The Journal of Emergency Medicine, Vol. 41, No. 5, pp. 513–519, 2011

0736-4679/$ - see front matter

ELSEVIER

doi:10.1016/j.jemermed.2011.02.001

Selected Topics: Prehospital Care

CERVICAL COLLARS ARE INSUFFICIENT FOR IMMOBILIZING AN UNSTABLE CERVICAL SPINE INJURY

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☐ **Abstract—Background: Cervical orthoses are commonly used for extrication, transportation, and definitive immobilization for cervical trauma patients. Various designs have been tested frequently in young, healthy individuals. To date, no one has reported the effectiveness of collar immobilization in the presence of an unstable mid-cervical spine. Study Objectives: To determine the extent to which cervical orthoses immobilize the cervical spine in a cadaveric model with and without a spinal instability. Methods: This study used a repeated-measures design to quantify motion on multiple axes. Five lightly embalmed cadavers with no history of cervical pathology were used. An electromagnetic motion-tracking system captured segmental motion at C5–C6 while the spine was maneuvered through the range of motion in each plane. Testing was carried out in intact conditions after a global instability was created at C5–C6. Three collar conditions were tested: a one-piece extraction collar (Ambu Inc., Linthicum, MD), a two-piece collar (Aspen Sierra, Aspen Medical Products, Irvine, CA), and no collar. Gardner-Wells tongs were affixed to the skull and used to apply motion in flexion-extension, lateral bending, and rotation. Statistical analysis was carried out to evaluate the conditions: collar use by instability (3 × 2). Results: Neither the one- nor the two-piece collar was effective at significantly reducing segmental motion in the stable or unstable condition. There was dramatically more motion in the unstable state, as would be expected. Conclusion: Although using a cervical collar is better than no immobilization, collars do not effectively reduce motion in an unstable cervical spine cadaver model. Further study is needed to develop other immobilization techniques that will adequately immobilize an injured, unstable cervical spine. © 2011 Elsevier Inc.**

☐ **Keywords—cervical injury; immobilization; cervical collars; prehospital care; trauma**

INTRODUCTION

Use of cervical collars is an established technique for extrication, transport, and immobilization of the patient with a suspected cervical spine injury. Multiple studies have compared the relative effectiveness of these orthoses in the prevention of spinal motion. A study by Richter et al. evaluated orthoses for a C1–2 instability using a cadaver with an unstable injury and radiographic measures (1). Other studies have used radiographic or video techniques to measure restriction of motion in healthy individuals with no instability (2–6). The effectiveness of collar immobilization has been indirectly evaluated in other studies involving cadavers and induced instabilities (7–17). In each of these studies, collars were used in an attempt to reduce spine motion during one or more transfer techniques. The purpose of this study was to determine the extent to which the cervical

This research received support from a grant from NOSCAE, Southwest Medical Foundation, Dallas, TX, and Aspen Medical Products, Irvine, CA.

RECEIVED: 21 January 2010; FINAL SUBMISSION RECEIVED: 8 June 2010;
ACCEPTED: 13 February 2011

spine is immobilized by cervical orthoses in a cadaveric model with and without a spinal instability.

METHODS

Five lightly embalmed whole body cadavers were utilized for this study. Lightly embalmed cadavers have the same soft tissue flexibility as fresh cadavers, but the minimal embalming allows them to be used for a longer time (18). A Liberty motion analysis device (Polhemus, Inc., Colchester, VT) was used to capture motion relative to the C5 and C6 vertebral bodies. This level was chosen because surveys of spinal injuries in sports report that a greater number of catastrophic cervical injuries occur in the lower cervical spine (19). The soft tissues overlying the anterior cervical spine were resected to allow for rigid attachment of sensors to the anterior vertebral bodies of C5 and C6. The Liberty system uses a transmitter of an electromagnetic field to measure relative motion between the sensors with embedded orthogonal coils that detect position and orientation. This technique has been described previously in several of our publications (8,9,12).

Testing was first performed on the intact spine (some superficial dissection was necessary to place the sensors). The primary outcome measurements were ranges of motion (flexion, extension, lateral bending, and rotation) occurring in the cervical spine. Range of motion (ROM) testing was repeated for the three collar conditions: a one-piece extraction collar (Ambu® Perfit, Ambu Inc., Linthicum, MD), a two-piece collar (Sierra Universal Collar, Aspen Medical Products, Irvine, CA), and without a collar. The order in which collar conditions were tested was randomized using a computerized random number generator.

