**Chapter 40
Trauma-stabilizing procedures**

**Derek R. Cooney and David P. Thomson**

**Introduction**

Physicians providing EMS medical oversight and those providing direct patient care in the prehospital environment must possess a significant level of expertise in the use of non-invasive and invasive procedures for the prehospital stabilization of trauma patients. The nature of the care and the procedures that are appropriate for different levels of providers is based on the education, training, and legal scope of practice of the providers in the EMS system. An EMS physician must be skilled in these procedures and maintain active educational programs and continuous quality improvement activities to insure these procedures are being performed correctly, and under the correct circumstances. In some cases, it may be appropriate that only an EMS physician perform a procedure, either due to special circumstances or due to the provider’s ability and/or scope. Appropriate hands-on and didactic training, as well as verification of procedural proficiency, should occur prior to implementing any procedural skill.

**Needle thoracostomy**

The placement of a needle to relieve tension pneumothorax is often used in ground EMS systems. Some air medical (and critical care) services have also authorized the placement of a formal tube thoracostomy by their crews. The placement of a needle into the pleural space can produce dramatic results in a patient suffering from a tension pneumothorax.

**Indication**

This procedure should be considered in any patient who suffers from rapid cardiopulmonary decompensation in an appropriate clinical setting. Although tracheal deviation and decreased breath sounds are commonly accepted as signs of a tension pneumothorax, they may not always be present and may not be appreciated in some prehospital environments [1]. Providers should be encouraged to perform this procedure in any blunt chest trauma patient who has a precipitously decreasing course, especially if there is a history of chronic obstructive pulmonary disease or asthma. Trauma patients with obvious subcutaneous emphysema can benefit from the early application of this technique. Eckstein and Suyehara reviewed their experience in a series of over 6,000 trauma patients [2]. Their conclusion, based on the 108 patients in this series who received needle decompression, was that this was a potentially life-saving intervention, with a low complication rate.

If the catheter is placed into the lung parenchyma, the puncture will be small and should heal rapidly. The resultant pneumothorax is an open one, and therefore the patient should suffer little further compromise. If the patient is intubated, the thoracostomy catheter may be placed and left open to the air. If the patient is spontaneously breathing, a one-way valve must be created to prevent reentry of air during inspiration. One-way valves, such as the Heimlich valve, are available with tubing that will connect with a standard venous catheter. Condoms may be used by puncturing the condom with the catheter and then unrolling it after the catheter has been placed in the patient. Surgical gloves have been used, but when compared with condoms, they may produce unacceptable air leakage. Some services will use an aquarium air pump check valve, but despite anecdotal success, there do not appear to be any available scientific data evaluating their use for this purpose. Other devices, such as the McSwain Dart, have also been used for chest decompression, but they confer no demonstrated advantage over a venous catheter.

For most EMS systems, needle thoracostomy is the safest, most rapid, and most effective way of providing pleural decompression.

**Technique**

Locate the second intercostal space, in the midclavicular line on the anterior chest wall of the affected side. An alternative site is the midaxillary line at the level of the nipple, similar to the usual chest tube site. Apply best possible sterile skin preparation with sterile prep. Load the pneumothorax catheter onto the tip of the 10 mL syringe. Direct the catheter perpendicular to the skin, keeping in mind that ideal placement is over the top of the rib and not into the inferior portion of the superior rib which risks damaging the neurovascular bundle. Enter the skin and, while gently withdrawing on the plunger, advance the catheter until air moves freely into the syringe (with or without blood return). The plastic catheter should then be advanced off the needle and into the chest. The syringe (frequently a larger syringe) may be used in conjunction with a stopcock to aspirate the air from the pneumothorax until resistance is noted on the plunger. A one-way valve may then be connected to the end of the catheter. A definitive thoracostomy tube will need to be placed after acute decompression with needle thoracostomy (typically in the hospital setting or in critical care transport situations).

**Complications**

The rate of significant complications is thought to be low. It is possible to puncture the subclavian vein and/or artery if the second interspace technique is done improperly and the needle is placed too high on the chest. If the lateral approach is used, abdominal organ injury may result from a needle placed too caudad. Laceration of the internal mammary artery and the risk of infection are two other complications to consider. Care is needed to avoid these complications by providing the best available level of preprocedural cleaning and utilization of landmarks when placing the needle.

**Tube thoracostomy**

This common surgical procedure, mostly limited in the field to air medical services or military situations, is used to evacuate air or blood from the pleural space. It is particularly useful when transport times are sufficiently long. Once the tube has been secured, one must decide what to do with the free end of the tube. If the patient is intubated the tube may be left open, creating an open pneumothorax. For a patient who is not intubated, a one-way valve must be created to prevent entry of air into the thorax during inspiration. The Heimlich valve, essentially a rubber flapper valve in a tube, is the most practical device for the paramedic. It may be connected to suction if required, and if there is a large amount of drainage, a urinary catheter bag may be attached to collect the drainage.

