Low Velocity Gunshot Wounds Result in Significant Contamination Regardless of Ballistic Characteristics

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Abstract

Controversy exists among the orthopedic community regarding the treatment of gunshot injuries. No consistent treatment algorithm exists for treatment of low energy gunshot wound (GSW) trauma. The purpose of this study was to critically examine the wound contamination following low velocity GSW based upon bullet caliber and clothing fiber type found within the injury track.

Four types of handguns were fired at ballistic gel from a 10-foot distance.

Various clothing materials were applied (denim, cotton, polyester, and wool) circumferentially around the tissue agar in a loose manor. A total of 32 specimens were examined. Each caliber handgun was fired a minimum of 5 times into a gel.

Regardless of bullet caliber there was gross contamination of the entire bullet track in 100% of specimens in all scenarios and for all fiber types. Furthermore, as would be expected, the degree of contamination appeared to increase as the size of the bullet increased.

Low velocity GSWs result in significant contamination regardless of bullet caliber and jacket type. Based upon our results further investigation of low velocity GSW tracks is warranted. Further clinical investigation should focus on the degree to which debridement should be undertaken.

In 2009, according to the Centers for Disease Control and Prevention, there were 66,769 nonfatal gun related injuries in the United States.[1] Controversy exists among the orthopedic community regarding the treatment of these injuries. The Tscherne classification stratifies soft-tissue wounds and degrees of contamination.[2] The degree of injury generally dictates the need for, and degree of, operative intervention. The tissue damage spectrum ranges from pin holes to large soft-tissue defects with or without bone defects. In the case of the large soft-tissue defect or gross contamination, surgery with a formal irrigation and debridement in the operating room is indicated. However in other cases, where there is a lesser degree of soft-tissue injury, the management of the wound is less clear. Traditionally, operative intervention has been dependent upon the velocity of the gunshot wound (GSW), degree of contamination, and associated bony injury.[3] With regard to low velocity wounds, those induced by a bullet traveling less than 609.60m/sec, have largely been treated by a superficial irrigation in the emergency department in concert with a short course of oral antibiotics.[4]

Penetrating trauma has become a significant health care concern.[5,6] Traumatic injury is the leading cause of death among persons younger than 44 years of age, and within this group, firearms are second only to motor vehicle collisions as the cause of such mortality.[7-12] Increasingly, more and more civilians own handguns.[13,14] Descriptions of ballistic injuries date back prior to the civil war when a low velocity GSW in an extremity could lead to either death from gangrene or an amputation. The need for amputation was secondary to imminent local infection leading to sepsis and possibly death. As time passed and technology progressed, bullet injury stratification was necessary in order to determine proper treatment.

It has been dogma that the bullet, once fired from a weapon, is itself sterile. A number of studies, however have demonstrated that the bullet is not sterile when fired from a weapon.[15-18] It has also been shown that the high temperature the bullet attains after being fired does not sterilize the surrounding matter the bullet enters.[4] Bacteria accumulated before the discharge of the missile can remain at the point of tissue impact.[19] It has been the senior author's experience that low velocity GSWs are almost always contaminated by matter brought in from the environment (**Figure 1**).

Figure 1. Projectile removed from patients with cloth material found attached to them.

When a bullet enters the

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Figure 2. (**A**).22 lr Smith and Wesson, (**B**) .38 Spl Smith and Wesson, (**C**) 9 mm Glock, (**D**) .45 GAP Glock.