The collars were applied by an orthopedic spine surgeon and certified orthotist. Gardner-Wells tongs were affixed to the skull and used to apply force to assess the movements of flexion, extension, lateral bending, and rotation. Using the tongs, the cadaver's head was placed in the neutral anatomical position. The spine surgeon began the application of force to move the head in one of the motions being tested. The cadaver's head was returned to the neutral position between trials. During testing, a third researcher (certified athletic trainer) stabilized the shoulders and upper torso to ensure that the measured motion was at the cervical level and not confounded with extraneous movements. The fourth researcher was the biomedical engineer responsible for controlling the Polhemus system.

The Polhemus system was used to capture segmental motion at C5–C6 while the spine was manually maneuvered through the ROM in each plane. A spring scale was used to measure a secondary outcome measure, which was the amount of force required to reach the extremes of the ROM. Data were recorded on a personal computer using custom LabVIEW software (National Instruments Corporation, Austin, TX) at a rate of 240 Hz.

After testing in the intact condition, a global instability was then created by an orthopedic spine surgeon at the C5–C6 level by sectioning the supraspinous and interspinous ligaments, the facet capsules, the posterior longitudinal ligament, the anterior longitudinal ligament, and the intervertebral disk through an anterior and posterior surgical approach. The movements (flexion, extension, lateral bending, and rotation) were then repeated and the ROM was recorded for the three collar conditions on the unstable spine. All movements were repeated twice for each cadaver. A repeated-measures analysis of variance was performed to analyze the following conditions: collar use (three levels: one-piece collar, two-piece collar, no collar) and instability (2 levels: intact and unstable). The Bonferroni adjustment was used because multiple comparisons were analyzed.

RESULTS

For all measures except extension, there was significantly more motion in the unstable state than the intact state (flexion, $p = 0.013$; right bending, $p = 0.022$; left bending, $p = 0.008$; right rotation, $p = 0.024$; left rotation, $p = 0.002$) (Figures 1–6). Extension measured in the unstable spine was greater than in the stable spine, but was not statistically different ($p = 0.59$) (Figure 2). In the unstable spine, the amounts of motion occurring in the one-piece, two-piece, and no-collar tests were not significantly different; however, the collars restricted motion better than no collar for five of the six conditions (Tables 1–6). The exception was left bending (Figure 4), where slightly more motion was measured when the one-piece

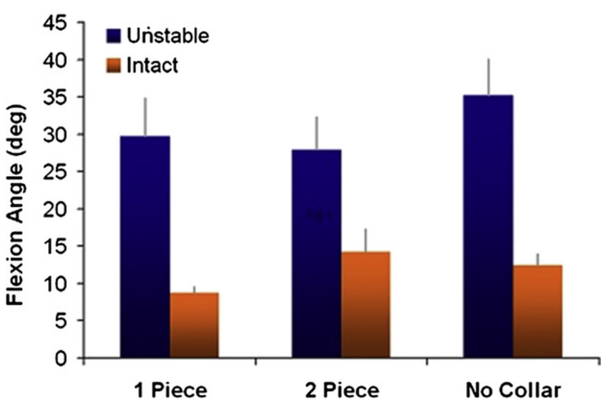

Figure 1. Degrees of flexion possible in intact and unstable cervical spines during bed transfer were significantly different ($p = 0.013$). Values are mean and error bars show standard deviation. Differences between collar conditions were not statistically significant.

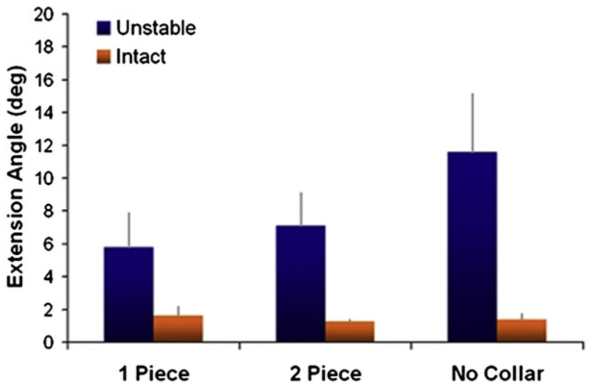

Figure 2. Degrees of extension possible in intact and unstable cervical spines during bed transfers did not differ significantly (p = 0.059). Values are mean and error bars show standard deviation. Differences between collar conditions were not statistically significant.