**Indication**

The ability to rapidly evacuate a large amount of blood from the trauma patient’s pleural space, converting a tension hemothorax into an open hemothorax, is this technique’s primary advantage. In some cases this may be life-saving but in others, the patient can exsanguinate from the tube, depending on the source of the bleeding. Placement of the formal thoracostomy tube may also be indicated if a large pneumothorax is present and a long transport time is expected. Potential advantages are the lower likelihood of kinking, clotting, and dislodgment of the tube in comparison to the needle technique.

**Technique**

Abduct and externally rotate the arm on the affected side so that it is up and out of the way. Locate the fifth intercostal space, in the midaxillary line on the chest wall of the affected side. Apply best possible sterile skin preparation with sterile prep. Locally inject the site with anesthetic. Using the #10 blade scalpel, make a 3–4 cm transverse incision onto the fifth rib at the midaxillary line. With a large Kelly clamp, bluntly dissect over the top of the fifth rib into the fourth intercostal space. Some force may be required to enter the pleural space and the operator should feel a definitive pop upon entering the pleural cavity. At this point there may be a rush of air and/or blood. Spread the tips of the Kelly clamp in the pleural cavity to widen access, then turn the clamp 90° and spread again. Insert a gloved finger into the pleural space to verify proper position and to hold the track while guiding the chest tube into place. The Kelly clamp may then be removed at the provider’s discretion. The tube may be inserted directly or facilitated by the use of a Kelly clamp to grasp the tip, through the eye, to help guide the tube. The tube should be inserted along the tract and into the pleural cavity, while directing it posteriorly and superiorly. The tube should slide smoothly without significant resistance and all of the fenestrations must be inside the chest wall to allow for suction.

If the tube will not advance, the operator may attempt to turn the tube; however, if the tube is drawn out of the chest, a new tube should be used on the next attempt to place through the same tract.

Once the tube is in position, secure the chest tube to the chest wall with a silk suture. Petroleum gauze with a single cut halfway across the middle of the gauze can then be placed around the tube. Dry gauze, with the same cut, is then placed over the petroleum gauze and the elastic adhesive tape is used to hold the dry gauze in position. The tube is then bolstered and taped to the chest wall. The end of the tube should then be connected to the chest tube drainage apparatus, or a Heimlich (one-way flutter) valve should be placed on the end.

**Complications**

The tube should be placed under sterile conditions. However, this may be difficult or impossible based on the potential prehospital environments in which this may be performed. This may lead to empyema, should the patient survive. Placement in the wrong interspace can result in injury to the abdominal organs, the heart, or great vessels, and the use of trocars or Kelly clamps to place the tube may cause injury to the lung parenchyma or other thoracic structures.

**Pericardiocentesis**

Pericardiocentesis is classically taught as the procedure of choice for treating cardiac tamponade. Its use in the prehospital setting has not been fully investigated. In the patient suffering from pulseless electrical activity (PEA) due to cardiac tamponade, pericardiocentesis may theoretically restore a perfusing rhythm. Medical directors may wish to include pericardiocentesis in a traumatic PEA protocol; however, its use should typically be reserved for patients in whom fluid challenge and needle thoracostomy have not resulted in palpable pulses.

**Indication**

The indication for this intervention is the presence of life-threatening physiological changes with signs of traumatic cardiac tamponade. The Beck triad (muffled heart sounds, jugular venous distension (JVD), and hypotension) and Kussmaul signs (pulsus paradoxus, a drop of >10 mmHg during inspiration, and paradoxical increase in JVD, as a sign of increased jugulovenous pressure) are indications of cardiac tamponade. Cardiac tamponade is present in up to 90% of penetrating injuries to the heart [3].

Pericardiocentesis is also indicated for resuscitation of a patient with PEA when other causes have been ruled out and the patient remains pulseless. Pericardiocentesis has been reported successful even in cases of cardiac tamponade from blunt trauma [4].

**Technique without ECG or ultrasound guidance**

Expose the subxiphoid region and prep the area with sterile antiseptic solution. Position an 18 G (either 3.5 or 6 inch) spinal needle so that it will enter the skin directly below or adjacent to the xiphoid process. The needle should be held at a 45° angle to the skin, aiming at the left shoulder (assuming normal anatomy). This technique minimizes the likelihood of injuring other important structures. The needle is advanced, maintaining angle and direction, while withdrawing on the plunger. The operator stops advancing when blood returns. After removal of up to 50 mL of blood, vital signs are reassessed. In cases of acute tamponade, removal of as little as 25–30 mL can lead to immediate improvement [4]. If hemodynamic status does not improve, perform additional aspiration of blood in 25 mL increments until condition improves. The stopcock may be place on the Luer-Lok end of the spinal needle and may be used for subsequent drainage (either through tubing into a bag or into a syringe with aspiration). If the needle is left in place it must be stabilized. If removed, the operator should consider drainage of pericardial blood until little to no blood returns, and then check for reaccumulation prior to removal. A sterile dressing should be placed over the site.

