Monitoring regional lung volumes during weighted restraint

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Abstract: Law enforcement and medical staff may need to physically restrain subjects, and there are many unknowns about the physiological effects of such restraint. We describe an EIT-based experimental methodology to analyze breathing parameters and regional lung volumes in healthy subjects during weighted restraint.

1 Introduction

Agitated and violent subjects are often physically restrained by law enforcement and medical staff for the safety of the subject, personnel or others. Subjects are often restrained in a horizontal position (typically prone) with a large weight applied to the upper torso. Although restraint can cause significant physical trauma [1], it is often necessary [2].

One key concern is the risk of asphyxia in the restrained subject, which is related to several factors: applied weight to the torso, agitation, physical exertion and obesity [3]. Since it is difficult to measure breathing physiology during restraint, it is unclear how reduced respiratory function and possible asphyxia are caused.

Especially in the context of law enforcement, restraint is subject to widespread public and media concern. Due to the risk posed, it is important to develop experimental models of restraint from which the mechanisms of injury can be investigated, and thus inform the development of restraint techniques and training to minimize the risk to subjects.

We propose that EIT is an ideal non-invasive technology to monitor lung (and eventually cardiac) function during experimental models of restraint. We describe an experimental procedure in which changes in lung function can be measured as a function of the applied weight, body position, and prior exercise (to simulate agitation or conflict).

2 Methods

With ethics approval, EIT measurements were made in three healthy male volunteers. Each subject assumed 3 postures for 5 minutes each: standing, lying in a prone position and lying prone with 50% bodyweight placed on the back. The weight was applied by placing sand bags evenly across the back from between the shoulder blades to the bottom of the rib cage. Arm positions whole prone were randomized between-subject, alternating between arms at the sides and arms extended above the head.

Electrodes were placed on the thorax in an evenly-spaced 2×16 pattern with 5-10 cm vertical separation, following [4]. Data were acquired with the Swisstom Pioneer set, and reconstructed using the GREIT 3D algorithm [5].

3 Results

Preliminary results show distinct and measurable changes in ventilation as measured with EIT across experimental models of restraint. During weighted restraint a reduction in tidal lung volume of up to 50% is observed across the first two minutes of the applied weight. Figure 1 shows the global impedance signal over the 2 minutes with selected tidal ventilation images displayed below. The regional ventilation images clearly show the reduction in ventilation regions as well as a clear shift in the centre of ventilation.

4 Conclusion

A weighted restraint protocol is able to induce repeatable and measurable changes in tidal lung volume and induce a shift in ventilated region. Impedance related to tidal lung volume decreases by up to 50% in restrained subjects. Using this protocol, we plan to add more subjects to further explore the effect of posture, weight and prior exercise.

References

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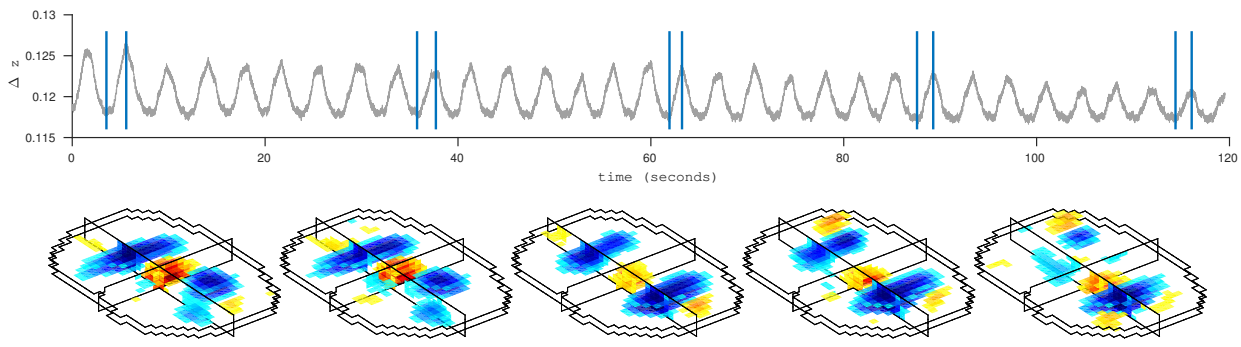

Figure 1: The sum of the impedance signal across all measurements over 2 minutes of weighted restraint is displayed with 5 reconstructed breaths shown with imaged breaths highlighted. The breaths displayed below in 3D clearly show the reduction in ventilation regions as well as a visible shift in the centre of mass.