Modelling the Blast Environment and Relating this to Clinical Injury: Experience from the 7/7 Inquest

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9.1 Introduction

On 2nd August 2010, the United Kingdom Surgeon General was instructed by Her Majesty's Assistant Deputy Coroner for Inner West London (Rt Hon Lady Justice Hallett DBE) to provide Expert Witness Reports relating to the terrorist events of 7 July 2005 on the London Public Transport Network (see Chap. 8, Sect. ii). These Reports were required to review the evidence that had been gathered during the investigations into the events surrounding the bombings. Her Majesty's Coroner asked a series of specific questions relating to the survivability and preventability (with respect to the medical interventions and care) of the deaths of many of the victims, and these had to be answered on an individual basis with a review of all of the relevant information. It was appreciated that the most appropriate and current experience of dealing with personnel injured in this type of event came from the UK Ministry of Defence Surgeon General's Department who are experienced in dealing with combat-related injuries; particularly in the context of the current operations. This was also assisted by the fact that the UK Military Medical community already had a proven technique for the regular review of operational mortality and medical response [1, 2].

There had also been concerns about the nature of the events, criticism about the initial response, and one review in particular was highly critical of the communication systems of the emergency services which led to delays in understanding what was happening during the first few hours of the events of 7 July 2005 [3]. Survivors had also raised concern at the response of the emergency services [4].

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9.2 Approach

In order to answer all of the questions posed by Her Majesty's Coroner, a multi-disciplinary team was essential. This would take expertise from the Royal Centre for Defence Medicine (RCDM) and Defence Science and Technology Laboratory (Dstl).

Her Majesty's Coroner was particularly concerned with the victims who were not killed immediately by the explosions, but died prior to reaching hospital. Of interest was what happened to them: what attention and/or treatment they received, whether there were any failings in the way that they were treated, the circumstances of their eventual death, and whether any failings in the emergency response contributed to or were causative of their death.

The decision was made at an early stage that a single report covering all personnel would be inappropriate and unique reports for each of the people in question would be written. There were two reasons for this:

- The victims were all individuals and should be regarded on an individual basis.
- The reports may be released to the families of the deceased and the reports would need to be redacted to ensure what was released was only relevant to their relative. There was a risk that such redaction would leave the feeling that some vital information had been removed, and this would simply amplify any conspiracy theory or any feeling that the Government (or in particular, the Ministry of Defence or Ministry of Justice) wanted to hide something of relevance.

This increased the workload substantially, resulting in multiple unique reports.

9.2.1 Work Strands

The broad ranging and complex nature of these questions required a substantial investment of time to address these questions. A three phase approach was adopted as the only practical way to answer the questions within the challenging timescale (3 months start to delivery). These three phases were conducted in series; however, any hypotheses, assumptions or conclusions from either of the analysis phases were not allowed to affect or influence the other, in order to keep all options open.

The first phase required an engineering expert in blast effects on structures and injury modelling to review photographs of the damaged carriages and bus to give a view on the likely physical effects on people close to the explosions. This was coupled with a review of the forensic evidence relating to the explosions. This provided one strand of opinion on the nature of the injuries (the blast effects and injury mechanism) that was used in the final comparison.

The second phase was a clinical review of the evidence by military clinicians to assess blast injury in the casualties. This used techniques developed both in the deployed environment and at regular morbidity and mortality reviews over a number of years [1, 2] to review mechanisms of blast injury and likely cause of death. This method has shown significant benefit in demonstrating the survivability and preventability of the deaths of personnel and to provide a robust evidence base to guide the changes in medical care and response to the critically injured patient. This was coupled with a review of the nature of injuries from other terrorist incidents to provide a baseline comparison of injury mechanisms, as well as a review in the progression of pre-hospital care to advise the Court of changes in treatment strategies that may assist in survival rates.

In the third phase, the blast environment was modelled by the structural dynamics experts [5] to assess likely blast loading on victims. This loading information was then assessed by physiology experts with access to data from experimental studies that provided a correlation of precisely measured blast data with injury, focusing principally on blast lung [6] since this is one of the most difficult aspects to evaluate from post-mortem reports. Simple modelling was also undertaken in isolation of the complex structural dynamics modelling to provide simple

