Care of the Multiply Injured Patient With Cervical Spine Injury

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Cervical spine injuries can be disastrous. The treatment begins at the accident scene by obtaining an appropriate history, physical examination, and evaluation of the mechanics of the accident. Emergency medical stabilization takes precedence, but the cervical spine should be stabilized until an injury in this area is ruled out. If the patient has suffered a head injury or is violent, cervical spine precautions should be maintained until spinal column injuries have been ruled out roentgenographically. Because of the complexities of the evaluation and treatment of cervical spine injury in the multiply injured patient, an algorithm to assist in the management and evaluation of the patient has been developed, and a multidisciplinary, specialized evaluation and treatment team is employed. Through this approach, mortality in the multiply injured patient with a cervical spine injury has been reduced to 22%. Of 58 patients with cervical spine injuries evaluated by this aggressive approach, 14 patients had associated spine fractures, and 9 patients had positive peritoneal lavage requiring surgical exploration. Injuries involving other organ systems were also diagnosed and treated. Formal, rigid evaluation plans and aggressive multidisciplinary treatment are useful in saving the lives and salvaging neurologic function of these patients.

A cervical spine injury, with or without neurologic deficit, presents a significant problem for patients, their families, and society in general.[3,4,12,17,34,46,57,58] The diagnosis and treatment of these injuries, particularly when associated with multiple trauma, present extremely complex and often controversial issues regarding evaluation and treatment priorities and decisions involving the cost of care in the trauma-unit evaluation process. To reduce the personal, socioeconomic, and medical impacts, a systematic approach to acute-care management is necessary.[2,16,20–22,36,41,48]

The causes of cervical spine injury vary regionally and have changed over the last two decades. Motor vehicle accidents cause 40%–50% of cervical spine injuries.[29,34,57] In some areas in recent years the rate of motorcycle accidents has increased significantly compared with other vehicular injuries. Firearms and falls account for 30%–40% of the injuries while water sports are responsible for approximately 10%.[17,34,58] Injury mechanisms also vary with age. The majority of individuals younger than 30 years of age sustain their spinal cord injuries following motor vehicle accidents or water-sport activities, while those older than 35 years have a higher incidence of injuries from falls and firearms. The mechanism of injury is significant, since an isolated gunshot wound or diving injury may not warrant the concern for injury to other systems as does a motor vehicle accident or a fall from a great height.

The National Spinal Cord Injury Data Research Center has estimated that each year in the United States more than 14,000 individuals sustain a spinal cord injury, with 10,000 surviving the initial traumatic event.[34] Of this

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group, 10% die in hospitals, with half of these deaths occurring during the first month.[41,51,57] The majority of these early deaths are related to respiratory failure. Cardiogenic causes account for another 20%. The highest in-hospital mortality from cervical spinal cord injury is related to C4–C5-level spinal cord disruption. The annual incidence varies by area, but an estimated 35–45 persons per one million population sustain a spinal cord injury and reach the hospital alive.[23,34,58] Although paraplegia once exceeded quadriplegia by a ratio of 2:1 or 3:1, the incidence of paraplegia has decreased and the figures now are roughly equal.[46] This change is likely related to increased awareness on the part of the prehospital personnel, improved stabilization and transport techniques, and more aggressive and defined trauma unit treatments, although alterations in speed limits and other factors also play a role in the reduced incidence.

Green has evaluated the effect of treating spinal cord-injured patients in specialized treatment centers versus treatment in areas lacking this interest or expertise.[23] His report reveals that the most dramatic neurologic changes occur within the first three months following injury. This suggests a need for early, aggressive treatment to stabilize the patient and the spinal cord in an attempt to take advantage of any potential neurologic recovery that may exist. According to Green, there is a trend toward improved neurologic function based on the type of hospitalization the patient receives. Observations in Australia support Green's assertion, since they have documented that treatment at a specialized trauma–spinal cord unit within 12 hours of injury can decrease the incidence of complications.[2–4,23,56]

The care and eventual rehabilitation of the cervical spinal cord-injured patient (SCI) are frequently complicated by associated head injury, musculoskeletal injury, or visceral damage.[5,6,9,25,29,30,32,35,38,43] In addition to concomitant medical instability, loss of consciousness, patient violence, or alcoholic intoxication makes the spinal cord injury difficult to diagnose and treat in the acute-care setting.

