, irrespective of whether the patient’s neurologic deficit is partial or complete.

### 2.3.3 Group III (Nonevaluable)

Patients who cannot be cleared at the time of the emergency center presentation constitute Group III [59]. Definitive clearance is not feasible in this group because of the patient’s medical instability, the patient’s inability to undergo a reliable clinical examination, or inconclusive results of the initially performed diagnostic studies. The majority of patients in this group present with an impaired level of consciousness due to head injury or intoxication, and this alone inhibits the clearance process. The adjunctive imaging in this group can detect obvious cervical injury, but it cannot definitively rule it out, even if it is negative. This group typically consists of two subgroups: patients who are temporarily nonevaluable and those who are indefinitely nonevaluable. The temporarily nonevaluable patients include those who are intoxicated or present with a distracting injury. These patients may be asymptomatic, but the presence of intoxication and/or distracting injury renders their clinical examination unreliable. The expectation is that these temporary conditions will resolve in 24–48 h, and these patients can subsequently be reclassified to enter either patient Group I or II, or will remain in Group III. The subgroup of indefinitely nonevaluable patients includes those who are obtunded, intubated, and/or pharmacologically compromised, and therefore they cannot submit to a meaningful clinical examination. For all Group III patients, strict adherence to basic principles of cervical spine external support and/or stabilizing precautions is recommended. Imaging is indicated for these patients to detect but not to definitively exclude cervical spine injury. Even if the cervical spine imaging is negative, the prudent physician is obliged to maintain all neck precautions until the patient becomes more alert and receptive to supplemental clinical assessment. Although some reports [19, 39, 89, 98] suggest that negative sophisticated imaging (CT and/or MRI) may adequately clear the cervical spine of these patients, the authors submit that definitive clearance cannot be reliably established until the patient is alert and a valid physical examination can be performed.

The efficiency of cervical spine clearance can be greatly enhanced by assigning patients to one of these three groups. Although one of the primary clinical objectives will always be to increase the sensitivity of cervical injury detection, the emergency clinicians must recognize that the greater challenge is to be proficient in cervical spine injury exclusion. Indeed, the inability to clinically clear a patient is not equivalent to the presence of injury, and always requires the use of adjunctive imaging. However, most imaging modalities are more sensitive for injury detection than being specific for its exclusion. Therefore, cervical spine imaging alone

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**Table 2.4 Clinical cervical spine clearance criteria as defined by the NEXUS group**

<table>
<thead>
<tr>
<th>Altered neurologic function is present if any of the following is present: (a) Glasgow Coma Scale score of 14 or less; (b) disorientation to person, place, time, or events; (c) inability to remember 3 objects at 5 min; (d) delayed or inappropriate response to external stimuli; or (e) any focal deficit on motor or sensory examination. Patients with none of these individual findings should be classified as having normal neurologic function.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients should be considered intoxicated if they have either of the following: (a) a recent history of intoxication or intoxicating substance ingestion; or (b) evidence of intoxication on physical examination. Patients may also be considered to be intoxicated if tests of bodily secretions are positive for drugs that affect the level of alertness, including a blood alcohol level greater than 0.08 mg/dL.</td>
</tr>
<tr>
<td>Midline posterior bony cervical spine tenderness is present if the patient complains of pain on palpation of the posterior midline neck from the nuchal ridge to the prominence of the first thoracic vertebra, or if the patient evinces pain with direct palpation of any cervical spinous process.</td>
</tr>
<tr>
<td>Patients should be considered to have a distracting painful injury if they have any of the following: (a) a long bone fracture; (b) a visceral injury requiring surgical consultation; (c) a large laceration, degloving injury, or crush injury; (d) large burns; or (e) any other injury producing acute functional impairment. Physicians may also classify any injury as distracting if it is thought to have the potential to impair the patient’s ability to appreciate other injuries.</td>
</tr>
</tbody>
</table>

Adapted from Hoffman et al. [44]
cannot substitute for a thorough clinical evaluation in establishing clearance. Furthermore, the effectiveness of imaging in cervical spine clearance is enhanced when combined with a meaningful clinical examination.

### 2.4 Patient Management Before and During Cervical Spine Clearance

Cervical spine injury should be assumed to be present in all patients during pre-hospital trauma management. Cervical spine immobilization is uniformly applied and typically consists of a cervical collar and/or securing the head to the backboard with sandbags and/or tape [1, 24]. Although neck immobilization in trauma patients has been questioned because of reported elevations in intracranial pressure and an increased risk for respiratory problems [70], routine rigid neck immobilization is still the standard recommended for all trauma patients [36].

After arrival at the hospital, all external neck support should be maintained. These principles apply even during the assessment of the airway; the head and neck should not be excessively flexed, extended, or rotated at this juncture. If external neck support must be temporarily removed (e.g., neck wound inspection), a member of the trauma team should manually maintain control of the head and neck using in-line immobilization techniques [1]. The physician’s adherence to these precautions cannot be overstated because a significant subset of cervical trauma patients can experience the onset or progression of neurologic deficit after arrival at the hospital [9]. The first premise in clearing trauma patients for cervical injury is the assumption that a cervical spine injury exists, and all patients should be managed accordingly until it can be definitely excluded [97].

If other injuries warrant more immediate or greater attention, the cervical spine evaluation can be safely deferred as long as cervical immobilization is diligently maintained. The only aspects of the initial trauma patient assessment that are of greater priority than the cervical spine are the patient’s airway, breathing, circulation, and head/brain. A patent airway should be expeditiously identified or established immediately after the trauma patient’s arrival to the hospital. Breathing must then be documented or external ventilation initiated. Hemorrhage, the most prevalent cause of preventable deaths posttrauma, must be quickly controlled to ensure hemodynamic stability [1]. Finally, a neurologic evaluation is performed to establish the patient’s level of consciousness, and if a brain injury exists, it must also be managed emergently. Cervical spine clearance becomes the focus of the evaluation, only after these “ABCs” have been addressed.

