Response to: Response to: Prone restraint cardiac arrest: A comprehensive review of the scientific literature and an explanation of the physiology

Alon Steinberg

I would like to thank Dr Vilke and his colleagues for their response to my recent publication. I highlighted their work because I felt it was important to address their faulty conclusions regarding the significance of ventilatory and physiologic changes associated with prone restraint. I am happy to have the opportunity to address their comments.

I disagree with the statement made by Vilke and co-authors that pulmonary function tests (PFTs) were similar in the prone and supine positions in their original study. A reported 21% decrease in maximal voluntary ventilation (MVV) among individuals in the prone maximal restraint position (PMRP) cohort is most certainly significant. Their study showed no rise in pCO2 post-exercise in individuals held in PMRP because participants did not undergo a significant degree of stress (post-exercise pCO2 achieved was 30.7 mm Hg with a pH of 7.28–7.33). The authors note, ‘It is unlikely that this period of exercise would simulate all the physiologic alterations that may occur with struggle and agitation. In addition, we did not reproduce the effects of trauma and psychological stress that often occur with apprehended individuals’.

A decrease in MVV seen with PMRP can equate to a decreased ventilation. Once the anaerobic threshold is achieved during exercise or in a struggle, minute volume (MV) increases significantly to compensate for the acidosis driven by pCO2 and H+ levels. Maximal ventilation (VE max) is ~72% of the MVV as it is difficult to maintain rapid and deep breathing for a significant amount of time. Given a maximal or fixed respiratory rate (RR) any decrease in tidal volume will result in a direct reduction in MVV, VE max or MV.

Cary et al. showed a 33% decrease in MVV when subjects were held in PMRP with a 75 kg weight on their back versus a seated position. Due to lack of sufficient stress, MV was maintained and compensated for by a 35% increase in RR thus no change in pCO2 (34.5 mm Hg) was observed. Hick et al. reported on five patients in agitated states due to recent cocaine use had an average post-struggle pCO2 of 25 mm Hg and pH of 7.0. It is critical to understand that with subjects in real-life conditions who are psychotic or drug-intoxicated, engaging in a struggle with fight-or-flight responses will result in excess acid production due to anaerobic metabolism placing tremendous demands on compensatory respiratory mechanisms used to augment alveolar ventilation.

Roeggla et al. tested end-tidal CO2 (etCO2) not F4CO2 on non-exercising subjects and showed an increase of 14.7%. Chan et al. tested the effects of weight force on subjects at rest and concluded ‘… the etCO2 levels remained below 45 mmHg and revealed no evidence of hypercapnia throughout the 5-min trials of each position’. This statement referred to Figure 5, which shows an ~9% increase in pCO2 at 5 min in subjects held in PMRP with 50 lbs weight on their backs compared to subjects in a sitting position and was associated with a 19–22% decrease in PFTs.

Vilke et al. poorly support their position by quoting Parkes and Carson who state they ‘… cannot simulate the absolute effect of a real life, worst case, restraint incident’ and that ‘… it is argued that restraint position should be considered a risk factor for sudden death during restraint’.

Vilke et al. find fault with the methodology used to measure cardiac output (CO) by Roeggla et al. However, the echocardiogram technique used by their group has notable limitations. Vilke et al. did not criticize studies that used the ‘gold standard’ thermodilution method identifying a significant 18–21% decrease in CO. Ho et al. found large reductions in inferior vena cava (IVC) diameter but only small changes in vital signs as increased peripheral resistance will compensate for reductions in CO in a healthy person who is not under stress.

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Krauskopf et al.\textsuperscript{15} also concluded that there were ‘major changes in IVC parameters and minor changes in cardiovascular parameters’ in response to a moderate weight force of 25 kg placed on the torso at rest.

Vilke et al. ignore epidemiologic data that linked prone restraint with death.\textsuperscript{16–19} The fact that agitated individuals can die while restrained in positions other than prone (for example, with a chokehold) does not in any way refute or contradict the conclusions presented in my review.

Vilke and Chan\textsuperscript{20} have argued that PMRP and prone position are ‘no more physiologically disruptive than any other position’. Similarly, Neuman\textsuperscript{21} states that PMRP and prone position are ‘from a medical point of view, perfectly acceptable positions in which to restrain and transport violent and out of control individuals’. These rash statements contradict the best available medical evidence as cited in my review and could have grave consequences by influencing law enforcement policy, training and decision making.

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**References**