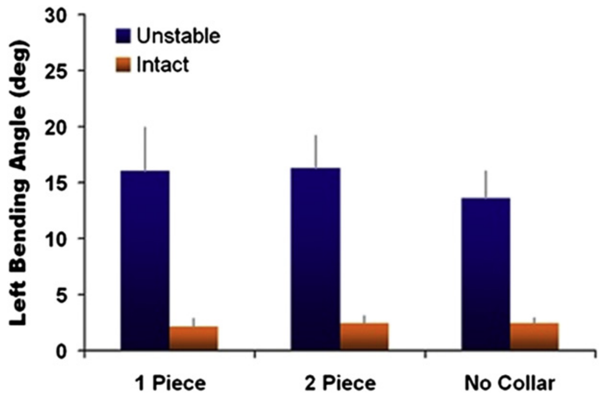

Figure 4. Left-bending range of motion occurring in intact and unstable cervical spines during bed transfers were significantly different (p = 0.08). Values are mean and error bars show standard deviation. Differences between collar conditions were not statistically significant.

(16.1 degrees) and two-piece (16.3 degrees) collars were used than when there was no collar (13.6 degrees).

DISCUSSION

Cervical orthoses are used universally in trauma situations to try to prevent catastrophic complications in case of spinal injury. Among severely injured trauma patients, 14% will have a cervical injury, with 7% being unstable (20). In the remaining 86% of trauma patients, a collar will provide no benefit. In fact, the risk of medical complications is increased by the use of collars (21). Ideally, only patients with unstable spines would have a cervical collar applied. But these patients cannot be identified in emergency situations; determining spinal injury in a hospital is not easy. Even when computer tomography and magnetic resonance imaging are used, a small number of patients will have an instability that is not recognized. Levi and coworkers conducted a retrospective review of 24 patients from eight level-I trauma centers who had an adverse neurologic outcome from a missed injury "despite the presence of experienced personnel and sophisticated imaging techniques" (22). For this reason, the use of cervical collars is mandated as part of the Advanced Trauma Life Support protocol, as well as others.

A variety of orthoses have been tested in multiple studies. In general, statistical differences in effectiveness have not been found among collars of similar classes. In one study using cadavers, different orthoses were tested before and after an odontoid instability had been created (1). From radiographic measurements, they determined that the soft collar provided no significant immobilization in the presence of the instability (1). The Miami J and Minerva braces showed moderate control. The halo was found to provide superior immobilization when

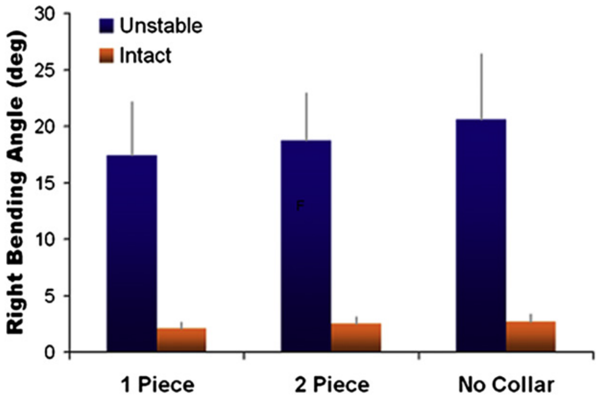

Figure 3. Right-bending range of motion occurring in intact and unstable cervical spines during bed transfers were significantly different (p = 0.022). Values are mean and error bars show standard deviation. Differences between collar conditions were not statistically significant.

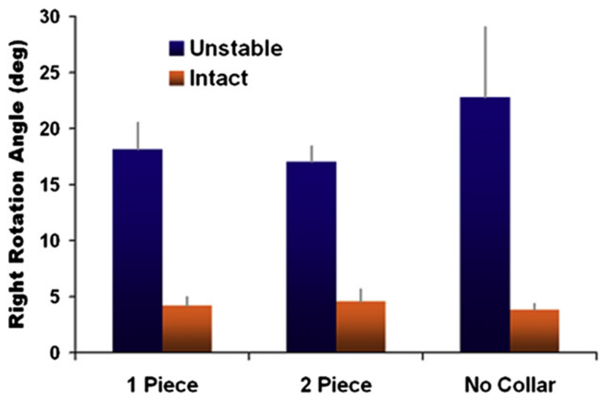

Figure 5. Right rotation occurring in intact and unstable cervical spines during bed transfers were significantly different (p = 0.024). Values are mean and error bars show SD. Differences between collar conditions were not statistically significant.