The cervical spine screening begins with each patient being assigned to one of the three patient groups following a brief clinical examination. The majority of the published clearance guidelines address the oriented and alert patient (Group I, Group II) [26, 42, 65, 68, 79, 92, 100], whereas in the indefinitely non-evaluable (obtunded) patients (Group III), the initial evaluation protocols are controversial [5, 10, 11, 14, 30, 67]. In Group I, reliable clinical clearance of the cervical spine can be achieved for those patients who present without symptoms or a history suggestive of cervical spine injury [57, 79, 96]. In an alert patient who presents with symptoms of possible cervical spine injury (Group II), clearance will require adjunctive imaging.

### 2.5 Clinical Clearance of the Cervical Spine

#### 2.5.1 History

A detailed history is essential in the cervical spine assessment of trauma patients. The initial priority in obtaining a valid history is an early, accurate determination of the patient’s level of alertness. Although the ideal history is the one obtained from an alert, oriented trauma victim, significant information is also available from a host of other individuals who may have experienced the same mishap, or are simply familiar with the scene of the accident (e.g., police, emergency medical technicians, other passengers, witnesses). In addition to documenting the mechanism of injury, the history should provide a detailed account of the events and patient’s condition from immediately postinjury up to the time of presentation to a medical facility. Information regarding the victim’s past medical history, especially as it pertains to previous cervical spine conditions, is especially helpful. Special attention should be given to the elderly patient who has sustained a fall or minor trauma; these individuals are particularly susceptible to cervical spine injury [27, 56].
The risk for cervical spine injury and its severity can be directly correlated with the energy associated with the traumatic insult [4, 47, 49]. Therefore, the level of energy (i.e., high vs. low) and the manner by which injury is sustained (direct vs. indirect) are crucial information. The clinician should determine if the accident is the result of a high-speed motor vehicle accident (MVA), or a fall from a considerable height vs. an altercation. If due to a fall, the approximate height of the fall should be calculated; if due to an MVA, the record should reflect if the patient was restrained or ejected from the vehicle. The possibility of direct vs. indirect whiplash injury should also be established.

The previously noted study by Jacobs and Schwartz [49] not only established the feasibility of clinical clearance of the cervical spine, but also identified a number of subjective variables that seemed to correlate with an increased risk for the cervical spine injury (Table 2.5). In a recent study, Stiell et al. [92] have also calculated the odds ratio of several clinical variables that could predict a significant cervical spine injury (Table 2.6). Although these variables may serve to heighten one’s awareness of the risk for cervical spine injury in a particular patient, ruling out the presence of these variables alone does not establish cervical clearance.

### Table 2.5

<table>
<thead>
<tr>
<th>Variable</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor vehicle accident</td>
<td>0.052</td>
</tr>
<tr>
<td>Fall &gt; 10 ft.</td>
<td>0.007</td>
</tr>
<tr>
<td>Neck tenderness</td>
<td>0.002</td>
</tr>
<tr>
<td>Numbness</td>
<td>0.001</td>
</tr>
<tr>
<td>Loss of sensation</td>
<td>0.001</td>
</tr>
<tr>
<td>Weakness</td>
<td>0.001</td>
</tr>
<tr>
<td>Neck spasm</td>
<td>0.001</td>
</tr>
<tr>
<td>Loss of muscle power (0–5)</td>
<td>0.001</td>
</tr>
<tr>
<td>Decreased sensation</td>
<td>0.001</td>
</tr>
<tr>
<td>Loss of anal tone/wink</td>
<td>0.001</td>
</tr>
<tr>
<td>Fall &lt;10 ft.</td>
<td>0.083</td>
</tr>
<tr>
<td>Low-energy injury</td>
<td>0.700</td>
</tr>
<tr>
<td>Drug/alcohol intoxication</td>
<td>0.400</td>
</tr>
<tr>
<td>Flexion/extension</td>
<td>0.400</td>
</tr>
<tr>
<td>Compression/torsion</td>
<td>0.960</td>
</tr>
<tr>
<td>Head trauma</td>
<td>0.370</td>
</tr>
<tr>
<td>Neck pain</td>
<td>0.140</td>
</tr>
<tr>
<td>Headache</td>
<td>0.140</td>
</tr>
<tr>
<td>Loss of consciousness</td>
<td>0.382</td>
</tr>
<tr>
<td>Bradycardic hypotension</td>
<td>0.760</td>
</tr>
</tbody>
</table>

Adapted from Jacobs and Schwartz [49]

### Table 2.6

<table>
<thead>
<tr>
<th>Variable</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dangerous mechanism(^b)</td>
<td>5.2 (3.7–7.3)</td>
</tr>
<tr>
<td>Age ≥65 years</td>
<td>3.7 (2.4–5.6)</td>
</tr>
<tr>
<td>Paresthesia in extremities</td>
<td>2.2 (1.4–3.3)</td>
</tr>
<tr>
<td>Ambulatory at any time after injury</td>
<td>1.0 (0.7–1.5)</td>
</tr>
<tr>
<td>Sitting position in EC</td>
<td>0.61 (0.3–1.2)</td>
</tr>
<tr>
<td>Delayed onset of neck pain</td>
<td>0.4 (0.3–0.7)</td>
</tr>
<tr>
<td>Absence of midline neck tenderness</td>
<td>0.5 (0.3–0.8)</td>
</tr>
<tr>
<td>Able to rotate neck 45° left and right</td>
<td>0.04 (0.01–0.3)</td>
</tr>
<tr>
<td>Simple rear-end MVA(^c)</td>
<td>0.08 (0.03–0.2)</td>
</tr>
</tbody>
</table>

