

Motion in the Unstable Cervical Spine When Transferring a Patient Positioned Prone to a Spine Board

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Context: Two methods have been proposed to transfer an individual in the prone position to a spine board. Researchers do not know which method provides the best immobilization.

Objective: To determine if motion produced in the unstable cervical spine differs between 2 prone logrolling techniques and to evaluate the effect of equipment on the motion produced during prone logrolling.

Design: Crossover study.

Setting: Laboratory.

Patients or Other Participants: Tests were performed on 5 fresh cadavers (3 men, 2 women; age = 83 ± 8 years, mass = 61.2 ± 14.1 kg).

Main Outcome Measure(s): Three-dimensional motions were recorded during 2 prone logroll protocols (pull, push) in cadavers with an unstable cervical spine. Three equipment conditions were evaluated: football shoulder pads and helmet, rigid cervical collar, and no equipment. The mean range of motion was calculated for each test condition.

Results: The pull technique produced 16% more motion than the push technique in the lateral-bending angulation

direction ($F_{1,4} = 19.922$, $P = .01$, $\eta^2 = 0.833$). Whereas the collar-only condition and, to a lesser extent, the football-shoulder-pads-and-helmet condition demonstrated trends toward providing more stability than the no-equipment condition, we found no differences among equipment conditions. We noted an interaction between technique and equipment, with the pull maneuver performed without equipment producing more anteroposterior motion than the push maneuver in any of the equipment conditions.

Conclusions: We saw a slight difference in the motion measured during the 2 prone logrolling techniques tested, with less lateral-bending and anteroposterior motion produced with the logroll push than the pull technique. Therefore, we recommend adopting the push technique as the preferred spine-boarding maneuver when a patient is found in the prone position. Researchers should continue to seek improved methods for performing prone spine-board transfers to further decrease the motion produced in the unstable spine.

Key Words: injuries, transfer techniques, logroll

Key Points

- A slight difference in motion was measured between the 2 prone logrolling techniques, with the push technique producing less lateral-bending and anterior-posterior motion than the pull technique.
- The logroll push technique should be adopted as the preferred spine-boarding maneuver when a patient is found in the prone position.
- Individuals who may need to perform this rescue procedure should practice and become proficient in the logroll push technique.
- Researchers should continue to seek improved methods for transferring patients positioned prone to spine boards to further reduce the motion transmitted to the unstable spine.

Each year, 12 000 incidents of nonfatal spinal cord injury are reported in the United States.¹ Approximately 8.0% of these injuries occur during sport participation.¹ Of all US sports, American football has by far the greatest number of spinal injuries. Between 1982 and 2007, the incidence of direct injuries in males playing American football was 1.89 per 100 000 participants in a college setting and 0.75 per 100 000 participants in a high school setting.²

The prehospital management of spinal cord injuries is critical to prevent exacerbation of the injury. In 3% to 25% of patients, neurologic deterioration occurs during the

initial management of spinal cord injuries.³ During immobilization and transportation of the patient to the hospital, precautions must be taken to transmit as little motion as possible to the spine. One of the first transfers that rescuers must perform is placing the injured athlete onto a long, rigid spine board. When the injured athlete is supine, lift-and-slide spine-board transfers produce less motion in the spine than logroll spine-board transfers.^{4–6} However, when the patient is found in the prone position, a lift-and-slide transfer cannot be performed successfully, and a logroll technique must be used.

Swartz et al⁷ recommended how to best manage a catastrophic spine injury in the athlete. They described 2 techniques for logrolling an athlete who is positioned prone: the prone logroll push and the prone logroll pull. Researchers⁸ have shown that the logroll push produces less motion in the unstable thoracolumbar spine. No one knows which of the prone spine-boarding techniques provides the best immobilization in the unstable cervical spine. Therefore, the primary purpose of our study was to determine if motion produced in the unstable cervical spine differs between 2 prone logrolling techniques. Our null hypothesis was that no difference would exist in the amount of motion allowed between the 2 prone logrolling techniques. Our secondary purpose was to evaluate the effect of equipment on the motion produced during the prone logrolling technique. Our null hypothesis was that no difference would exist in the amount of motion allowed among any of the equipment conditions.