Apart from mechanical compression, an injury to the spinal cord leads to deleterious metabolic and tissue changes. Maintenance of adequate perfusion to the spinal cord is important for adequate protection of remaining viable tissue. In addition, the pathologic consequences of local tissue hypoxia should be avoided. The changes, including cellular edema, ischemia, autolysis, release of cellular breakdown products, alteration of electrical potential of adjacent neurons, alteration in pH, and resultant metabolic acidosis, all begin within seconds of the impact.[14] Therefore, acute awareness of a spinal cord injury or cervical spine injury is critical in the early management of the multiply injured patient.

To aid in the evaluation and treatment of these patients, the authors have developed an algorithm to be used at the time the patient is admitted to the trauma unit.[21,22] However, since the initial care is usually administered in the field and during transport to the trauma unit, the authors' recommended treatment protocol for the emergency medical service (EMS) team will be reviewed.

PREHOSPITAL CARE

EMS personnel must be aware of the possibility of injury to the cervical spine or cervical spinal cord in all victims of accidents (*e.g.*, motor vehicle accidents, falls, recreational accidents) that may produce excessive mechanical loading of the spine.[52–54] A high index of suspicion and increased vigilance for spinal stabilization prior to evacuation of a patient from a trauma scene is one factor that has contributed to the decline in the percentage of complete spinal cord injury lesions (from 50% to 39%).[24]

A brief investigation at the accident scene and reconstruction of the injury mechanism can aid in assessing the victim's chance of having a spinal injury coupled with other systemic involvement. As mentioned previously, an isolated gunshot wound to the neck or a pool-diving accident (particularly in shallow water) would suggest, in an acutely quadriplegic patient, that any associated hypotension is related to neurogenic, as opposed to hypovolemic, shock. On the other hand, motor vehicle accidents are frequently associated with multiple trauma, particularly if the patient is thrown from the automobile. Huelke and colleagues have reported that if an automobile involved in an accident requires towing, the victim in the injury has one chance in 300 of sustaining a serious neck injury.[29] If the victim is ejected from the automobile, the chance of serious spinal cord injury increases 36 times.[29] In motorcycle accidents, Yeo reports a higher incidence of cervical spine injury in victims wearing open-face protective helmets than in those with closed-face models.[55] Although lap–sash seatbelt use has decreased the incidence of thoracolumbar flexion–distraction fractures,[11,45] two cervical injury patterns have developed from their use. If victims slide under the belt on impact, they may catch their chins and hyperextend their necks, which leads to a characteristic extension-type injury, if not decapitation.[47] If, however, the victim's chest is restrained and he or she does not slide down, a hyperflexion–distraction injury of the neck over the top of the shoulder strap may occur, resulting in a cervical spine subluxation or dislocation.[51]

A significant percentage of spinal cord-injured patients also have head injuries.[32,34] This is more often seen in motor vehicle and diving accidents when the patient either has been ejected from the vehicle or has struck his or her head on a rigid object.[29] Until it can be definitively proved otherwise, all unconscious patients and all patients injured by falls, diving, or motor vehicle accidents should be treated as potentially having a spinal cord injury.

The above-listed considerations are particularly important if the patient cannot respond or provide an adequate history and/or localize pain or dysfunction. After taking the history, a physical examination, including attention to neurologic function, should be rapidly performed. Inspection of the head for abrasions or lacerations may suggest a possible cervical spine injury. The spine should not be moved, but tenderness along the neck should be noted. The neurologic examination need not be minutely detailed but should include at least a cursory evaluation for extremity weakness. A superficial sensory examination should also be performed.

Medical Treatment

Standard emergency care is administered in all cases of potential multiple trauma.[36] However, if spinal column injury or instability is suspected, specific observations and precautions should be made in an attempt to minimize further damage.