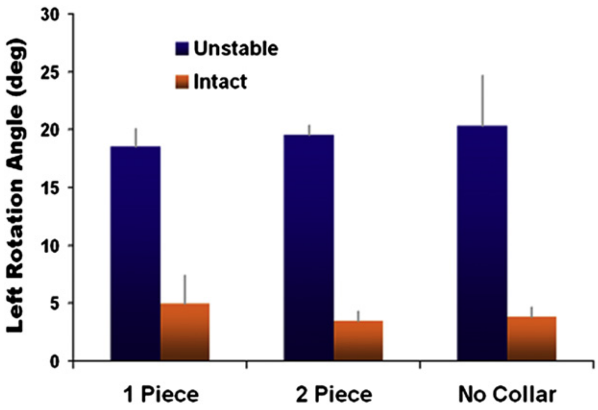

Figure 6. Left rotation occurring in intact and unstable cervical spines during bed transfers were significantly different (p = 0.002). Values are mean and error bars show SD. Differences between collar conditions were not statistically significant.

compared to no collar, a soft collar, Miami J, and Minerva collar. This is the only study other than ours designed to test the immobilizing effects of orthoses with an unstable cervical spine model.

Most studies have evaluated collars using healthy volunteers as subjects. In a systemic review of the literature involving healthy volunteers, Kwan and Bunn concluded that spinal immobilization effectively reduces spinal motion (23). However, potential adverse effects include pain and ventilator restriction. Sandler and colleagues tested active and passive motion using the CA-6000 Spine Motion Analyzer (OSI Inc., Union City, CA) (24). The order of collar effectiveness they found (least to most restrictive) was soft collar, Philadelphia, Philadelphia with extension, and a Sternal Occipital Mandibular Immobilizer (SOMI). Differences between collars were small, and none were as effective as previously reported. The most effective orthosis (SOMI) on the best trial (least motion) allowed a minimum of 19 degrees of flexion-extension, 46 degrees of axial rotation, and 45 degrees of lateral bending.

In a more recent study, 45 healthy adults were used to compare the Philadelphia collar, Aspen cervical collar, PMT cervical collar (PMT Corporation, Chanhassen, MN), Miami J cervical collar, Minerva cervicothoracic orthosis, Lehrman non-invasive halo, and a SOMI (25). They used a non-invasive measuring technique in addition to supplemental fluoroscopic imaging to investigate the differences between upright and supine positioning. The Aspen and Miami J were found to be the most comfortable, but they provided the least restriction of motion. The cervical collars were comparable, as were the cervical thoracic orthosis collars and halos. The residual motion was still 30–50 degrees for the cervical collars. These findings were consistent with those from another investigation using a comparable group of orthoses and radiographic measures (26).

Similar results were found when the effectiveness of the Aspen collar was tested in spines of normal, healthy volunteers (3). Motion was reduced to 31 degrees of flexion-extension, 15.9 degrees of lateral bending, and 26.8 degrees of rotation. A more interesting outcome was that with collar immobilization, paradoxical motion occurred in adjacent segments. This “snaking” effect means that the overall angles measured with external, global measurement systems may not accurately reflect the actual motion taking place at the segmental level.