Adapted from Stiell et al. [92]

\(^a\) OR odds ratio; CI confidence interval; MVA motor vehicle accident

\(^b\) Fall from ≥1 m; axial load to the head; high-speed MVA, rollover, or ejection; bicycle collision; recreational motorized vehicle collision

\(^c\) Excludes vehicle pushed into oncoming traffic, hit by bus or large truck, rollover, or hit by high-speed vehicle; collision

### 2.5.2 Physical Examination

The physical examination, albeit challenging in the acute posttraumatic environment, is essential for valid clearance of the cervical spine. This principle exists regardless of whether adjunctive imaging is also deemed necessary to complete the process. The physical examination can be accomplished only in patients who demonstrate a Glasgow Coma Scale score >14, and therefore, it is feasible only for patients from Groups I and II. Unlike the obtunded patients in Group III, the Group I and II patients are alert and oriented to participate in a physical examination, which must demonstrate their ability to respond to complex commands, voluntarily mobilize their neck, indicate symptomatic anatomic regions, and undergo a comprehensive neurologic evaluation. Group II patients, although suitable for physical examination, are not candidates for clinical clearance and must undergo...
appropriate imaging to complete a valid clearing process. Only Group I patients can undergo physical examination and have the cervical spine definitively cleared by clinical assessment alone if that examination is normal.

The initial cervical spine examination in the trauma patient should consist of a static assessment. At this stage, the physical examination is performed while the external cervical support remains in place, the neck is not manipulated, and the patient is maintained in a supine posture. The static stage components of the physical examination that have positively correlated with cervical spine injury include the presence of neck pain, focal neck tenderness or spasm, and/or neurologic deficits [49, 78]. Neurologic deficit of any degree precludes the ability to achieve clinical clearance, and adjunctive cervical spine imaging is mandatory [59]. Many clinicians suggest that cervical spine injury should be assumed to be present in the neurologically compromised patient until further workup can conclusively establish its absence. Particular attention must be given to patients who sustain direct face, head, or neck trauma [3, 6, 35, 41, 87]. Although neck injury usually occurs through an indirect injury mechanism (e.g., whiplash), patients who sustain direct trauma above the shoulders are at particularly significant risk for cervical spine injury.

The second phase of the physical examination consists of a dynamic evaluation. External neck support should be removed and, while still supine, the patient should be asked to voluntarily perform neck flexion–extension, rotation, and lateral bending. If these maneuvers are successfully performed without pain or a change in the patient’s neurologic status, the examiner should apply gentle axial load to the cervical spine by way of compressing or distracting the skull. If the neck/patient remains asymptomatic after these maneuvers, the patient may be permitted to sit or stand upright. The components of the static assessment should be reviewed as needed to ensure that they are unchanged. At this juncture, the clinician must also determine if the patient projects any degree of apprehension related to his neck or neurologic status that would warrant further evaluation. If the patient is nonapprehensive, and conclusively demonstrates a normal physical examination in both the static and dynamic phases of assessment, the cervical spine can be clinically cleared without adjunctive diagnostic modalities.

The physical examination alone can be unreliable in select patients even if they appear lucid. Major distracting injuries to the chest, abdomen, pelvis, or even the extremities (e.g., open fractures) may alter the patient’s perception of subtle neck or neurologic symptoms and, thereby, negate the feasibility of clinical clearance. As previously noted, a patient’s history of past neck pathology would do likewise. The most frequently encountered setting that threatens reliable clinical clearance is the unruled intoxicated or drugged patient in whom accurate imaging is not possible. These patients are often briefly admitted to the hospital for observation and/or until they become detoxicated. Although a later physical examination may suggest that cervical spine injury is unlikely, the clinician must still consider supplemental imaging if any degree of the patient’s behavior appears altered.

### 2.6 Imaging Clearance of the Cervical Spine

Cervical spine clearance of the Group II patients who present with neck pain, tenderness, or neurologic symptoms require radiographic imaging as an adjunct to physical examination to evaluate their cervical spine. Imaging options include plain radiography, flexion–extension radiography, CT, and MRI.

#### 2.6.1 Plain Radiography

Given its availability and relatively low cost, plain radiography is usually the first imaging modality for patients who cannot be cleared solely by clinical assessment [23, 37, 51, 57, 61, 62, 75, 85]. However, there are currently no validated guidelines for the use of plain radiography in trauma patients [32, 92]. The overall sensitivity of plain radiography is rather low, ranging from 52 to 85%, although many missed injuries have little significance [29, 46]. The clearance effectiveness of plain radiography is dependent on the number and/or type of views obtained [61] technical adequacy of the study [21], and the interpretive skills of the clinician. It has been suggested that cervical X-rays are not very specific for cervical spine injury and some clinicians advocate a variety of views, or more sophisticated adjunctive imaging. However, Mower et al. [68] from the NEXUS group demonstrated that plain radiography in conjunction with a thorough clinical examination in alert and nonintoxicated patients can result in a very small (0.07%)
The major limitation of plain radiography is its inability to reliably delineate injuries at the occipitocervical and cervicothoracic junctions in many patients.

The first radiograph to obtain is a single lateral view [23, 39, 51, 61, 62, 80, 85]. The lateral view alone is typically considered to be insufficient [51, 61, 99]. The sensitivity of the single lateral view among patients with cervical spine injury ranges from 74 to 86% [8, 51, 62, 99]. In a retrospective study, Shaffer and Doris [85] reported that 21% of all cervical spine injuries were missed with a lateral view alone. MacDonald et al. [61] found that the lateral view missed 16 of 92 cervical spine injuries; moreover in 18 cases, it was falsely read as positive. The accepted standard currently consists of a full cervical series (FCS), which includes anteroposterior, lateral, and open-mouth odontoid views as the minimum projections necessary for maximum specificity and sensitivity.