METHODS

Specimen Preparation

We determined that a sample size of 5 would be required to detect a clinically relevant difference of 4° among conditions for this repeated-measures study, assuming a standard deviation of 2.44°,⁹ α level of .05, and power of 0.80. Five fresh, lightly embalmed cadavers (3 men, 2 women; age = 83 ± 8 years, mass = 61.2 ± 14.1 kg) with no evidence of cervical spine pathologic conditions were obtained from the University Anatomical Gift Program of the University of Rochester. The cadavers in this study were lightly embalmed with a highly diluted mixture of formalin, water, and alcohol. This formulation used much less formalin than traditional embalming methods and maintained soft tissue flexibility similar to that of fresh cadavers while slowing tissue degradation.

Instability Model

A 3-column global instability was created at the C5–C6 level by surgically transecting the disc; disrupting the facets; and dissecting the anterior longitudinal, posterior longitudinal, and interspinous ligaments. This model represents a condition of cervical spine instability sufficient to endanger the spinal cord and has been used in several reports.^{5,9–15} The instability was verified by manually manipulating the spine through a range-of-motion measurement under a constant force of 5 to 7 pounds (2.25–3.15 kg).

Equipment

To investigate the effect of football equipment and rigid cervical collar use, cadavers were tested with 3 equipment conditions: football shoulder pads and helmet, collar only, and no equipment. Appropriately sized shoulder pads were used for each cadaver. A standard helmet also was used, and padding was inserted between the helmet and head to achieve a tight fit if necessary. For the collar-only condition, we used a 2-piece rigid cervical collar (Sierra; Aspen Medical Products, Irvine, CA).

Motion Measurement

We assessed the amount of dynamic angulation and translation motion in all 3 anatomic planes (flexion-extension, axial rotation, lateral bending, medial-lateral [ML] translation, axial translation, and anterior-posterior

[AP] translation) during each maneuver using an electromagnetic motion-analysis device (LIBERTY; Polhemus Inc, Colchester, VT). The LIBERTY device uses electromagnetic fields to establish the 3-dimensional position and orientation of its sensors. It detects angular motions with an accuracy of 0.3° within its optimal operating range of 10 to 70 cm, according to the manufacturer's specifications.¹⁶ This technology has been used extensively by researchers to document motion in the spine.^{5,6,9,12,14,15,17–20} The system consists of 1 transmitter that emits an electromagnetic field and sensors with embedded orthogonal coils that detect position and orientation. We recorded signals from the sensors for processing at a sampling rate of 240 Hz. Given that the electromagnetic sensors detect motion with a high signal-to-noise ratio, we did not filter or smooth the raw data. We fixed the sensors to the anterior bodies of C5 and C6 with custom-made mounting brackets. The relative motion that occurred between C5 and C6 was measured as the cadavers were moved. The data were recorded directly from the LIBERTY device onto a laptop computer. Joint angles were calculated using previously described methods.^{11,13,15,17}

Prone Logroll Techniques

Logroll Pull. Five rescuers are required for the maneuver (Figure 1). Rescuer 1 remains at the patient's head and stabilizes the cervical spine. Rescuers 2 through 4 are positioned along the patient's body opposite from the direction in which the patient's head is facing; rescuer 2 is at the shoulders and chest, rescuer 3 is at the hips, and rescuer 4 is in control of the patient's legs. Rescuer 5 is in charge of the spine board. Rescuer 1 starts the process by stabilizing the patient's head in a crossed-hands position; the hands are uncrossed by the end of the maneuver. On command from rescuer 1, rescuers 2 through 4 slowly pull the patient toward them as rescuer 5 positions the spine board between their upper extremities and the patient's body. Rescuers 2 through 4 slowly lower the patient onto the spine board.⁷

Logroll Push. The logroll push is completed with 5 rescuers (Figure 2). Rescuer 1 remains at the patient's head and stabilizes the cervical spine. Rescuers 2 through 4 are positioned at the shoulders and chest, hips, and legs on the same side that the patient's head is facing. Rescuer 5 is in charge of the spine board. Rescuer 1 directs rescuers 2 through 4 to carefully roll the patient away from them by pushing toward rescuer 5, who is holding the spine board at a 45° angle beneath the patient. Rescuers 2 through 4 slowly lower the patient onto the spine board controlled by rescuer 5.⁷

Procedures

The same group of 5 rescuers participated in both maneuvers. Rescuers 1 (G.D.R.) and 2 (M.H.H.) were athletic trainers with 10 and 25 years of experience, respectively, and rescuers 3 (M.P.) and 4 (G.R.R.) were spine surgeons with 5 and 30 years of experience, respectively. Rescuer 5 (not an author) was an undergraduate athletic training student. The athletic trainer with the most experience providing emergency care (M.H.H.) was selected to ensure manual in-line stabilization of the head and neck for all trials. All members of the rescue team practiced the 2 prone logrolling techniques before data collection to become familiar with the experimental



Figure 1. Sequence of the prone logroll pull procedure. A, The patient is prone and facing left, and the rescuers are positioned on the patient's right. The logroll maneuver is performed with a counterclockwise rotation, pulling the patient toward the rescuers. B, The spine board has been inserted between the rescuers and the patient at an angle of approximately 45°. C, The logroll maneuver has been completed. The patient lies supine on the spine board still facing left.

protocol and to learn how to coordinate the execution of each technique.

