Effect of Spinal Immobilization Devices on Pulmonary Function in the Healthy, Nonsmoking Man

In the prehospital management of trauma, a variety of devices are used for immobilization of the spinal column during extrication and transport. Two of these commonly used immobilizers, the Zee Extrication Device® and the long spinal board, use crisscrossing straps over the thorax to affix the patient to the device. Our study was designed to determine if these two devices alter pulmonary function in the healthy, nonsmoking man. We took 15 healthy, nonsmoking male volunteers and tested four pulmonary function parameters: forced vital capacity (FVC), forced expiratory volume in one second (FEV1), the ratio FEV1:FVC, and forced mid-expiratory flow (FEF 25%-75%). A Breon spirometer was used to test these functions both before and after the volunteers were strapped into the two devices. Three separate trials were given for each parameter and the best scores were used for data computation. Strap tension was controlled by placing a sphygmomanometer beneath each strap and adding tension to produce 10 mm Hg pressure. We found a significant difference (P < .05) between prestrapping and poststrapping values for three of the four functions tested using the long spinal board: FVC (P = .0079), FEV1 (P = .0001), and FEF 25%-75% (P = .0252). Similarly significant differences were found for three of the four parameters using the Zee Extrication Device®: FVC (P = .004), FEV1 (P = .0022), and FEF 25%-75% (P = .008). These differences reflect a marked pulmonary restrictive effect. The ratio FEV1:FVC can be normal or even slightly elevated with restrictive airway disease due to proportional reductions of each parameter. Correspondingly, we found no significant difference between prestrapping and poststrapping FEV1:FVC values (P > .05). We conclude from our data that these devices produce a significantly restrictive effect on pulmonary function in the healthy, nonsmoking man.

INTRODUCTION

In the prehospital management of trauma, a variety of devices are used for immobilization of the spinal column during extrication and transport. Two of these commonly used devices, the Zee Extrication Device® (ZED) (Zee Medical Products, Irvine, California) (Figure 1) and the long spinal board (Figure 2), use crisscrossing straps over the thorax to affix the patient to the device (Figures 3 and 4). Our study was designed to determine if these two devices alter pulmonary function in the healthy, nonsmoking man because they are used universally in emergency departments, and their effect on pulmonary function may have clinical significance.

No studies have addressed this particular issue. However, Abraham et al used pulmonary function tests to analyze the effects of pneumatic trousers on respiratory function, and Ranson and McSwain also studied respiratory function after pneumatic trouser application but used arterial blood gas measurements.

MATERIALS AND METHODS

Study approval was granted by the Human Investigations Committee of William Beaumont Hospital. Study participants were 15 male volunteers 23 to 28 years old who had no history of recurrent respiratory disease, heart
disease, or current respiratory symptoms (ie, cough, nasal discharge, or congestion), and who were non-smokers. Before participation, a brief physical examination including lung auscultation was performed, and none of the volunteers was observed to have abnormal findings. Volunteers were aware of the mechanics of the study but were not informed of its purpose.

Two immobilization devices were tested in the study. One device, the ZED, is used commonly in extrication when spinal immobilization is necessary. It consists of an oblong piece of durable cloth material reinforced with long, thin metal bars. Multiple criss-crossing straps affix the patient's torso to the board. The second device tested was a long spinal board routinely used for patient transport if spinal injury is suspected. It also uses crisscrossing straps across the thorax. The same two boards were used throughout the study.

To test the effect of each device on pulmonary function, both control trials and poststrapping trials were conducted. Subjects were placed on each board in the supine position, and pulmonary functions were measured with a Breon spirometer. Measurements included forced vital capacity (FVC), forced expiratory volume in one second (FEV1), forced midexpiratory flow (FEF 25%-75%), and the FEV1:FVC ratio. Three prestrapping trials were performed on each subject on each board. Testing was done by two respiratory therapists blinded to the purpose of the study and experienced in performing pulmonary function testing. Coaching techniques were kept consistent throughout the study. A one-minute rest was allotted between each trial. Results were recorded with the spirometer on a separate piece of graph paper for each trial.

