# Current Review

# Extrication, immobilization and radiologic investigation of patients with cervical spine injuries

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**Most cervical spine injuries are due to motor vehicle accidents. Proper extrication of the victims is vital; the ideal device should be easily assembled and applied, should facilitate removal of victims from automobile seats without changing the body's position, must not hinder airway access or the performance of cardiopulmonary resuscitation, must accommodate all types of patients, including children and obese or pregnant patients, and must completely immobilize the patient, especially if hyperextension is suspected. Current methods of immobilization, such as the use of a soft collar and sandbags, allow neck extension; the short board protects against extension but interferes with airway access. Newer devices are discussed in this article. Injuries of the upper cervical spine are less common but more serious than those of the lower portion and usually involve the vertebral arch. Radiologic examination of the first and second cervical vertebrae and the seventh cervical and first thoracic vertebrae should be emphasized. If lateral and anteroposterior views do not reveal abnormal findings and injury is still suspected, oblique views and computed or conventional tomography should be used. Cervical spinal cord injuries can be minimized or prevented if proper early management is applied.**

**Les traumatismes de la colonne cervicale résultent pour la plupart d'accidents de véhicules-moteurs. La manière dont on retire la victime est de première importance; à cette fin il faut un appareil facile à assembler et à utiliser, permettant d'y parvenir la victime sans changer la position corporelle et sans nuire à l'accès aux voies aériennes ou la réanimation cardio-respiratoire, s'adaptant à tous genres de victimes, comme enfants, sujets obèses et femmes enceintes, et réalisant une immobilisation totale, surtout lorsqu'on craint des lésions par hyperextension. Les moyens disponibles actuellement, comme la minerve souple et les sacs de sable, n'empêchent pas l'extension du cou; si la planche courte empêche celle-ci, elle nuit à l'accès aux voies aériennes. On décrit de nouveaux apparails. Les traumatismes de la colonne cervicale haute, s'ils sont moins fréquents que ceux de sa partie inférieure, sont plus graves et intéressent ordinairement l'arc vertébral. La radiologie devrait mettre en évidence la première et la deuxième vertèbres cervicales et la septième vertèbre cervicale et la première vertèbre thoracique. Lorsque les clichés de face et de profil sont normaux et qu'on craint encore des lésions, on aura recours soit aux clichés en oblique, soit à la tomographie classique ou informatisée. Le traitement précoce adapté permet de prévenir ou de réduire au minimum les lésions de la moelle cervicale.**

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Patients with cervical spine injuries are seen in every centre that receives trauma victims. The devastating complication is injury to the spinal cord. Severe injuries are almost always permanent, with little hope for restoration of neurologic function. Patients with head and neck injuries must be carefully and expeditiously removed from the site of the accident. In addition, the cervical spine must be adequately immobilized

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in the field. Unfortunately, there are no universally accepted devices for such immobilization, and the methods vary widely. Recent studies have provided strong evidence that many of the devices in use are inadequate.[1-3]

In the emergency department cervical spine trauma is often assessed with the use of the standard radiologic "trauma series" of cross-table lateral, anteroposterior and open-mouth odontoid views. These views are now regarded by many as being inadequate for ruling out bony injuries of the cervical spine.[4-6] Criteria for early and subsequent radiologic investigation vary among emergency physicians, and significant injuries may go undetected.

In this article we examine the current knowledge on cervical spine injuries and highlight the controversies in immobilization and radiologic assessment. Recommendations for research into better extrication and immobilization devices and a protocol for radiologic investigation are presented.

## Cervical spine injuries

### *Cause*

In most countries, including Canada, motor vehicle accidents are the main cause of cervical spine injuries (Table I).[7-10] In some areas of Canada sports-related or recreational accidents have replaced work-related accidents as the second most frequent cause. Radiographs and findings at autopsy in 100 consecutive cases of fatal traffic accidents revealed a 24% incidence of cervical spine fractures and dislocations.[11] Up to 25% of cervical cord trauma occurs because of improper immobilization after the accident.[3]

### *Distribution*

Injuries occur in either the upper region of the cervical spine, which includes the atlas and axis, or the lower region, which comprises the third to seventh cervical vertebrae (Table II).[12] Most of the injuries in the upper region (82%) occur at the second cervical vertebra, and 76% of those in the lower region are clustered at the fifth, sixth and seventh vertebrae.[11-13] The distribution of injuries by anatomic structure is also important. The area most often injured is the vertebral arch (Table III[12]); 70% of the patients in one series[6] and 50% in another[12] had such injuries. This finding would explain the inadequacy of radiologic investigation, because vertebral arch structures are not well visualized on the lateral, anteroposterior and open-mouth odontoid views.