For each cadaver, the order of testing was first randomized for the 3 equipment conditions. Next, the order of testing of the 2 spine-boarding techniques was randomized. All randomizations were performed with a computerized random number function. Each technique was repeated 3 times and began with the cadaver in a standard starting position, which consisted of the cadaver lying prone on the ground and the head and neck aligned with the torso. To minimize the level of fatigue that the rescue team experienced, only 1 cadaver was tested per day.

Research Design and Data Analysis

We analyzed 6 dependent variables: 3 angular motions and 3 linear motions. These variables of interest were flexion-extension, axial rotation, lateral bending, ML translation, axial translation, and AP translation produced at the C5–C6 spinal segment. For each trial, the total range of motion was calculated by subtracting the minimal angle or displacement from the maximal angle or displacement. A 2-way analysis of variance (ANOVA) with repeated measures was used to analyze the following independent variables: equipment condition (3 levels: football shoulder pads and helmet, collar only, no equipment) and transfer technique (2 levels: push, pull). The average range of motion from the 3 trials performed with each cadaver was included in the statistical analyses. Within-subjects post

hoc comparisons were used to analyze the 3 different levels of the equipment variable. Given that we made 3 different comparisons, the family-wise error rate (.05) was divided by 3, so each test was run at the $.05/3 = .0167$ level (Bonferroni correction). We selected this test because it is more conservative and less likely to result in type I error than the more liberal least significant difference test. A Mauchly test was applied to evaluate the sphericity assumption that variances of differences between groups are equal. If the assumption of sphericity was violated, the Greenhouse-Geisser correction factor was applied. All statistical analyses were performed with SPSS statistical software (version 17.0; SPSS, Inc, Chicago, IL) with the α level set a priori at equal to or less than .05.

RESULTS

Results for angulation and translation in each anatomic plane are presented in Figure 3.

Flexion-Extension

In flexion-extension, we found no difference between the transfer techniques ($F_{1,4} = 0.149$, $P = .72$, $\eta^2 = 0.036$). The ANOVA identified a difference among the equipment conditions ($F_{2,3} = 9.026$, $P = .009$, $\eta^2 = 0.693$), but when we evaluated the pairwise comparisons after making the Bonferroni adjustment, we observed no differences. We



Figure 2. Sequence of the prone logroll push procedure. A, The patient is prone and facing left, and the rescuers are positioned on the patient's left. The logroll maneuver is performed with a counterclockwise rotation, pushing the patient away from the rescuers. B, The spine board, which has been held at an angle of approximately 45°, begins to receive the patient. C, The logroll maneuver has been completed. The patient lies supine on the spine board still facing left.

