BLAST: An Expert System for Blast Injury Diagnosis and Treatment

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***Abstract*—We discuss the design of and demonstrate a prototype of BLAST, an expert system for diagnosing and treating blast injuries. The cellular level damage to living tissue caused by a high-pressure wave is unlike any other mechanism of injury, and therefore has never been seen by most health-care providers, even those who are expert in managing the other three types of trauma (penetrating wounds, blunt-force trauma, and burns). Blast injuries often exhibit delayed or subtle presentations that can be easily missed in the chaos of mass casualty incidents. Further complicating the matter, many of the standard treatments for clinical presentations (such as positive pressure ventilation) can exacerbate primary blast injuries and are indicated for some injuries and contraindicated for others. This expert system is designed to help clinicians best apply their knowledge and the expertise of those who have treated many blast victims by giving them guidance based on both incident type and patient symptoms. It is also designed to serve as a training tool for doctors, nurses, medical and nursing students, those involved in city and hospital level disaster management planning, and emergency responders of all types.**

***Index Terms*—Expert system, blast trauma, primary blast injury, emergency medicine, knowledge representation and reasoning, CLIPS, automated reasoning.**

I. Introduction

The incidence of the use of explosives by terrorists in civilian settings has increased dramatically over the past 15 years [5]. With it has come an increased likelihood for those in the emergency medical community of being required to treat the complex, multiple traumas caused by blasts, which were once primarily from industrial accidents and military conflicts. As the probability of dealing with such a disaster increases, many health care providers "feel undertrained for the unique aspects of the patient's presentation and management" [9]. We briefly describe the physics of explosions, the mechanisms of blast injuries, highlight an example in which blast injury management differs from other trauma, discuss special considerations for expert system design for medical applications, and outline the design of BLAST.

II. Physics of explosions

There are two main categories of explosives: high-energy and low-energy [2]. High-energy explosives transform from a solid state to a gaseous one almost instantly, creating a high-pressure wave that travels outward from the point of detonation. This high-pressure wave can cause serious damage to any solid object, and in particular to the tissue of the human body. The blast wave is followed by a blast wind that lifts and carries objects in its path. These projectiles impact bodies causing injuries, and sometimes bodies are themselves thrown. Low-energy explosives exhibit a blast wind but not a blast wave, though the pressure changes can still be harmful, particularly in a closed environment. The setting and geometries of explosions greatly effect the complicated dynamics of the blast wave and blast wind and the consequent injury patterns [7]. Knowing the setting and type of explosive give physicians an information advantage in proper diagnoses and treatment of blast injuries.

III. Blast Injuries

A. Mechanisms of Injury

The types of injuries sustained by blast victims are generally grouped into four categories: primary (cellular level damage caused by the blast wave), secondary (penetrating wounds caused by projectiles carried in the blast wind or blast wave), tertiary (blunt force trauma caused by a person being thrown by the blast wind or by heavy objects being thrown into them), and quaternary (injuries caused by the explosion that do not belong to any of other categories such as burns from resulting fires; psychological trauma; exposure to dangerous particulate, chemical, or biological matter; and radiation exposure) [9]. Primary blast injuries are caused only by the high-pressure waves of explosions and occur particularly at air-fluid interfaces such as in the ears, lungs, and intestines. The presentation of primary blast injuries can be delayed or subtle [8], making them easy to miss in the triage and initial treatment phases.

B. One Example of an Injury Management Difficulty

Victims with primary blast injuries most often have primary injuries to more than one body system (for example auditory and pulmonary, or auditory, pulmonary and abdominal). Positive pressure ventilation (PPV) is indicated for adult respiratory distress syndrome in patients with abdominal blast injuries, penetrating wounds, and blunt force trauma. However, PPV can cause further lung damage and even death in patients with blast lung injury (BLI) via for example, arterial air embolism. If BLI is known or suspected, unorthodox ventilation techniques that would not be suitable in other situations, such as positive end-expiratory pressures (PEEP), permissive hypercapnia [9], high-frequency jet ventilation, and inhaled nitrous oxide [6] are advised.

IV. Purpose of the System

It is clear that a systematic, reliable way to augment the knowledge and treatment of emergency clinicians, especially at the time of an incident, would be of use. The purpose of this expert system is two-fold: to assist health-care professionals in the diagnosis and management of blast trauma thereby leading to better outcomes for blast victims; and to serve as a training tool to enhance preparedness for mass casualty incidents. BLAST is not a replacement for careful observation by physicians nor should it supplant the judgement of the attending clinicians.

V. Effective Expert Systems in Medicine

Software design elements which have been shown in [4] to statistically significantly correlate to the improvement in patient care with software use are adopted; in particular, BLAST provides: insights and recommendations at the time and in the location where they are used; and actionable, computer-generated recommendations. It can furthermore justify its reasoning and support its conclusions, giving clinicians the ultimate authority to accept or not accept the suggestions and reasoning of the expert system.

VI. Expert System Design

BLAST is programmed in the existing expert system shell CLIPS (C Language Integrated Production System). CLIPS, originally designed for NASA, is highly portable, low cost, extensively tested, and has open source code. Portability is critical as hospitals use many different software and hardware systems.

CLIPS consists of three basic components: the fact list (the data with which CLIPS can reason), the knowledge base (the rules), and the inference engine (controls which rules fire and in what order) [3]. Rules were extracted from published literature and consultation with a human expert.

BLAST takes into consideration both the circumstances of the explosion (e.g., geometry of the location, explosive type) and the symptoms of the patient. The user prompt first makes inquiries into the general event and then asks for particular diagnostic information. Based on the information provided, BLAST performs forward-chaining reasoning by pattern matching the left hand side of IF ... THEN statements to arrive at possible diagnoses and suggested tests.

We chose to use an incremental linear model for software development. This, the prototype version, consists of the most critical rules and advice for diagnosing and treating primary blast injuries. To test the performance of BLAST, the information of patients whose outcomes were known were given to the expert system to see that it gave the proper recommendations. Finally potential situations were given to BLAST and the advice of BLAST was compared to that of an expert.

The prototype does not support fuzzy reasoning, though future generations of BLAST will.

VII. User Group

The users of this expert system include all emergency responders and emergency planners.

VIII. Development

Developed for: The United States Army Research Lab Human Research and Engineering Directorate. Developed by: the author.

IX. Technology Used, Systems Requirements, and Duration of Demonstration

The software was developed on a Dell Latitude E6410 with an Intel Core™ i7 CPU M620 @ 2.67 GHz processor, 4.00 GB RAM, and a 32-bit operating system running Windows Vista SP2.

Systems requirements: a PC running Windows XP or later with CLIPS and an ANSI compliant C or C++ compiler installed; a keyboard and mouse. Duration of the demonstration is 20 minutes.

X. Conclusion

The increased use of explosives by extremist groups with the goal of generating civilian casualties has created a new era for first responders and health-care providers, one in which there is a substantially higher chance of being required to manage a mass casualty incident involving blast trauma. For most civilian doctors, their first such incident will be the only one they ever see. Thus the assistance of expert knowledge both for training and to guide care in an emergency is valuable and desired. This expert system is being designed to provide that expert knowledge and training with the goal of reducing casualties and improving quality of life in survivors of blast trauma worldwide.

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