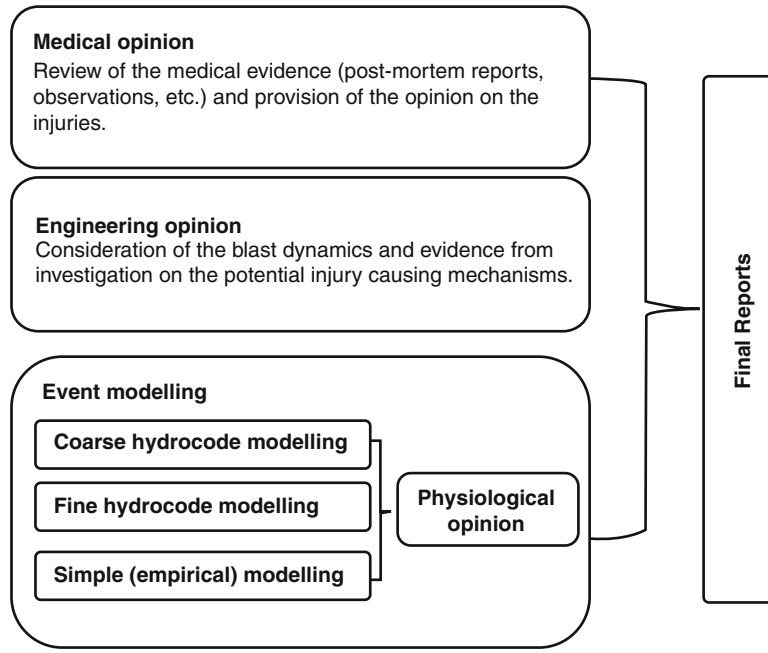

Fig. 9.1 Relationship of three phase work strands

predictions of the risk of blast lung and other injury mechanisms.

The relationship of these phases is shown in Fig. 9.1.

The outputs from these three phases were combined into a joint report and a single opinion on the nature of the injuries and the survivability of personnel as described in the transcripts from the Inquest [7–9]. Each report was formatted to provide a main section written by the principal author and summarising the work that was undertaken.

9.2.2 Model Design and Risk Reduction

Substantial risks were inherent in the mathematical models of the blast environment because of the model complexity and the degree of uncertainty (exact charge size, exact charge dynamics, exact charge location, location and orientation of victims, etc.). As a result, three different levels of model were run for each of the events in the trains:

- A coarse hydrocode model (see Chap. 17, Sect. 4.2) was used to:
  - Study the mechanisms of blast load development and provide broad levels of peak overpressure and specific impulse.
  - Establish 'zones of blast wave intensity'.
  - Determine the extent to which the fireball extended within the carriage during the event.
- A fine hydrocode model to quantify the probable pressure time history loading sustained by occupants within each carriage. This model also produced images and videos of the effects of the blast that showed the blast propagation (see Fig. 9.2). These images were useful for the team, the Court and families to understand the nature of the blast environment.
- A simple (uniform blast wave model) to give an empirical relationship of blast pressure from idealised explosives and compare the results to simple estimates of lethality from blast lung.

