

Pain and Tissue-Interface Pressures During Spine-Board Immobilization

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Study objectives: Although spine boards are one of the main EMS means of immobilization and transportation, few studies have addressed the discomfort and potential harmful consequences of using this common EMS tool. We compared the levels of pain and tissue-interface (contact) pressures in volunteers immobilized on spine boards with and without interposed air mattresses.

Design: Prospective crossover study.

Setting: Emergency department of Methodist Hospital of Indiana, Indianapolis, Indiana.

Participants: Twenty healthy volunteers who had not taken any analgesic drugs in the preceding 24 hours, were not experiencing any pain at the time of the study, and did not have history of chronic back pain.

Interventions: To simulate prehospital transport conditions, we immobilized volunteers with hard cervical collars and single-buckle chest straps on wooden spine boards with or without commercially available medical air mattresses. The crossover order was randomized. After 80 minutes, immobilization measures were discontinued and the subjects were allowed to get off the boards for a recovery period of 60 minutes. Subjects were then studied for a second 80-minute period with the opposite intervention. At baseline and at 20-minute intervals, the level of pain was rated with a 100-mm visual analog scale. Tissue-interface pressures were measured at the occiput, sacrum, and left heel.

Results: Mean pain on the visual analog scale was 9.7 mm at the end of the mattress period and 37.5 mm at the end of the no-mattress period ($P=.0001$). Although there were no significant differences in pain between the two groups at time 0, volunteers reported significantly more pain during the no-mattress period at 20 ($P=.003$), 40 ($P=.0001$), and 60 minutes ($P=.0001$). All 20 subjects reported that immobilization on the spine board with the

mattress was "much better" (five-point scale) than that without the mattress. Interface pressure levels were significantly less in the mattress period than in the no-mattress period measured at occiput ($P=.0001$), sacrum ($P=.0001$), and heel ($P=.0001$).

Conclusion: In a simulated immobilization experiment, healthy volunteers reported significantly less pain during immobilization on a spine board with an interposed air mattress than during that on a spine board without a mattress. Tissue-interface pressures were significantly higher on spine boards without air mattresses. This and previous studies suggest that immobilization on rigid spine boards is painful and may produce tissue-interface pressure high enough to result in the development of pressure necrosis ("bedsores"). Emergency care providers should consider the use of interposed air mattresses to reduce the pain and potential tissue injury associated with immobilization on rigid spine boards.

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INTRODUCTION

Rigid spine boards are commonly used in prehospital care as a means of immobilizing and transporting accident victims. Several studies, however, have associated spine-board use with patient discomfort and the development of pressure ulcers ("bedsores").¹⁻⁴ Bedsores are assumed by many to be complications only of extended in-patient or nursing home care. That they may result from ischemic tissue injury occurring before hospitalization (eg, during the emergency medical phase of care) may come as a surprise to emergency specialists. Yet, an accident victim often lies strapped to the hard, flat, unyielding surface of a rigid spine board, unable to turn or roll, for a protracted length of time. For example, a study in our ED found that accident victims who were ultimately discharged from the ED spent an average of 80 minutes and as long as 230 minutes on the boards.³

Pressure-relieving products—including foam mattresses, low-air loss beds, and static (no-air loss) air mattress overlays—have been used clinically to help prevent pressure ulcer formation. We investigated the use of a commercially available low-pressure, low-volume air mattress as an overlay for rigid spine boards. The levels of pain and tissue-interface (contact) pressures in volunteers

immobilized on spine boards with and without the interposed air mattresses were compared.

MATERIALS AND METHODS

This study was conducted in the Emergency Medicine and Trauma Center of Methodist Hospital of Indiana, Indianapolis, Indiana, between July 17 and August 1, 1994. Healthy volunteers who had not taken any analgesic drugs in the preceding 24 hours, were not experiencing pain of any kind, and did not have history of neck or low back (lumbar) pain were studied while lying on a spine board with or without an interposed air mattress. To standardize the experiment, we instructed volunteers to wear comfortable, loose-fitting clothing. Belts, shoes, and all objects in pockets were removed. We conducted the experiment in one of the ED hallways to simulate the atmosphere of an ED in which ambulance patients are queuing to be treated. To minimize distractions, volunteers were not allowed to read, listen to music, or talk. One to five volunteers were studied simultaneously.

Two treatment groups, air mattress and nonmattress, were compared. Volunteers were placed supine on a wooden long spine board with or without an interposed air mattress. The volunteers were immobilized with hard cervical collars, and a one-buckle strap was cinched across each volunteer's chest. The vinyl mattress overlays and pressure-measuring devices used in this experiment, all commercially available, were supplied by EHOB, Incorporated. The mattress is a class I medical device, is in widespread clinical use in North America and Europe, and costs approximately \$35 US. To prevent overinflation, we inflated each mattress with a hand pump just to the point at which the subject reported he or she was suspended above the board by air.