Aspiration of gastric contents and shock are the two most common causes of prehospital death in SCI patients.[41] If cardiopulmonary resuscitation is required, care must be taken to minimize neck manipulation while providing respiratory assistance.[40] Airway maintenance is paramount, but if possible, the neck should be controlled in a neutral position if the potential for cervical injury exists. Emesis should be anticipated, and suctioning should be performed regularly to avoid aspiration. If respiratory excursions are limited (due to intercostal or diaphragm muscle dysfunction), manual ventilation with a mask–bag assistive device or intubation should be performed. This is particularly critical in light of the deleterious effect of hypoxemia on the spinal cord.[14–16,18,19,26]

Shock, which is frequent in these patients, can be hypovolemic (hemorrhagic) or neurogenic. Hemorrhagic/hypovolemic shock should be treated with intravenous asanguinous fluid.[26] Pneumatic antishock garments can also be used to sustain blood pressure during transport.[44] Neurogenic shock due to the loss of sympathetic innervation of the blood vessels can be cautiously treated with vasopressors, provided that hemorrhagic shock has been ruled out. Neurogenic shock is characterized by bradycardia, whereas tachycardia is present in hypovolemic shock. Assessing the heart rate, therefore, is extremely important in determining the possible cause of hypotension in the patient with spinal cord injury.

Some EMS protocols include the routine use of glucocorticoids in SCI patients. Theoretically, glucocorticoids are capable of stabilizing the cellular membrane, reducing edema, counteracting cellular sodium and potassium imbalances, and counteracting the decreased serum cortisol frequently seen with cervical spinal cord injuries.[8,10,14] However, this treatment has not been proved to be effective.[6,10,13,15,50] Recently, the National Acute Spinal Cord Injury Study Group conducted a multicenter randomized clinical trial to examine the efficacy of administering a high dose of methylprednisolone compared with a standard dose. No significant difference in neurologic recovery was found one year after injury.[37] There has never been a consistently observed, documented improvement in the neurologic status of patients with complete lesions who were given steroids; however, in central cord syndromes, some benefit has been suggested, although this is not universally accepted.[6] Therefore, the present authors do not routinely recommend the use of steroids in the SCI patient. Furthermore, the administration of steroids may predispose patients to infectious complications.

SCI patients frequently have dysfunction of their temperature control mechanisms. As soon as possible, the patient's temperature should be monitored and cooling or heating applied as needed. This is particularly important since metabolic rates may be affected by systemic temperature.[3,14]

Spinal Stabilization

After emergency medical stabilization has been achieved, spine stabilization should be performed. Preferably, this should occur prior to extrication of the high-risk individual or patient complaining of neck pain. The patient's airway status can help determine the position for spinal immobilization. If the airway has not been compromised, the neck should be stabilized in the position in which the patient is found. If the airway has been compromised, manual cervical–head traction should be applied in line with the trunk. Nasotracheal intubation is the preferred mode of airway access since it minimizes neck manipulation. Cricothyroidotomy or tracheostomy should be avoided unless it is absolutely essential, since surgical violation of the anterior cervical soft tissues may mitigate against subsequent anterior cervical spine operation. Sandbags, cloth tape across the forehead, external orthoses, or extrication frames should be routinely employed for cervical spine immobilization.[22,33,42,52,53] Soft collars should be avoided since they provide no significant degree of immobilization and give patients and emergency personnel a false sense of security.[33,52]

Transportation

The mode of transport (ground ambulance, helicopter, or other aircraft) is dependent on availability, distance, terrain, and geographic constraints. Certainly, the distance between the accident site and the trauma hospital, coupled with the severity of injury, must be integrated into the transportation decisions.

HOSPITAL CARE

Although a spinal cord injury is a catastrophic event and neurologic deterioration must be minimized, the critical initial demand on the trauma service is preservation of life. Some maneuvers required to reverse a potentially lethal situation may compromise strict spine immobilization rules, but these life-saving measures must take precedence.[5,6,24] To assist in the management of these complex situations, the authors follow a set of algorithms that attempt to encompass all patients with possible spinal column dis-

