In-Silico Modelling of Blast Trauma

Updates on an Innovative Pre-Hospital Project

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1 INTRODUCTION

Blast injuries are complex physical traumas arising from either direct or indirect exposure to an explosion. They form an increasingly common feature of industrial accidents, military conflict, and terrorist attacks on civilian populations [1].

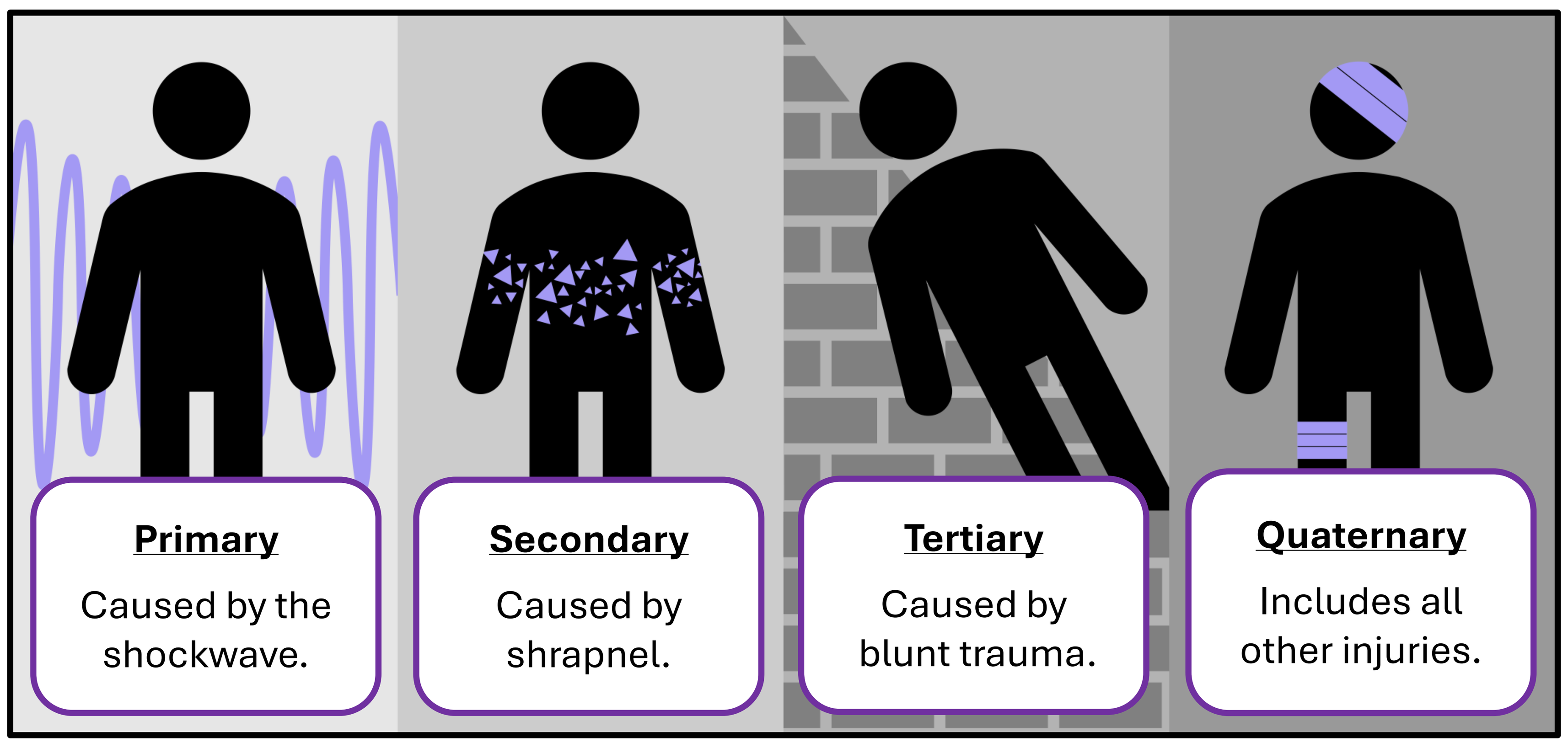

Figure 1. Blast injury classification. Within these classifications, blast injuries are often further delineated based on both the specific tissues affected and the type of trauma they cause. Blast injuries are rarely simple, however, and patients often present with a mixed injury profile.