After these control trials, the straps were applied to the subjects, and three trials of pulmonary functions were carried out on each board as outlined above. Strapping was done by the same investigator at all times. Strap tension was regulated by placing a sphygmomanometer bladder under each strap and applying tension until 10 mm Hg was recorded at functional residual capacity (end-expiration point). This value of 10 mm Hg for strap tension was obtained before the study by having an experienced paramedic blinded to the study strap a volunteer to the board. His strap tension was recorded on three separate occasions (mean, 10 mm Hg).

The results of prestrapping and poststrapping values for both boards were derived from the graph paper recordings. Recommendations by the American Thoracic Society for computation of data were used. For each set of three trials, the largest FVC and FEV1 values were taken for data computation, even if they were from different recordings. Reproducibility of

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Prestrapping (L/min)</th>
<th>Poststrapping (L/min)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>FVC</td>
<td>5.41 ± 0.81</td>
<td>4.78 ± 0.73</td>
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<tr>
<td>FEV1</td>
<td>4.43 ± 0.67</td>
<td>3.95 ± 0.59</td>
<td>.0022</td>
</tr>
<tr>
<td>FEF 25%-75%</td>
<td>4.56 ± 1.28</td>
<td>3.90 ± 0.96</td>
<td>.0080</td>
</tr>
<tr>
<td>FEV1:FVC</td>
<td>0.816 ± 0.05</td>
<td>0.820 ± 0.04</td>
<td>.6107</td>
</tr>
</tbody>
</table>

Values are mean ± SD.

FVC, forced vital capacity; FEV1, forced expiratory volume in one second; FEF 25%-75%, forced midexpiratory flow; FEV1:FVC, ratio of FEV1 to FVC.
FVC and FEV₁ was ensured because the best two of three spiromgrams for these parameters did not vary by more than 5% of the largest value or by more than 100 mL. The FEF 25%-75% values then were taken from the tracing with the largest sum of FVC and FEV₁, as recommended by the Society. The back-extrapolation technique as described by Smith and Gaensler was implemented to extract values on recordings in which the steepest slope of the curve did not occur at the onset.

To determine whether either board had a significant effect \( P < .05 \) on pulmonary function values, poststrapping values were compared with prestrapping values, and Hotelling's T² multivariate analysis of variance was performed on the mean vectors. This statistical method was chosen to eliminate accumulation of Type I errors because pulmonary functions were not independent. This value was significant at \( P = .0287 \) and indicated a significant effect by the ZED or long spinal board. Individual Student's \( t \) tests then were performed on all four pulmonary functions for each board to isolate significant effects.

Finally, to determine if there was a significant difference between the ZED and the spinal boards, Hotelling's T² multivariate analysis was applied to the mean vectors.

RESULTS

For the ZED board, the values are shown (Table 1). A significant effect was noted for three of the four pulmonary functions: FVC \( [P = .004] \), FEV₁ \( [P = .0022] \), and FEF 25%-75% \( [P = .008] \). FEV₁:FVC was not affected significantly \( [P = .61] \).

For the spinal board, the values are shown (Table 2). The same three pulmonary functions were affected by strapping: FVC \( [P = .0001] \), FEV₁ \( [P = .0079] \), and FEF 25%-75% \( [P = .0252] \). Again, FEV₁:FVC was not significantly altered.

No significant difference in effect between the two boards was found \( [P = .413] \) (Table 3) when the difference between prestrapping and poststrapping values of each parameter were compared.

DISCUSSION

The results of this study indicate a restrictive effect on pulmonary function by both the ZED and the spinal boards. In restrictive airway disease (ie, pulmonary fibrosis, pleural fibrosis, or chest wall abnormalities), values for FVC are significantly reduced, reflecting decreased total lung volume. Such an effect was found with both devices in this study. Decreases in FEV₁ are most notable in obstructive airway disease but because expiratory flow in a maximal effort is dependent on lung volume, FEV₁ may be reduced with restrictive abnormalities.