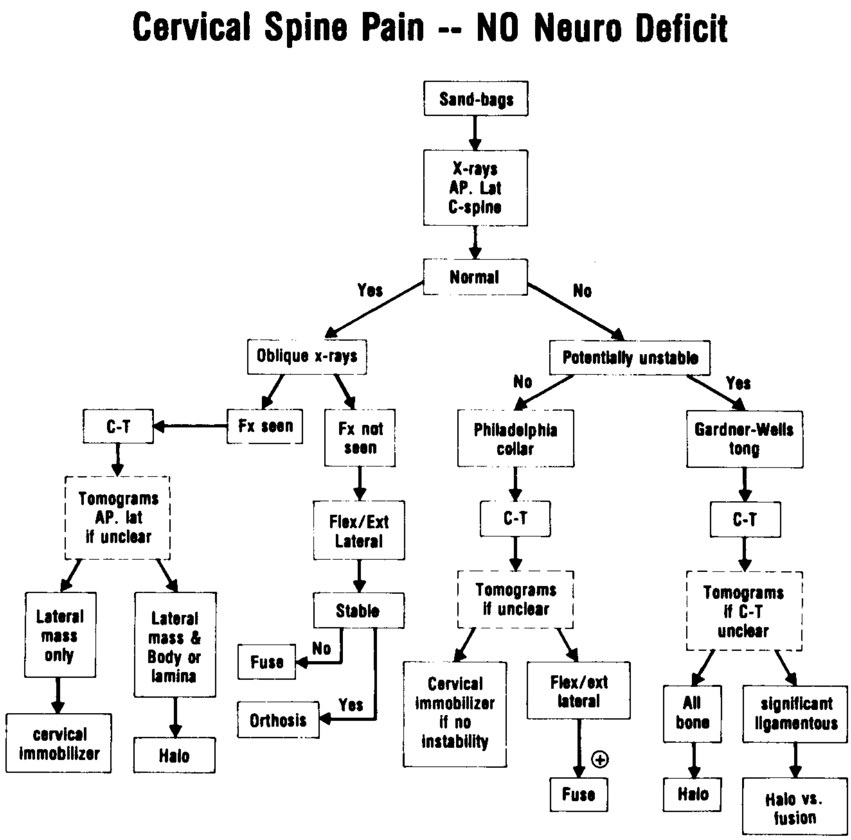

FIG. 1. Algorithm for patient with suspected cervical spine injury (without neurological deficit). (Reproduced with permission from Garfin, S. R., Katz, M. M., and Marshall, L. F.: The vertebral column: Clinical aspects. *In* Nahum, A. A., and Melvin, J. (eds.): The Biomechanics of Trauma. Norwalk, Connecticut, Appleton-Century-Crofts, 1985, Fig. 10A.)

ruption.[21] While the algorithms shown in Figures 1 and 2 suggest that roentgenographic evaluation is simultaneous with trauma evaluation and treatment, the latter take precedence. During or immediately after the initial resuscitation, cervical spine films should be obtained, after which treatment planning can proceed in an orderly, organized fashion.

Initial Resuscitation

Ideally, the patient is alert, oriented, and responsive to sensory and motor evaluation. If these conditions exist, the task of determining potential injuries and the extent of any spinal cord involvement is simplified. However, if the patient is violent or unconscious, a neurologic deficit may be difficult to determine; in these cases, an injury of the spinal cord in the cervical spine should be assumed.

Life-threatening problems such as hypotension, pulmonary or cardiac dysfunction, or injury to abdominal or thoracic viscera must receive immediate treatment. If time allows, prior to moving the patient to the operating room (if required), anteroposterior (AP) and lateral roentgenograms of the cervical spine should be obtained. In addition, if the patient cannot respond appropriately, AP and lateral roentgenograms of the thoracic and lumbar spine should also be obtained because of the known incidence of multilevel

