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Original Contribution

The long spine board does not reduce lateral motion during transport—a randomized healthy volunteer crossover trial☆,☆☆,☆☆☆

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ABSTRACT

Objective: For thirty years, emergency medical services agencies have emphasized limiting spinal motion during transport of the trauma patient to the emergency department. The long spine board (LSB) has been the mainstay of spinal motion restriction practices, despite the paucity of data to support its use. The purpose of this study was to determine reduction in lateral motion afforded by the LSB in comparison to the stretcher mattress alone.
Methods: This was a randomized controlled crossover trial where healthy volunteer subjects were randomly assigned to either LSB or stretcher mattress only. All subjects were fitted with a rigid cervical collar, secured to the assigned device (including foam head blocks), and driven on a closed course with prescribed turns at a low speed (<20 mph). Upon completion, the subjects were then secured to the other device and the course was repeated. Each subject was fitted with 3 graduated-paper disks (head, chest, hip). Lasers were affixed to a scaffold attached to the stretcher bridging over the patient and aimed at the center of the concentric graduations on the disks. During transport, the degree of lateral movement was recorded during each turn. Significance was determined by *t* test.
Results: In both groups, the head demonstrated the least motion with 0.46 ± 0.4-cm mattress and 0.97 ± 0.7-cm LSB ($P \le .0001$). The chest and hip had lateral movement with chest 1.22 ± 0.9-cm mattress and 2.22 ± 1.4-cm LSB ($P \le .0001$), and the hip 1.20 ± 0.9-cm mattress and 1.88 ± 1.2-cm LSB ($P \le .0001$), respectively. In addition, lateral movement had a significant direct correlation with body mass index.
Conclusion: The stretcher mattress significantly reduced lateral movement during transport.

1. Introduction

Since J.D. Farrington first formally described the long spine board (LSB) in "Death in a Ditch" [1], emergency medical services (EMS) providers have used this medical device during extrication and transport of trauma patients. The immobilization process is intended to hold the head in line with the torso to prevent secondary injury to the neurotissue protected by the spinal column. Secondary injury holds the potential to result in devastating morbidity with a significant risk of mortality. Because of the gravity of these complications, historically, EMS providers have used this device on any patient with suspected cervical spine injury. This "conservative" treatment results in significant overtriage [2].

Use of the LSB followed a practical and theoretical approach to spinal motion restriction, yet there is a paucity of data documenting the efficacy of this procedure. Proving efficacy is a key question because the LSB is not a benign medical device. Complications resulting from the use of the LSB include the following: pain [3], increased anxiety following a traumatic event, cutaneous pressure ulceration after use [4], elevated intracranial pressure [5], and increased difficulty in airway management [6]. In addition, use of the LSB may lead to unnecessary diagnostic radiologic testing due to difficulty in distinguishing if pain is resulting from the traumatic injury or from being secured [7] to the LSB [8].

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The complications and perhaps efficacy of the LSB lies in its design. Essentially, it is a smooth, hard flat surface. Patients requiring a protracted transport, or interfacility transport, may be exposed to the LSB for a considerable time. Increasing the time that a patient is secured to the LSB thus affects the risk-benefit consideration.

Modern ambulance stretchers have a padded mattress that conforms to a patient's anatomy. In combination with a cervical collar, the stretcher mattress essentially becomes a flat surface to secure the patient, and with a conforming fit and nonslick surface, patient movement may be reduced without many of the complications of the LSB, but this has not been proven. To date, there have been no randomized controlled trials of spinal immobilization strategies for the transport of spinal trauma patients [9].

The goal of this study is to evaluate the theoretically reduced movement provided by the LSB as compared with the stretcher mattress alone in healthy volunteers.

Hypothesis: We hypothesized that the LSB will not reduce lateral motion as compared with the stretcher mattress alone.

2. Methods

2.1. Study design

This was a randomized, unbalanced, 2-period 2-treatment 2-sequence crossover healthy volunteer study of the effect of 2 treatments (LSB, mattress) on a measure of motion at each of 3 locations (chest, head, hip). The immobilization technique was blinded to the ambulance driver, but not to the evaluators in the back of the ambulance, or to the volunteer.

2.2. Regulatory

The University of Texas Health Science Center at San Antonio Institutional Review Board approved this study. Informed consent was obtained from all subjects prior to participation.