Two-thirds of all patients with cervical spine injuries have multiple injuries to the spinal column, which generally occur at adjacent levels, predominantly in the lower region of the cervical spine.[12] Thus, the finding of one fracture or dislocation should compel the clinician to rule out additional injuries.

### *Mechanism of action*

The forces that cause cervical spine injuries are hyperflexion, hyperextension, lateral flexion, rotation, axial loading (compression) and distraction. The upper region of the cervical spine allows flexion, extension, lateral flexion and most of the rotation of the head and neck. Although injuries in this area account for approximately one-third of the cervical spine injuries (Table II), they are responsible for 80% of the deaths from cervical spine trauma; of those who survive, up to 70% may suffer significant neurologic deficits, such as paraplegia and tetraplegia.[14]

The motion of the lower region of the cervical spine is mainly flexion and extension, with a small amount of rotation and lateral flexion. Although injuries may occur in any of these directions some studies have indicated that hyperextension is the commonest mechanism of injury and accounts for approximately one-third of such cases.[12,15] Hyperextension may damage the spinal cord through

**Table I — Causes of cervical spine injuries[7]**

| Cause | % of injuries |
|---|---|
| Automobile accidents | 62.5 |
| Falls | 23.0 |
| Motorcycle accidents | 4.8 |
| Diving accidents | 4.8 |
| Sports events | 1.9 |
| Firearms (missiles) | 1.0 |
| Other | 1.9 |

**Table II — Distribution of cervical spine injuries, by vertebral level[12]**

| Level of injury | % of patients* |
|---|---|
| C1 | 6 |
| C2 | 27 |
| C3 | 10 |
| C4 | 10 |
| C5 | 18 |
| C6 | 27 |
| C7 | 18 |

*Some patients had multiple vertebral injuries.

**Table III — Distribution of cervical spine injuries, by anatomic structure[12]**

| Structure | % of patients |
|---|---|
| Vertebral arch | 50 |
| Vertebral body | 30 |
| Intervertebral disc | 29 |
| Posterior ligament | 16 |
| Odontoid process | 14 |
| Articular processes | 12 |
| Anterior ligament | 2 |

temporary dislocation associated with rupture of the anterior ligament and spontaneous reduction; this form of injury would not be detected on roentgenograms. Taylor and Blackwood[16] showed that spinal cord damage could occur without vertebral injury because of the inward bulging of the ligamentum flavum during hyperextension. Marar[15] reported that in 30% of spinal cord injuries the x-ray films appeared normal.

The mechanism for injury of the vertebral arch is considered to be compressive hyperextension.

## Extrication and immobilization

Immobilization of the cervical spine is one of the most critical maneuvers in the successful extrication and transportation of trauma victims. The device has to be applied at the accident site and should be removed only after injury has been definitively excluded or complete stabilization has been achieved. Immobilization and extrication have to be accomplished quickly and with the least degree of neck movement, especially in the case of the unconscious victim, whose neck muscles may not provide any protective spasm.

Few studies have measured the efficacy of immobilization devices. Although techniques have differed widely, all investigators have agreed that the devices commonly used in the prehospital phase do not eliminate all cervical movement. Soft collars were found to be no more than "flags" to alert the emergency physician to the possibility of cervical trauma. Colachis and colleagues[2] found that soft collars allowed 96% of normal neck flexion and 73% of normal extension when properly applied. Podolsky and collaborators,[3] comparing the effectiveness of commonly used immobilization collars with that of tape and sandbags, showed that the four types of collars tested allowed significant freedom of movement and failed to immobilize the cervical spine (Table IV). Tape and sandbags applied on a hard resuscitation table limited flexion but failed to completely limit extension. The use of tape and sandbags together with a Philadelphia collar was the most effective method but still allowed about 35% of normal extension. Thus, no collar by itself can completely immobilize the cervical spine. Collars depend on the shoulder girdle for support; however, the girdle is mobile.

To adequately immobilize the cervical spine the head and shoulders must be fastened to a common rigid plane. This important principle should be incorporated into the design of devices, because successful extrication requires removal of the patient from the accident site and transportation to an ambulance as one unit, with minimal movement of the entire spine. Emergency medicine technicians and paramedics, who are well versed in the mechanics and maneuvers of successful extrication, require devices that will allow them to adequately immobilize the cervical spine and successfully remove the patient from various situations. Commonly used devices include extrication splints; these allow early immobilization of the head by means of a collar and immobilization of the neck by means of a short-board device.