We used a crossover experiment design. The volunteers were studied for 80 minutes, then allowed off the boards for a "washout" period of 60 minutes. They were then studied for a second 80-minute period while being subjected to the other treatment. Order of treatment was randomly assigned. To ensure that treatment groups would have equal sex ratios, we used sex as a blocking variable in our randomization scheme.

Level of pain was measured at baseline and at 20-minute intervals (20, 40, 60, and 80 minutes) with a 100-mm, unnumbered, horizontal visual analog pain scale. The label "no pain" appeared at the left end of the scale, and "worst possible pain" appeared at the right. After completing both study periods, the subject was asked to rate comfort on the air mattress, compared with that on the

spine board alone, on a five-point categoric scale (a lot worse; a little worse; the same; a little better; a lot better). Interface or contact pressures between the subject and board or mattress overlay were measured at the occiput, sacrum, and left heel with a Talley-Scimedics Pressure Evaluator MK II (Talley Medical Group). An average of three readings was obtained at each location at baseline and at 20-minute intervals. After each reading, the pressure-evaluating device was turned off and the transducer air bladder removed, deflated, and repositioned between the surface and the subject. Subject height and weight were recorded, and we determined body type by dividing weight by height (pounds-per-inch ratio).

A sample size calculation, using data from an unpublished pilot study we conducted in 1991 comprising 10 volunteers, demonstrated that 20 subjects would provide 90% power to detect a 50% reduction in pain. The demographics of the two treatment orders were compared by means of Wilcoxon rank-sum tests. We used two-way (treatment and volunteer) repeated-measures ANOVA to determine whether the mattress group differed significantly from the no-mattress group in pain and pressure levels and tested if significant changes occurred over time. If repeated-measures ANOVA indicated significant differences, we performed univariate ANOVA for each time point. We used ANCOVA to determine whether age, sex, height, and weight were significantly related to pain and pressure levels in all subjects while on the spine board without mattress. ANCOVA was also used to determine whether the order-of-treatment group assignment affected reported pain. The relationship of total pressure (occiput+sacrum+heel) to height, weight, and pain was analyzed with regression analysis.

This study was approved by the Methodist Hospital of Indiana institutional review board.

RESULTS

Of the 20 volunteers studied, 12 (60%) were female and 8 (40%) were male. The average age was 29.9 years (SEM, 2.2; range, 16 to 50 years), the average height was 66.2 inches (SEM, .9; range, 59 to 73 years), the average weight was 165.7 pounds (SEM, 9.4; range, 122 to 261 pounds), and the average pound-to-inch ratio was 2.5 (SEM, .1; range, 1.9 to 3.7). The two treatment orders (mattress, then no mattress, and no mattress, then mattress) were not significantly different in age ($P=.30$), height ($P=.88$), weight ($P=.68$), or pounds-to-inch ratio ($P=.50$).

Pain and pressure levels are reported in the Table. Mean pain at baseline was 3.0 mm during the mattress

period and 2.8 mm during the no-mattress period ($P=.9$). Mean pain was 9.7 mm at the end of the mattress period and 37.5 mm at the end of the no-mattress period ($P=.0001$). Repeated-measures ANOVA indicated that pain levels changed significantly over time ($P=.0001$) and that the two treatments differed in the amounts of pain ($P=.0001$) and in the pattern of pain change over time ($P=.0009$). Although there were no significant differences in pain between the two treatments at time 0, volunteers reported significantly more pain during the no-mattress period at 20 ($P=.003$), 40 ($P=.0001$), 60 ($P=.0001$), and 80 minutes ($P=.0001$). All 20 subjects reported that the mattress was "much better" than immobilization on the spine board without the mattress.

Interface pressure levels were significantly less during the mattress period than during the no-mattress period at the occiput ($P=.0001$), sacrum ($P=.0001$), and heel ($P=.0001$) (repeated-measures ANOVA). Unlike pain, pressure did not change significantly over the 80-minute

Table.
Pain and interface-pressure levels.

