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A preliminary study into injuries due to non-perforating ballistic impacts into soft body armour over the spine

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ABSTRACT

The UK Home Office test method for ballistic protective police body armours considers anterior torso impacts to be the worst-case scenario and tests rear armour panels to the same standards as front panels. The aim of this paper was to examine the injuries from spinal behind armour blunt trauma (BABT) impacts. This study used a cadaveric 65 kg, female pig barrel and 9 mm Luger ammunition (9 × 19 mm, FMJ Nammo Lapur Oy) into HG1/A + KR1 soft armour panels over the spine. Injuries were inspected and sections removed for x-radiography and micro-CT assessment.

All shots over the spine resulted in deep soft tissue injuries from pencilling of the armour and the shirt worn under the armour. The wounds had embedded fabric debris which would require surgery to remove resulting in increased recovery time over injuries usually seen in anterior torso BABT impacts, which are typically haematoma and fractured ribs. The shot with the deepest soft tissue wound (41 mm) also resulted in a fractured spinous process. Shots were also fired at the posterior and anterior rib area of the pig barrel, for comparison to the spine. Similar wounds were seen on the shots to the posterior rib area while shallower, smaller wounds were seen on the anterior and one anterior rib shot resulted in a single, un-displaced rib fracture. The anatomical differences between pigs and humans would most likely mean that injury to a human from these impacts would be more serious.

Introduction

Body armour covers the torso and can be tailored to protect wearers from a range of threats including fragmentation, sharp-weapons, low velocity (handgun) and high velocity (rifle) ammunition [1]. The most common armour worn by routine patrol officers is HG1/A + KR1 which provides protection from low velocity handgun ammunition and sharp weapons using a fabric based 'soft' solution [1]. The level of protection provided to the posterior torso is the same as the anterior. Non-perforating impacts onto body armour will often result in behind armour blunt trauma (BABT) [2,3]. BABT refers to a non-penetrating injury which is the result of rapid deformation of body armour from a ballistic impact [2]. During BABT there is an initial compression wave (high amplitude, short duration) as the bullet impacts the armour and can result in injuries such as rib fractures and internal contusions. This is followed by a compression wave from the deformation of the rear face of the armour into the body which can cause skin abrasions and contusions [4,5]. The deformation of the armour is used as a measure in body armour testing and is a record of the depth of an indentation formed in Roma™ Plastilina no. 1 clay when there is a non-perforating impact onto body armour mounted in front of the clay [6,7]. The depth of this indentation is called the back face signature (BFS) and is typically hemispherical in shape. The standards for ballistic and knife resistant body armour for civilian law enforcement agencies in the UK are managed by the Home Office Centre for Applied Science and Technology (CAST). HG1/A body armour is currently tested against 9 mm and 0.357″ ammunition at velocities within range of 365 ± 10 m/s and 390 ± 10 m/s respectively and has a maximum BFS depth of 44 mm for the armour to pass testing [7]. Many studies measure the BFS and attempt to correlate this to injuries in humans however there is no proven correlation between these two factors [8]. There are case studies of contusions from non-penetrating impacts onto body armour and reports of broken ribs however there have been no reports of BABT resulting in life threatening injuries [3,9].

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Pencilling is an injury mechanism specific to BABT impacts onto soft body armour. Instead of the usual hemispherical BFS the body armour, and clothing underneath, form a more tapered deformation which penetrates into the soft tissue directly under the body armour [10]. The resulting injury can appear similar to a ballistic entry wound and has been noted during research into BABT as well as studied in its own right [10].

Predominantly research into BABT has considered projectiles fired at the anterior rib cage and abdomen [2–4,11–18] and there is currently a limited understanding of the injury mechanisms involved in BABT impacts over the spine. Only three peer reviewed journal papers were found concerning BABT shots over the spine and they varied widely in armour type, ammunition, velocity and data measurements taken [19–21].

Although human cadavers and live animals are occasionally used in ballistic testing there are considerable moral and ethical issues involved with both. Cadaveric pig tissue has been used frequently for both ballistic and medical research due to its similarities with human tissue and it has become an acceptable substitute for the human torso [9,22–25].