Unfortunately, very few quantitative studies have assessed the effectiveness of extrication splints. Cline and coworkers[1] compared the effectiveness of collars with that of the short board (a prototype of the Ohio Extrication Short Board) and measured the degrees of movement by means of radiography. The short board limited movement to 12% in the sagittal plane (flexion–extension) but allowed 36% of normal lateral flexion and 29% of axial rotation. In addition, the short board is bulky, takes a considerable amount of time to apply and immobilizes the neck in various degrees of extension. It also interferes with airway access, which is of great concern in patients with multiple injuries. The guidelines of the Advanced Trauma Life Support Course state that in patients with suspected cervical spine injuries who require mechanical ventilation, nasotracheal intubation should be done;[17] however, if the patient is apneic or if nasotracheal intubation fails, endotracheal intubation together with inline traction and immobilization of the cervical spine should be attempted. Surgery is required if both methods fail or if severe maxillofacial or oropharyngeal injuries are present.

The ideal device, therefore, has to allow ready access to the patient's oropharynx and anterior region of the neck. Newer extrication splints use the same principles of immobilization but are superior to the stiff, nonconforming short board. The Kendrick Extrication Device (KED) (Ferno-Washington, Inc., Wilmington, Ohio) is assembled from slats encased in nylon and, thus, affords

**Table IV — Degrees of movement allowed with the use of six cervical immobilization methods in 25 healthy volunteers[3]**

| Movement | Method; degree of movement, mean (and standard deviation) | | | | | | |
|---|---|---|---|---|---|---|---|
| | No immobilization | Soft collar | Extrication collar | Hard collar | Philadelphia collar | Tape and sandbags | Tape, sandbags and Philadelphia collar |
| Flexion | 35.7 (5.1) | 34.2 (6.4) | 26.4 (6.4) | 25.8 (6.0) | 24.2 (7.8) | 0.1 (6.0) | 0.1 (0.4) |
| Extension | 21.0 (5.8) | 18.1 (5.8) | 16.4 (6.7) | 15.4 (5.3) | 12.0 (7.0) | 15.0 (6.9) | 7.4 (5.5) |
| Lateral movement | 21.2 (5.4) | 21.1 (4.6) | 15.4 (4.9) | 14.2 (6.3) | 17.4 (5.0) | 1.8 (1.7) | 1.4 (1.5) |
| Rotation | 75.8 (6.5) | 67.4 (11.7) | 48.9 (11.6) | 49.9 (15.3) | 49.9 (14.2) | 2.5 (2.2) | 4.0 (3.0) |

greater flexibility. The KED is easy to place into a contoured driver's seat, can be quickly applied by a single rescuer, allows airway access and conforms to any body size. Although the KED is considered to be the ideal extrication device by technical reviewers, it has yet to be evaluated for its immobilization of the cervical spine. The role and performance of the device in transferring patients by road or air, including situations in which traction is required, must be addressed.

## Radiologic investigation

Radiologic investigation is indicated for (a) patients with a normal sensorium who complain of neck pain after trauma to the head or neck or who have tenderness on palpation of the neck anteriorly or posteriorly, (b) patients with altered sensorium, and (c) high-risk patients, such as victims of high-speed motor vehicle accidents, those who have fallen from heights or have suffered diving injuries and those who present with neurologic deficits. A physician must accompany and supervise the technicians during all radiologic procedures and perform the flexion and extension of the cervical spine if such views are indicated.

The investigation should start with the lateral, anteroposterior and open-mouth odontoid views. However, significant findings may still be missed. The lateral view is the first obtained and often guides subsequent management of the patient. Areas of the first and second cervical vertebrae are occasionally difficult to evaluate, and injuries of the lower region of the cervical spine may not be easily visualized because of the overlapping soft tissue or bony structures of the shoulders. Fractures of the transverse processes and of the vertebral arches due to hyperextension may be inadequately demonstrated by the lateral view.[6] However, Shaffer and associates[18] surveyed Chicago emergency physicians and found that all would start with the lateral view and that most would allow mobilization of the neck on the basis of those findings, without the use of other views. Clearly, such management places patients with undetected fractures at some risk; however, the proportion of such fractures that are actually unstable is unknown.

The accuracy of all three views is only marginally better than that of the lateral view alone. For example, in the series of 71 blunt injuries reported by Streitwieser and colleagues,[6] the accuracy of all three views was 84%, as compared with 77% for the lateral view alone. Indeed, 70% of the fractures later diagnosed by means of thin-section tomography remained undetected in the three views.[6] Binet and collaborators[4] found that 9 of 21 odontoid fractures that were missed in the three views were detected by means of tomography. In 67% of 79 patients with acute cervical spine injuries and no neurologic deficits Maravilla and coworkers[5] found that the plain films appeared normal but that the fractures were demonstrated by means of tomography. In addition, thin-section tomography significantly altered patient management in 12% to 18% of the cases of suspected cervical spine injuries.[4,5]

Additional views are required if the three initial views fail to detect an abnormality or there are suspicious clinical or radiographic findings, such as widening of the soft-tissue shadow anterior to the spine and loss or reversal of the normal cervical lordotic curve. Additional views should be requested if hyperextension is suspected.