Parameters	Mattress		No Mattress		P
	Mean	SEM	Mean	SEM	
Pain					
0 min	3.0*	2.2	2.8	1.3	.9
20 min	2.7*	1.1	10.6	2.7	.003
40 min	4.8*	1.2	24.4	4.4	.0001
60 min	7.1*	1.5	29.7	5.4	.0001
80 min	9.7	2.5	37.5	6.4	.0001
Tissue-interface pressures					
Occipital					
0 min	30.4	1.4	56.3	2.5	.0001
20 min	29.4	1.1	59.1	4.2	.0001
40 min	29.8	1.2	58.4	3.6	.0001
60 min	30.5	1.3	55.2	2.3	.0001
80 min	29.2	1.0	56.6	1.9	.0001
Mean	29.9	1.2	57.1	2.9	
Sacral					
0 min	49.0	5.6	148.7	14.8	.0001
20 min	48.7	5.5	149.0	14.1	.0001
40 min	46.6	5.7	145.7	13.8	.0001
60 min	49.0	6.4	136.6	13.4	.0001
80 min	49.3	6.2	147.6	13.7	.0001
Mean	48.5	5.9	145.5	14.0	
Heel					
0 min	36.0	1.7	50.5	3.0	.0001
20 min	35.9	2.0	49.3	2.6	.0001
40 min	33.2	1.4	49.0	2.1	.0001
60 min	32.9	2.0	51.2	3.0	.0001
80 min	34.5	1.6	50.0	2.8	.0001
Mean	34.5	1.7	50.0	2.7	

*Not significantly different from 0 ($P>.05$).

period of measurement (occiput, $P=.53$; sacrum, $P=.27$; heel, $P=.21$). Pressure was significantly less during the mattress period at all time points ($P=.0001$).

None of the demographic variables was significantly related to the amount of pain reported by volunteers (ANCOVA). Pain levels in the mattress and no-mattress groups were not significantly different on the basis of order of treatment group assignment ($P=.41$ and $.93$, respectively; ANCOVA). Total pressure was significantly related to height ($P=.008$; F test) and not significantly related to weight ($P=.11$; F test). Total pressure was not significantly related to pain ($P=.76$; F test).

DISCUSSION

Though a fixture of prehospital care for decades, the use of rigid spine boards for patient immobilization and transport is being challenged by several studies noting their potential for patient discomfort and tissue pressure. Mawson et al¹ reported that time spent on spine boards was described as "very painful" by patients. Chan et al² investigated the effects of spine-board immobilization on 21 healthy volunteers. They found that all volunteers had pain after only 30 minutes of immobilization, with 55% rating pain as moderate to severe. Delbridge et al⁵ and Hauswald et al⁶ found there was more discomfort during immobilization on traditional wooden spine boards than that in vacuum splints. A previous study at our institution found that some trauma victims had pain while on the board but not off it, suggesting that immobilization on the board produced the pain.³ Thus some accident victims may be subjected to unnecessary radiography for evaluation of this pain. If immobilization on a rigid surface is uncomfortable, patients may attempt to shift their weight and move around. We speculate that spine boards could actually contribute to "antiimmobilization."

Prolonged immobilization on spine boards has been associated with the development of pressure sores in spinal cord-injury victims. In a retrospective study, Linares et al⁴ concluded that the development of pressure sores was associated with prolonged immobilization between the time of injury and admission to the ward. The delays in arrival on the nursing ward appeared to be the cumulative effect of a slower pickup and transportation time, longer radiography procedures, and longer waiting time in the ED before radiography. They also noted that most of the patients were not turned until they reached the ward. In a prospective study (a follow-up to the Linares study), Mawson et al¹ found that time spent on spine boards was "strongly associated" with develop-

ment of pressure ulcers within 8 days of spinal cord injury. They concluded that time spent on the spine board should be recognized as an important risk factor for pressure ulcers. The authors recommended that spine boards "be redesigned to reduce the risk of ischemic injury and necrosis and that the patient be taken off it (the spine board) as soon as possible after reaching the accident room."

Pressure ulcers are alterations in skin integrity related to unrelieved pressure over bony prominences resulting in varying degrees of tissue damage and necrosis.⁷ They have been described as the most complex form of wounding known.⁸ Pressure sores not only reduce quality of life and increase morbidity and mortality, they add to the fiscal burden of health care. It costs \$5,000 to \$40,000 to treat and heal a skin breakdown.⁹ Pressure sores are particularly prevalent over bony prominences including the sacrum, coccyx, ischial tuberosity, greater trochanter, and heel. They are the result of an intricate interplay of intrinsic and extrinsic factors.¹⁰ Malnutrition, anemia, and hypoproteinemia are examples of intrinsic factors.¹¹ Extrinsic factors include vertical shear¹², friction, and moisture¹³, although, as the name implies, unrelieved pressure is believed to be the main cause of pressure sores.