2.3. Population

Healthy adult volunteers were screened for preexisting medically treated spinal problems, relevant medications (anxiolytics, or prescription pain control medications), pregnancy, or feeling ill the day of the study. Participants randomly selected a packet that contained consent document, informational pamphlet, and their randomization card. Subjects provided signed consent, and the process was explained. The subjects were blinded to the hypotheses of the study.

2.4. Setting

The ambulance used was a Type 1 Frazer Built (Houston, Tex) ambulance on a 2013 Dodge chassis, with a standard patient compartment configuration. The patient was secured to a stretcher (Stryker, Kalamazoo, Mich) or LSB (BaXstrap; Laerdal, Wappingers Falls, NY).

2.5. Protocol

For both groups, participants were in a supine position and properly fitted with a rigid cervical collar. In the stretcher mattress group, once in place on the stretcher, the subject was secured with 3 straps (torso approximately 4-6 in. below the shoulders, across the hips, and just above the knee) as per local practice (there are no published standards for strap tightness [10]). The subject's head was secured to the stretcher mattress using foam head blocks and 2-in. medical tape. The spine board group was secured as above, except that a plastic commercially marketed LSB was placed on the stretcher prior to the subjects positioning themselves on the surface. Three straps from the LSB were used in addition to the above-described stretcher straps.

Once the subject was secured, three 6-cm 2-dimensional graduated disks were placed at the level of the patient's forehead and manubrium, and as near to the iliac crest as possible to provide level placement. A laser, affixed to a scaffold (affixed to the stretcher) above the subject, was focused on the center of the graduated disk to allow for analog recording of subject movement.

The ambulance was then driven over a prescribed course in a closed parking lot. The course consisted of 15 right turns, 15 left turns, 10 starts, and 10 stops. Maximum speed achieved during transport was 20 mph. The driver was blinded to the immobilization technique.

2.6. Measurements

Data were gathered by 4 study staff members, 3 were assigned to each observe one of the disks during the driving course, and the fourth acted as scribe. During each turn, the amount of lateral deviation from the center was verbally reported by the observer and recorded by the scribe. After the completion of each transport time, the volunteer reported level of anxiety and pain on a 10-cm visual analog scale (VAS).

2.7. Outcome

The primary outcome was the amount of lateral motion afforded by each of the immobilization events. The secondary outcome was the difference in pain and anxiety experienced by each of the study volunteers.

2.8. Statistical methods

This proof-of-concept study sample size was based on a convenience sample based on, cost, ambulance availability, and time constraints (8 hours). We approached this study in a state of equipoise, not knowing what we would find, and conducted an exploratory data analysis, summarized here, that is intended to generate hypotheses to be, perhaps, pursued in a new and properly designed study.

The statistical significance of variation in the mean motion with regard to treatment was assessed with paired *t* tests and with a linear model of motion in terms of sequence, subject nested in sequence, period, and treatment. Carryover was assumed nonexistent. The linear model analysis was carried out without and with adjustment for body mass index (BMI), and all analyses were carried out by location. All statistical testings were 2 sided with a significance level of 5%. SAS version 9.3 for Windows (SAS Institute, Cary, NC) was used throughout. Descriptive statistics and graphical representations were developed using Microsoft Excel (Redmond, Wash).

3. Results

Nine subjects participated, 67% were female, mean age was 46 (median 41 $\pm$ 10) years, and mean BMI was 31 (median, 29 $\pm$ 6) kg/m^2 Table 1. Movement data from subject 1 were excluded due to a complication of data collection during the experiment. The data collection problem was corrected prior to the second transport iteration; however, the principal investigator chose to exclude the patient in an effort to eliminate the possibility of bias due to longer exposure to the LSB. Of the 8 subjects, 5 were randomized to LSB followed by mattress and 3 to mattress followed by LSB. All patients reported feeling well and

Table 1
Demographics of enrolled healthy volunteer subjects

	Mean	Median	SD	Range
Age (y)	46	41	10	39-70
Height (in.)	68	68	4	63-76
Weight (lb)	207	215	43	134-260
BMI (kg/m^2)	31	29	6	24-40

pain-free at the time of completing the prescreening and informed consent.

Each driving iteration resulted in a mean of 29 (±2) lateral forces during the course; the course typically took less than 8 minutes each.

The LSB allowed 0.8 cm ($P = .0001$) greater mean lateral motion for all measurements in aggregate than did the stretcher mattress alone. See Fig. 1. When comparing the measurements taken at the 3 individual points of measurement, there was 0.5 (±0.4), 1.7 (±1.2), and 0.8 (±1.3) cm greater lateral motion for the head, torso, and hip, respectively. See Table 2.

