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Less lethal projectile wound pattern identification using synthetic skin

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ABSTRACT

Less lethal munitions are frequently used for crowd control during protests and riots. The injuries inflicted by impacts from less lethal projectiles can range from minor contusions to severe head trauma. Two common types of less lethal projectiles are beanbag rounds and foam rounds. Both have been frequently deployed in crowd control scenarios and have been occasionally responsible for severe head injuries (Rajaram et al., 2022). Forensic investigations may be required to determine the type of less lethal projectile responsible for an injury. In an effort to develop a reliable, cost-effective approach to address this issue, we have conducted preliminary tests in which less lethal projectiles were fired at targets covered with synthetic skin. The objective of the study was to determine whether the defect patterns created by the less lethal projectile impacts could provide a means of distinguishing between scalp wounds created by beanbag rounds and foam rounds. Our preliminary tests were able to identify several features of the defect patterns which indicate the utility of synthetic skin as substrate for differentiating between scalp wounds due to impacts between these two types of less lethal projectiles. In particular, we found that the size of the defect, the extent of the penetration, the likelihood of laceration and the presence of stippling were features that distinguished beanbag round impacts from foam round impacts

1. Introduction

In recent years, the deployment of less lethal projectiles during crowd control, protests, and riots has drawn increasing scrutiny due to the potential for injuries incurred by individuals involved in such events [1]. Law enforcement agencies commonly deploy less lethal munitions like beanbag rounds and foam rounds to manage public order and disperse crowds [2]. Despite their intended less lethal nature, a growing body of literature has documented instances of injuries resulting from these projectiles, prompting a critical examination of their safety and the underlying biomechanical mechanisms causing harm [3,4]. The present study aims to contribute to this discourse by investigating the patterns of injuries caused by less lethal projectiles.

Of particular interest, is the identification of injury patterns resulting from different types of less lethal projectiles. The types of injuries inflicted by beanbag rounds and foam rounds are often similar, frequently resulting in contusions [5]. However, lacerations and more serious injuries have also been documented [4,6]. In some forensic cases, the question may arise as to the type of less lethal projectile responsible for a specific injury. In addition, injuries resulting from less lethal projectiles raise issues around safe deployment as well as legal issues related to litigation. The present study focuses on the damage produced by less lethal projectile impact on synthetic skin. Using synthetic skin as a surrogate for human scalp tissue, damage patterns are compared to the patterns of real-world injuries inflicted by less lethal projectiles. By correlating the damage patterns with documented injuries, we aim to provide a foundation for determining whether tests with synthetic skin could serve as a tool in forensic investigation of injuries produced by less lethal projectiles.

2. Methods

Less lethal projectiles were fired at a metal target covered by of a sheet of synthetic skin (8 N SynTissue®), designed to require a penetration force of 8 N (Fig. 1). Some of the mechanical properties of SynTissue® have been documented in a previous study [7], which suggest that the synthetic skin has similar elastic properties to human scalp and is suitable as a surrogate for the human scalp in investigating lacerations produced by blunt force trauma. A synthetic skin sheet, measuring 20 cm by 20 cm, was mounted on a 1 mm aluminum plate which was then secured to a stand with adjustable inclination. The aluminum substrate was selected to approximate the anatomical condition of the

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human scalp, which is characterized by relatively limited subcutaneous adipose tissue and is supported by the hard, flat surface of the calvarial bone. The shooter was stationed at distances of 22.86 m (75 ft), 15.24 m (50 ft) or 7.62 m (25 ft) from the target, depending on the accuracy of the shooter. Shots were fired with the target inclined either at 45° or 90° (perpendicular) with respect to a straight-line trajectory from the shooter to the target.

The less lethal projectiles tested were Accusox Beanbag (40 g) and 2581 Super Sock Beanbag (40 g), fired with a Remington 870 shotgun with an 18.5" barrel, and 40 mm 4557 Foam Baton (58 g) and 40 mm eXact iMpact (30 g) fired with a 40 mm LMT® Tactical Single Launcher and Multi-Shot Variant. Muzzle velocities were precisely measured using ballistic Doppler radar (LabRadar). The projectiles were weighed after firing with an Accuteck ShipPro scale (110 lb (50 kg) capacity, 0.1 oz (2.8 g) accuracy).

Orthogonal photos with a forensic ruler placed on the synthetic skin sheet were taken with a Nikon D5600 camera for each impact. The forensic ruler provided a scale for subsequent measurement of the defect area created by the projectile impact. Muzzle velocity and projectile mass were used to estimate kinetic energy. The defect area was then used to calculate energy density.

