

Quantification of damage in alveolar morphology in post-blast lung using synchrotron micro-CT

Kalpani Vitharana^{1,2}, J. Sherwood², Thuy-Tien Nguyen³, Andrew J Bodey⁴, Angelo

Karunaratne^{2,5} and Hari Arora^{1,2}

¹The Royal British Legion Centre for Blast Injury Studies

²Department of Bioengineering, Imperial College London, London, SW7 2AZ

³Department of Physics, Imperial College London, London, SW7 2AZ

⁴Diamond Light Source Ltd, Didcot, Oxfordshire, OX11 0DE

⁵Department of Mechanical Engineering, University of Moratuwa, Sri Lanka
hari.arora04@imperial.ac.uk

Introduction

Injury to lungs resulting from blast waves, known as **blast lung**, is one of the most prevalent forms of primary blast injury encountered not only in warzone areas, but also in terrorist attacks and gas explosions. Rapid compression and expansion of lung tissue via primary shock waves is thought to lead to alveolar rupture and coalescence of neighboring alveoli, causing damage. Understanding the pathophysiology and mechanisms of pathogenesis of blast lung has been a real challenge due to the complex nature of the lung and the shock loading. Current treatments such as mechanical ventilation can aggravate the patient's pulmonary function, which means there is a need to improve the mitigation of this injury [1]. Even though *in-vivo* models have shown changes in post-blast lung tissue, there is limited knowledge on the effects of duration and magnitude of shock wave exposure to the lung. These are characteristics that play a crucial role in tissue damage [1,2]. The severity and type of damage based on different types of explosives is not known and so it is crucial to be able to quantify damage which can aid in understanding the severity of injury as well as how to mitigate such trauma. It is the hypothesis of this project that morphological changes to these alveoli are key components in the pathophysiology of blast lung. The effect of shock wave positive phase duration and incident peak overpressure were used to investigate changes in the microarchitecture of the lung using the Diamond-Manchester Imaging Beamline I13-2 to perform high-resolution tomography scans. The reconstructed images were processed using Avizo. Findings from these analyses show that average alveolar volume is an appropriate metric to quantify severity of blast lung injury. Alveolar volume has been shown to relate with the impulse of the shock wave profile and chest wall velocity.

Methodology

Freshly culled naïve cadaveric Sprague-Dawley rats were ventilated at a fixed pressure to assess the mechanical integrity of the lungs. The samples were then mounted on the outlet of the shock tube to induce primary blast lung injury. The lungs were shock loaded at firing pressures of 4 bar and 16 bar at short and long durations (<1ms and >2ms, respectively). After shock loading, the lungs were excised, placed on a sample holder and then mounted on a micro-CT platform for scanning.

The lungs were visualised using the Diamond Branchline of the Diamond Light Source in Oxfordshire, UK. A 2560 x 2160 pixel PCE Edge 5.5 CMOS camera was used with an X-ray photon energy of 20keV. Avizo Lite 9.1.1 was used for three-dimensional visualisation and quantitative morphological analysis of blasted and unblasted alveoli. The images were filtered to remove any background noise and segmented using the Watershed method. The alveoli were 3D reconstructed which enabled to visualise the alveoli of different blast parameters. Different metrics such as alveolar volume and sphericity were analysed for the individual alveoli.

Results

Fig 1 shows the raw images from micro-CT scans which demonstrate the effect of peak overpressure and wave duration on lung tissue. From the images it is clear that the greater the intensity or duration, the alveoli increase in size, creating a ballooning effect.

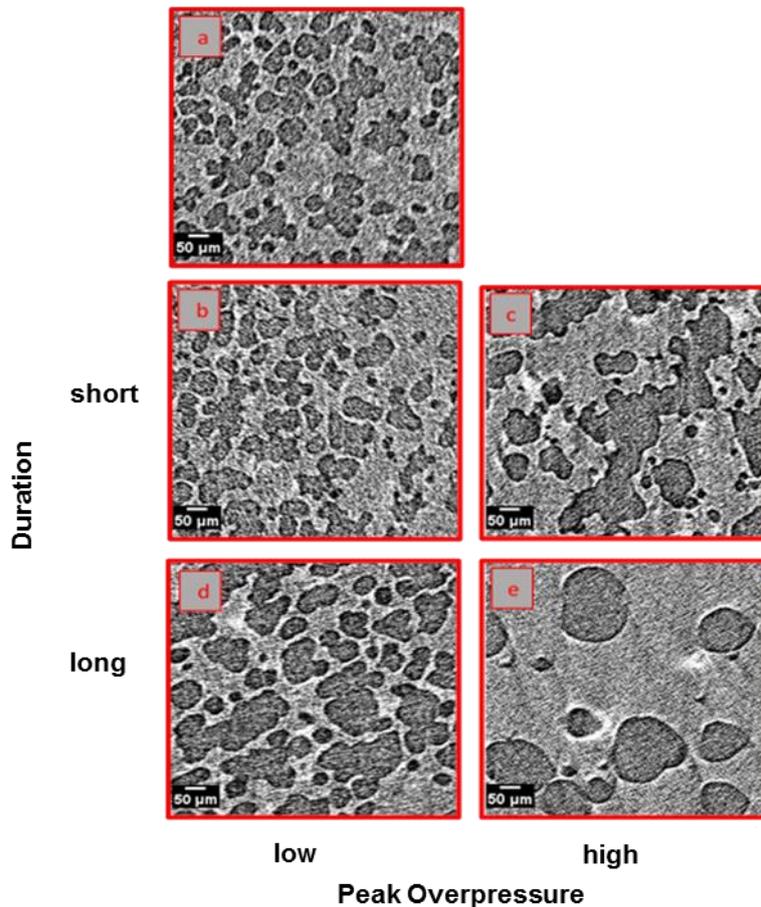


Figure 1 - Raw synchrotron micro-CT scans of alveoli from rat lungs after different loading conditions (a) control (b) low intensity, short duration blasted tissue (c) high intensity, short duration blasted tissue (d) low intensity, long duration blasted tissue (e) high intensity, long duration blasted tissue

Conclusion

Blast lung injury has been quantified in terms of changes measured in alveolar morphology (for example, volume) and related to the impulse of the shock wave profile and the chest wall velocity. The findings have shown that long duration waves and high intensity wave profiles create a ballooning effect on the alveoli, whereby neighbouring alveoli coalesce by the rupture of alveolar walls. These findings could explain the reasons why patients with different severity of blast lung respond differently to treatment and why in some situations it may aggravate a patients situation.

References

- [1] WB Hubbard, C Hall, S Siva , SV Suijith, E Lavik, P VandeVord . Biomed Sci. Instrum. Vol. 50 (2014), p. 92-99
- [2] E Kirkman, S Watts. Philos Trans R Soc Lond B Biol Sci. Vol. 366 (2011), p 286-290