Plotting the amount of movement from each patient as a function of BMI reveals a direct correlation of increased movement with increased BMI Fig. 2. This correlation persists with or without the LSB.

After the completion of each iteration, the subjects responded to a 4-question VAS scale questionnaire regarding pain and anxiety. For the 4 questions, there was no statistically significant difference in pain and anxiety on exit after either LSB or stretcher mattress alone. See Tables 3.

Table 2
Lateral movement as measured in 3 anatomic areas in healthy volunteers during transport on either the LSB or the ambulance stretcher

	Stretcher			LSB		
	Head	Chest	Hip	Head	Chest	Hip
Mean	0.5	1.2	1.2	0.97	2.22	1.88
SD	0.4	0.9	0.9	0.66	1.41	1.20
Range	0-2	0-5	0-OTS	0-5	0-OTS	0-6
95% CI	0.38-0.49	1.08-1.31	1.05-1.29	0.96-1.14	2.06-2.40	1.07-2.00
n	205	205	205	205	205	204

All measurements given in centimeters, with SD, total range, and 95% CI of movement. For calculation, all OTS score received a 6-cm movement.
CI indicates confidence interval; n, total number of measurements; OTS, off the 6-cm scale.

4. Discussion

This was a small proof-of-concept study that demonstrated an increase in lateral movement of healthy subjects during transport on an LSB in comparison to the stretcher alone. There is limited empirical evidence that it improves patient outcomes, and there is some evidence that there are negative consequences. Despite this, theoretically there is a goal to limit significant spinal motion in settings of potential spine injury. This is the first study to examine differences in lateral movement in 3 anatomic areas in healthy volunteers and may be the first step in understanding other acceptable methods for spinal immobilization.

The arguments for the use of LSBs in patients with potential or known spine injuries have historically revolved around the idea of “immobilization” of the spine, similar to the concept of splinting of other bony injuries [11]. In the case of long bone suspected fractures, the intents for immobilizing the affected limb are to reduce any secondary soft tissue and neurovascular injury, and to reduce pain [12]. Pain reduction decreases the potential negative physiological effects of pain on the body [13]. This treatment approach, understandably, leads to an expected overtriage, with many patients receiving splint absent significant injury. However, the properly applied splint functions as intended and restricts bony movement and stabilizes the limb with minimal, if any, negative effects to a nonfractured limb.

This concept of acceptable “overtriage” has also been applied to patients with potential spine fractures and/or cord injuries. Treatment is sometimes initiated based on mechanism of injury alone despite all clinical evidence to dispute spine fracture or cord injury. The historical argument is to use LSBs in patients with vertebral bone or vertebral joint injuries to prevent furthering any spinal cord damage that could result in a worse neurologic outcome [1]. Based on this principle, spinal motion restriction during all elements of prehospital patient care should be optimized, and given the potential devastation associated with spinal cord damage, overtriage in the use of the LSB has historically been the accepted practice. The assumption was that a rigid “spine splint” would reduce the risk of movement in the prehospital environment.

There is limited scientific evidence to support the spine splint stabilization theory [6,14]. There are, however, studies using imaging and cadaver models suggesting that excessive movement could be harmful and that there is minimal acceptable cervical spinal cord movement within the spinal canal before cord injury could theoretically occur [15]. Interestingly with these assumptions, even the best immobilization may not be effective. However, the current literature on the subject does not specifically establish how much movement is clinically relevant [6] and there do not seem to be scores of patients who started out neurologically intact and then developed significant cord injures regardless of immobilization effectiveness [14], calling into question the