The aim of this paper was to examine the injuries from spinal BABT impacts. This study used a 65 kg, female pig barrel and 9 mm Luger ammunition (9 × 19 mm, FMJ Nammo Lapur Oy) into HG1/A + KR1 soft armour panels over the spine. Injuries were inspected, and sections removed for x-radiography and micro-CT assessment.

Ethical approval for the work was granted by Cranfield University (approved 16/11/2016, ref: CURES/2151/2016)

Materials and methods

Materials

A food grade, cadaveric pig barrel was collected on the morning of the test day.

A standard UK police polo shirt (50% polyester, 50% Nano Kool), and body armour carrier were used in combination with HG1/A + KR1 body armour test panels (Fig. 1).

The ammunition used was 9 mm Luger (9 × 19 full metal jacket; made by - Nammo Lapur Oy, Finland), (Fig. 2).

Method

The pig barrel was photographed and soft tissue (skin and fat layers) thickness measured with forensic scale prior to testing. The barrel was placed on a clear topped table 10 m down range with the spine facing the end of the muzzle. The pig barrel was loosely tied to a beam to keep it upright during impact but allow natural movement (Fig. 3). An Enfield Number 3 Proof Housing with a 127 mm barrel fitted was used to fire the ammunition; this is a standard apparatus used in ballistic test ranges (Fig. 4). The pig barrel was covered in the polo shirt and then the body armour panel in a carrier - secured over the spine. Shots were aimed to hit the armour over a vertebra. All shots were aimed at least 50 mm from other shots resulting in five shots along the spine. The projectile impact velocities were recorded using a Weibel W-700 Doppler radar. A Phantom V1212 high-speed video camera recorded the impact events from underneath (20,000 frames per second, 5 μs exposure time, 512 × 384 frame resolution).

Analysis

Photographs were taken of damage to the body armour and clothing and of the resulting wounds to the pig barrel using a Nikon D300 SLR digital camera with 55 mm lens.

Post ballistic testing debris was collected from the pig barrel wounds which were measured and photographed with a forensic scale. The barrel was then dissected, using scalpel and bolt cutters, by removing ribs and then cutting between vertebra at least one above and below the impact location. Damage to the

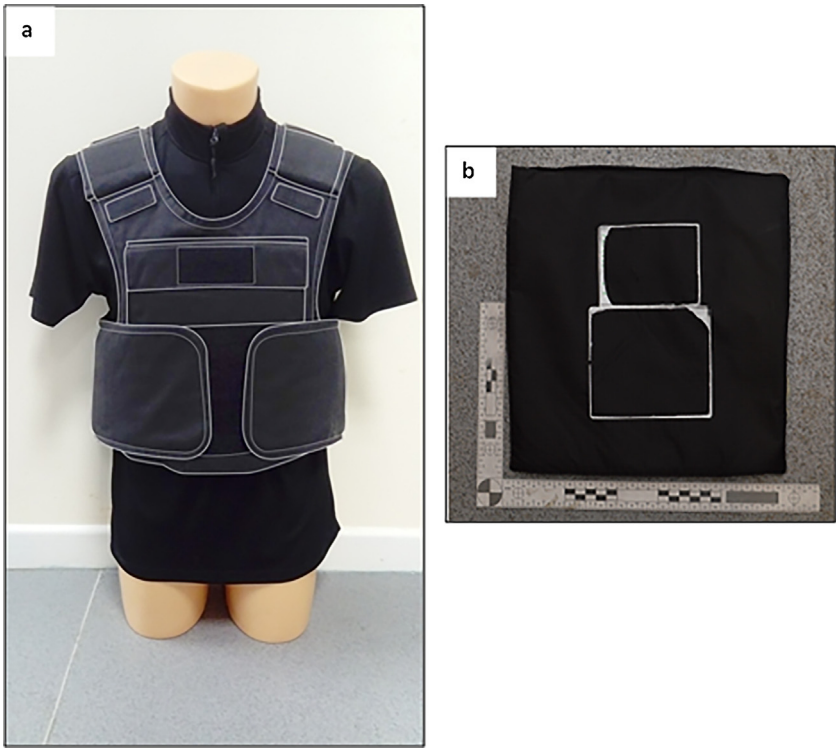

Fig. 1. a) Typical police polo shirt with carrier vest over the top and b) standard UK ballistic test panel of HG1/A + KR1 body armour.

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