The efficacy of cervical X-rays is highly dependent on the quality of the views obtained. In a study by Davis et al. [21], 94% of the errors leading to missed or delayed diagnosis of cervical spine injuries were the result of the failure to obtain adequate cervical spine radiographs. Ross et al. [80] reported that a technically adequate FCS could significantly increase the diagnostic accuracy of plain radiography. However, misinterpretation errors by trauma surgeons and emergency physicians can be frequent [31, 76]. Even when FCS is of adequate quality and properly interpreted, significant cervical spine injuries may occasionally go undetected. Some authors recommend the addition of two oblique views to better delineate spinal alignment.

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**Fig. 2.1** The distribution of the patients from the NEXUS study classified by the injury status and radiographic findings.
and the integrity of the facets and pedicles [25, 94]. The swimmer’s view, which provides better visualization of the cervicothoracic junction, has also been recommended [50]. However, the practice of using additional X-ray views in the trauma setting usually leads to escalation of costs in time and resources. Freemyer et al. [28] prospectively compared the three-view vs. the five-view cervical spine series and noted that the latter did not increase injury detection but allowed only more specific diagnosis. Therefore, for the purposes of screening, the three-view FCS should suffice. If further imaging is still required, more sophisticated modalities (e.g., CT, MRI) are preferred.

2.6.2 Flexion–Extension Radiography

Despite the adequacy of the studies obtained, static cervical spine radiographs may fail to detect an unstable cervical spine injury [53]. Lateral flexion–extension views should be considered only in alert patients with a negative FCS and persistent pain, who can voluntarily perform the study. The efficacy of lateral flexion–extension views in the acute setting is controversial. In a retrospective review, Lewis et al. [55] reported that flexion–extension views in the emergency setting detected cervical spine instability in approximately 8% of patients otherwise cleared by FCS. None of these patients experienced adverse neurologic sequelae and the authors recommended their use in the acute setting. On the other hand, the NEXUS group [53, 74] reported that flexion–extension films obtained acutely added little to the screening process for the risk involved. Anglen et al. [2] included flexion–extension films in the acute evaluation of 837 trauma patients and concluded that they were not cost effective since they did not detect significant injury that was not detected by other modalities. These authors recommended that other modalities (e.g., MRI, CT) be used in the acute setting, and flexion–extension films be reserved for the delayed setting.

2.6.3 Dynamic Fluoroscopy

Lateral flexion–extension views are indicated in the alert patient with persistent pain and negative static X-rays. Dynamic views, however, are thought to be hazardous in the obtunded patient who is without the normal protective reflexes. In obtunded patients, Cox et al. [17] reported that dynamic fluoroscopy was an effective modality that did not miss injuries, nor did it compromise the patient’s neurologic status. This was further supported by Brooks and Willet [11], who noted that dynamic fluoroscopy was a quick way to identify more subtle cases of cervical spine instability without reported neurologic complications. Sees et al. [84] also reported that fluoroscopy was both safe and effective in the assessment of the cervical spine.

In the acute setting, dynamic fluoroscopy also has its detractors. Davis et al. [20] reported that isolated ligamentous injuries of the cervical spine without fractures are rare, and in their reported series, such patients accounted for only 0.04% of all trauma patients. In the two patients identified with isolated ligamentous injury without fracture, the cervical spine was stable and did not require surgical consideration. These authors concluded that routine dynamic lateral flexion–extension imaging was not indicated to clear obtunded trauma patients because its potential risks exceeded any potential benefits.

2.6.4 Computed Tomography

CT is indicated in patients who have negative X-rays but continue to have symptoms, in those with questionable radiographic abnormalities, and those with plain radiography depicting prevertebral swelling that can be suggestive of cervical spine trauma. Plain radiographs, static or dynamic, may fail to detect many cervical spine injuries and/or accurately depict the full extent of a cervical spine injury [10, 11, 80]. In a retrospective review Woodring and Lee [100] analyzed consecutive patients with cervical spine injury and determined that FCS failed to identify 61% of the fractures and 36% of the subluxations/dislocations. Barba et al. [5] studied patients who underwent head CT following a lateral view plain radiography and demonstrated that the combination of FCS with CT increased the accuracy of injury detection from 54 to 100%. Schenarts et al. [82] reported that CT can be especially effective in the evaluation of the upper cervical spine (occiput through C3). In obtunded patients, plain radiography identified only 55% of these injuries compared with 95.7% identified by CT. Berne et al. [7] found CT
to be efficacious in imaging intensive care patients as the sensitivity of X-rays was only 60% in comparison to 90% with CT scans. In a study of 120 patients, 93% could be cleared within 24 hours by CT without missing a single injury [10, 11].

Recently, CT with reformations has gradually replaced plain radiography for cervical spine clearance. Helical, multidetector CT (MDCT) offers volume imaging, provides quick and efficient imaging in all planes and is becoming the primary method for the detection of spinal injury in many trauma centers. MDCT has equal sensitivity in all planes so that there is less risk for missing nondisplaced transverse fractures such as a type II dens fracture. CT alone identified 99.3% of all cervical spine fractures; the missed fractures required minimal or no treatment [12]. Recent studies have recognized the cost effectiveness of helical CT to complement its superior sensitivity [64]. The cost effectiveness of cervical spine CT is even greater when applied as an extension of a primary CT of other organs (head, thorax, abdomen). Some authors advocate CT as the preferred initial imaging modality for patients with moderate to high risk for cervical spine injury [33].

The disadvantages of CT include its greater expense, increased radiation exposure, and limited availability (compared with plain radiography). Additionally, CT is ineffective in detecting some ligamentous injuries. CT is best utilized in conjunction with plain radiography to increase both the accuracy and the sensitivity of the clearance process [7].