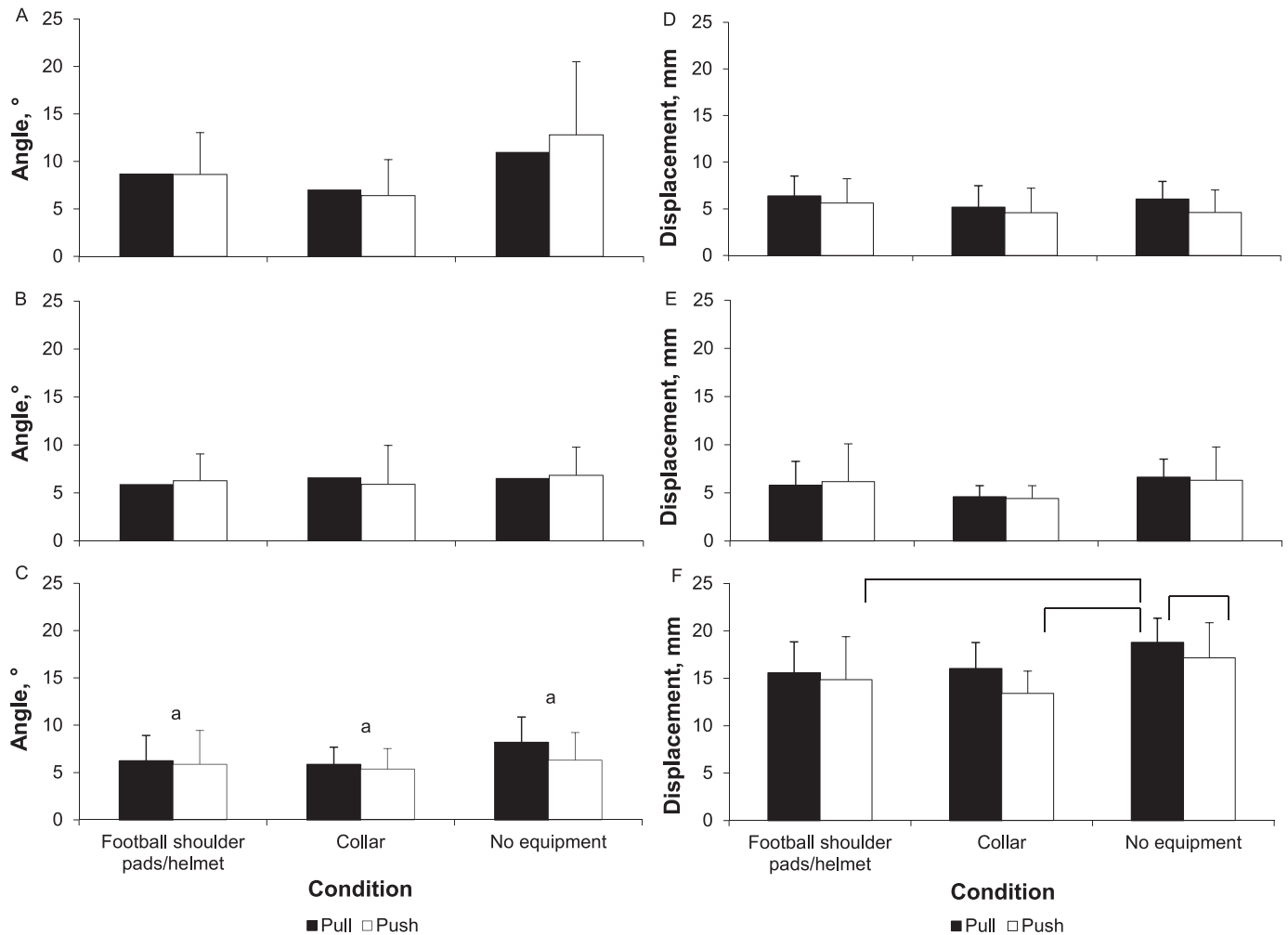


Figure 3. Angulation and translation during the logroll push and logroll pull procedures. **A**, Cervical flexion-extension. **B**, Cervical axial rotation. **C**, Cervical lateral bending. **D**, Cervical medial-lateral translation. **E**, Cervical axial translation. **F**, Cervical anterior-posterior translation. In lateral bending, we found a difference between the 2 transfer techniques ($F_{1,4} = 19.922$, $P = .01$), with the push method producing less motion than the pull method. In anterior-posterior translation, we found an interaction effect between equipment used and transfer technique ($F_{2,3} = 4.580$, $P = .047$), with the push technique producing less motion than the pull technique in the no-equipment condition. We found no other differences among experimental conditions.

noted no interaction effect between the equipment used and the transfer technique ($F_{2,3} = 0.360$, $P = .71$, $\eta^2 = 0.083$).

Axial Rotation

In axial rotation, we found no differences between the transfer techniques ($F_{1,4} = 0.008$, $P = .93$, $\eta^2 = 0.002$) or among equipment conditions ($F_{2,3} = 0.203$, $P = .82$, $\eta^2 = 0.048$). No interaction effect was seen between the equipment used and the transfer technique ($F_{2,3} = 0.789$, $P = .49$, $\eta^2 = 0.165$).

Lateral Bending

In lateral bending, we found a difference between the transfer techniques ($F_{1,4} = 19.922$, $P = .01$, $\eta^2 = 0.833$), with the logroll push method producing less motion than the logroll pull method. We noted no difference among equipment conditions ($F_{2,3} = 2.614$, $P = .13$, $\eta^2 = 0.395$). No interaction effect was seen between the equipment used and the transfer technique ($F_{2,3} = 1.769$, $P = .23$, $\eta^2 = 0.307$).