Askins and Eismont tested the Philadelphia (Philadelphia Cervical Collar Co., Thorofare, NJ, USA), Aspen (Sierra Universal Collar, Aspen Medical Products, Irvine, CA), Stifneck (Laerdal Medical Limited, Armonk, NY), Sierra Universal Collar (Aspen Medical Products, Irvine, CA), NecLoc® (Jerome Medical, Moorestown, NJ), and Miami J (Jerome Medical, Moorestown, NJ) collars (2). They assessed motion at each spinal level using a lateral radiograph. At the C5–C6 level, there was 8.8 degrees of flexion without a collar. This was reduced to 4–6 degrees

Table 2. Degrees of Extension Possible With and Without an Instability

Condition	Collar	Mean	Standard Error	95% Confidence Interval
Unstable	1 Piece	5.8	2.1	−0.1–11.7
	2 Piece	7.1	2.0	1.4–12.7
	No Collar	11.6	3.6	1.7–21.5
Stable	1 Piece	1.6	0.6	0.1–3.1
	2 Piece	1.3	0.2	0.8–1.7
	No Collar	1.4	0.3	0.5–2.3

Table 1. Degrees of Flexion Possible With and Without an Instability

Condition	Collar	Mean	Standard Error	95% Confidence Interval
Unstable	1 Piece	29.7	5.1	15.5–43.9
	2 Piece	27.9	4.4	15.8–40.1
	No collar	35.2	4.9	21.7–48.7
Stable	1 Piece	8.7	0.8	6.6–10.9
	2 Piece	14.2	3.0	5.8–22.7
	No collar	21.4	1.6	7.9–16.8

Table 3. Degrees of Right Bending Possible With and Without an Instability

Condition	Collar	Mean	Standard Error	95% Confidence Interval
Unstable	1 Piece	17.4	4.7	4.4–30.5
	2 Piece	18.7	4.2	7.0–30.5
	No collar	20.6	5.8	4.5–36.7
Stable	1 Piece	2.1	0.6	0.5–3.6
	2 Piece	2.5	0.6	0.8–4.2
	No collar	2.7	0.6	1.0–4.4

Table 4. Degrees of Left Bending Possible With and Without an Instability

Condition	Collar	Mean	Standard Error	95% Confidence Interval
Unstable	1 Piece	16.0	3.9	5.1–26.9
	2 Piece	16.3	2.9	8.3–24.3
	No collar	13.6	2.4	6.9–20.3
Stable	1 Piece	2.1	0.7	0.1–4.2
	2 Piece	2.4	0.7	0.5–4.4
	No collar	2.4	0.5	1.0–3.9

with the various orthoses. Overall, the percentage of flexion that was allowed with the orthoses in place was 17–41% of the normal ROM. The Stifneck and NecLoc collars are meant to be extrication collars and are so rigid that prolonged use is not practical due to patient discomfort and likelihood of skin breakdown. The 8.8 degrees of motion at C5–C6 in the normal individuals by Askins and Eismont corresponds well with our measures using cadavers in the intact condition.

An optical measurement system was used in a different study to compare ROM in healthy volunteers as they completed 15 preset movements while wearing four collars (Miami J, C-Breeze, Aspen, and XTW) and without a collar (5). All of the collars reduced flexion, extension, and lateral flexion by 30–40 degrees from the no-collar condition. This motion was similar for all orthoses and in each plane of motion (5). A second investigation used an electromagnetic tracking device and healthy volunteers to measure motion in the presence of the soft collar, Miami J, Miami J with chest extension, SOMI, and halo vest (6). The soft collar provided almost no immobilization, whereas the halo was the most restrictive. The overall degrees of immobilization provided by the other collars tested were not dramatically different. This study also tested the effect of an ill-fitting Miami J. If the orthosis was too small or too large, more motion was allowed (6).

In our earlier studies using a similar cadaveric model and electromagnetic measurement of motion at the C5–C6 level, we assessed the effectiveness of collars indirectly (7,10,14–16). In these previous studies, transfer techniques were evaluated as a cadaver was moved either onto a spineboard, from one hospital bed to another, or from supine to prone for surgical positioning. Under these circumstances, the addition of a collar tended to reduce motion, but the reduction was not statistically significant. In each of these studies, the spine was being stabilized by an experienced person. This reduced the motion to approximately 10–15 degrees. As has been shown by the previously referenced studies, the collars allow at least 30 degrees of motion, which may be why there is not much of a difference between collars in these tests when the head holder can reduce this to approximately 10–15 degrees.