However, MRI is not indicated for primary cervical spine clearance imaging. MRI requires extensive time to perform, interferes with the patient’s monitoring equipment, and is expensive. MRI is most useful in patients for whom other imaging modalities are not consistent with the patient’s neurologic presentation. It has been reported that 25% of patients with cervicothoracic injuries and a neurologic deficit on presentation had their preliminary treatment plan altered after MRI, while it had no effect on neurologically intact patients [95]. Although MRI can have a negative predictive value approaching 100%, its positive predictive value has been less gratifying [69].

MRI provides valuable information regarding cervical ligaments, disks, and joint capsules without placing the spinal cord and/or neural elements at risk. Currently, however, no consensus exists on the imaging criteria for establishing a significant ligamentous injury. Fat suppression sequences including T2 and STIR are most sensitive to fluid and hemorrhage, whereas T1 sagittal images can depict the anterior and posterior longitudinal as well as the supraspinous ligaments. A disruption of the black stripe on T1 and increased signal that extends through normal ligamentous structures on fat-suppressed images can be indicative of ligamentous injury. Delays that allow resolution of edema and hemorrhage can decrease MRI sensitivity in cervical spine clearance; although 48–72 h has been suggested as an optimal time interval, no data exist to substantiate this notion [69].

### 2.6.5 Magnetic Resonance Imaging

MRI is an effective noninvasive imaging tool for the detection of neural, ligamentous, or disk injury. MRI is primarily indicated for those patients who present with neurologic deficit. In this setting, MRI is an effective and safe method for evaluating the spinal cord because it can depict (a) epidural hematoma; (b) spinal cord edema; and (c) spinal cord compression. Additional MRI is indicated when ligamentous injury is suspected. This includes clinical findings of focal tenderness or gaps present between spinous processes on examination or where kyphosis or inter-spinous widening is seen on CT or plain radiographs.

### 2.7 Current Cervical Spine Clearance Guidelines

#### 2.7.1 ATLS Recommendations

The ATLS protocol [1] was developed by the American College of Surgeons with the intent of creating a reproducible approach to rapidly identify injuries and initiate intervention for life- and limb-threatening injuries. In addition, the ATLS recommendations seek to reduce the incidence of missed injuries and delayed diagnosis and are applicable to any patient in any trauma situation. The initial vital steps in the ATLS evaluation
include assessment of the airway, breathing, and circulation while maintaining strict vigilance toward spinal precautions.

The ATLS recommendations [1] for screening patients for cervical spine injury are listed in Table 2.7. Their recommendations for clinical clearance are applicable only to the adult patient who is fully awake, alert, and sober. When these criteria are met, the next priority is to establish the patient’s neurologic status. Any degree of neurologic deficit would suggest that clinical clearance alone is not feasible and appropriate imaging is mandatory. In the alert, neurologically intact patient, the external cervical support (collar) can be removed, and the neck assessed for pain while the patient remains supine. During this assessment, the clinician should determine if the neck is symptomatic while at rest, voluntarily mobilized, or upon palpation. The absence of neck pain without neurologic deficit in these alert patients achieves clinical clearance of the cervical spine, and the focus of the trauma workup can be directed elsewhere. However, if focal neck symptoms can be elicited, and/or neurologic deficit exists, clinical assessment alone is insufficient, and further diagnostic modalities are warranted before clearance can be accomplished. For patients with midline cervical tenderness with palpation or neck pain with active range of motion, a screening cervical spine CT scan performed with an MDCT scanner is indicated. A similar protocol is initiated in patients who exhibit altered levels of consciousness, or who have distracting injuries. For patients who are unable to undergo CT imaging, a lateral cervical plain film is warranted to provide initial information on the status of the cervical spine. In the event of significant malalignment, cranial tongs can be placed and traction applied during the resuscitation period. Further definitive radiographs can be obtained once the patient is stabilized. If the cervical spine cannot be cleared clinically, the patient’s status reverts to the ATLS category of “suspected unstable cervical injury” and the collar is left in place.

**Table 2.7** ATLS guidelines for clearing cervical spine

<table>
<thead>
<tr>
<th>Description</th>
<th>Instructions</th>
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<tbody>
<tr>
<td>The presence of paraplegia or quadriplegia is a presumptive evidence of spinal instability</td>
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<tr>
<td>Patients who are awake, alert, sober, and neurologically intact, have no neck pain or midline tenderness: These patients are extremely unlikely to have an acute C-spine fracture or instability. With the patient in a supine position, remove the collar. If there is no significant tenderness, ask the patient to voluntarily move his neck from side to side. Never force the patient’s neck. If there is no pain, C-spine radiography is not necessary</td>
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<tr>
<td>Patients who are awake, alert, neurologically intact, cooperative, but do have neck pain or midline tenderness: All such patients should undergo three-view radiography (lateral, AP, open-mouth odontoid) of the C-spine with axial CT images of suspicious areas or of the lower cervical spine, if not adequately visualized on the plain films. If these films are normal, remove the collar. Under the care of a knowledgeable doctor, obtain flexion and extension, lateral cervical spine films with the patient voluntarily flexing and extending the patient’s neck. If the films show no subluxation, the patient’s C-spine can be cleared and the collar removed. However, if any of these films are suspicious or unclear, replace the collar and obtain consultation from a spine specialist</td>
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<tr>
<td>Patients who have an altered level of consciousness or cannot describe their symptoms: Lateral, AP, and open-mouth odontoid films with CT supplementation through suspicious areas should be obtained on all such patients. If the entire C-spine can be visualized and is found to be normal, the collar can be removed after appropriate evaluation by a doctor skilled in the management of spine-injured patients. Clearance of the C-spine is particularly important if the pulmonary or other care of the patient is compromised by the inability to mobilize the patient</td>
<td></td>
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<tr>
<td>When there is doubt leave the collar on</td>
<td>Consult: doctors who are skilled in the evaluation and management of the spine-injured patient should be consulted in all cases in which a spine injury is detected or suspected</td>
</tr>
<tr>
<td>Backboards: patients who have neurologic deficits (quadriplegia or paraplegia) should be evaluated quickly and taken off the backboard as soon as possible. A paralyzed patient who is allowed to lie on a hard board for more than 2 h is at high risk for developing serious decubiti</td>
<td>Emergency situations: trauma patients who require emergent surgery before a complete workup of the spine can be accomplished should be transported and moved carefully with the assumption than an unstable spine injury is present. The collar should be left on and the patient log-rolled</td>
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The ATLS recommendations also provide a number of recommendations on how to optimally protect the cervical spine throughout the entire trauma diagnostic and therapeutic process [1]. First, external neck support should be maintained until a conclusive position on the cervical spine has been established. Second, ATLS suggests that the backboard, a necessity in the acute phase, should be eliminated by 2 hours to avoid decubiti. Next, if the patient requires surgery to thwart a life-threatening condition prior to cervical spine clearance, the clinician should assume that an unstable neck injury exists and the entire surgical team should approach the patient accordingly. Finally, the ATLS recommendations recognize that a thorough cervical spine evaluation may occasionally exceed the capabilities of the trauma physician, and it suggests that a physician with spine expertise be consulted not simply for detected injuries, but when cervical clearance cannot be decisively established.