A number of additional views can be useful.[19] For example, oblique views provide good visualization of the vertebral arches, whereas these elements are obscured by bony structures anteroposteriorly and laterally.[20] Before computed tomography (CT) or conventional tomography is used it may be helpful to obtain other views, such as pillar views, which highlight the laminae and surrounding structures of the vertebral arch. Visualization of the seventh cervical and first thoracic vertebrae, although frequently neglected, is essential. This can be achieved by pulling on the patient's arms slowly and steadily with the use of wrist straps and crossing of the arms at the elbows. One may also attempt the "swimmer's view", or transaxillary approach, by having the patient place one arm up and one arm down or by applying traction upward to one arm and downward to the other.

CT scanning or conventional tomography is indicated if (a) a known fracture has to be further evaluated, (b) there are suspicious clinical signs, (c) there are suspicious radiographic findings, (d) one fracture or dislocation has been detected and additional injuries must be ruled out, and (e) one or more levels of the cervical spine cannot be adequately visualized by other means. CT scanning has been of major benefit in the early investigation of acute cervical spine trauma. We believe that flexion–extension views are not part of the initial examination and should be obtained only after additional views and computed or conventional tomograms have been taken. Flexion–extension views are contraindicated in patients with neurologic deficits.

Current studies underscore the importance of an organized approach to the radiographic investigation of cervical spine injuries. It is often difficult, however, to obtain adequate and satisfactory results in cases of multiple injuries; early consultation with a radiologist should therefore be done in all difficult or doubtful cases.

A small proportion of patients whose injuries are treated conservatively may have late spinal instability. For example, previously undetected injuries of the ligaments may fail to heal, and subluxation or dislocation may occur after discharge from hospital. Therefore, adequate follow-up radiologic investigations, including flexion and extension views, should be considered for all patients with cervical spine injuries who continue to experience pain, especially within 3 to 6 months

after discharge. Surgical intervention to stabilize the cervical spine may be required for those who demonstrate ligamentous disruption at follow-up.

## Summary

Injuries of the upper region of the cervical spine are less frequent but are associated with higher mortality and morbidity rates than the more common injuries of the lower region, which tend to occur at multiple levels and to cluster in the fifth to seventh cervical vertebrae. Injuries in the lower region often involve the vertebral arch and are caused by hyperextension of the neck.

Most cervical spine injuries today are due to car accidents. Thus, extrication techniques are very important. The ideal device (a) should facilitate the removal of victims with multiple injuries from automobile seats without significantly disturbing the cervical spine, (b) must not hinder airway access or the performance of cardiopulmonary resuscitation, (c) should be easily assembled and applied, (d) must accommodate all types of patients, including children and those who are pregnant or obese, and (e) must completely immobilize patients, especially in cases of hyperextension.

Current methods of immobilization are not completely adequate. Tape and sandbags together with the Philadelphia collar allow significant extension and are inadequate as extrication devices. The short board offers better protection against extension but is bulky, takes too much time to apply and often interferes with airway access. The newer devices such as the KED may be better than the others, but they have not been completely evaluated. Universal standards of care in the prehospital phase must be established. To accomplish this, radiologic measurements can be used to compare the effectiveness of immobilization offered by the newer devices with that of the short board.[1]

Closer adherence to the recommended criteria for the radiologic investigation of cervical spine injuries and a more complete understanding of the fracture patterns, such as the distribution and mechanism of these injuries, will increase the number of injuries detected and decrease the associated mortality and morbidity rates. The first two cervical vertebrae and the seventh cervical and first thoracic vertebrae are common sites of injury; thus, radiologic examination must include visualization of both these regions anteroposteriorly and laterally. Additional views, such as the oblique and swimmer's views, should be used to visualize vertebral arch structures, especially in cases of suspected hyperextension. Furthermore, we recommend that CT scanning or conventional tomography be used if clinical suspicion is high and other methods have failed to detect injury or if additional injuries must be ruled out.

The most effective way to deal with spinal cord injury is prevention. A concerted effort to improve the management of cervical spine injuries will decrease the extent of cord damage by preventing additional injury.

We thank the following physicians for their thoughtful and constructive reviews: Bruce M.T. Rowat, chairman, Academy of Emergency Medicine, University of Toronto; Brian Steinhart, Department of Emergency Medicine, St. Michael's Hospital, Toronto; Fred Gentili, Division of Neurosurgery, Toronto General Hospital; and Anne M. Keller, Department of Radiology, Toronto General Hospital.

Special thanks go to Ines Oblak and Joanne Pizzey for their patience and effort in typing this paper.

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