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Original communication

The effect of the prone maximal restraint position with and without weight force on cardiac output and other hemodynamic measures

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A R T I C L E I N F O

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A B S T R A C T

Background: The prone maximal restraint (PMR) position has been used by law enforcement and emergency care personnel to restrain acutely combative or agitated individual. The position places the subject prone with wrists handcuffed behind the back and secured to the ankles. Prior work has indicated a reduction in inferior vena cava (IVC) diameter associated with this position when weight force is applied to the back. It is therefore possible that this position can negatively impact hemodynamic stability.
Objectives: We sought to measure the impact of PMR with and without weight force on measures of cardiac function including vital signs, oxygenation, stroke volume (SV), IVC diameter, cardiac output (CO) and cardiac index (CI).
Methods: We conducted a randomized prospective cross-over experimental study of 25 healthy male volunteers (22–43 years of age) placed in 5 different body positions: supine (SU), prone (PR), prone maximal restraint with no weight force (PMR-0), prone maximal restraint with 50 lbs added to the subject's back (PMR-50), and prone maximal restraint with 100 lbs added to the subject's back (PMR-100) for 3 min. Heart rate (HR), blood pressure (BP), and oxygenation saturation (O_2 sat) were monitored. In addition, echocardiography was performed to measure left ventricular outflow tract diameter (LVOTD), and SV, CO, and CI were then calculated. Data were analyzed using repeated measures ANOVA with pair-wise comparisons when appropriate to evaluate changes with each variable with respective positioning.
Results: Despite a small decrease in SV between SU and PMR positions, there were no statistically significant differences in CO between the 5 different positions. There were also no differences in CI between positions other than a small decrease when comparing SU and PMR-50 only (mean difference −0.39 L/stroke, $p = 0.005$). There was no evidence of hemodynamic compromise in any of the PMR positions when evaluating HR, MAP or O_2 sat.
Conclusions: PMR with and without weight force did not result in any changes in CO or other evidence of cardiovascular or hemodynamic compromise.

1. Introduction

Prehospital and law enforcement personnel often confront violent and sometimes dangerous individuals who require physical restraint in order to ensure the safety of the restrained individual, on-lookers, and the officers themselves. Numerous physical restraint techniques have been developed and established to subdue and control such individuals in the field. The prone maximal restraint position (PMR), often referred to as the hobble or hogtie position has been used extensively by first responder personnel. This position places a subject prone with their wrists handcuffed behind the back and secured to the ankles with varying degrees of freedom allowed for the movement of the legs.[1,2]

Because of reports of sudden deaths of individuals placed in this restraint position, interest has arisen regarding the physiologic effects of the PMR position, as the exact cause of death in many of these cases remains unclear.[3–6] It has been suggested that PMR, as well as

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the force required to place combative individuals in that position, can adversely impact cardiovascular function and hemodynamic parameters, such that restrained individuals may be at risk for significant morbidity and mortality.[7–9] However no previous study has directly addressed whether weight force applied to the back while in the PMR position adversely affects cardiac output (CO).

In this study, we assessed sonographically-measured left ventricular outflow tract diameter (LVOTD) and other vital signs to determine whether body position or restraint technique with or without weight force can cause changes in CO or hemodynamic status that could produce a significant clinical effect.

2. Methods

2.1. Study design

We performed a randomized, cross-over comparison controlled trial in 25 male volunteer subjects. The study protocol was approved by our institutional human subjects research review committee.

2.2. Study setting and population

Volunteer subjects were recruited from the university campus by study investigators. No subjects were excluded based on age, ethnicity or health history. The study was conducted in a university hospital patient care room. All subjects received a small monetary gift card of their choosing for participation in this study.

2.3. Study protocol and measurements

Baseline data from each subject were collected including age, weight, height, and body mass index (BMI). Each subject then underwent 5 separate trials in different body positions in random order: supine (SU), prone (PR), prone maximal restraint without weight force (PMR-0), prone maximal restraint with 50 pounds of weight on the center of the back (PMR-50), and prone maximal restraint with 100 pounds of weight on the center of the back (PMR-100).

In the SU group, subjects were positioned in a supine fashion with arms at their sides on a standard hospital patient examination gurney. For PR and PMR positions, the subject lay prone on a special wooden board constructed with a 20 × 20 cm cutout around the chest area to allow for a sonographic probe during echocardiographic evaluation. For PMR positions, the subject lay prone with wrists secured behind the back and ankles secured together within 1–2 feet of the wrists via restraint straps. In order to simulate the force often required to place individuals in the PMR position, standardized plate weights were placed on the back of subjects for PMR-50 and PMR-100 (Fig. 1).

The order of each position trial was randomized and each subject served as their own control as a cross-over comparison investigation. The subject remained in each position 3 min before any measurements were collected to allow for physiological adjustment to the new position. Between each trial, subjects rested at least 5 min before being placed in a new position for repeated study measurements.

Measurements obtained from each subject included heart rate (HR), oxygen saturation (O_2 sat), and systolic and diastolic blood pressure; (SBP, DBP), Mean arterial blood pressure (MAP) was then calculated from the SBP and DBP.

While in each position, an RDMS-certified, Emergency Medicine board-certified physician conducted an echocardiographic evaluation on the subject, obtaining sonographic images of the heart as well as abdominal sonographic images of the inferior vena cava (IVC). A Zonare ultrasound machine with a phased-array probe (P4-1C) was used to these obtain images. In each position, a parasternal

Fig. 1. Photograph of study subject placed in PR-100 position with wrists secured behind the back and ankles secured together within 1–2 feet of the wrists via restraint straps.

long axis (PLAX) view was obtained to measure the left ventricular outflow tract at its maximal diameter (LVOTD) (Fig. 2). Additionally, in the same PLAX view, the LVOT velocity time integral (LVOT VTI) was obtained utilizing cardiac ultrasound software designed to measure this variable as a reflection of the velocity of blood traveling during systole. Cardiac output (CO) was then determined by the equation,

$$HR \times SV = CO$$

and SV was calculated based upon the following equation,

$$SV = \pi(LVOTD/2)^2 \cdot LVOT\ VTI.$$

Cardiac Index (CI) was then calculated by the following,

$$CI = CO/BSA$$

Where BSA was calculated body surface area according to the Mosteller formula[10] of,

$$BSA = \sqrt{(Weight\ (kg) \cdot Height\ (cm)/3600)}$$

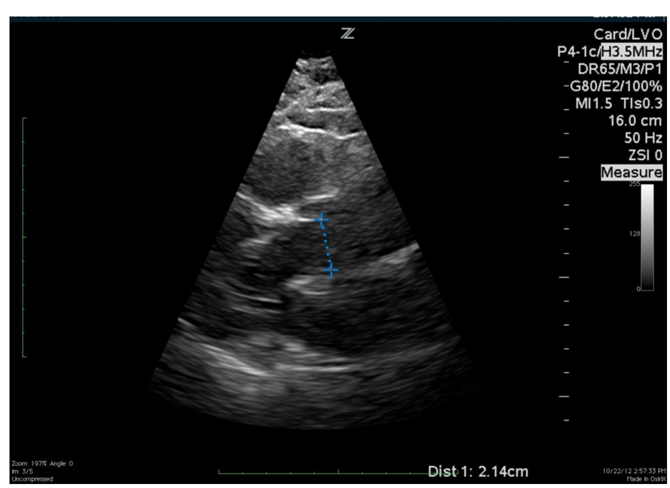

Fig. 2. Ultrasonographic image of heart measuring left ventricular outflow tract diameter (LVOTD).