It must be emphasized that the ATLS cervical spine recommendations were developed for the physician providing initial care for the traumatized patient. These recommendations provide a basic diagnostic and therapeutic algorithm designed to assist the nonspecialized physician in maintaining a rational, generalized approach to cervical spine clearance [15, 39]. Therefore, the ATLS recommendations are not intended to be the authoritative treatise on cervical spine injury detection or treatment; their intent is to minimize the risk for overall patient morbidity/mortality in the trauma patient due to an early inadequate suspicion of or external support for neck injuries. Furthermore, although the ATLS recommendations were compiled by knowledgeable specialists, they have been advocated without scientific validation.

2.7.2 EAST Guidelines

The Eastern Association for Surgery of Trauma (EAST) recognized the merits of an evidenced-based protocol and endeavored to establish a number of trauma national consensus-based clinical guidelines that included screening recommendations for cervical clearance [71]. These clinical guidelines were formulated by a panel of trauma surgeons who were instructed to assess the scientific quality of the available evidence on the topic. The panel then rendered criteria for cervical spine clearance based on the extent to which they could be supported by the evidence that existed at the time. The final recommendations were abridged after presentation to the EAST National Meeting in 1997, and these revisions were adopted. Subsequently, an update to EAST guidelines [63] has been available online in the EAST website for download (http://www.east.org/tpg/chap3.pdf).

The EAST group recognized cervical spine instability as a frequent, challenging problem confronting physicians providing acute trauma care. The complexity of this problem not only encompasses a number of serious medical concerns (e.g., missed or inappropriately treated cervical spine injury), but also represented major economic and legal issues. The clinical question initially addressed by this group was simply which trauma patients require cervical spine radiography? This suggests that there is a core group of trauma patients in whom X-rays are not warranted. Furthermore, EAST noted that although there was a plethora of literature on cervical spine instability and trauma, a Level I (prospective, randomized, and controlled) clinical trial did not exist at that time. Therefore, their recommendations were made from Level II evidence, and were deemed only reasonably justifiable [71].

Although the EAST cervical clearance recommendations for high-risk trauma patients (i.e., with neck symptoms, neurologic compromise, or an altered mental state) remain controversial, clinicians’ support for the feasibility of select cervical spine clearance solely by clinical evaluation has been sustained.

The EAST guidelines incorporated clinical criteria for excluding imaging [31], specified the minimum number and type of radiographs to be obtained in the indicated patients, established specific criteria for obtaining CT, and recognized the benefit of voluntary lateral flexion–extension stress views in select patients. The consensus EAST recommendation identified that there were select trauma patients who could be successfully cleared for cervical spine injury without radiography. Their indications for clinical screening included patients who are awake; have no mental status changes; are without neck pain; have no distracting injuries, and have no neurologic deficit. By their selective criteria, all other patients required imaging. The EAST guidelines also encouraged the prompt use of MRI in all trauma patients in whom neurologic deficit could be documented [63, 71]. The principal
disadvantage of these guidelines was their lack of clinical validation.

### 2.7.3 NEXUS Guidelines

The NEXUS guidelines constitute the largest study to date designed to validate clinical criteria that could reliably clear the cervical spine in trauma patients [42]. In this multicenter, prospective, observational study, five clinical criteria were used to exclude the need for cervical spine radiography in the trauma setting. These criteria were: (1) normal alertness; (2) the absence of intoxication; (3) the absence of cervical tenderness; (4) the absence of focal neurologic deficit; and (5) the absence of a painful distracting injury (Table 2.4) [44]. Standard trauma three-view radiography was obtained for all patients and was correlated with clinical criteria.

The NEXUS study reviewed 34,069 patients; cervical spine injury was determined in 818 patients, and the clinical criteria failed to suggest injury (false negative) in only eight patients (Fig. 2.1). Among the false-negative patients, only two had injuries that were considered clinically significant. Although this decision instrument was 99.6% sensitive for the presence of injury, it was only 12.9% specific. These clinical cervical clearance criteria would have eliminated radiography in 4,309 (12.6%) patients. The authors concluded that these clinical assessment criteria were reliable in excluding injury and effective in decreasing the need for routine cervical spine imaging.