Medial-Lateral Translation

In ML translation, we found no differences between the transfer techniques ($F_{1,4} = 5.132$, $P = .09$, $\eta^2 = 0.562$) or among equipment conditions ($F_{2,3} = 0.844$, $P = .47$, $\eta^2 = 0.174$). We observed no interaction effect between the equipment used and the transfer technique ($F_{2,3} = 0.218$, $P = .81$, $\eta^2 = 0.052$).

Axial Translation

In axial translation, we found no differences between the 2 transfer techniques ($F_{1,4} = 0.003$, $P = .96$, $\eta^2 = 0.001$) or among equipment conditions ($F_{2,3} = 3.705$, $P = .07$, $\eta^2 = 0.481$). We found no interaction effect between the equipment used and the transfer technique ($F_{2,3} = 0.155$, $P = .86$, $\eta^2 = 0.037$).

Anterior-Posterior Translation

In AP translation, we found no differences between the transfer techniques ($F_{1,4} = 6.269$, $P = .07$, $\eta^2 = 0.610$) or among equipment conditions ($F_{2,3} = 5.750$, $P = .07$ [after

Greenhouse-Geisser correction], $\eta^2 = 0.590$). We observed an interaction effect between the equipment used and the transfer technique ($F_{2,3} = 4.580$, $P = .047$, $\eta^2 = 0.534$), with the logroll pull technique in the no-equipment condition producing more motion than the push technique in any of the equipment conditions.

DISCUSSION

The purpose of our study was to determine if motion produced in the unstable cervical spine differs between 2 prone logrolling techniques and to evaluate the effect of equipment on the motion produced during prone logrolling. We also evaluated the effect of equipment on the motion produced during prone logrolling. On average, the pull technique produced 7% more motion than the push technique across all directions of motion ($7.3^\circ \pm 2.9^\circ$ and 9.4 ± 2.4 mm for the pull versus $7.2^\circ \pm 4.1^\circ$ and 8.6 ± 3.2 mm for the push technique). This was only different in the lateral-bending angulation direction, which had 16% more motion during the pull ($6.8^\circ \pm 2.6^\circ$) than the push ($5.8^\circ \pm 2.8^\circ$) technique. Given that the pull technique had more lateral-bending motion, we reject the null hypothesis that no difference exists between the prone spine-boarding techniques. We found no differences among the equipment conditions; therefore, we cannot reject the null hypothesis that no difference exists in motion allowed among equipment conditions. We observed an interaction between equipment and technique; the pull technique in the no-equipment condition produced more motion than the push technique in any of the equipment conditions. This observation further supports our previous finding that a difference exists between the techniques, with the push maneuver resulting in less motion to the unstable cervical spine during prone spine boarding.

Immobilization is a critical step in the acute care of a patient who has experienced cervical spine trauma. The currently available evidence for directing the management of patients in this situation is lacking. One of the tenets that has emerged consistently from many researchers is that the logroll maneuver potentially can produce motion in an unstable spine.^{4,5,9,12,15,17,21–23} In previous evaluations of spine-board transfers, only transfers with the patient in the supine position have been considered. We are the first to measure cervical spine motion during transfers with the patient starting in the prone position, which is not an uncommon scenario clinically. When a patient is found in the prone position, a logroll maneuver must be used to position the patient supine on the spine board.

Swartz et al⁷ presented 2 methods for performing a prone logroll. As noted, with the pull technique, the rescuer may have difficulty sliding the board between the other rescuers and the injured athlete without touching the rescuers' upper extremities and potentially jeopardizing their hold on the athlete; however, no data were available to support the use of one technique over the other. Our results suggest that during the pull technique, any difficulty sliding the board between the athlete and the rescuers only produced additional motion in the spine for lateral bending. We suspect that the reduction in lateral-bending motion during the push technique could be attributed to the spine board's being placed adjacent to the patient from the initiation of the movement. This placement would allow the board to act as a rigid backstop to prevent the body from shifting during

the rolling motion. During the pull technique, enough space must be provided between the rescuers' knees and the patient to slide the board. The initiation of the rolling motion requires the most effort on the part of the rescuers because one side of the patient's body must be lifted off the ground. During the push technique, the rescuers are in a more ergonomic position at initiation, exerting a lifting force very close to their bodies. During the pull technique, the rescuers must reach over the patient and lift the body on the opposite side from where they are positioned, which may require more effort and exertion from the low back.