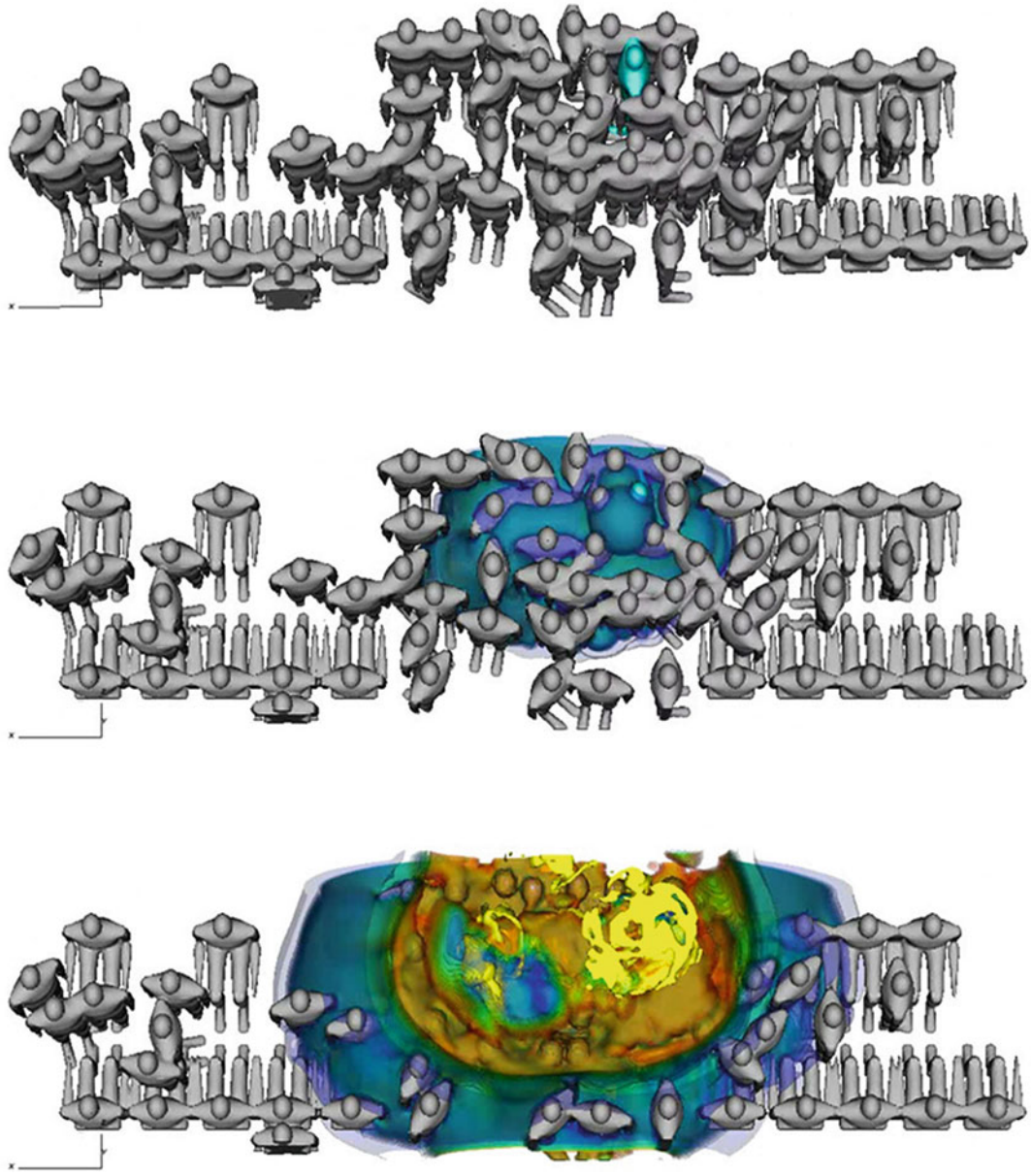

Fig. 9.2 Sample blast propagation from fine hydrocode model

9.2.3 Resources

The team had access to a combination of scene photographs, post mortem photographs, external post mortem reports and witness statements (see Chap. 8, Sect. ii) to form an opinion of the internal and external injuries received by the victims and for how long they showed signs of life after the bombing (if at all).

The team looked particularly at witness statements to understand if the victims were noted to be breathing and have a pulse after the bombing, whether or not they were conscious and the likely time course over which they died from their injuries.

Information provided by the court to support this activity was stored on encrypted memory drives, secured at Dstl Porton Down and at

RCDM Birmingham, where they could be examined in a secure environment.

The scene reports included seating plans for the underground carriages and the bus indicating positions of individuals pre- and post-explosion (where this information was known) and during recovery of the deceased.

As some deceased and live casualties had to be moved at some of the bombing locations after the attacks to allow access to other casualties, the position of a victim post-explosion does not always indicate where that person was prior to the explosion or if that position was the location where they died. This meant that the team needed to use a number of methods to try and work out how close a victim was to the seat of the explosion and from this offer a view on likely internal injuries, as well as providing a review of relevant related information to inform a final opinion on the probable nature of injuries.

9.2.4 Challenges: Quality of Information

Usually when conducting such a review the clinicians and scientists looking at the information would have a complete list of the victim's injuries derived from a combination of a full post-mortem examination plus X-ray imaging. This in turn would be used to calculate mathematical trauma and injury scores which help in assessing whether or not a particular combination of injuries would or would not be expected to be survivable. On this occasion the information from internal post-mortem examination was not available and the X-ray imaging information was limited to fluoroscopy. The fluoroscopic examination was used to identify some fractures and foreign materials present in the victims' bodies.

The team, therefore, relied upon a number of sources of information and scientific methods to come to a considered opinion for each of the victims; however, in an ideal world, more structured observations, measurements and opinions would have been available for the team to consider.

The amount of information missing from a simple external post-mortem was a significant challenge in this work. If anything can be stressed from this work, the importance of a detailed post-mortem examination must be one element.

9.3 Conclusion

We believe that this detailed understanding of the nature of injury from blast and fragmentation threats, and the modelling and understanding of the physical interaction of combat related threats can only come from a multi-disciplinary grouping such as the group formed to address the events of 7 July 2005 and the applicability of this form of analysis should be considered in the event of other terrorist events.

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