The NEXUS study could be criticized for its low 12.9% specificity. Furthermore, two of the clinical parameters, intoxication and painful distracting injuries, were found to be poorly reproducible [92]. In this large, well-controlled study, the low incidence of cervical spine injury further emphasized the need for a more efficient clinical instrument to clear cervical spine without imaging.

### 2.7.4 Canadian C-Spine Rule

Stiell et al. [92] performed a prospective cohort study of alert, stable trauma patients to determine the clinical parameters that would exclude the need for imaging to clear the cervical spine (Fig. 2.2). The top priority of neck clearance was readily accepted by these authors who also recognized that 98% of acute trauma patients present without cervical spine injury. The indiscriminate use of radiology as a screening tool was viewed not only as increasing costs, but also as prohibiting an expeditious acute trauma workup. The study assessed trauma patients for 20 standardized clinical parameters in a multicenter effort to determine whether cervical clearance could be reliably achieved without radiography.

The study possessed several unique features. First, its primary outcome measure was not simply the absence of injury, but the absence of clinically significant injury. Clinically significant injury was defined as a fracture, dislocation, neurologic deficit, or soft tissue injury that would require stabilization or specialized follow-up. Clinically insignificant cervical injuries included osteophyte avulsions, isolated transverse process fractures, isolated posterior spinous process fractures, and vertebral body compression fractures with <25% collapse. Clinically insignificant injuries were confirmed after 14 days by the following criteria: (1) no/mild neck pain; (2) no/mild restriction of neck mobility; (3) no cervical collar requirement; and (4) the patient being able to return to full/normal employment.

The Canadian C-Spine Rule study prospectively applied its clinical variable to 8,424 patients. The study was able to successfully exclude the necessity for cervical spine clearance radiography for patients who could satisfactorily respond to three simple questions related to presence of high-risk factors (increased age, dangerous mechanism, parathesia), low-risk factors that would prohibit the safe assessment of neck range of motion, and the patient’s ability to voluntarily rotate the neck (Table 2.6). The initial multicenter study utilizing this instrument demonstrated that only 58% of trauma patients warranted radiography, with a sensitivity of 95% for cervical spine injury detection, and a specificity of 42.5% for cervical spine injury exclusion. Moreover, the Canadian C-Spine Rule proved to be relatively favorable with regard to intraobserver reliability.

However, this study has several limitations. Although all patients were followed up clinically, only selected patients received confirmatory radiography. The distinction between important and unimportant cervical spine injury can be biased, and, therefore is controversial. Furthermore, the study’s cohort did not constitute a consecutive series of patients. Despite this, the Canadian C-Spine Rule added credence to the merits of
Clinical cervical spine clearance criteria in select alert trauma patients [52].

### 2.7.5 Obtunded Patient Clearance Protocols

Clearance of the cervical spine in patients with impaired consciousness is controversial and unresolved. The decision to discontinue the cervical collar for these patients is not synonymous with determining that the cervical spine has been cleared as in Groups I and II. In each of these patients, the risks of an occult cervical spine injury must be weighed against the morbidities of continued cervical immobilization. The concern is that cervical injuries resulting from high-energy trauma may have soft tissue damage that may not be readily identifiable on plain radiographs or CT. Chiu et al. [14] estimated a 0.6% incidence of isolated ligamentous cervical spine injuries in all blunt trauma patients. These isolated soft tissue injuries are difficult to detect, and may result in neural injury, ranging from minor sensory deficits to complete tetraplegia [73, 88, 89]. Neurologic sequelae...
associated with a spinal injury are ten times more likely to occur in the event of a missed injury [22].

There is consensus that patients who have altered mentation require imaging of their cervical spine [1, 18, 38, 40]. A variety of methods have been recommended, but no “gold standard” currently exists. Numerous algorithms have been advocated that incorporate clinical examination (often unreliable), plain radiographs, dynamic fluoroscopy, CT, and MRI. In the last decade, CT and MRI have largely replaced these other imaging modalities and the current debate revolves around the extent to which an MDCT can direct clearance of the cervical spine.

Several recent investigations have advocated CT as a single modality capable of detecting all clinically significant cervical spine injuries [7, 16, 38, 45, 54, 93]. Harris et al. [38] analyzed obtunded trauma patients by using CT and reported that all clinically significant cervical spine injuries were identified. Furthermore, CT failed to detect minor injury in only one patient. Tomycz et al. [93] analyzed 180 obtunded blunt trauma patients with no neurologic deficit and GCS score <13 by CT and normal by MRI. In 21% of patients with a negative CT, MRI was able to identify acute abnormalities; however, none of the injuries identified by MRI were deemed clinically significant. This led the authors to conclude that the use of MRI is obviated by a negative MDCT [16, 83]. CT was found to have a 98.9% negative predictive value for ligament injury and a 100% negative predictive value for cervical instability. In this investigation, four of the 366 patients with negative CT had isolated ligamentous injuries on MRI, none of which were felt to be unstable. Comparison of the results of a clinical examination CT and MRI demonstrated that CT alone had equal sensitivity to MRI, but was faster and resulted in 67% fewer adverse events such as decubiti, delirium, and hospital-acquired pneumonia while awaiting imaging [90].

While CT is sensitive in the identification of osseous abnormalities, it has not been shown to have the same level of accuracy in detecting an isolated ligamentous injury. Analysis of obtunded trauma patients who had negative CT demonstrated an 8.9% incidence of abnormality identified by MRI [66]. In this study, two patients found to have a normal cervical spine by CT interpretation required surgical intervention for ligamentous injury while 14 others required immobilization in an orthosis. These researchers concluded that CT imaging cannot reliably detect all clinically significant cervical injuries and MRI remains a necessary adjunct in the evaluation of obtunded patients with suspected cervical trauma. Similarly, Diaz et al. [22] reported 32% sensitivity for CT for cervical spine ligamentous injuries. This group found that the negative predictive value of CT for ligamentous injury was only 78%. On the basis of these findings, it was concluded that CT imaging was not effective in evaluating ligamentous injuries and recommended that obtunded patients undergo MRI.

