Blast wave intensity can predictably modulate growth plate injury in a murine model

Sumudith B.W. Jayasuriya[1], Alba M. Paterson[1], Anthony M.J. Bull[1]
[1]Department of Bioengineering, Imperial College London, London, United Kingdom
Email: s.jayasuriya23@imperial.ac.uk

Summary

Children living in conflict zones can be exposed to severe blast-related injuries to the lower limb. Blast exposure can cause growth plate insult and alter normal bone development, potentially affecting the child in the medium to long-term. An *in vivo* model of blast-induced growth plate injury would facilitate investigation into the unique effects of blast injury on growth plates and the extent to which these can manifest as growth disturbances. This study outlines the first steps towards establishing such a model where a protocol is developed to achieve blast-induced growth plate injury in cadaveric rat specimens using a gas-powered shock tube.

Introduction

An estimated 473 million children live in conflict zones worldwide [1] and can be exposed to high-order explosives during and post-conflict. This can result in severe extremity injuries due to blasts. Blast wave exposure can cause profound mechanical disruption to the growth plates and adjacent bone [2]. Growth plate injuries can result in growth disturbances such as limb length discrepancies and angular deformities [3], which can contribute to functional deficits and secondary musculoskeletal conditions [4]. This work details the development of a protocol to induce blast-related growth plate injury in cadaveric rat specimens using a shock tube. The study aims to assess the extent to which growth plate injury severity is influenced by blast wave exposure intensity and to identify the minimum blast wave intensity necessary for localised growth plate injury without incurring unintended organ and bone damage. This protocol will help establish an *in vivo* blast-induced growth plate injury model.

Methods

Seven Sprague-Dawley rat cadavers (42-48 d/o) were placed on a protective platform mounted on the outlet flange of a pneumatically driven shock tube. The platform was used in conjunction with a targeting insert to confine blast wave exposure to the proximal tibia of the left hind limb. Physical constraints were applied at the knee and ankle, and blast waves of varied pressure (2, 4, 5, and 6 bar) were fired from the shock tube at the proximal tibia. Following blast exposure, X-ray imaging was conducted to evaluate the presence of bone fractures and intra-abdominal gas. Micro-CT was utilised to assess damage to the proximal tibial growth plate and the adjacent epiphyseal and metaphyseal bone in blast-exposed limbs, while contralateral limbs served as controls.

Results and Discussion

X-ray images exhibited an absence of intra-abdominal gas in all specimens, which suggests adequate prevention of organ damage caused by blast wave-related bodily displacement.

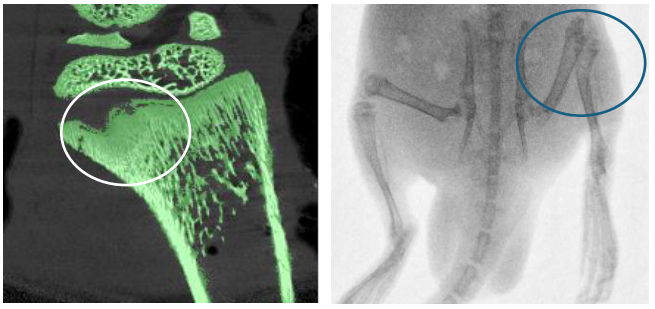

Figure 1: (a) Micro-CT scan segmented and masked in Mimics 25.0 (Materialise, Belgium) exhibiting proximal tibial metaphysis damage following blast exposure (5 bar). (b) X-ray image exhibiting tibial fracture following blast exposure (6 bar)

Fractures of the tibia or fibula were apparent in 1/2 limbs exposed to 5 bar blast waves and 2/2 limbs exposed to 6 bar blast waves. Fractures did not occur in the limbs exposed to 2 and 4-bar blast waves. Microcracks were observed through micro-CT in the proximal tibial metaphysis of 1/1 limbs exposed to 2 bar blast waves, 1/2 limbs exposed to 4 bar blast waves, 2/2 limbs exposed to 5 bar blast waves, and 2/2 limbs exposed to 6 bar blast waves. At 4 bar, 1/2 of the limbs could not be imaged with micro-CT due to separation at the proximal tibial growth plate during sample preparation. Growth plate insult can be inferred from the metaphyseal bone microdamage. Metaphyseal damage can be associated with disrupted blood supply to the growth plate. Impaired vasculature and direct growth plate insult may cause growth disturbance. The extent of metaphyseal damage appeared to increase with increasing blast wave intensity, indicating that growth plate injury severity is likely to increase with blast exposure intensity. Bone damage was not observed in the contralateral limbs. Further testing is required to optimise blast wave exposure in relation to desired injury outcomes before proceeding to an in vivo model to study the profound long-term effects of blast exposure on the growth plate.

Conclusions

A protocol has been developed to reproducibly achieve blast-induced growth plate disruption in rat hind limbs, where severity is modulated by blast wave intensity. Further optimisation is required for translation to an *in vivo* model.

Acknowledgements

Save the Children UK funded this research in the Centre for Paediatric Blast Injuries.

References

[1] Anderson et al. (2024). Stop the War on Children; Save the Children International.
[2] Guy et al. (1998). J Royal Naval Medical Service, 84:79-86.
[3] Meyers et al. (2019). Pediatric Radiology, 49:1595-1609.
[4] Nguyen et al. (2017). Radiographics, 37:1791-1812.