Cervical Spine Motion During Extrication: A Pilot Study

Jeffery S. Shafer, MD, EMTP
Rosanne S. Naunheim, MD
Washington University School of Medicine, Division of Emergency Department

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Spinal immobilization is one of the most commonly performed pre-hospital procedures. Little research has been done on the movement of the neck during immobilization and extrication. In this study we used a sophisticated infrared six-camera motion-capture system (Motion Analysis Corporation, Santa Rosa, CA), to study the motion of the neck and head during extrication. A mock automobile was constructed to scale, and volunteer patients, with infrared markers on bony prominences, were extricated by experienced paramedics. We found in this pilot study that allowing an individual to exit the car under his own volition with cervical collar in place may result in the least amount of motion of the cervical spine. Further research should be conducted to verify these findings. In addition, this system could be utilized to study a variety of methods of extrication from automobile accidents. [*West*JEM. 2009;10:74-78.]

INTRODUCTION

It is estimated that 3-25% of spinal cord injuries may be significantly worsened during transport or early treatment, and therefore are preventable.[1,2] Because of this concern for subsequent injury, full spinal immobilization remains the standard of care for Emergency Medical Services (EMS) throughout much of the United States.[1] Currently, full spinal immobilization, as recommended by the American College of Surgeons, consists of application of a cervical collar (CC), immobilization on a long backboard, and the addition of lateral immobilizing devices.[3,1] The Kendrick Extrication Device (KED) is also available as an effective adjunct to spinal immobilization.[4,5,6]

However, full spinal immobilization is not without risk. It has been associated with a multitude of complications, including airway compromise, aspiration, increased intracranial pressure, cutaneous pressure ulcers, iatrogenic pain, combativeness of intoxicated patients and increased cost and time of extrication.[7-22] And backboards place most patients in a position of relative cervical extension.[18,23,24] Removal of patients from a spine board is also problematic with studies showing that "log rolling" a patient results in significant motion of the thoracolumbar spine.[25] Given that the majority of patients who are trauma packaged will have no spinal injury, efforts are underway to identify those whom EMS personnel may safely forego spinal immobilization.[26-29] While pre-hospital cervical spine clearance may prove successful, not all patients will be candidates, possibly due to serious or distracting injury, intoxication, or neck pain. Even if EMS medical directors were to adopt pre-hospital cervical spine clearance protocols, they would require considerable effort to institute and maintain.

While immobilization is problematic in itself, a broader question that must be answered is whether the act of immobilizing the spine results in movement of vertebral segments. Spinal motion has been studied with cadavers, using photogrammetry (analysis of multiple photographs recreating a three-dimensional picture by sterotaxis)[30,31] and via radiographic analysis of cervical motion.[4,5]

Previously, no one had the ability to examine spinal movement during immobilization and actual extrication from an automobile. Roozmon[32,33] had suggested a more comprehensive motion-capture system as the best method for further study of motion in the cervical spine. This system has been used to study kinematics and cervical motion.[34,35] Pearcy[36] demonstrated that skin markers reflect the underlying bony structure if they are placed over relatively fixed points in the skin; ie., sternum, acromion and zygoma. (In a previous study, the displacement error in finding bony landmarks has been estimated at less than one degree.)[37] This study[36] also

Table 1. Cervical spine motion in degrees for patients exiting vehicle independently.

	Unassisted, no CC		Unassisted, with CC	
	Mean	Std Dev	Mean	Std Dev
Starting Angle (in degrees)	8	2.8	4.2	3.9
Mean Change (average angle during movement less the starting angle)	8.7	11.9	1.4	4
Variation During Movement (std dev during movement)	10.6	7.5	1.2	0.1
Peak change (range of motion)	39.8	19.3	6.8	1.8

CC, cervical collar; *Std*, standard deviation

defined the orthogonal base vector system for two rotating bodies, which has become the standard for motion-capture systems. By using a group of markers to define a plane, the relative motion of the head as compared to the torso can be determined mathematically. This involves the absolute angles of the orthogonal vectors in each frame, which are determined trigonometrically with respect to a fixed calibration frame. Next, a transformation matrix rotates the coordinate systems to the absolute reference frame by using Euler's angles to translate from one coordinate system to another.

Our goal was to conduct a pilot study using an infrared video motion-capture system to examine, for the first time, extrication from a mock automobile. We will determine feasibility of further studies with the motion-capture equipment and provide preliminary data.

METHODS

The study was approved by the Washington University Institutional Review Board, and written informed consent was obtained from all parties.

Using as our model a 2001 Toyota Corolla that had significant damage to the interior compartment, with significant dash intrusion and steering wheel deformity, we constructed a mockup to scale, including ground height, floorboard space, dash, center console, steering wheel, ceiling, and doors. We included all deformity rendered by the high-speed accident. The actual Toyota seats were removed and placed in the mock vehicle. To allow visualization of markers by the motion analysis system, direct line of sight with two of six cameras had to be established and maintained at all times. Therefore, we removed the seat back cushions and replaced them with plexiglass. The frame of the vehicle was constructed from ½" PVC conduit and a bent-wire frame.

The Motion Analysis Corporation (MAC) six-camera motion-capture system (Santa Rosa, CA) was used to track 0.5 inch reflective markers on the head (forehead, crown, zygomas), C7, and the trunk (acromion, humerus, clavicle, sternum, anterior superior iliac spine, and greater trochanters bilaterally). This allowed the identification of planes defining the head and torso. Calibration of the system involved measuring deviations from known distances between fixed markers and deviations from known angles as measured by the six cameras, using a triangulation system with the EVa Real-Time Software (EVaRT) (MAC, Santa Rosa, CA). We recorded the position of each marker (calibrated accuracy to 0.5mm) using EVaRT at a frame rate of 60/sec. Standard analysis programs (Excel) allowed the calculation of the change of angle between the head and torso. Starting position of the subject was in the driver's seat of the mock automobile.