At this point, if equipped, the operator may choose to utilize the Seldinger guidewire technique and place a flexible plastic catheter instead of leaving the metal spinal needle.

**Technique with ECG guidance**

Prior to initiating the procedure described above, the operator uses an alligator clip jumper cable to bridge from the ECG lead (V1 in the case of 12-leads, lead II for 3-lead) to the proximal metal portion of the spinal needle. The same procedure may be used, and advancement of the needle is now additionally guided by blood returned and the change on the ECG lead to ST elevation on the monitor. The rest of the procedure is the same as above.

**Technique with ultrasound guidance**

If prehospital ultrasound is available, it may be employed to guide placement of the needle into the pericardium. The operator will identify the point of maximal effusion in order to guide site selection. The site should represent a superficial access to the effusion and will not likely be the subxiphoid site, due to the ability of the ultrasound to visualize both the effusion and the needle during the procedure. Angle and depth will be guided by the ultrasound. The operator should use the probe before (to identify the site) and during the procedure (in order to guide the needle to the effusion), and after initial drainage (to check for reaccumulation). The rest of the procedure is the same as the blind technique above.

**Complications**

Classically, the use of this technique has been discouraged in the patient with a traumatic tamponade as it may delay the implementation of thoracotomy. Thoracostomy is not usually available in the prehospital setting unless a properly trained and equipped EMS physician is present [5]. Theoretically, the needle could also cause injury to the myocardium or puncture or lacerate a coronary vessel.

**Spinal immobilization**

The most critical aspects of patient packaging are those interventions designed to protect the spinal cord from further injury. Before the appearance of organized EMS services and paramedic training, motor vehicle crash victims were often extricated and transported without the use of any form of spinal immobilization. These patients were simply pulled from their vehicles or placed on stretchers without any consideration of splinting or spinal stabilization. It was reported that patients presented to the hospital with completed spinal cord injuries [6]. Immobilization has since become one of the most fundamental interventions provided by prehospital providers. Although this process has been accepted for decades, no formal studies have assessed its validity or effectiveness, and it is not without its problems. Changes in automotive design since the institution of spinal immobilization in the 1960s have led some to question the need for universal spinal immobilization of motor vehicle crash victims. Like so many prehospital interventions, this is a difficult procedure to study given the current medicolegal climate.

In light of recent studies exposing the lack of evidence of the effectiveness of cervical collars and long spine boards in the maintenance of spinal alignment, coupled with the detrimental effects of routine immobilization, it is important to carefully consider protocol design and quality assurance processes in order to limit the adverse effects of this now ubiquitous but not evidence-based practice [7–20].

### Indications

Spinal immobilization has been considered important for a wide variety of mechanisms including motor vehicle crashes, falls, and athletic injuries. Even falls from the standing position, especially in the elderly, may result in spinal injuries. Despite the routine use of spinal immobilization in trauma victims, indications for use in prehospital care remain an active area of research. Although occult spinal injuries may be difficult to detect reliably in the field, studies have noted the discomfort caused by the use of backboards and collars and have questioned whether immobilization should be performed in the absence of signs and symptoms [7].

Recent studies have reported a lack of effectiveness in spinal immobilization using a long spine board [7–9]. Multiple authors have questioned the utility of backboard use due to a lack of data to support their effectiveness in preventing secondary injury, and the documented potential harm associated with backboard use including iatrogenic pain, skin ulceration, increased use of radiographs, aspiration, and respiratory compromise [7,9–19]. The National Association of EMS Physicians (NAEMSP) and the American College of Surgeons Committee on Trauma (ACS-COT) joint position paper on the topic notes the risks associated with the use of long spine boards and cites the need to remove the patient from them as soon as possible [20]. A 2013 paper suggests the mean backboard time for patients might be nearly an hour [21]. Based on available evidence, limiting the use of long spine boards to extrication, and removing the patient from the board while maintaining spinal precautions, may be preferable.

#### Penetrating trauma

In some geographical areas, gunshot wounds are the leading cause of spinal cord injuries, whereas nationwide they are the third most common source of spinal injury [22]. Although well accepted for blunt trauma, the tactical EMS community, citing data from the WDMET study of Vietnam War casualties, has actively discouraged the use of spinal immobilization for gunshot wounds[23]. These studies suggest that the injuries to the spinal cord from bullets are either complete at the time of wounding or are stable and do not require immobilization [24–28]. Heck et al. also point out that cervical collars may preclude good observation in patients with neck wounds [23]. A review of the Israeli experience with penetrating neck trauma concurs with this view [29]. Jallo agrees that spinal instability is rare with these types of penetrating injuries, but cautions that “optimal management has not been determined” [30]. Other authors have advocated for a middle ground, suggesting that if the cervical collar interferes with patient care then it can safely be removed, but that otherwise it should be left in place [31]. However, the 2013 NAEMSP and ACS-COT joint position statement on use of long spine boards states that patients with penetrating injury and no signs of spinal injury should not be immobilized on long spine boards [21].