We also observed that the presence of football shoulder pads and a helmet does not affect the amount of motion generated. Before this study, we suspected that the football-shoulder-pads-and-helmet condition would limit the range of motion in the spine and provide greater stabilization than the no-equipment condition. However, we could not reject the null hypothesis for the equipment condition. Segmental motion was reduced by an average of 1.7° and 0.9 mm in the football-shoulder-pads-and-helmet condition compared with the no-equipment condition; however, this finding was not different. The collar-only condition provided marginally better reduction of motion (2.4° and 1.9 mm) than the no-equipment condition, but this finding also was not different. These observations highlight the difficulty in immobilizing an unstable spine segment through the use of external devices.

We are not the first to note the insufficiency of collars to immobilize the cervical spine. Horodyski et al²⁴ observed that collars did not reduce the total range of motion allowed in the unstable spine of a cadaver model. Using a similar cadaver model with an instability created at C1–C2, Ben-Galim et al²⁵ showed that cervical collars can increase the amount of distraction in the upper cervical spine. Other researchers have found no reduction in motion with a collar when used during various transport maneuvers, including spine boarding,¹⁰ bed transfers,¹³ kinetic therapy,^{15,26} and prone positioning in the operating room.^{12,27} Even in studies of healthy volunteers with stable spines, cervical collars have allowed approximately 30° of global cervical spine motion.^{28–30} It is important to recognize the limitations of collars to immobilize the unstable cervical spine.

Compared with the supine logroll maneuver,²⁷ the prone logroll maneuver results in about twice the amount of flexion-extension; 4 times the amount of AP translation; and similar amounts of lateral bending, axial rotation, ML displacement, and axial displacement. The differences in sagittal-plane motion between the prone and supine logroll could be attributed to the extension alignment of the head when the patient is in the face-down position. This dramatic increase in motion during the prone logroll maneuver is not surprising considering that the patient must be rotated through a complete 180° arc. During the standard supine logroll maneuver, the patient only needs to be rotated approximately 45° so the board can be placed under the body. The difficulty in stabilizing the cervical spine during the logroll is due to the complex path of motion that the head must travel. The person providing in-line stabilization of the head and neck must simultaneously rotate and translate the head. The movement must be coordinated temporally and spatially with the movement of the torso to minimize motion occurring through the cervical spine. During the prone logroll, the upper extremities of the

rescuer holding the head begin in a crossed position so they are parallel after the 180° rotation. Providing coordinated rotational and translational control of the head and neck while the upper extremities are crossed is particularly challenging.

For all combinations of equipment and transfer technique, we observed a substantial amount of motion (approximately 7° of angulation and 9 mm of translation). We could not determine if the motion we observed would surpass the threshold required to cause neurologic deterioration. Improved methods that can reduce this amount of motion are needed.

Our investigation had some limitations. We studied cadavers so we could test the motion that occurs in an unstable spine during prone spine-board transfers. Whereas cadavers lack the muscle tone of living patients, muscular contractions do not play an important role in stabilizing the spine after substantial spine trauma when a patient may be unconscious. Given the natural stability of the intact spine, evaluating motions in the worst-case scenario, which is a globally unstable spine, is important. We could not have conducted this study in a vulnerable population, such as living patients with unstable spine injuries. Although the degree of injury that was modeled may be infrequently encountered clinically, the advanced trauma life support guidelines of the American College of Surgeons³¹ recommend that all trauma “patients should be presumed to have an unstable cervical spine injury . . . until all aspects of the cervical spine have been adequately studied and an injury excluded.”

CONCLUSIONS

We found a slight difference in the motion measured during the 2 prone logrolling techniques tested, with the logroll push technique producing less lateral-bending motion than the pull technique. Based on this finding, we recommend that the push technique be adopted as the preferred spine-boarding maneuver when a patient is found in the prone position. Given the potential for a large amount of motion to be imposed on an unstable spine, we also recommend that individuals who may be performing this rescue procedure practice and become proficient in the maneuver. Even though collars did not reduce motion, we do not recommend that collar use be abandoned, because it has some benefits. For example, collars can remind medical personnel to maintain spinal precautions, and in alert patients, they can be a cue to limit voluntary neck movements. However, a rigid cervical collar or football shoulder pads and helmet provide minimal, if any, additional stabilization to the spine. Researchers need to continue to seek improved methods for performing prone spine-board transfers so the motion produced in the unstable spine can be further reduced.

ACKNOWLEDGMENTS

This study was supported with resources from and the use of facilities at the Bay Pines VA Healthcare System.

DISCLAIMER

The views expressed herein are those of the authors and do not necessarily reflect the views of the Department of Veterans Affairs or the United States Government.

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