3. Results

Fig. 2 shows a defect to the synthetic skin sheet produced by the impact of each type of projectile at each of the two inclination angles. The defects were generally circular in shape for all projectiles, regardless of the target inclination. Note that the beanbag trials were performed at shorter distances (15.24 m or 7.62 m) from the target than the foam rounds because of their lower accuracy, i.e. the shooter found it difficult to hit the target with the beanbag rounds at a distance of 22.86 m. Beanbag rounds generally either penetrated completely through the synthetic skin (Fig. 2A,F) or left a stippled pattern with tears around the edges (Fig. 2B). The stippling is similar to that seen in human wounds sustained from some beanbag round impacts (Fig. 3). Foam rounds, in contrast, generally flattened the synthetic skin exposing the mesh matrix without completely penetrating (Fig. 2C,D,G), although there were often small penetration tears at the edges (Fig. 2D,G,H). Some hits at the 45° target inclination produced creases in the synthetic skin without a clear circular outline, although generally also creating a small tear (Fig. 2E, H).

Table 1 lists the mean kinetic energy, mean impact area and mean energy density, together with the number of registered hits for each type of projectile. Only hits for the 90° inclination were included in the calculations, since it cannot be assumed that the target absorbed all of the kinetic energy when it was inclined at 45°.

The defect area created by a projectile impact on the synthetic skin was smaller for the beanbag rounds than the foam rounds (Fig. 4), even when the kinetic energy was similar. Consequently, the energy density was less for the foam rounds than the beanbag rounds.

4. Discussion

Using synthetic skin as a simulant for human scalp, we were able to find differences between defects created by impacts with beanbag rounds and foam rounds. The surface area of the defects was smaller for beanbag rounds than foam rounds. In addition, the beanbag rounds generally penetrated the synthetic skin whereas the foam rounds crushed the synthetic skin without complete penetration. When the beanbag rounds did not completely penetrate the synthetic skin, they produced a stippling pattern similar to that seen in human wounds sustained from beanbag round impacts. Although foam round impacts did not completely penetrate the synthetic skin, they often created small tears similar to lacerations [7].

Whereas we anticipated that we would be able to reliably identify differences in the defects produced when the target was inclined at 90° to the shooter's nominal trajectory compared to when it was inclined at 45°, we did not find any consistent distinguishing features. There were two cases (Fig. 2E,H) where the skin tended to crease and tear with the 45° target inclination rather than being subject to penetration or crushing, but this was not a consistent finding. However, since we did not find such creasing when the target was inclined at 90°, creasing without penetration could tell us that the round made contact at an angle as opposed to a direct (perpendicular) impact.

Our energy density estimates are consistent with published reports [9,10]. However, it is likely that the true energy density was lower than our estimates since our estimates are based on measured muzzle velocity whereas the velocity of the projectiles at the point of impact would have been less than the muzzle velocity due to slowing produced by air resistance as they travelled towards the target.

The principal motivation for investigating the defect patterns produced by the impact of less lethal projectiles was to determine whether tests with synthetic skin could serve as a tool in forensic investigation of scalp injuries produced by less lethal projectiles. In particular, we were

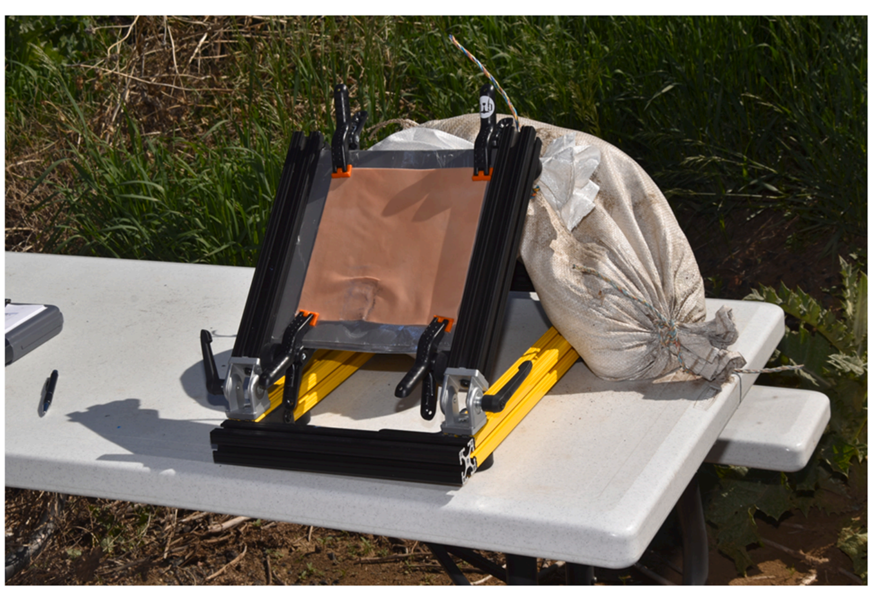

Fig. 1. Target setup shown inclined at 45°, covered with sheet of SynTissue®.