#### Blunt trauma

Immobilization for blunt trauma and falls has been studied in much better detail. Domeier et al. retrospectively reviewed a large group of patients with spinal fractures in Michigan [32]. They concluded that patients with altered mental status, neurological deficit, spinal pain, evidence of intoxication, or suspected extremity fracture were more likely to have significant spinal injuries. In a further study, Domeier et al. prospectively reviewed the above set of spinal immobilization criteria and found that these criteria would have been 95% sensitive and 35% specific, and had a negative predictive value of 99.5% for spinal injury [33]. Domeier suggested that if applied clinically, these criteria might have reduced spinal immobilization by as much as 35%. He pursued this concept by applying the criteria in a prospective clinical study, finding a 39% reduction in spinal immobilization [34]. In this study, the criteria were found to be 92% sensitive and 40% specific. Of the 8% (n = 33) of patients with spinal column injuries that were missed, none had documented spinal cord injuries. Of these 33 patients, 18 had immobilization techniques applied at the hospital. Seventeen of the 33 missed patients were over the age of 70. During retrospective chart review, the authors reported some difficulties with algorithm non-compliance and incorrect assessments by prehospital personnel.

In a similar study, Muhr’s group attempted to reduce spinal immobilization use in trauma patients who did not meet trauma system activation criteria. They prospectively applied an eight-point immobilization algorithm. Before algorithm application in their system, 98% of these patients were spinally immobilized. The authors demonstrated a 33% decrease in immobilization [35]. Interestingly, spinal immobilization for blunt trauma is not practiced throughout the world. In a unique comparative study, Hauswald et al. compared neurological outcomes between immobilized and unimmobilized blunt trauma victims in New Mexico and Malaysia [36]. In the Malaysian system, none of the patients received any form of prehospital spinal immobilization, while in the New Mexican system, all studied patients were immobilized. Their results indicated that there was less neurological injury in the Malaysian population than in the New Mexican group. This study has significant limitations, which are described in an accompanying editorial by Orledge and Pepe [37], but the findings are intriguing nonetheless.

Hankins et al. describe another set of clinical criteria that may be used to indicate which patients might be eligible for clinical spinal clearance: no extremes of age (<12 or >65 years old), no altered mental status or language barriers, no neurological deficits, no distracting injuries, and no midline or paraspinal pain or tenderness [38]. Again, it is important to note that NAEMSP/ACS-COT position statement also includes the concept that maintenance of spinal precautions does not require use of a long spine board [20,21].

## Application of cervical collar

The first step in spinal immobilization is typically manual stabilization of the head, followed by placement of a rigid cervical collar. Numerous collars are available on the market, ranging from cloth-covered foam rubber to stiff plastics of various designs. The soft collar provides no immobilization and has no place in prehospital care [39].

### Indication

Immobilization of the cervical spine is performed to avoid secondary injury in patients who have the potential for unstable fractures. In a 1986 study, McCabe and Nolan compared cervical spine motion on radiographs with volunteers immobilized in Philadelphia, hard extrication, and two versions of the Stifneck collar [40]. The Stifneck collars were better than either the Philadelphia or hard extrication collars in immobilizing the patient in all directions except extension. Dick and Land, in a review of all spinal immobilization devices, found that the Stifneck collar provided the best immobilization among all collars tested [41]. A number of similar plastic collars are currently available, but limited data are available regarding the effectiveness of specific devices. Regardless of the brand utilized, the collar should be made of rigid plastic and sized properly for the patient’s neck. Due to the controversy surrounding the utility of the cervical collar and complications it may cause, some authors have advocated very limited use or for spinal precautions only [42,43].

### Technique

To ensure the best potential patient outcome, the cervical collar must be properly sized prior to placement. The operator holds out his or her hand and extends all of the fingers. The hand is placed on the side of the neck with the pinky almost touching the shoulder. An imaginary line from the inferior chin is considered and matched up to one of the fingers on the measuring hand. The hand can then be matched up to the cervical collar and the collar adjusted to the correct height based on the distance between the sizing mark/line on the collar and the bottom of the plastic portion of the collar. The chin section of the collar is placed into position first, with the rest of the collar then wrapped around the neck. Allowing for a snug (not tight) fit, close the collar with the hook-and-loop fasteners. The collar should be snug enough to keep your patient from flexing and extending the head, but not so tight as to stop the patient from being able to open the mouth. Immobilization with the cervical collar may be enhanced when used in conjunction with head blocks and the long spine board.

### Complications

Application of an improperly sized collar is very uncomfortable for the patient and may be counterproductive to the goal of spinal immobilization. In patients for whom no collar seems to fit properly, padding with towels and securing the head and torso directly to a spine board or extrication device may be preferable, though data are limited. Respiratory compromise and vascular occlusion can occur when not properly fitted.

## Application of a long spine board (backboard)

Since the late 1960s the long spine board has been considered an important component of prehospital trauma care in the United States. If immobilization is thought to be clinically useful for a given patient, then proper application and technique should be observed.