Interface (contact) pressures over bony prominences are commonly indicators of high risk for pressure ulcer formation.¹⁴ When interface pressures exceed approximately 32 mm Hg, they collapse or crimp off the capillary network (capillary closing or threshold pressure), impeding the delivery of oxygen and nutrients to cells and the elimination of waste from cells, resulting in ischemic necrosis of tissue or pressure ulceration. Recent studies indicate that closing pressures may be significantly lower in older patients and patients with compromised tissue perfusion.⁹ Time spent on the surface contributing to pressure is also a factor. Experimentally, low pressures maintained for long periods of time induce more tissue damage than high pressures for short periods.¹⁵

In our study, mean interface pressures were as high as 149 mm Hg measured at the sacrum in the no-mattress group and were significantly higher at all time points and anatomic sites in the no-mattress group than in the mattress group. It is important to note that even in our mattress group, mean interface pressures measured at the sacrum and heel exceeded 32 mm Hg at all time points. Conner and Clark¹⁴ compared a board, mattress overlays of varying thicknesses of foam, and vinyl air mattress overlay (the same used in our study) plus 3-inch foam. The highest interface pressures were

recorded on the board without an overlay (mean, approximately 125 mm Hg).

Pressure-relieving supports fall into three main groups: alternating-pressure mattresses, turning beds, and constant low pressure mattresses. Constant low pressure mattresses—such as soft overlays of fiber, foam, air, water, and gel—are intended to provide interface pressures over the whole undersurface of the body below the average capillary closing pressure of 32 mm Hg.¹⁶ One potential modification to the rigid spine board is the addition of a low-pressure mattress. Walton et al¹⁷ reported that addition of closed-cell foam padding to a long spine board significantly improved subject comfort without compromising cervical spine immobilization. In the Conner and Clark study¹⁴, the air mattress plus foam had the lowest interface pressures and lowest degree of vertical tissue shear and provided the greatest area of contact between surface support and subject, resulting in a greater distribution of applied load. We studied the use of a spine board with an air mattress overlay, a pressure-relieving surface in widespread clinical use. Patients in the mattress group reported significantly less pain than did the no-mattress group. In addition, tissue-interface pressures measured at the occiput, sacrum, and heel were significantly lower in the mattress group than in the no-mattress group.

The results of our study must be interpreted in light of several limitations and potential sources of error. First, because our experiment could not be blinded, bias cannot be ruled out. Second, we only allowed a 60-minute washout period, which may not have been long enough to eliminate the carryover effects of the first treatment group assignment. Statistical analysis, however, demonstrated that treatment order did not significantly affect reported pain. Third, although we approximated EMS immobilization techniques, the subjects were healthy, were not subjected to the jostling of an ambulance ride, and had belts and objects in their pockets removed. Fourth, we did not test the durability of the air mattress overlay and ease of maintenance in actual prehospital use. Fifth and finally, interface pressures are only reflective of true tissue pressures. Pressures near bony prominences can be high enough to cause ischemia even when the contact pressure measured at the skin is below the capillary closing pressure.^{14,18} Clark¹⁰ has described numerous methodologic problems associated with the use of electropneumatic sensors (used in our study) to measure interface pressures on patient support surfaces.

Although we believe emergency care providers should consider the use of interposed air mattresses to reduce the

pain and potential complications of immobilization on rigid spine boards, we interject a note of caution. The use of a medical device alone will not completely prevent the potential for pain and pressure necrosis in immobilized prehospital and ED patients. A comprehensive approach must be adopted. All emergency specialists should recognize that pressure-induced tissue injury can begin in the prehospital and ED phases of care. Accident victims may be immobilized for long periods on rigid surfaces. Certain groups of patients, including extended care-facility patients and spinal cord-injury victims, are at higher risk for pressure sores. Patients should be moved as rapidly and safely as possible off spine boards, and patients immobilized by disease or injury must be frequently rolled and turned. Furthermore, spine boards are not the only uncomfortable, unyielding patient support surfaces in the emergency medical environment. Finally, it is worth remembering the words of one of our study subjects, herself an emergency nurse for 21 years. After being allowed to get off the spine board without the mattress, she noted, "I now have a lot of sympathy for patients who have to lie on spine boards for a long time."

CONCLUSION

In a simulated-immobilization experiment, healthy volunteers reported significantly less pain on spine boards with interposed air mattresses than on spine boards without such mattresses. All 20 subjects reported that the mattress was much better than immobilization on the spine board without the mattress. Tissue-interface pressures were significantly higher on spine boards without air mattresses. This and previous studies suggest that immobilization on rigid spine boards is painful and may produce tissue interface pressure high enough to cause tissue necrosis (bedsores). Emergency care providers should consider the use of interposed air mattresses to reduce the pain and potential complications of immobilization on rigid spine boards.

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