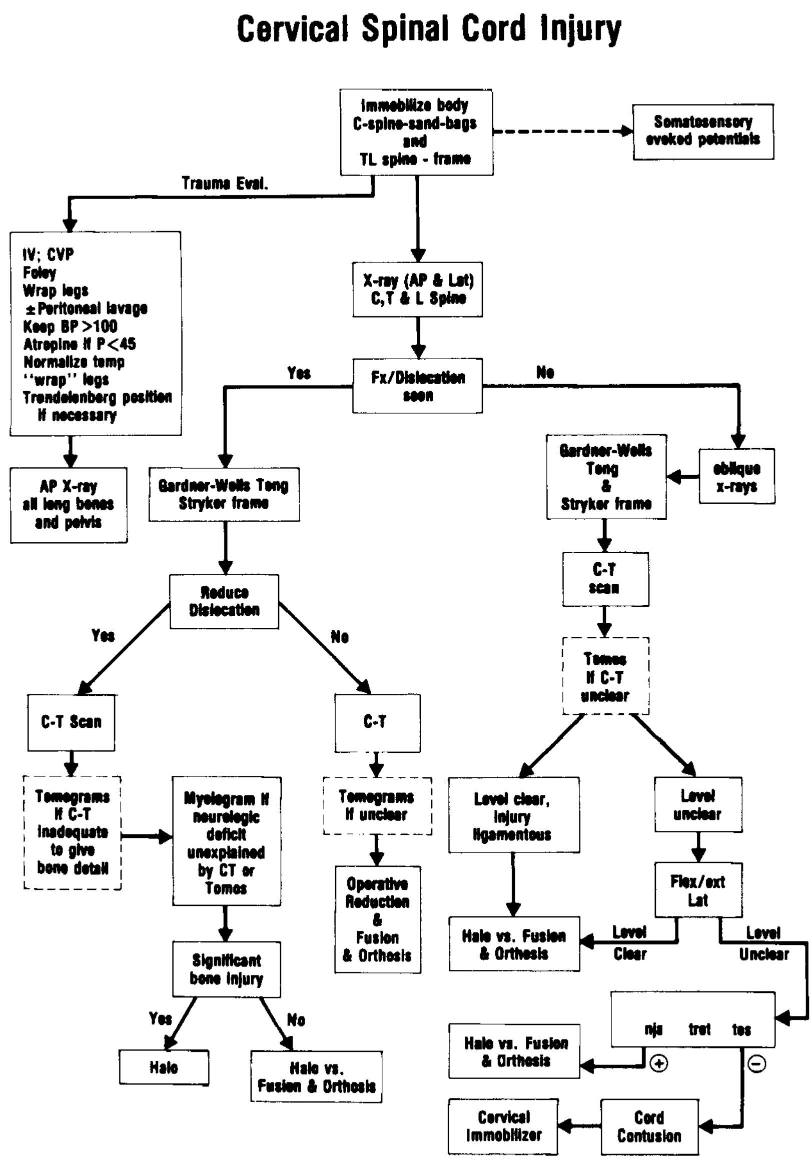

FIG. 2. Algorithm for patient with cervical spinal cord injury (with neurological deficit). (Reproduced with permission from Garfin, S. R., Katz, M. M., and Marshall, L. F.: The vertebral column: Clinical aspects. *In* Nahum, A. A., and Melvin, J. (eds.): The Biomechanics of Trauma. Norwalk, Connecticut, Appleton-Century-Crofts, 1985, Fig. 10B.)

spinal injuries.[5,6] A detailed cervical spine evaluation, including oblique roentgenograms, computed tomographic (CT) scans, tomograms, magnetic resonance (MR) scans, and/or myelography can be delayed until the patient is stable.[41]

SUSPECTED CERVICAL SPINE INJURY

If the patient is neurologically intact and complains of cervical spine pain, the neck should be immobilized with sandbags and tape or with a rigid collar until appropriate roentgenograms are reviewed. If the initial studies are normal but neck pain persists, the patient should be maintained in the hard collar until flexion–extension lateral films or stress films can be obtained. If the patient notes significant pain and appears to have cervical guarding, flexion–extension studies should be delayed until muscle spasms and pain diminish enough to allow a good effort at flexion–extension. A White–Panjabi stretch test should be considered if one cannot obtain a good flexion–extension lateral film and cervical spine disruption is still suspected.[52,54]

If an injury is detected and is primarily ligamentous, external immobilization provides only a 50%–60% union rate.[52] With this relatively high nonunion rate, early surgical stabilization should be considered. In addition to stability, internal fixation may aid rehabilitation. In bony injuries, stability should be assessed,[1,5,6,16,21,22,27,28,43,52–54] a cervical orthosis or halo immobilizer should be applied, or a surgical fusion should be performed.[7]

If the initial roentgenograms show an unstable fracture subluxation, a Gardner–Wells skulltong (Codman and Shurtleff, Randolph, Massachusetts) should be applied and skeletal–skull traction maintained with the patient on a kinetic treatment table (Rotorest, Kinetic Concepts, San Antonio, Texas) or a hard hospital bed.[49] CT scans should be obtained. If the injury is in the transverse plane (*e.g.*, Type II odontoid or facet fracture–dislocation), tomograms may provide useful information. With a medically stable patient, an MR scan may be considered, but may be less important if there is no associated spinal cord injury.