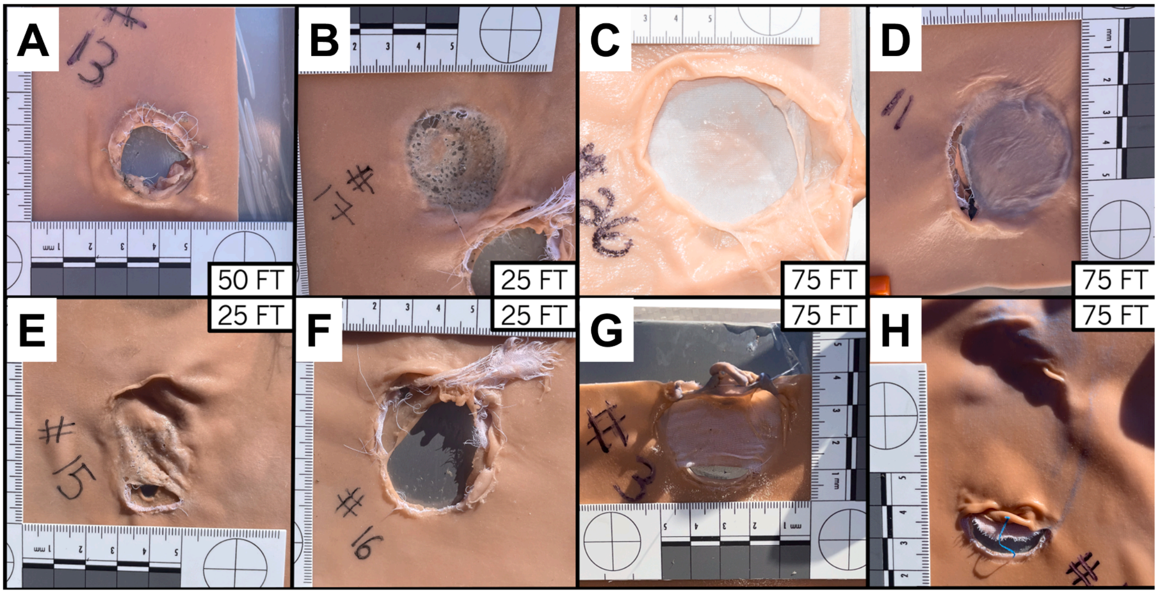

Fig. 2. Defects created by less lethal projectiles fired with the target inclined at 90° (top row) and at 45° (bottom row) A. Accusox beanbag round fired from 15.24 m. B. 2581 beanbag round fired from 7.62 m. C. 4557 foam round fired from 22.86 m. D. eXact iMpact foam round fired from 22.86 m. E. Accusox beanbag round fired from 7.63 m. F. 2481 beanbag round fired from 7.62 m. G. 4557 foam round fired from 22.86 m. H. eXact iMpact foam round fired from 22.86 m.

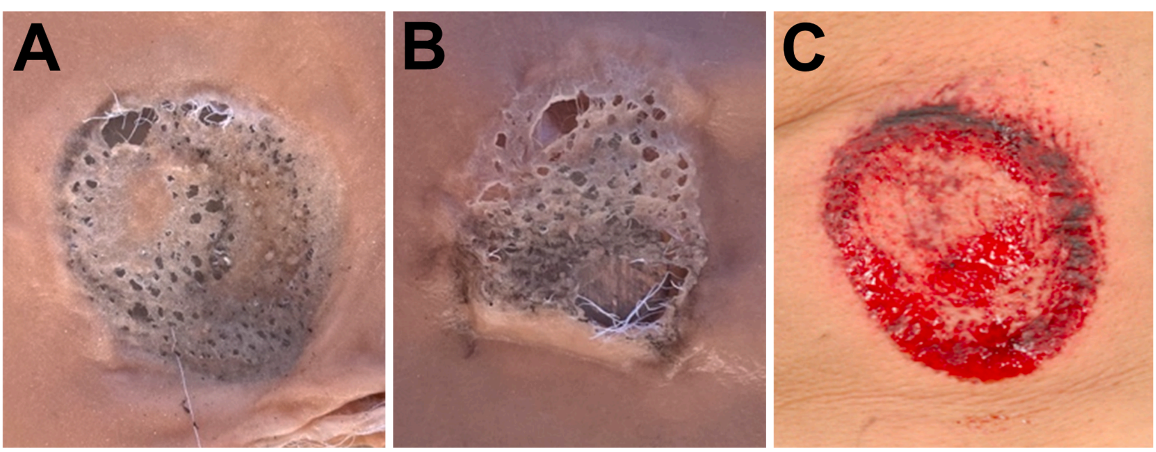

Fig. 3. A, B. Stippling pattern created by impact from beanbag rounds with the synthetic skin. C. Stippling pattern seen in a beanbag inflicted human wound (reproduced from Hudson [8]).