### Indication

NAEMSP/ACS-COT position paper on use of spinal precautions and long spine boards states that spinal precautions *may* be appropriate in patients with blunt trauma and altered level of consciousness, spinal pain or tenderness, a neurological complaint (numbness or motor weakness), anatomical deformity of the spine, or a high-energy mechanism of injury and any of the following: drug or alcohol intoxication, inability to communicate, or distracting injury [21].

### Equipment

Several immobilization devices are available, each with a slightly different application technique. Devices commonly in use include long spine board, scoop stretcher, vacuum mattress, and the Kendrick Extrication Device (KED).

#### Long spine board technique

Throughout the procedure, manual inline cervical spine alignment must be maintained until the cervical collar is placed correctly. One team member will maintain manual inline cervical stabilization during all movements. Team members should respond to the leader’s commands and count to ensure synchronicity of movement in order to maximize spinal immobility. The team may use the logroll technique or the lift and slide technique to place the patient onto the long spine board. The patient is then strapped to the board. The chest strap is usually secured first, followed by the waist and then the thighs and lower legs. All voids between the board and the patient should be padded. The head is always immobilized last. Head blocks are placed on either side of the head. In some cases, occipital padding may be needed. The head may then be secured using tape or commercially available straps.

#### Scoop stretcher technique

As with the long spine board technique, the cervical spine should be immobilized and the provider at the head should command the operation. The scoop stretcher is opened and placed with the hinged portion at the head with the open portion toward the feet (or it may be taken completely into two halves). The scoop stretcher is then closed under the patient. If the patient is not on a smooth hard surface, pinching may occur at the buttocks and/or the shoulders. In order to decrease pinching, gentle lateral traction on the patient’s clothing may help. If the patient is on a sheet, the sheet should be pulled tight during the procedure to limit the potential for pinching. The head (first) and foot (second) hinges are locked. The patient is then strapped to the stretcher (chest, waist, legs, then head).

#### Vacuum mattress technique

First the vacuum mattress is inspected and laid flat on the ground. If there are any holes or tears, this technique must not be used. The vacuum valve should be facing up and be positioned at the patient’s feet. The patient is then placed on the mattress (lift and slide, logroll off a backboard, placed onto the mattress using a scoop stretcher, or logroll onto a sheet on top of the mattress) and positioned onto the middle of the mattress. The mattress is pumped several times to make it slightly firmer. The mattress is then molded to the patient and the straps are placed. The mattress is molded around the head manually and the mattress pump is used to vacuum the air from the mattress until it is firm and in a molded form. The mattress can be moved on a long spine board or in some cases may be carried with straps if it is sufficiently rigid in the vacuumed state and has been designed for this use.

#### Extrication device technique

Once a stiff cervical collar is placed, a team member must place the extrication device behind the patient in the upright position, aligning it with the patient. The middle torso strap is secured first, followed by the bottom torso strap. The leg straps and top torso strap are then secured, followed by the head strap, with adequate padding to fill voids. The patient is then extricated using the extrication device haul straps and placed on the long spine board. At this point the operator will disconnect the leg straps, allowing the patient’s legs to lie flat on the long spine board. The patient is then secured to the long spine board while still in the extrication device.

### Complications

Complications associated with spine board use include discomfort, increased use of x-ray in immobilized patients, potential for decubitus ulcer formation, and risk for respiratory compromise [15,29,44–46]. Medical directors of EMS systems should actively investigate ways to ensure that only those patients who need this intervention receive it, and that those who are immobilized to long spine boards are removed from the boards into less harmful spinal precautions as early as possible.

Pregnant patients who are >20 weeks gestation may experience compression of the abdominal great vessels and should be positioned with the board wedged toward a left lateral slant while maintaining immobilization. Patients with respiratory distress or cardiac decompensation may need to be positioned in the semi-upright to upright position. In this case, use of a short board or extrication device alone may be necessary. If this is also impractical due to body habitus, the cervical collar may need to be used alone while attempting patient positioning that maintains as much spinal immobilization as possible while avoiding life-threatening cardiopulmonary complications.

### Padding

Due to the significant discomfort associated with spinal immobilization, alternative methods of immobilization have been proposed. Additional concern for elderly or bedridden patients is also appropriate considering the associated unequal areas of tissue interface pressures that may lead to tissue damage and breakdown. Hauswald et al. compared four spinal immobilization techniques with healthy volunteers: traditional backboard, blanketed backboard, backboard with gurney mattress, and backboard with gurney mattress and foam pad [47]. Not surprisingly, they found these techniques were rated in the same order, from least to most comfortable. A study by Lerner et al. revealed that occipital padding to produce neutral positioning in spinal immobilization subjects does not reduce pain [7]. Walton et al. described a significant reduction in discomfort, without reduction in the effect of immobilization, when the long board is padded with closed-cell foam [48]. Another alternative to the standard long board is the vacuum mattress device. Multiple studies have shown marked advantages in comfort and some advantages in immobilization when these devices are employed [49–51]. Another option is a specially designed air mattress. Several brands of approved spine board air mattresses are available.