Recently, Muchow et al. [69] published a meta-analysis involving five Level I studies, representing 464 trauma patients evaluated using MRI and plain radiographs or CT. Comparable to other reports in the literature, these authors found a 20.9% incidence of abnormalities on MRI that were not detected by plain radiographs or CT. They found that MRI demonstrated a sensitivity of 97.2%, a specificity of 98.5%, and a negative predictive value of 100%. Based on these findings, it was concluded that a negative MRI should be the gold standard for cervical spine clearance in the obtunded patient. However, the high rate of false negatives makes the usefulness of MRI as a screening tool questionable. Stassen et al. [89] advocated an algorithm in which obtunded trauma patients received both CT and MRI to facilitate cervical spine clearance. In this investigation, 30% of the patients with negative CT demonstrated abnormal findings on MRI (p<0.01). Furthermore, MRI identified all abnormalities that were indicated by CT. These authors suggested that both CT and MRI be employed in the evaluation of the cervical spine in obtunded trauma patients. Such a recommendation is in accord with the American College of Radiology’s (ACR) Appropriateness Criteria on suspected spine trauma [18]. The ACR has stated that CT and MRI are the most appropriate modalities for cervical spine evaluation in the obtunded trauma patient.

### 2.7.6 Authors’ Cervical Spine Clearance Algorithm

Following an exhaustive review the existing literature, the authors have developed their own algorithm for clearing the cervical spine in accordance with specific patient group designation (Figs. 2.3–2.5). The algorithm begins with the assumption that a cervical spine injury is present in all trauma patients. The initial clinical
examination should immediately establish the level of patient consciousness and assign patients to one of three clearance groups.

Fully alert (Ransohoff Class 1, Glasgow Coma Scale >14) patients without neurologic deficit, neck pain, or a major distracting injury (Group I) constitute the only patients for whom clinical clearance of the cervical spine is appropriate (Fig. 2.3). Cervical spine imaging is not indicated in those Group I patients. In these select patients, cervical spine precautions can be discontinued, and the trauma team should direct its focus to the other aspects of the patient’s care.

Fully alert patients with neurologic deficit, neck pain (with or without voluntary neck mobilization), or a major distracting injury (Group II) cannot be cleared until adjunctive imaging confirms the absence of cervical spine injury. The authors’ algorithm for the imaging clearance of the cervical spine is depicted in (Fig. 2.4).

For Group III patients who have impaired consciousness, imaging is indicated to detect cervical spine injury, but not to clear the cervical spine (Fig. 2.5). Even if the imaging is negative, conclusive clearance cannot be achieved until the patient becomes lucid. This management scenario typically occurs in the intoxicated and/or distracting injury (temporally non-evaluable) patient, but should also be applied to obtunded (indefinitely nonevaluable) patients with traumatic brain injury. If the patient becomes alert after detoxication, or distracting injuries are resolved, a reliable and thorough history and physical examination can be performed and clearance becomes feasible.
2.8 Summary and Conclusions

Although the modern approach to clearing the cervical spine in the trauma patient has improved dramatically in recent years, many aspects of the existing evaluation protocols are still inadequate. The algorithms that are currently applied are not sufficiently comprehensive, forgo ease of application for improved specificity, or are more often focused on cervical injury detection than its exclusion.

The absence of penetrating trauma to the neck in existing cervical spine clearance protocols reflects their failure to be suitably comprehensive. Epidemiological studies suggest that gunshot injury has become a leading cause for spinal cord injury in the United States, and much of this is due to direct neck trauma [48, 58]. The surgical literature has recognized the increased risk for patient morbidity and mortality with civilian gunshot injury to the neck; however, current cervical spine clearance guidelines continue to neglect the inclusion of this injury mechanism. Clinical cervical spine clearance is not feasible in trauma patients with a penetrating injury to the neck. All of these patients should be assessed by plain cervical spine radiography; many of these patients may warrant more sophisticated imaging (e.g., arteriography, barium swallow, CT, etc.) to rule out the presence of visceral injury [58]. If the present gunshot injury trends continue, future cervical spine clearance guidelines must be expanded to include this mechanism in their evaluation algorithms.
The next major consideration for cervical spine clearance protocol would be the ease by which it can be applied in the hectic, highly stressed emergency center environment. The Canadian C-Spine Rule has the highest reported specificity (42.5%) (Table 2.8) of the currently validated clinical decision-making instruments. However, the physician has to evaluate an exorbitant number of clinical variables with this algorithm [92]. This inherent complexity would require a clinical study to establish its inter- and intrarater reliability. Conversely, the NEXUS algorithm, with its lower specificity (12.6%) consists of only five simple criteria (Table 2.8). The less complex nature of the NEXUS instrument not only ensures its timely application, but also suggests that it would be more readily accepted. Therefore, the optimal clinical cervical spine clearance protocol must not only solely establish high sensitivity and specificity, but also demonstrate sensibility to be universally accepted [59, 91, 92].
as the information they seek differs. Cervical spine injury detection algorithms are in response to the inquiry, “Is a cervical spine injury present?” It is always the second question to be asked and the answer may require complex and sophisticated diagnostic modalities. However, cervical spine clearance algorithms are in response to the inquiry, “Is a cervical spine injury absent?” This is the first question to be asked when assessing trauma patients, and if it cannot be reliably answered in the affirmative, the second question must be asked. The more adept the future guidelines become at answering the first question, the more proficient we will become in clinically clearing the cervical spine in trauma patients.

References