Table 1
Mean kinetic energy, mean impact area and mean energy density for each projectile type.

Projectile Type	Hits	Kinetic Energy (J)	Impact Area (cm^2)	Energy Density (J/cm^2)
Accusox Beanbag	2	120	4.4	29.0
2581 Beanbag	3	161	9.6	18.0
4557 Foam	1	164	18.0	9.1
eXact iMpact Foam	3	145	12.6	11.6

interested in determining whether it would be possible to differentiate between an injury produced by a beanbag round and a foam round, as well as whether an injury was due to a direct hit by a less lethal projectile or by an impact at an angle. Three findings stand out in relation to our objectives.

First, the defect created by beanbag rounds created a smaller defect surface area than foam rounds and penetrated the synthetic skin whereas foam rounds crushed the synthetic skin. This suggests that a penetrating wound is more likely to have been caused by a beanbag round than a foam round. Although a contusion without penetration is more likely to have been caused by a foam round than a beanbag round, it is still possible to have been caused by a beanbag round. In particular, headware can attenuate the effect of less lethal projectile impact reducing the likelihood of scalp penetration. Nevertheless, the presence of a stippling pattern, when present, was exclusively associated with beanbag round impacts. Second, the larger surface area of the defects produced by foam round impacts suggests that the surface area of contusions produced by less lethal projectile impacts could serve to distinguish between impacts from beanbag round and foam rounds. However, such a distinction is tenuous at this point since we do not know the relation between the surface area of a skin contusion and the surface area of a synthetic skin defect created by the impact of a less lethal projectile. Third, small tears in the synthetic skin are analogous to skin lacerations [7]. Although these occurred for both beanbag round and foam round impacts, they tended to occur more frequently when the target was inclined at 45° than when it was inclined at 90°.

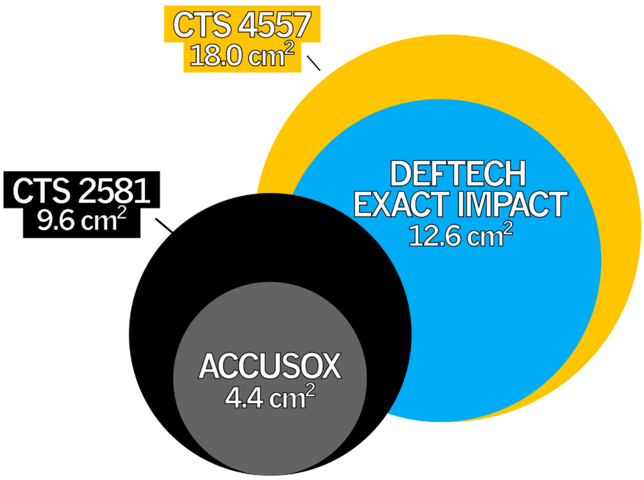

Fig. 4. Comparison of mean defect surface area for beanbag and foam rounds illustrated to scale.

Overall, the tests with the synthetic skin demonstrated that the defect pattern created by the impact of a less lethal projectile can provide useful information in a forensic investigation attempting to identify the type of less lethal projectile responsible for a scalp injury. The size of the defect, the extent of the penetration, the likelihood of laceration and the presence of stippling are characteristic distinguishing features between beanbag round impacts and foam round impacts. The present preliminary study was limited by the number of less lethal rounds available for testing. More comprehensive tests should include targets set at different distances to determine the effect of air resistance, as well as measurement of impact velocity and force rather than muzzle velocity. In addition, less lethal projectile firing conditions, corresponding to cases such as those documented in Rajaram et al. [4], should be replicated with synthetic skin, including a subcutaneous fat simulant, to better determine how human wound characteristics map to synthetic skin defects.

CRediT authorship contribution statement

Marc-André Nolette: Writing – review & editing, Visualization. **Desmoulin Geoffrey:** Writing – review & editing, Supervision, Funding acquisition, Data curation, Conceptualization. **Milner Theodore:** Writing – original draft, Formal analysis.

Declaration of Competing Interest

The authors have no conflict of interest as a result of being involved in this study and the entire study was funded internally by GTD Scientific Inc.

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