In a study by Cordell et al., a standard long board was compared to standard long board with air mattress [52]. The two groups reported their discomfort on a 100 mm visual analog scale. At 80 minutes the air mattress group reported a mean 9.7 mm rating, versus a 37.5 mm rating in the standard long board group. They also measured tissue interface pressures and found that the air mattress group had significantly less pressure at the occiput, sacrum, and heel. The time of spinal immobilization should be limited and consideration paid to measures to decrease the ill effects, especially in high-risk patients.

### Children

Several commercial devices are available for immobilization of children. For smaller children, a short board, well padded under the torso, can be used. Markenson et al. described using the KED for pediatric immobilization [53]. Because of its versatility with both adult and pediatric patients, they suggest that this is “an ideal device” for pediatric immobilization. Although immobilization is meant to protect the spine from further injury, it may compromise ventilation. Even in the majority of children, who would be unlikely to suffer from chronic lung disease, spinal immobilization can produce a significant decrease in forced vital capacity [54]. Providers must be ready to assist with ventilation, should immobilization result in respiratory compromise. Infants and neonates who are found adequately restrained in undamaged car seats, who do not require other assessment and/or interventions, may be best transported immobilized in the car seats.

## Selective spine immobilization

Selective spinal immobilization was originally studied in the emergency department and its use has been extrapolated to the prehospital environment.

### Indication

It is reasonable to employ protocols that limit spinal immobilization to patients in whom there may be some benefit. A number of studies suggest the validity of this concept and potential for successful implementation [35,55–58].

### Technique

The selective spinal immobilization algorithms most commonly used in the emergency department for determining appropriateness of clinical clearance of the cervical spine are the NEXUS and Canadian C-Spine rules. Nexus asks the EMS provider to determine the absence of focal neurological deficit, midline spinal tenderness, altered level of consciousness, intoxication, and distracting injury before electing to omit application of spinal immobilization [59]. The Canadian C-Spine Rule asks three questions.

1. Is there any high-risk factor present that mandates radiography (i.e. age ≥65 years, dangerous mechanism, or paresthesias in extremities)?
2. Is there any low-risk factor present that allows safe assessment of range of motion (i.e. simple rear-end motor vehicle collision, sitting position in ED, ambulatory at any time since injury, delayed onset of neck pain, or absence of midline cervical spine tenderness)?
3. Is the patient able to actively rotate the neck 45° to the left and right? [60]

Both of these rules were developed to more appropriately guide the use of radiography in the emergency department and not to guide paramedics using selective spinal immobilization in the field. However, both rules have been studied in the prehospital environment and found to function effectively [34,61].

## Conclusion

Emergency medical services physicians must provide effective and knowledgeable medical oversight for the application of trauma-stabilizing procedures in the prehospital environment. An EMS physician must be skilled in these procedures and maintain active educational programs and continuous quality improvement activities to insure these procedures are being performed correctly, and under the correct circumstances. Appropriate hands-on and didactic training, as well as verification of procedural proficiency, should occur prior to implementing any procedural skill.