We recruited three paramedics, each with more than five years EMS experience. One paramedic, acting as the driver, was extricated by the other two using each of four techniques:

1. The "driver" was allowed to exit the vehicle on his/her own volition and lie on a backboard.
2. The "driver" was allowed to exit the vehicle on his/her own volition with a CC in place and lie on a backboard.
3. The "driver" was extricated head first via standard technique by the remaining two paramedics with a CC alone.[29,30] (Standard technique involves turning the driver so that the legs are in the passenger's seat, allowing the driver to lie back and raising the right hip so a long board can be placed under the hip. A second paramedic who enters the front seat passenger's door helps slide the "driver" up on to the board.)
4. The "driver" was extricated head first via standard technique by the remaining two paramedics with a CC and KED.

RESULTS

We were able to calculate the absolute angle of movement of the cervical spine using extrapolated lines connecting the head (forehead, crown, zygomas), C7, and the trunk (acromion, humerus, clavicle, sternum, anterior superior iliac spine, and greater trochanters bilaterally) which created planes of the head and the torso, respectively.

Ultimately, we documented the least movement of the cervical spine in subjects who had a cervical collar applied and were allowed to simply get out of the car and lie down on a stretcher. [mean change 1.4 ± 4.0 deg, and peak change 6.8 ±

Table 2. Cervical spine motion in degrees for patients requiring assistance.

	Assisted, no CC		Assisted, with KED and CC	
	Mean	**Std Dev**	**Mean**	**Std Dev**
Starting Angle (in degrees)	8.6	4.2	3.8	1.8
Mean Change (average angle during movement less the starting angle)	1	4.5	2	2.3
Variation During Movement (std dev during movement)	4.7	2.9	2.9	0.9
Peak change (range of motion)	26.6	14.2	31.1	17.6

CC, cervical collar; *Std*, standard deviation; *KED*, Kendrick Extrication Device

1.8 deg]. See Table 1. Extricating the driver/subject head-first by standard technique to a long spine board was associated with significant cervical spine motion, both with the collar alone [mean change 1.0 ± 4.5 deg, and peak change 26.6 ± 14.2 deg] and even with a cervical collar and KED [mean change 2.0 ± 2.3 deg, and peak change 31.1 ± 17.6 deg]. See Table 2.

DISCUSSION

The American Association of Neurological Surgeons and the Congress of Neurological Surgeons recognized in 2002 that insufficient evidence exists to support treatment standards or guidelines with respect to pre-hospital spinal immobilization.[1] However, they acknowledge that it is unlikely that all trauma patients require full spinal immobilization.[1] Some patients, such as those with neurologic deficits or altered mental status clearly will require full immobilization for transport and protection of the spine. However, full immobilization of patients with isolated neck or back pain may result in more manipulation of the spine than simply allowing those patients to move themselves.

The National Association of EMS Physicians Standards and Clinical Practice Committee[26] states that patients without altered mental status, intoxication, neck or back pain/tenderness, or distracting injury may forego spinal immobilization. Of two recent studies, only 48 of 13,652 patients with spinal injuries were missed by application of this pre-hospital criteria.[28,29] No patient suffered an adverse outcome. At least one retrospective study suggests that ambulatory trauma patients have little/no risk of thoracolumbar fractures.[34] We may never have the capability to discern which movements result in worsening injury, since this is dependent on the type of injury and the specific individual. The best course of action may be to identify those at high risk for possible injuries through clinical criteria and treat them with the method involving the least spinal movement.

LIMITATIONS

We noted several limitations of the motion capture system. Flexion/extension of the cervical spine may not be analyzed correctly if a line drawn through the frontal plane of the head and a second line drawn through the acromia representing the torso both flex forward, causing the relative motion to be zero. We remedied this by creating a three-point plane of the head and a second one for the torso. We also placed a marker on C7 (with a small portion of the CC removed); however, the marker was still only intermittently visible during the extrication process. Ultimately video was needed to exclude the presence of any flexion/extension. We also needed video to exclude the presence of isolated shoulder movement. These errors may be remedied in future studies by placement of additional markers. In addition, the MAC system was unable to provide sufficient data to evaluate movement of the thoracolumbar spine. (Hardware not requiring line of sight for location of markers will prove superior in the future, if markers are small). Neither were we able to obtain sufficient pelvic data from the markers located over the greater trochanters and anterior superior iliac spines to elucidate any movement of the thoracolumbar spine. This was particularly true when the KED was placed.

Other limitations include the use of a mock automobile and our choice of subjects. We involved only healthy, cooperative, EMS-educated personnel, whose depth of medical knowledge was another drawback.

This study was designed to serve as a pilot study. No changes in current treatment protocols should be made based on it alone. Our research was limited by a lack of power to make such determinations.

A more definitive, appropriately powered study should be conducted to demonstrate if allowing ambulatory patients to leave the vehicle independently with CC alone ± an adjunctive device would be superior to standard immobilization on a backboard. It will be necessary to study a larger number of patients. We further hope that, in the future, we may use this technology to study a variety of extrication techniques for those patients who do require full spinal immobilization.

CONCLUSION

In those ambulatory subjects who do not complain of back pain, the least motion of the cervical spine may occur when the subject is allowed to exit the car in a c-collar without backboard immobilization. This may have implications for decreasing extrication time in the pre-hospital setting and reducing complications of long spine board use.

Address for Correspondence: Jeffery S. Shafer, MD, EMTP, Washington University School of Medicine, Division of Emergency Medicine, 660 S. Euclid Ave, Campus Box 8072, St. Louis, MO 63110. Email: shaferj@wusm.wustl.edu.

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