Cervical Spinal Cord-Injured Patient

Any patient with definite cervical spinal cord and/or head injury should be treated with total spine immobilization. For preservation of spinal cord function, diastolic blood pressure should be maintained at or above 70 mmHg.[6,31] If there are no contraindications and hypotension persists, the lower extremities should be wrapped to decrease blood pooling secondary to loss of vasomotor tone. Because of the risks associated with intraabdominal hemorrhage and the lack of reliability of the abdominal exam, particularly in a head-injured or SCI patient, peritoneal lavage or abdominal CT scan should routinely be performed.

Once the diagnosis is clarified and the patient is stabilized (medically, surgically, and cervically), a roentgenogram should be taken of all long bones distal to the suspected spinal cord injury. In SCI and head-injured patients there is a reported 35% incidence of concomitant fractures and an 11% incidence of missed fractures distal to the injury level, therefore all bones should be roentgenographed.[30,32,34,39] Since, at the initial presentation, the degree of neurologic recovery cannot be determined, the authors recommend aggressive rigid internal fixation of all long-bone fractures to aid in nursing care and rehabilitation efforts. This is particularly important for insensate or motor-deprived limbs because of skin problems that may develop in casts or braces. Internal fixation lessens skin problems, decreases the incidence of pressure sores under rigid external immobilizers, and decreases the need for external support, which may compromise nursing and rehabilitative efforts. The extremity fractures should be treated after medical stabilization has been achieved.

Once the medical, surgical, and orthopedic evaluations have been completed and documented, the spine can be evaluated more thoroughly. In the majority of cases this includes CT scans. If there is a spinal cord injury and there is no significant bony involvement, an enhanced CT scan is preferred since it will outline the spinal cord and may demonstrate a herniated disc that may not appear on a routine CT scan. If the cervical injury is in the transverse plane, tomograms may be used to supplement the CT scan (unless thin CT cuts are performed and the films can be laterally reconstructed).[40] An MR scan may be useful to evaluate the spinal cord, but in most centers it is not easily obtained. Therefore, if the CT scan, tomograms, and plain films do not adequately explain the neurologic deficit, a myelogram with or without follow-up CT should be considered. If posterior element disruption, vertebral body retropulsion, significant compression, or subluxation/dislocation is noted, surgery may be considered. The sooner surgery is performed, the more beneficial it is in decreasing rehabilitation time and medical costs.[5,12,16] On the other hand, a recently reported multicenter study observed an increased risk of neurologic and pulmonary compromise if surgery is performed within 96 hours of injury onset. It should be noted, however, that this was not a controlled study and the reasons for surgical delay may have influenced the results. However, it is the largest and most detailed study available and its recommendations should be taken into consideration.[37]

Halo cervical immobilizers should be applied if a rigid external immobilizing device is required and the medical or surgical condition precludes surgical stabilization. If cardiopulmonary complications limit the use of the halo vest, the patient can be maintained on a turning frame or a kinetic treatment table. A Stryker frame should be avoided, since cervical motion may occur during turning and the degree of immobilization obtained is less than ideal.[49]

If the diagnostic evaluation is complete and the injury level is still unclear, lateral flexion–extension roentgenograms should be obtained once the patient can help perform the study. If these are normal, a White–Panjabi stretch test should be performed.[52,54] If the flexion–extension films and/or the White–Panjabi test are abnormal, then the instability is most likely ligamentous. If all studies, including the stretch test, are normal, by exclusion, the determined cause of the spinal cord injury is a cord contusion; in this case, the spinal column can be considered relatively stable.

In the Operating Room

If there are multiple orthopedic injuries, the authors prefer to stabilize the spine first and then, if the patient is medically stable and there are no contraindications, under the same anesthetic all other long bones are openly reduced and internally fixed. If surgery is needed for life-threatening injuries, cervical spine surgery is deferred until the laparotomy or thoracotomy has been completed and the patient stabilized. Assuming the primary indication for surgery is cervical stabilization, the anesthetic technique includes an awake intubation. For safety reasons and to avoid neck manipulation, the intubation is usually done on a lightly sedated patient over a flexible bronchoscope inserted nasotracheally. Once the tube is inserted and adequate ventilation assured, the tube is secured to the patient by taping anteriorly, avoiding any ties posteriorly around the neck. If the patient is to be operated upon in the prone position, positioning is accomplished prior to the induction of anesthesia. During turning, traction is maintained with the surgeon controlling the head and shoulders. The patient is asked to keep his or her neck in a rigid posture, to keep the extremities and trunk (if neurologic control is present) firm, and not to assist with the turning. Assistance is necessary to turn the patient as a rigid unit to the operating table and head holder. If a collar is in place or a halo immobilizer has been applied, these are left secured until the patient is properly positioned. After positioning and neurologic status are confirmed to be unchanged, a lateral roentgenogram is obtained, and any last-minute adjustments are performed prior to administering the general anesthetic.