The unpredictability and scale of blast injuries precludes traditional clinical research exploring pathophysiology and potential medical countermeasures. Animal research is also hindered by significant costs and appropriately stringent ethical considerations.

Computational modelling is readily accessible, cheap, and allows for the estimation of otherwise unknowable internal characteristics. These advantages mean computational modelling is uniquely positioned to progress blast injury research.

2 WIDER PROJECT

In response to recommendations arising from the Manchester Arena Bombing Inquiry [2] we are utilising computational modelling to investigate the interaction between different types of blast injury on immediate survivability.

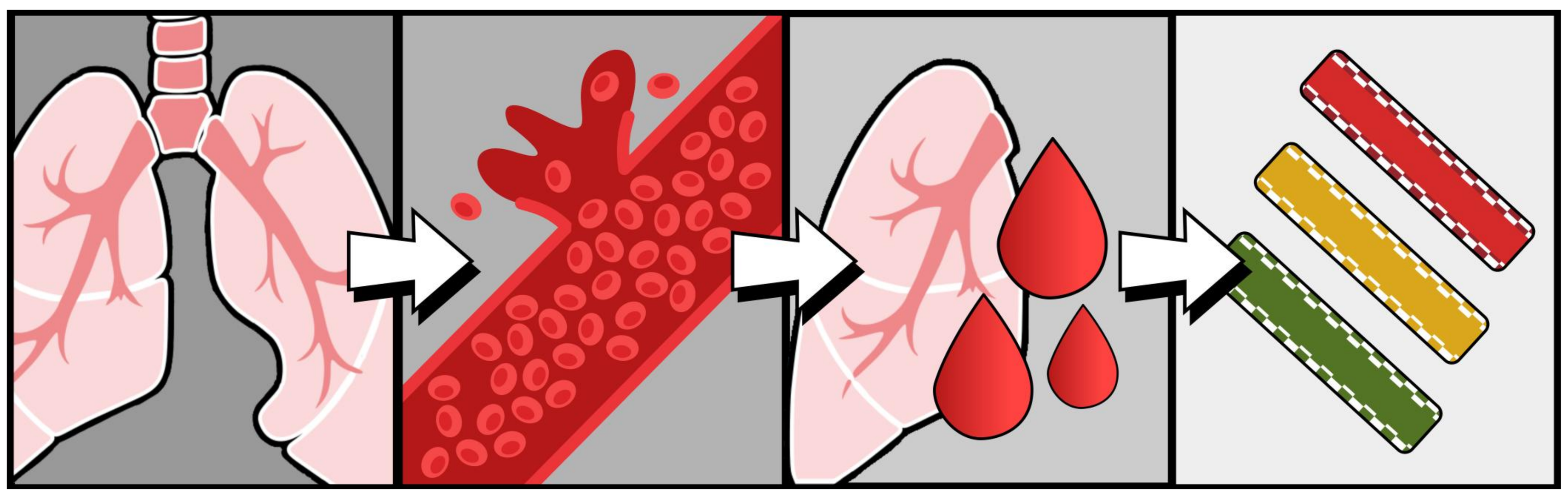

Figure 2. Project plan. After developing models of isolated blast lung and major haemorrhage (which forms a surrogate for secondary and tertiary blast injuries) we will then build a model of combined injury. These models will form the basis of investigations into triage and treatment.

As the first stage in this project, we have recently developed a novel model of primary blast lung injury in an otherwise healthy adult.

