The cardiopulmonary effects of physical restraint in subjects with chronic obstructive pulmonary disease

Carolyn Meredith, Samer Taslaq *, Onn Min Kon, John Henry

Academic Department of Accident and Emergency Medicine, Imperial College, St Mary’s Hospital, University of London, UK

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Abstract

Police officers commonly encounter violent individuals in their line of duty, with the use of physical restraint sometimes being necessary. A major criticism of previous studies of the effect of restraint on cardiac and pulmonary function has been that they have only recruited young healthy adults. This study aims to assess the cardiopulmonary effects of restraint positioning in individuals with chronic obstructive pulmonary disease (COPD). Eight patients with stable COPD were recruited. Subjects were randomly allocated to the following five positions: Wrist restraint behind the body whilst seated; wrist restraint in front of the body whilst seated; lying prone with wrists restrained behind back; lying prone with arms free; lying supine with wrists restrained in front. The outcomes measures studied were pulmonary function at 10 min. There was no significant difference in FEV1 or FVC between groups, (one way ANOVA \( p = 0.94 \) and \( p = 0.99 \), respectively). The difference in FEV1 between the seated position and seated position with wrists restrained behind the back were also compared (\( p = 0.8 \)) as was the effect of wrist restraint in the prone position compared to no restraint prone (\( p = 0.69 \)). However, three subjects could not tolerate the prone position due to a clinical deterioration in symptoms. The response to the prone position with or without wrist restraint appears highly individual, with some individuals tolerating the prone position with no measurable clinical effects and others suffering a clinical deterioration in symptoms. The reasons for this individual variation remain unclear.

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1. Introduction

Each year in Britain a small number of people die while being physically restrained.1 The topic of restraint related death has been the subject of a number of studies, looking at the effects of prone restraint on cardiorespiratory function.2,3,4 Whilst there is considerable debate regarding the role of positional asphyxia in these deaths, deterioration in pulmonary function in the prone position has been demonstrated.2,5 Prone restraint with the arms secured behind the back causing hyperextension of the shoulders is considered to be an additional detriment.6 Chan et al.5 demonstrated a statistically significant (\( p < 0.01 \)) reduction in forced expiratory volume in 1 s (FEV1), forced vital capacity (FVC) and maximal voluntary ventilation (MVV) in the restraint position when compared to sitting with a progressive reduction in ventilatory capacity from supine to prone to hog-tied positions.4 However, one major criticism of these studies has been that they were carried out on young healthy subjects, who are not representative of the population most likely to suffer from restraint related death.3 This study is the first to look at the cardiorespiratory effects of physical restraint in an unhealthy population. Patients with chronic obstructive pulmonary disease (COPD) were investigated. Respiratory conditions, including COPD, are recognised as being potential risk
factors for restraint related injuries and a patient with COPD will already have some degree of respiratory compromise. In addition, a study of patients with COPD could help to indicate areas of high risk for individuals with normal respiratory function.

2. Methodology

This was a randomised crossover experimental study of 8 patients with chronic obstructive pulmonary disease (COPD) as defined by a FEV$_1$ <80% predicted and FVC/FEV$_1$ <70% predicted by the COPD Guidelines group of the Standards of Care Committee of the British Thoracic Society. Local ethics committee approval was obtained. Patients aged 45–80 years with stable COPD were recruited. During a single testing session each subject performed baseline pulmonary function tests (PFT); FEV$_1$, FVC and peak expiratory flow (PEFR). A minimum of 30 seconds was allowed between repeat measures. Pulmonary function testing was conducted on a Sensor Medics spirometer (V$_{max}$ series 229). A trained pulmonary function technician carried out all testing.

Subjects were then randomly allocated to the following five positions sequentially;

- Wrist restraint behind the body, seated on a stool.
- Wrist restraint in front of the body, seated on a stool.
- Lying prone on couch with wrists restrained behind back.
- Lying prone on couch with arms free.
- Lying supine on couch with wrists restrained in front.

Volunteers were restrained in wrist restraints made of a soft fabric. The arm positioning was identical to that of standard issue police handcuffs but avoided any confounding factors of weight and general discomfort.

Each position was maintained for a 10 min period. During this time the subject underwent continuous monitoring of electrocardiogram (ECG), heart rate and oxygen saturation and transcutaneous CO$_2$ measurements. Non-invasive blood pressure and respiratory rate were recorded at 5 min intervals. At the end of each 10 min period pulmonary function was measured (FEV$_1$, FVC and PEFR) and the patient’s perception of feeling short of breath as measured by a dyspnoea rating scale (modified Borg Scale).

Termination criteria specified prior to study commencement were

- Any feeling of subjective distress or wheeze.
- Fall in oxygen saturation to <92%.
- Heart rate >100 beats/min.
- Respiratory rate >25/min.

The primary outcome measure was pulmonary function testing at 10 min. Secondary outcome measures were: heart rate, respiratory rate, oxygen saturation, transcutaneous CO$_2$ and dyspnoea rating between 1 and 10 min.

Statistical analysis was carried out using the statistical programme SSPS (version 11.0.0). Data distributions were assessed for evidence of normality (Shapiro–Wilks test and visual inspection of P–P plots and Q–Q plots). A one-way ANOVA with repeated measures was used to determine differences between positions. A paired samples t test was used to detect if there was any statistically significant difference between wrist restraint and no restraint in the seated and prone positions. A probability value of less than 0.05 was considered statistically significant.

