INSTRUMENTED TORSO MODEL

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of the co-pending U.S. Provisional Patent Application No. 60/325,317, filed on Sep. 27, 2001, and herein incorporated by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an instrumented torso model that simulates anatomical features and measures the effects on a body caused by various types of impacts.

2. Background

People have used body armor such as wooden and metal shields, vest plates, chain mail and other types of armor throughout history. The technology of soft body armor to protect against bullets matured in the 1970's with the development of an aramid fiber (Kevlar®) by the DuPont Corporation. Bulletproof vests incorporating soft body armor are generally preferred over vests that use rigid plates because of weight and comfort concerns.

Soft body armor is designed to prevent projectiles from penetrating the body. When effective, soft body armor spreads the impact of a bullet over a wide area of the body and prevents a puncture wound. However, experiments in the 1970's using laboratory animals demonstrated that even when soft body armor prevents a puncture wound the liver, heart, spleen and spinal cord are still vulnerable to severe injuries known as Behind Armor Blunt Trauma (BABT). See Carroll, A. W. and Soderstrom, C.A., "A New Nonpenetrating Ballistic Injury", *Ann. Surg.,* 188, 6,pp753–757 (1978). Other studies have used high-speed photography to show that when impacted by a bullet the body acts as a highly damped or "viscous" system. When a bulletproof vest successfully stops a bullet, the human torso behind the vest exhibits viscoelastic behavior that includes the propagation of several types of BABT inducing waves, including: 1) stress waves—longitudinal pressure waves that travel at or slightly faster than the velocity of sound in tissue; 2) shock waves—waves of high pressure characterized by an effectively instantaneous wavefront propagated through underlying tissue at a velocity faster than the velocity of sound in tissue; and 3) shear waves—transverse waves of long duration and relatively low velocities that produce gross distortions of tissue and organs. Finally, the wearer of a bulletproof vest may also be subject to crush injury. Crush injury results from the intense static impulse load that is applied to underlying tissue when a bullet is stopped by body armor.

The modes by which the above bullet-induced waves and forces damage bones, organs and tissue are very complex. For example, stress and shear waves account for many injuries distant from the blunt impact. Stress waves in tissue may result in very high local forces producing small but very rapid distortions. Such rapid distortions usually do not result in gross lacerations to tissue; rather their effects are largely concentrated at the microvascular level to produce extravasations of blood. Shear waves may produce marked distortion of internal organs adjacent to the body wall that results in contusions or lacerations. Crush injury from a bullet impacting body armor may include bowel laceration from the gross compression of the anterior abdominal wall resulting in contact with the retroperitoneal surface. Finally, sternal fracture and gross myocardial injuries show a significant correlation to the degree of chest displacement when pigs are subjected to non-penetrating midsternal impact.

The nature of the above injuries in a specific case of a bullet impacting a human torso that is protected by body armor is based on complex relationships between numerous variables. The anatomical location and direction of impact are also significant factors that determine the extent of injury. However standard tests for body armor do not measure these anatomical factors. Current methods of testing body armor include use of clay physical models. According to the National Institute of Justice (NIJ) ballistic standard 0101.04 for the testing of body armor, a flat 10.2 cm (4.0 inch) deep layer of clay is placed behind soft personnel protective armor and shot with different munitions. The depth of deformation of the clay is then measured and, for the armor to pass the test, must be less than 4.4 cm. Other tests include wrapping soft armor around blocks of "ballistic gelatin", a low water content mixture of Knox Gelatin, to simulate a torso. The gelatin acts as an analog for soft human tissue to show the damage path and wound area during penetration tests of body armor. For non-penetrating tests the deformation in the gelatin can be captured with high-speed photography or x-rays. Unfortunately testing techniques involving only clay or ballistic gelatin are not capable of accurately estimating internal injury to a person when a bullet strikes a particular point on their bulletproof vest.

Effective body armor minimizes injury by transferring the kinetic energy of a projectile over an extended time-scale or surface area. Body armor that accomplishes such energy transfer using lightweight materials that are comfortable to wear involves sophisticated technology and engineering. Effective testing methods for such body armor also require the use of sophisticated technology. Existing testing methods do not include sensors and instrumentation for recording the deformation of ribs and the effect of the shock, shear and stress waves that pass through the human torso. To better assess the quality of new body armor designs, new injury criteria are needed to quantify the damage of different non-penetrating munitions to the internal organs. Therefore there is a need for a human surrogate torso for the purposes of measuring deformation of ribs and the sternum and kinetic energy imparted to organs from different types of non-penetrating munitions.

An anatomically correct instrumented model of the human torso capable of measuring how the above bullet-induced waves and forces damage particular organs, bones and tissue could significantly improve the design and testing of body armor. Such a model could yield measurements that show, for example, that a new prototype design of body armor would be very effective at preventing injury when a bullet strikes one area of the torso but leaves the wearer vulnerable to significant injury if a bullet strikes another area of the torso.

Prior art devices related to an instrumented torso for testing body armor include the anthropometric test devices (ATDs) or crash dummies used primarily in vehicle crash analyses. Such ATDs are designed to simulate the general overall dynamics of humans during vehicle crashes, but are generally not anatomically accurate on more local anatomical scales. For example, most ATDs are expensive and are therefore designed to withstand numerous vehicle crashes before they need replacement. Therefore the ribs of ATDs are generally made of steel, rather than of a more anatomically accurate bone simulant. ATDs have been designed to measure more local anatomical effects of vehicle crashes such as chest deflection. But the torso instrumentation used in these designs is very simple such as a single linear variable differential transducer (LVDT) mounted on a steel sternum. Such an ATD would be of limited use in estimating damage to internal organs caused by a bullet impacting body armor.

An anatomically accurate instrumented torso model would also be useful in designing and testing other types of law enforcement devices such as "bean bags" and other