## References

1. 1 Ross DS. Thoracentesis. In: Roberts JR, Hedges JR (eds) *Clinical Procedures in Emergency Medicine*. Philadelphia: W.B. Saunders, 1985, p.85.
2. 2 Eckstein M, Suyehara D. Needle thoracostomy in the prehospital setting. *Prehosp Emerg Care* 1998;2:132–5.
3. 3 Thourani VH, Feliciano DV, Rozycki G, et al. Penetrating cardiac trauma at an urban trauma center: a 22-year perspective. *Am Surg* 1999;65:811–18.
4. 4 Lu LH, Choi WM, Wu HR, Liu HC, Chiu WC, Tsai SH. Blunt cardiac rupture with prehospital pulseless electrical activity: a rare successful experience. *J Trauma* 2005;59:1489–91.
5. 5 Callaham M. Pericardiocentesis. In: Roberts JR, Hedges JR (eds) *Clinical Procedures in Emergency Medicine*. Philadelphia: W.B. Saunders, 1985, pp.208–25.
6. 6 Green BA, Eismont FJ, O’Heir JT. Pre-hospital management of spinal cord injuries. *Paraplegia* 1987;25:229–38.
7. 7 Lerner EB, Billittier AJ 4th, Moscati RM. The effects of neutral positioning with and without padding on spinal immobilization of healthy subjects. *Prehosp Emerg Care* 1998;2:112–16.
8. 8 Holla M. Value of a rigid collar in addition to head blocks: a proof of principle study. *Emerg Med J* 2012;29:104–7.
9. 9 Kwan I, Bunn F, Roberts I. Spinal immobilisation for trauma patients. *Cochrane Database Syst Rev* 2001;2:CD002803.
10. 10 Ay D, Aktaş C, Yeşilyurt S, Sarikaya S, Cetin A, Ozdogan ES. Effects of spinal immobilization devices on pulmonary function in healthy volunteer individuals. *Ulus Travma Acil Cerrahi Derg* 2011;17:103–7.
11. 11 Bauer D, Kowalski R. Effect of spinal immobilization devices on pulmonary function in the healthy, nonsmoking man. *Ann Emerg Med* 1988;17:915–18.
12. 12 Hunt K, Hallworth S, Smith M. The effects of rigid collar placement on intracranial and cerebral perfusion pressures. *Anaesthesia* 2001;56:511–3.
13. 13 Johnson DR, Hauswald M, Stockhoff C. Comparison of a vacuum splint device to a rigid backboard for spinal immobilization. *Am J Emerg Med* 1996;14:369–72.
14. 14 March JA, Ausband SC, Brown LH. Changes in physical examination caused by use of spinal immobilization. *Prehosp Emerg Care* 2002;6:421–4.
15. 15 Schafermeyer RW, Ribbeck BM, Gaskins J, Thomason S, Harlan M, Attkisson A. Respiratory effects of spinal immobilization in children. *Ann Emerg Med* 1991;20:1017–19.
16. 16 Thumbikat P, Hariharan RP, Ravichandran G, McClelland MR, Mathew KM. Spinal cord injury in patients with ankylosing spondylitis: a 10-year review. *Spine* 2007;32:2989–95.
17. 17 Vickery D. The use of the spinal board after the pre-hospital phase of trauma management. *Emerg Med J* 2001;18:51–4.
18. 18 Clarke A, James S, Ahuja S. Ankylosing spondylitis: inadvertent application of a rigid collar after cervical fracture, leading to neurological complications and death. *Acta Orthop Belg* 2010;76:413–15.
19. 19 Theodore N, Hadley MN, Aarabi B, et al. Prehospital cervical spinal immobilization after trauma. *Neurosurgery* 2013;72:S22–34.
20. 20 NAEMSP, ACS-COT. EMS spinal precautions and the use of the long backboard. *Prehosp Emerg Care* 2013;17:392–3.
21. 21 Cooney DR, Wallus H, Asaly M, Wojcik S. Backboard time for patients receiving spinal immobilization by emergency medical services. *Int J Emerg Med* 2013;6:17.
22. 22 Kihtir T, Ivatury RR, Simon R, Stahl WM. Management of transperitoneal gunshot wounds of the spine. *J Trauma* 1991;31:1579–83.
23. 23 Heck J, Kepp JJ, Walos G, Vayer J (eds) *Emergency Medical Technician – Tactical Provider*, 16th edn. Bethesda, MD: Casualty Care Research Center, 2001.
24. 24 Shafer JS, Naunheim RS. Cervical spine motion during extrication: a pilot study. *West J Emerg Med* 2009;10:74–8.
25. 25 DuBose J, Teixeira PGR, Hadjizacharia P, et al. The role of routine spinal imaging and immobilisation in asymptomatic patients after gunshot wounds. *Injury* 2009;40:860–3.
26. 26 Stuke LE, Pons PT, Guy JS, Chapleau WP, Butler FK, McSwain NE. Prehospital spine immobilization for penetrating trauma – review and recommendations from the Prehospital Life Support Executive Committee. *J Trauma* 2011;71:763–9.
27. 27 Lustenberger T, Talving P, Lam L, et al. Unstable cervical spine fracture after penetrating neck injury: a rare entity in an analysis of 1,069 patients. *J Trauma* 2011;70:870–2.
28. 28 Ahn H, Singh J, Nathens A, et al. Pre-hospital care management of a potential spinal cord injured patient: a systematic review of the literature and evidence-based guidelines. *J Neurotrauma* 2011;28:1341–61.
29. 29 Barkana Y, Stein M, Scope A, et al. Prehospital stabilization of the cervical spine for penetrating injuries of the neck –is it necessary? *Injury* 2000;31:305–9.
30. 30 Jallo GI. Neurosurgical management of penetrating spinal injury. *Surg Neurol* 1997;47:328–30.
31. 31 Medzon R, Rothenhaus T, Bono CM, Grindlinger G, Rathlev NK. Stability of cervical spine fractures after gunshot wounds to the head and neck. *Spine* 2005;30:2274–9.