Table 5. Degrees of Right Rotation Possible With and Without an Instability

Condition	Collar	Mean	Standard Error	95% Confidence Interval
Unstable	1 Piece	18.2	3.1	8.5–28.0
	2 Piece	16.1	1.5	11.4–20.8
	No collar	19.8	7.1	−2.7–42.3
Stable	1 Piece	4.0	1.0	1.0–7.1
	2 Piece	4.7	1.4	0.1–9.3
	No collar	4.3	0.4	2.9–5.7

Table 6. Degrees of Left Rotation Possible With and Without an Instability

Condition	Collar	Mean	Standard Error	95% Confidence Interval
Unstable	1 Piece	19.4	1.7	14.1–24.7
	2 Piece	19.4	1.0	16.1–22.2
	No collar	17.2	3.9	4.9–29.5
Stable	1 Piece	2.6	0.6	0.6–4.6
	2 Piece	3.3	1.1	−0.1–6.7
	No collar	3.3	0.9	0.4–6.2

As seen in the normal volunteers, the collars continue to allow approximately 30 degrees of motion distributed throughout the cervical spine (5,6,26). In the current study, this 30 degrees of motion took place at the injured segment, and motion that was not measured may have occurred between other segments. In healthy individuals without instability, the collars will be more effective because the patient will provide internal stability with normal muscle tone and strength. Pain, along with functional paraspinal musculature, may induce a stabilizing "splinting" effect in a conscious, alert patient.

Limitations

One weakness of this study is that only a single "worst-case" scenario, global instability, was studied. At other points on the continuum ranging from intact to global instability, the cervical collars might have shown some usefulness for immobilization of the injured cervical spine. The use of a cadaver model negates the natural ability of the alert patient to "splint" the neck with muscle tone. Thus, this study cannot account for the "dynamic" stabilizing effect of neck musculature. The means of inducing neck ROM in this study can also be considered a possible weakness. Although it was standardized and tested over multiple samples, maximum ROM is never tested on a patient in a hospital setting. An alert patient with a cervical instability would be unlikely to attempt the ROM to which the cadavers in this study were subjected. Nor is it likely that an unconscious patient in an emergency department or intensive care unit would be subjected to such extreme cervical spine motion. When the patient is mobilized to a chair, log rolled, or placed head up in bed, there are various mechanical forces with a resultant motion. As has been previously shown, the only effective technique to immobilize an unstable cervical spine is by use of a collar and a kinetic treatment table (11,12). This study was meant to test the ability of a cervical collar to restrict ROM as the sole means of protection (which it is clearly not meant to be) in the unstable cervical spine.

Strengths

This study used direct measurement of motion between cervical levels rather than relying on indirect measurement means such as X-ray study or external sensors. The cadaver model and application of ROM using tongs allowed standardization of technique and reduction of variability in the testing process. This model also permitted us to approximate maximum ROM allowed by several collar conditions in an unstable cervical spine.

CONCLUSION

Collars do serve a purpose. They provide postural cues for alert patients and provide a warning to caregivers of the need for cautious handling and transfer of the unconscious patient with an injury. In a patient with an unstable injury or fracture in lower cervical levels, the collar can also help to reduce the motion while the injury heals. Future research is needed to assess to what extent cervical collars achieve immobilization in upper-level cervical instabilities. The orthosis cannot be expected to completely or rigidly immobilize an unstable segment. In a patient with an unstable injury, effective stabilization with, for example, a spine board or Kendrick Extrication Device, should be carried out as soon as practical.

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ARTICLE SUMMARY

1. Why is this topic important?

Cervical orthoses are universally used for extrication, transportation, and immobilization for cervical trauma patients; however, most studies examining effectiveness of cervical orthoses have been conducted in healthy, conscious volunteers. The amount of motion cervical orthoses allow in an unconscious patient or one with a serious cervical injury has not been determined.

2. What does the study attempt to show?

The purpose was to measure the effectiveness of cervical orthoses in restricting spinal motion in a cadaveric model. We chose this model to more closely replicate the unconscious patient with a cervical injury.

3. What are the key findings?

Cervical collars alone did not prevent cervical motion during transfers performed by an experienced team even in cadavers with an intact cervical spine. When a cervical instability was present, a potentially dangerous amount of spinal motion occurred with or without collars. Techniques in addition to collars are needed to adequately immobilize an unstable cervical spine.

4. How is patient care impacted?

Understanding that cervical orthoses cannot effectively prevent motion in an unstable cervical spine should result in health care workers using techniques in addition to collars to immobilize the spine of patients with suspected cervical injury. This should result in fewer exacerbations of cervical spine injuries in patients during prehospital and early hospital management.