This model builds upon a previously validated cardiopulmonary simulator, which is implemented using a series of deterministic, mass-conserving algebraic equations. Each equation is solved iteratively and is obtained or approximated from the published literature, experimental data, and clinical observations.

3 THE NEW MODEL

In response to a user-specified injury severity, our new model of primary blast lung injury can simulate both the initial injury and the compensatory response within the first two hours of exposure.

A The model simulates the initial injury by increasing lung stiffness and minimum alveolar opening pressures to replicate the effects of pulmonary oedema. Simultaneously, the model reduces the structural forces that keep individual alveoli open, thereby replicating the need for an increased work of breathing.

B The model simulates the compensatory response by increasing the rate and depth of breaths to replicate hyperventilation. In addition, the model simulates the baroreflex autoregulation response, which targets cardiovascular homeostasis in response to deviations in mean arterial pressure.

4 PRELIMINARY RESULTS

Using simulated DO_2 as a surrogate marker of survivability, our preliminary results suggest that injuries greater than 53% severity are not survivable without intervention. It would also appear that the relationship between injury severity and minimum DO_2 is nonlinear.

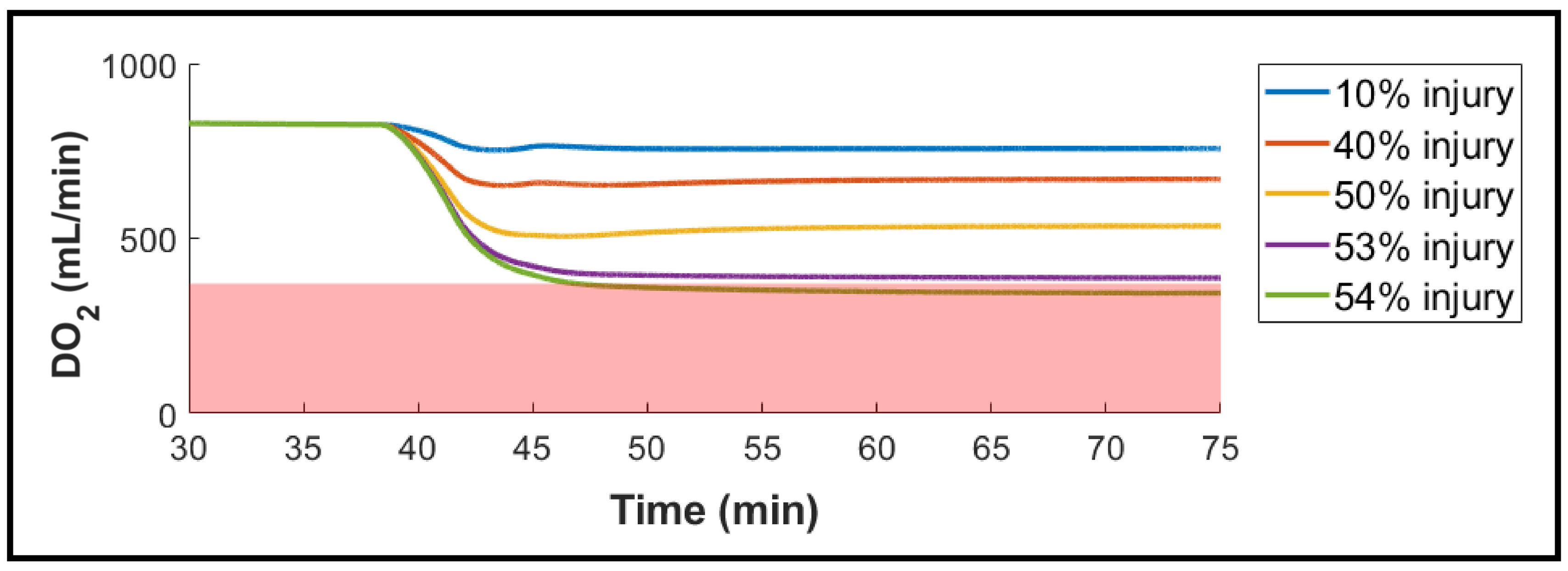

Figure 3. Simulated oxygen delivery after isolated primary blast lung injury in an otherwise healthy 70kg adult. Blast exposure occurs at 40 minutes. The red shaded area represents levels of oxygen delivery that are deemed unsurvivable as per human experimental data [3].