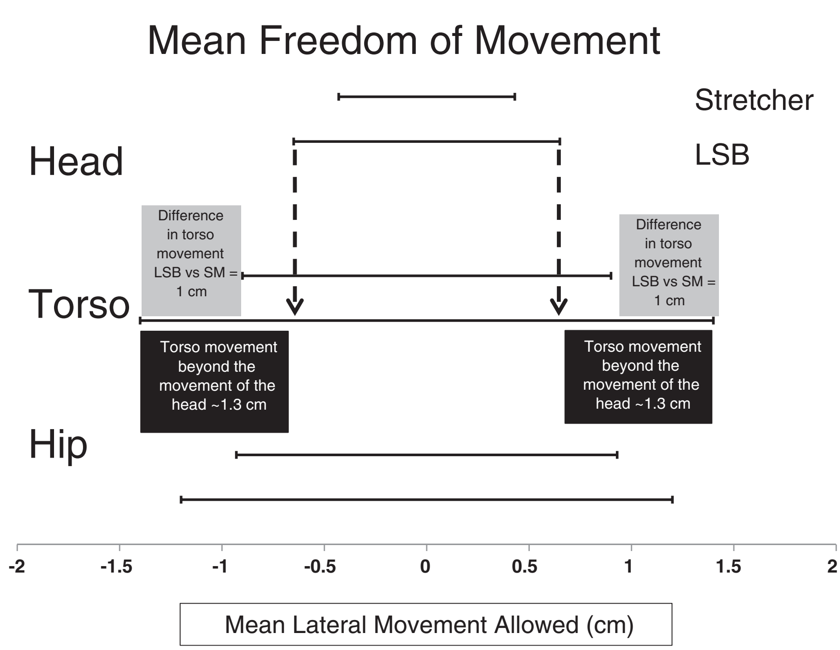

Fig. 1. Mean freedom of movement. Subject movement during transport was measured on a 6-cm graduated disk. Each movement was recorded in centimeters, and the mean movement is represented in the bars above. There was a 1-cm increase in torso movement while positioned on the LSB (time interval depicted by the gray box). Also, there was a 1.3-cm greater amount of movement of the torso than the head (time interval depicted by the black box).

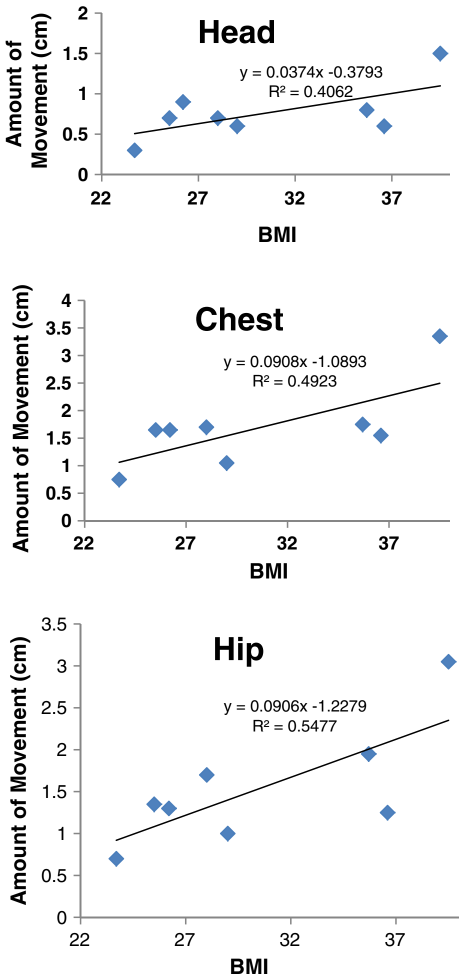

Fig. 2. The mean lateral movement of each health subject as a function of BMI.

clinical relevance of spine splint. Despite the limited information available at this time, the low frequency, but high criticality of spinal cord injuries makes it still seem prudent to limit spinal movement during all stages of prehospital patient treatment. Secondary spinal cord injury from unacceptable movement of the spinal cord in an improperly immobilized patient is of theoretical concern. If, like extremity splints, the negative effects of the LSB were minimal, this historic approach to their overuse would not be of clinical concern or scientific interest.

Backboard use for spinal immobilization has been known for some time to produce multiple negative patient effects, including pain, respiratory compromise, increased anxiety, and injuries in the form of skin breakdown [6]. Long spine boards have also consistently been shown to increase pain and discomfort to the patient [3]. This pain may increase the frequency of otherwise unnecessary radiologic testing by confounding the clinical team at the receiving facility [8]. Although there were no statistical differences in the current study, the subjects were only exposed to the LSB typically for only 10 minutes; this is probably an artificially short period as compared with a more typical EMS transport and transition of care to the emergency department.

Our study shows that during the transport phase of patient care, when compared with placement on the stretcher mattress alone, the LSB allows for increased patient movement and, more importantly, more torso movement relative to the head, thereby focusing the torque to the cervical area. Torque in the cervical area is arguably the most concerning movement in a potentially spine-injured patient. From a simple physics standpoint, it makes sense that a hard, flat, smooth surface would not prevent lateral movement as compared with a softer, conforming surface that tends to be more cradling in nature.