32. 32 Domeier RM, Evans RW, Swor RA, Rivera-Rivera EJ, Frederiksen SM. Prehospital clinical findings associated with spinal injury. *Prehosp Emerg Care* 1997;1:11–15.
33. 33 Domeier RM, Swor RA, Evans RW, et al. Multicenter prospective validation of prehospital clinical spinal clearance criteria. *J Trauma* 2002;53:744–50.
34. 34 Domeier RM, Frederiksen SM, Welch K. Prospective performance assessment of an out-of-hospital protocol for selective spine immobilization using clinical spine clearance criteria. *Ann Emerg Med* 2005;46:123–31.
35. 35 Muhr MD, Seabrook DL, Wittwer LK. Paramedic use of a spinal injury clearance algorithm reduces spinal immobilization in the out-of-hospital setting. *Prehosp Emerg Care* 1999;3:1–6.
36. 36 Hauswald M, Ong G, Tandberg D, Omar Z. Out of hospital spinal immobilization: its effect on neurologic injury. *Acad Emerg Med* 1998;5:214–19.
37. 37 Orledge JD, Pepe PE. Out-of-hospital spinal immobilization: is it really necessary? *Acad Emerg Med* 1998;5:203–4.
38. 38 Hankins DG, Rivera-Rivera EJ, Ornato JP, et al. Spinal immobilization in the field: clinical clearance criteria and implementation. *Prehosp Emerg Care* 2001;5:88–93.
39. 39 Podolsky S, Baraff LJ, Simon RR, Hoffman JR, Larmon B, Ablon W. Efficacy of cervical spine immobilization methods. *J Trauma* 1983;23:461–5.
40. 40 McCabe JB, Nolan DJ. Comparison of the effectiveness of different cervical immobilization collars. *Ann Emerg Med* 1986;15:50–3.
41. 41 Dick T, Land R. Spinal immobilization devices. Part 1: cervical extrication collars. *J Emerg Med Serv* 1982;7:26–32.
42. 42 Plumb JO, Morris CG. Cervical collars: probably useless; definitely cause harm! *J Emerg Med* 2013;44:e143.
43. 43 Schouten R, Albert T, Kwon BK. The spine-injured patient: initial assessment and emergency treatment. *J Am Acad Orthop Surg* 2012;20:336–46.
44. 44 Vickery D. The use of the spinal board after the pre-hospital phase of trauma management. *Emerg Med J* 2001;18:51–4.
45. 45 Haut ER, Kalish BT, Efron DT, et al. Spine immobilization in penetrating trauma: more harm than good? *J Trauma* 2010;68:115–20.
46. 46 Johnson DR, Hauswald M, Stockhoff C. Comparison of a vacuum splint device to a rigid backboard for spinal immobilization. *Am J Emerg Med* 1996;14:369–72.
47. 47 Hauswald M, Hsu M, Stockoff C. Maximizing comfort and minimizing ischemia: a comparison of four methods of spinal immobilization. *Prehosp Emerg Care* 2000;4:250–2.
48. 48 Walton R, DeSalvo JF, Ernst AA, Shahane A. Padded vs. unpadded spine board for cervical spine immobilization. *Acad Emerg Med* 1995;2:725–8.
49. 49 Cross DA, Baskerville J. Comparison of perceived pain with different immobilization techniques. *Prehosp Emerg Care* 2001;5:270–4.
50. 50 Johnson DR, Hauswald M, Stockhoff C. Comparison of a vacuum splint device to a rigid backboard for spinal immobilization. *Am J Emerg Med* 1996;14:369–72.
51. 51 Luscombe MD, Williams JL. Comparison of a long spinal board and vacuum mattress for spinal immobilisation. *Emerg Med J* 2003;20:476–8.
52. 52 Cordell WH, Hollingsworth JC, Olinger ML, Stroman SJ, Nelson DR. Pain and tissue-interface pressures during spine-board immobilization. *Ann Emerg Med* 1995;26:31–6.
53. 53 Markenson D, Foltin G, Tunik M, et al. The Kendrick Extrication Device used for pediatric spinal immobilization. *Prehosp Emerg Care* 1999;3:66–9.
54. 54 Schafermeyer RW, Ribbeck BM, Gaskins J, Thomason S, Harlan M, Attkisson A. Respiratory effects of spinal immobilization in children. *Ann Emerg Med* 1991;20:1017–19.
55. 55 Burton JH, Dunn MG, Harmon NR, Hermanson TA, Bradshaw JR. A statewide, prehospital emergency medical service selective patient spine immobilization protocol. *J Trauma* 2006;61:161–7.
56. 56 Hankins DG, Rivera-Rivera EJ, Ornato JP, et al. Spinal immobilization in the field: clinical clearance criteria and implementation. *Prehosp Emerg Care* 2001;5:88–93.
57. 57 Dunn TM, Dalton A, Dorfman T, Dunn WW. Are emergency medical technician-basics able to use a selective immobilization of the cervical spine protocol?: a preliminary report. *Prehosp Emerg Care* 2004;8:207–11.
58. 58 Stroh G, Braude D. Can an out-of-hospital cervical spine clearance protocol identify all patients with injuries? An argument for selective immobilization. *Ann Emerg Med* 2001;37:609–15.
59. 59 Hoffman JR, Mower WR, Wolfson AB, Todd KH, Zucker MI. Validity of a set of clinical criteria to rule out injury to the cervical spine in patients with blunt trauma. National Emergency X-Radiography Utilization Study Group. N Engl J Med 2000;343:94–9.
60. 60 Stiell IG, Wells GA, Vandemheen KL, et al. The Canadian C-spine rule for radiography in alert and stable trauma patients. *JAMA* 2001;286:1841–8.
61. 61 Vaillancourt C, Stiell IG, Beaudoin T, et al. The out-of-hospital validation of the Canadian C-Spine Rule by paramedics. *Ann Emerg Med* 2009;54:663–71.