The Development of a Novel Perfused Post-Mortem Human Subject Model for Evaluation of Soft Tissue Trauma

Karin A. Rafaels, Cynthia A. Bir, Michael Minneti

I. INTRODUCTION

The thoraco-abdominal region contains critical organs that, if injured, can result in serious injury or death. Consequently, many impact experiments have been performed on post-mortem human subjects (PMHS) and animal surrogates to relate the biomechanical responses from these impacts to the resulting injuries. The PMHS experiments allow researchers to utilise a human model with the appropriate anatomy under injurious impacts, and have focused primarily on the structural response and skeletal injuries, like rib fractures. The animal models have been used to investigate physiological responses and injuries to the soft tissue and internal organs since PMHS do not possess the respiratory or cardiac activity present in living people. However, the applicability of animal models to humans is uncertain because of differences in the anatomy, physiology and geometry between the animal and human. Being able to understand, predict and assess soft tissue and organ injuries is especially important for the military population since these tissues are more susceptible to injury from high-rate impacts than bones [1].

Blast and behind-armour impacts, which are higher-rate impacts than witnessed in automotive crash scenarios, can result in organ injuries with no skeletal involvement [2-3]. Epidemiology research for these types of impact is difficult due to the complex nature of the exposure conditions. Furthermore, the battlespace is constantly evolving and the retrospective nature of epidemiology makes it difficult to apply the findings to current or future weapons and/or protection systems. Because these high-rate impacts can affect soft tissue and organs, the majority of the injury research into these impacts has occurred using animal models. But the differences in responses from the various species that have been used highlight the precariousness of directly applying the results to the human [4]. Although some of the injuries from these types of impact can be exacerbated through physiological sequelae, the initial injury is typically due to a mechanical failure. As such, an anatomically correct model might be the best tool to understand the tissue response to the mechanical loading.

As previously mentioned, the PMHS model does not exactly mimic a living person, but previous research using this model has pressurised the vasculature and respiratory system in an effort to simulate their physiological pressures [5-9]. Most of the studies have pressurised the PMHS to investigate the overall thoracic deflection response; however, to our knowledge there have been no scientific studies to validate these techniques for organ responses in the body. Consequently, the utility and value of pressurising the cardiovascular system has been questioned. Moreover, issues associated with some of these techniques, such as difficulty maintaining proper levels of pressure, incomplete perfusion and fluid accumulation [10], need to be addressed to consistently and precisely apply the pressurisation. The goal of this study is to improve upon the techniques to pressurise the PMHS and to investigate the suitability of PMHS model for soft tissue and organ injuries for high-rate impacts.

II. METHODS

A novel perfusion method was developed at LAC+USC by Minnetti *et al.* [11] for surgical simulation. This method included perfusion of the PMHS occurred through the femoral artery and vein. Once these vessels were exposed, they were ligated, opened and cannulated with Sims connectors. The arterial and venous systems were then massaged and flushed to remove any clots within the system, to improve upon the incomplete perfusion seen with other techniques. Saline with a dye was used as the blood surrogate. Vinyl tubing was used to create the blood circuit from the centrifugal pump to the Sims connectors. The pulsatile flow was regulated by serial clamping and unclamping of the tubing to provide a more realistic pressure profile in the arteries instead of the sustained pressures of previous models. To reduce the accumulation of fluid in the thoraco-abdominal cavity, the pulmonary branch arteries were ligated to prevent the flow from travelling into the lungs and leaking into the cavity. The pump and blood circuit were de-gassed to avoid issues with compressible flow. The mean arterial pressure was regulated to 80 mmHg, and the venous pressure was set to 15 mmHg. The lungs were attached to a ventilator to pressurise them to approximately 6 kPa.

III. INITIAL FINDINGS

Early findings indicate that this method fully perfuses the tissue [12]. The skin demonstrated a colour change when pressurisation was taking place, and demonstrated a bleeding response when cut with a scalpel. The heart displayed distended atria and ventricles and clear perfusion of the coronary artery and veins. The lungs inflated, changed colour and demonstrated perfusion in the capillaries when pressurised. Utilising an oral-gastric tube and ligating the pulmonary branches reduced the amount of fluid accumulation in the thoraco-abdominal cavity compared to some of the previous methods.

IV. DISCUSSION

Post-mortem human subjects provide a realistic model for characterising the human structural and kinematic response that cannot be replicated by any other surrogate at this time. The perfusion model of the PMHS used in this study appears to be biofidelic, qualitatively. Additional characterisation of the model with regards to its biofidelity for impact research will need to take place. Future efforts to validate this model include recreating high-rate blunt impact events with known soft tissue and/or internal organ injuries (e.g. pulmonary contusion), using this model for comparison. Additional validation efforts may include comparing the thoracic deflection response of lower rates to living subjects for comparison.

V. REFERENCES

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