Based on our observations, transferring the patient onto stretcher mattress rather than leaving the patient on an LSB during transport potentially reduces lateral spinal motion and is a safer transport intervention. Even at the low speeds over a short distance in this study, the difference in movement was significant between the LSB and the EMS stretcher. If extrapolated to the higher speeds of actual EMS transport, the effect would remain and, very likely, be even more pronounced.

Finally, one must remember that the intended use of the LSBs as a medical device is to minimize spinal motion. All other potential pluses for LSB use, such as moving patients from vehicles or ditches, are conveniences for the provider. The absence of true motion restriction by the spine board suggests that the risk of harm to the patient outweighs any intended benefit. No other medical device would be allowed to exist simply for the convenience of the medical provider if it did not achieve its intended medical use, particularly if it also potentially caused harm to the patient without benefit. This study suggests that this is exactly the case with LSB.

Ultimately, the LSB may retain some usefulness in the prehospital environment and this study is neither sufficiently powered nor comprehensive enough to be a definitive answer to the overall question surrounding its use. However, even in this small scout study, the LSB shows no improvement and, in fact, worse restriction of spinal movement than a stretcher mattress alone. Its continued routine use as an approved medical device should come under significant scrutiny to assure its effectiveness as intended throughout all aspects of prehospital care.

5. Limitations

The results here are biased by the use of healthy volunteers. Conscious patients with real spinal injuries will likely self-splint to reduce motion. Without the pain of movement in health volunteers, self-splinting would not have occurred. However, spine-injured patients with decreased mental status or neurologic compromise may also not self-splint. We did not explore this potential confounder.

Any potential movement of the spine board on the stretcher as opposed to the movement of the patient on the spine board would not have been appreciated by the evaluator. The spine board was not necessarily fixed to the stretcher, as was the scaffold; rather, it was resting on the stretcher mattress. The weight of the patient on the rigid board did impress the LSB into the soft mattress, thereby significantly limiting movement. However, if the spine board itself was moving, then theoretically, the disks would not be measuring lateral movement of the body on the board but actually lateral movement of the board itself.

Table 3
Subjects reported levels of pain, anxiousness, breathing difficulty, and comfort after each transport

	Mean		Median		SD		Range		*P*
	Stretcher	LSB	Stretcher	LSB	Stretcher	LSB	Stretcher	LSB	
Pain	0.21	0.82	0.20	0.00	0.25	1.29	39-70	0-0.7	.18
Anxiousness	0.21	0.53	0.00	0.10	0.30	0.96	63-76	0-0.7	.35
Breathing	0.38	0.32	0.00	0.00	0.78	0.66	134-260	0-2.4	.86
Comfortable	0.70	2.23	0.30	2.00	0.96	2.02	24-40	0-2.7	.06

A 10-cm VAS was used, and the means, medians, ranges, and SDs are reported in centimeters.

We used a low-speed transport in a level, well-maintained parking lot. This driving area reduced the multivectoral forces that would normally be encountered during transport on typical urban streets. Data gathering was unblinded and based on investigators reporting lateral movement on the measuring disk. This individual measurement approach potentially allowed for variation in precision of the measurements. However, each observer reported for the same subject during both modalities, so any inaccuracy should have occurred for both arms, thereby negating any potential bias. Our study only evaluates gross lateral movement of external body and cannot evaluate the direct clinical correlation to possible spine movement. In addition, we only observed movement along a single plane. With planned further study, movement in additional planes (rotational or vertical) may demonstrate additional findings regarding the effectiveness of spine boards. However, the clinical relevance of multiaxial measurement is still uncertain and difficult to establish.

Another limitation of this study is that we specifically evaluated the effectiveness of 2 different spinal restriction modalities during transport only. This study did not address other aspects of patient extrication or movement, and the LSB may still have important use in the prehospital environment; however, LSB use during extrication may also be suboptimal [16].

The results of our study are broadly generalizable to EMS systems using stretchers with contoured mattress pads and using traditional spine boards during transport of patients experiencing potential cervical spine trauma. It does not address the use of spine boards in any setting except ground ambulance transport. In addition, the results cannot be extrapolated to other immobilization devices, such as vacuum spinal restriction devices.

6. Conclusion

During transport, traditional spine board immobilization allows for more lateral movement than stretcher mattress alone. Although reducing spinal motion in potentially spine-injured patients is still a major tenet of emergency transport, the LSB is likely not the right medical device for this purpose.

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