Unlike that seen with obstructive disease, however, the decrease in FEV₁ seen in restrictive conditions is pro-

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**TABLE 2. Long spinal board**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Prestrapping (L/min)</th>
<th>Poststrapping (L/min)</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>FVC</td>
<td>5.52 ± 0.79</td>
<td>4.98 ± 0.67</td>
<td>.0001</td>
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<tr>
<td>FEV₁</td>
<td>4.29 ± 0.64</td>
<td>3.99 ± 0.57</td>
<td>.0079</td>
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<tr>
<td>FEF 25%-75%</td>
<td>4.11 ± 1.12</td>
<td>3.68 ± 1.02</td>
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<tr>
<td>FEV₁:FVC</td>
<td>0.791 ± 0.05</td>
<td>0.793 ± 0.05</td>
<td>.8541</td>
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</table>

Values are mean ± SD.
paring prestrapping with poststrapping results. The findings of a significant normal or slightly elevated FEV₁:FVC ratio are consistent with restriction. A decrease in FEV₁ and a lack of significant lowering of FEF 25%-75% ob-served in this study is consistent with this cause.

Standard pulmonary function values based on age, sex, and height have been described by various authors. By convention, subjects in these studies were either standing or sitting. In contrast to the present study where subjects were tested supine. Nevertheless, 14 of 15 subjects tested supine in this study had baseline pulmonary function values that were within the acceptable range for age, sex, and height, as recommended by the American Thoracic Society for standing or sitting values. This includes an FVC and FEV₁ more than 80% of predicted values and FEF 25%-75% more than 60% of predicted values. One subject had an FVC of 79% of predicted value.

Limitations of this study included study in the laboratory versus a true clinical setting, the small sample size, and an estimation of average strap tension by a blinded paramedic; these should be noted when interpreting the results of this study.

Other investigators have outlined the detrimental effects of the supine position on pulmonary function, presumably related to redistribution of blood flow with subsequent increased pulmonary volume. Because the purpose of this study was to detect differences in pulmonary functions induced by these devices, subjects serving as their own controls were tested supine. The practical implication of this is exemplified by analyzing time relations in the clinical setting regarding supine versus sitting positions. Although suspected spinal trauma vic-tims may spend a brief period in the sitting position during extrication with a ZED device, the vast majority of their time while strapped in either of these immobilizers is spent supine. This would include transport time and time elapsed during evaluation in the emergency care facility.

Based on the results of this study, it becomes apparent that closer observation of patient ventilatory function while affixed to these devices is indicated. The common practice of leaving patients strapped to these boards while in the emergency center could hamper respiratory function. This del-eterious effect, when coupled with co-existent traumatic or chronic pulmonary pathology, may serve to further compromise the patient’s ventilation. Although effective spinal immobilization in suspected spinal injury pa-tients is mandatory, strap tension may need to be adjusted judiciously so as not to restrict chest wall excursion.

CONCLUSION

Our study demonstrated that the long spinal board and the ZED board used for spinal immobilization have restrictive effects on pulmonary function in the healthy, nonsmoking man. Further studies are needed on actual patients, but clinicians should consider this factor as another potential source of respiratory compromise in the traumatized patient.

### TABLE 3. Comparison of effect on pulmonary function — Long spinal board vs ZED board

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Poststrapping − Prestrapping (L/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Long Board</td>
</tr>
<tr>
<td>FVC</td>
<td>0.532</td>
</tr>
<tr>
<td>FEV₁</td>
<td>0.297</td>
</tr>
<tr>
<td>FEF 25%-75%</td>
<td>0.407</td>
</tr>
<tr>
<td>FEV₁:FVC</td>
<td>0.002</td>
</tr>
</tbody>
</table>

REFERENCES