3. Results

Eight patients were recruited, four male and four female. The mean age was 66 years (range 47–79 years). Baseline mean for FEV$_1$ and FVC were 1.29 L (SD 0.52) (55% predicted) and 2.7 L (SD 0.76) (88% predicted), respectively. Mean peak flow values were 50% of predicted. Baseline means for heart rate were 85 bpm, respiratory rate 17 breaths per minute, O$_2$ saturation 96% and transcutaneous CO$_2$ 4.7 kPa.

The results of pulmonary function testing in the differing positions are shown in Fig. 1. The prone restraint data refers to the 5 subjects who were able to complete 10 min of this positioning. Three patients were unable
to tolerate lying prone with wrist restraint. There was no significant difference in FEV₁ or FVC between groups, one way ANOVA \( p = 0.94 \) and \( 0.99 \), respectively. The difference in FEV₁ between the seated position and the seated position with wrists restrained behind the back were also compared \( (p = 0.8) \) as was the effect of wrist restraint in the prone position compared to no restraint prone \( (p = 0.69) \). Similarly no differences were seen in the FVC between these same groups \( (p = 0.8 \) and \( p = 0.79) \).

Of the three subjects who were unable to tolerate lying prone, one was a 69-year-old man with a baseline FEV₁ of 0.86 L (29% predicted) and FVC of 2.18 L (57% predicted). He became acutely breathless and distressed when attempting to assume the prone position. The second subject was a 70 year old female who became wheezy after 7 min lying prone with wrists unrestrained. Her baseline FEV₁ was 0.95 L (60% predicted) and FVC was 1.57 L (81% predicted). The third subject, a 67-year-old man, tolerated 7 min of lying prone unrestrained before a fall in oxygen to 91% (from a baseline of 94%) necessitated termination of the study. He recovered to the baseline \( \text{O}_2 \) saturation shortly after finishing the test.

There was no significant change in secondary outcome parameters throughout the restraint positions (Table 1).

<table>
<thead>
<tr>
<th></th>
<th>Unrestrained</th>
<th>Seated wrists front</th>
<th>Seated wrists behind</th>
<th>Supine</th>
<th>Prone wrists behind</th>
<th>Prone unrestrained</th>
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</thead>
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<tr>
<td>Heart rate (beats per minute)</td>
<td>86</td>
<td>86</td>
<td>85</td>
<td>85</td>
<td>82</td>
<td>84</td>
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<tr>
<td>Respiratory (rate/min)</td>
<td>17</td>
<td>17</td>
<td>17</td>
<td>16</td>
<td>17</td>
<td>18</td>
</tr>
<tr>
<td>( \text{O}_2 ) saturation (%)</td>
<td>97</td>
<td>96</td>
<td>96</td>
<td>96</td>
<td>95</td>
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<tr>
<td>Transcutaneous CO₂ (kPa)</td>
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<td>4.7</td>
<td>4.7</td>
<td>4.6</td>
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<tr>
<td>Borg rating</td>
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<td>0.25</td>
<td>0.62</td>
<td>1.1</td>
<td>2</td>
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</tbody>
</table>

4. Discussion

Previous studies evaluating the effects of restraint on cardiorespiratory function have looked at healthy volunteers.\(^2^,\(^3^,\(^4\) Chan et al. demonstrated a significantly significant fall in pulmonary parameters in the prone and restraint positions compared to the sitting position.\(^2\) However, they argued that because the measurements were still above 80% of predicted values, while statistically significant they were clinically insignificant.\(^1\) By studying patients who already have a compromised respiratory system the aims were to extend and improve the clinical applicability of study results. Patients with respiratory compromise due to chronic obstructive pulmonary disease (COPD) were therefore studied. This study aimed to look at two variables, body positioning and wrist restraint.

Whilst no previous studies have examined the effects of restraint in patients with COPD, the postural effects on lung function in patients with respiratory pathology including COPD have been demonstrated with varying results reported. Chou et al.\(^1\) compared the effect of erect and supine body positioning on diffusing capacity for carbon monoxide in COPD patients. Diffusing capacity and pulmonary capillary lung volumes were higher in the supine position. Nishimura et al.\(^1\) looked at the effects of supine posture as opposed to sitting on bronchial reactivity in patients with asthma. Pulmonary function variables and bronchial reactivity were unchanged between the sitting and supine position. The supine position leads to a reduction in maximal inspiratory and expiratory pressures in patients with COPD but results in an increase in maximal inspiratory transdiaphragmatic pressures.\(^1\) No previous work however has considered the effects of prone positioning. We found that no significant difference could be demonstrated when comparing the seated position with the prone and supine positions. However three subjects could not complete 10 min lying in the prone position due to wheeze, acute breathlessness and oxygen desaturation indicating significant clinical detriment in that position. For two subjects the position could not be assumed for even a short period, which precluded measurement of any of the parameters under investigation.

Physical restraint whilst seated where the wrists are tied behind or in front of the body did not adversely affect subjects. Similarly, in those subjects who could tolerate the prone position the addition of wrist restraint behind the back did not cause any detriment in pulmonary function. However the numbers remaining were too small for meaningful analysis.

The population of subjects who die in restraint situations is younger than the COPD patients studied. Extrapolating from this population however, it would appear that the response to the prone position with or without handcuffs appears highly individual with some subjects with significant respiratory impairment tolerating the prone position with no measurable clinical effect and others suffering a clinical deterioration in symptoms. The reasons for this individual variation remain unclear.

There appear to be many factors involved in restraint related deaths. While it would be both difficult and unacceptable to replicate the whole range of risk factors in a single study, there still remains both an opportunity
and a need for further research into the different mechanisms involved in the pathophysiology of restraint-related deaths.

Acknowledgement

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References

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