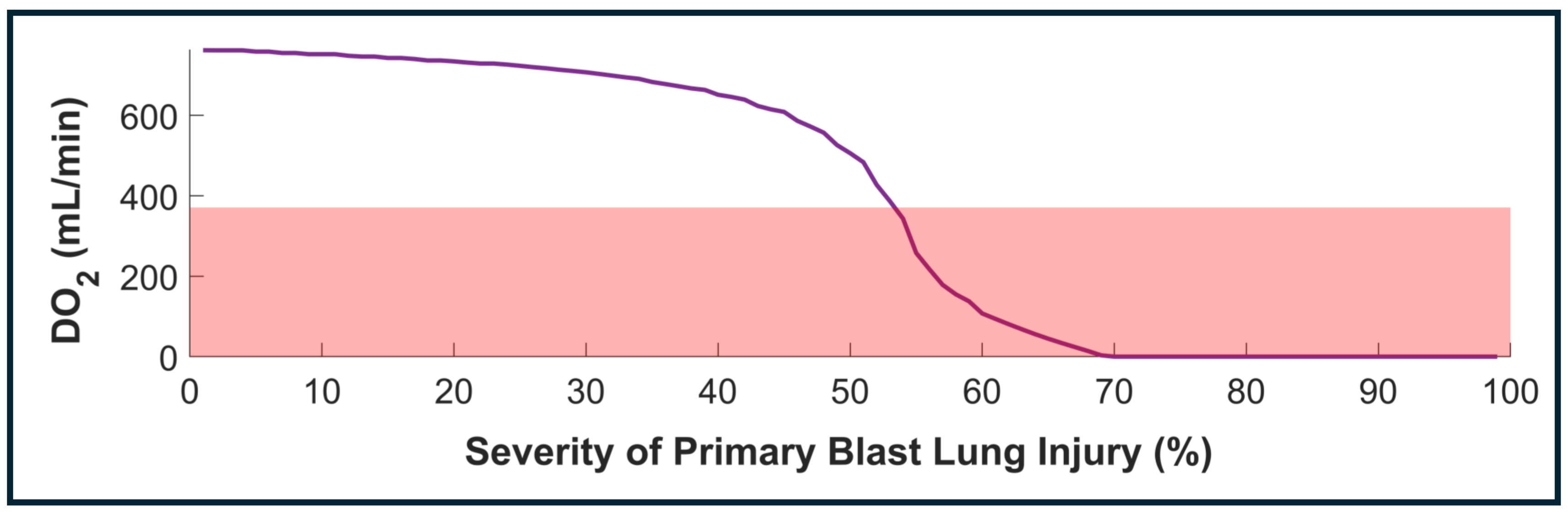

Figure 4. The relationship between severity of primary blast lung injury and lowest levels of simulated oxygen delivery in an otherwise healthy 70kg adult. The red shaded area represents levels of oxygen delivery that are deemed unsurvivable as per human experimental data [3].

This work highlights the value of computational modelling as a tool to investigate blast injuries. The finalised tool will allow researchers to probe the pathophysiology of complex blast injuries and determine feasible on-scene treatment options, ultimately saving lives.

[1] Blast injuries, Jorolemon, Lopez, and Krywko, StatPearls [Internet], 2025. [2] Recommendations for victim survivability assessment methodology based on the Manchester Arena Bombing Inquiry, Ballard et al, Forensic Science International: Synergy, 2025. [3] Identifying critical DO2 with compensatory reserve during simulated hemorrhage in humans, Koons et al, Transfusion, 2022.

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