Once the safety of the turn has been assured and all lines have been appropriately secured, general anesthesia is given. In other areas of the spine, somatosensory evoked potential (SSEP) monitoring is routinely employed. However, for cervical spine injuries, distraction and significant mobilization or manipulation are not generally required; the authors, therefore, do not routinely employ SSEP. However, if there is an incomplete injury and/or the patient is not able to cooperate with an awake intubation, then evoked-potential monitoring is employed to help monitor the spinal cord function during the turning and realignment processes (closed and/or open). Meticulous attention should be paid to maintenance of arterial blood pressure at or above preinduction levels. Hypotension superimposed on a preexisting spinal cord mechanical compression or blood flow compromise due to interstitial edema or vascular injury may produce a major threat to neural function and/or recovery potential.[14]

THE ALGORITHM

The algorithms reproduced in Figures 1 and 2 were developed and instituted at the authors' institution for the initial treatment of patients admitted to the trauma unit.[21] In 1986–1987, 58 patients were admitted with proved cervical spine fractures. Seventeen of these had spinal cord injuries. The most common mechanism of injury was motor vehicle accident. Of patients injured in this manner, 88% were drivers of the car and 12% were passengers. Motorcycle accidents caused cervical spine injury in three individuals. Other frequent modes of injury included falls (six) and vehicle–pedestrian accidents (eight). Of the 58 patients, 14 had at least one associated spine fracture. Peritoneal lavage was performed in 45 patients with cervical fractures (including all patients with cord injuries). Of these, 18% were positive for cervical spine injury and required surgical exploration. Associated significant injuries are shown in Table 1; associated bone and vertebral column injuries are shown in Table 2.

DISCUSSION

An aggressive diagnostic approach to the cervical spine-injured patient, a regionalized trauma center, and an acute awareness of the possibility of spinal cord injury occurring in the multiply injured patient have led to the establishment of, and adherence to, the algorithms presented in Figures 1 and 2. The mortality rate for multiply injured patients with cervical spine injuries is 22% among patients admitted through the authors' trauma unit. This rate, which is lower than the 40% rate reported nationally,[40,41] is most probably related to the awareness of these lesions and to the organized approach to this problem. The proportion of patients with complete loss of neurologic function (below the level of in-

TABLE 1. Major Nonvertebral Injuries Associated With Cervical Spine Injury (n = 58)

Injury	*Number*
Concussion	30
Skull fracture	18
Pneumothorax	11
Severe closed head injury	10
Subdural hematoma	2
Epidural hematoma	1
Facial fracture	10
Pulmonary contusion	10
Liver laceration	10
Hemothorax	8
Myocardial contusion	8
Ruptured spleen	7
Renal contusion	6
Flail chest	3
Ruptured diaphragm	1

TABLE 2. Orthopedic and Vertebral Column Injuries Occurring at the Time of Cervical Spine Injury (n = 58)

Injury	*Number*
Lumbar spine fracture	7
Thoracic spine fracture	3
Cervical spine fracture (more than one level)	3
Pelvic fracture	16
Long-bone fracture (upper extremity)	11
Long-bone fracture (lower extremity)	11

jury) has declined to less than 40%. Prevention of additional neurologic deterioration as well as reversal of some degree of apparent neurologic loss have improved with advances not only in hospital care but also in management at the accident scene and during transportation. EMS personnel must remain suspicious of actual or potential spinal cord injury. Spinal stabilization should be achieved, if possible, prior to attempts to move the patient. The possible injury patterns and the effect of ischemia and hypoxia on the spinal cord should always be considered. The skills necessary to medically and surgically stabilize the patient and the cervical spine must be maintained at the highest level within the hospital and trauma-unit setting. Newer techniques of cervical stabilization (cervical anterior and posterior plates and screws) provide additional means to decrease external restraints, improve rehabilitation, and, possibly, improve spinal cord function. In the authors' experience, the combined general surgical, orthopedic, neurosurgical, and neuroanesthetic approach to these complex problems has proved useful.

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