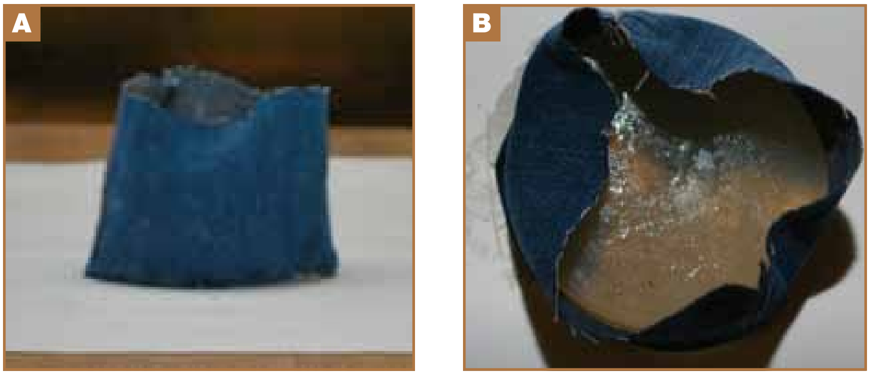

Figure 3. Photograph of 13 cm diameter ballistics gel with circumferential denim on shooting stand. (A) Looking directly at target from shooting stand. (B) Looking down on target from above.

body there is a temporary cavity that is created[3,4,20] which may introduce foreign material.[16,21,22] Based upon these facts, it is reasonable to assume that most, if not all, bullet wounds would be contaminated and require formal irrigation and debridement. This, however, has not been common practice. No consistent treatment parameters exist in the US. The usual practice is not to perform a formal irrigation and debridement for low velocity GSWs that are neither grossly contaminated nor involved with a fracture or neurovascular injury.

Handguns are considered low energy weapons with muzzle velocities below 426.72 mps. The 3 most common caliber handguns involved with nonfatal gun injuries in the US are the 9 mm, .22 caliber, and .38 caliber.[23] It has been shown that bullet caliber identified in low energy civilian GSWs has been increasing[20] over the past 2 decades. The purpose of this study was to critically examine the wound contamination following low velocity GSW based upon bullet caliber and clothing fiber type found within the bullet cavity and injury track.

Materials and Methods

This study was performed in conjunction with the New York State Police. In order to examine the most common handgun injuries encountered at our large Urban trauma center we studied 4 handguns: the .22 caliber Smith and Wesson (22 lr), .38 Smith and Wesson (.38 Spl), 9 mm Glock (9 mm luger), and a .45 caliber Glock (.45 GAP) (**Figures 2A-2D**).

To simulate human tissue, we used a well established tissue model of ballistic gelatin.[24] Gelatin 1 kg, was added to 9 L of distilled water and maintained at 7° to 10° C. The gelatin-water mixture was agitated by stirring to wet all particles and kept in the refrigerator for 2 hours to hydrate all gelatin particles. The container was then heated in a hot water bath with mild stirring to avoid all bubbles. The bath was maintained at 30° to 38° C until all the gelatin was in the solution and evenly dispersed throughout the container. The gelatin solution was then poured into cylindrical molds resembling the circumference and diameter of the average adult human thigh and allowed to congeal at 7° to 10° C for approximately 12 to 18 hours. All gels were single use only and used within 36 hours. The solid translucent nature of the gels allowed detailed examination of the entrance and exit wounds as well as the path of the projectile.

Each weapon was fired from a 10-foot distance to the gel, which is considered close range.[14] In order to simulate the real world conditions we applied various clothing materials circumferentially around the tissue agar in a loose manor (**Figures 3A-3B**). Clothing fibers included denim, cotton, polyester, and wool.

All weapons were fired by one of the authors under the supervision of the State Police lead sharpshooter. Each agar was shot at only once. Following each simulated GSW, the agars were examined for penetration and signs of contamination from the clothing debris by visual macroscopic examination and microscopic examination using 3.5X magnification loupes. Under the direction of a police provided ballistics expert, the entrance and exit wounds were inspected as well as the pattern in which the gel was damaged. Then the ballistic gels were cut in half along the course of the bullet and the tract was examined for depth of penetration of the contaminate clothing or bullet fragments. We classified each wound based upon the classification of wound contamination by Gugala and Lindsey.[25] Typical clean low-energy GSWs are assigned as C-1, wounds contaminated with clothing as C-2, and heavily contaminated wounds with missile disruption of the viscous or traversing bowel as C-3.

Both full metal jacket (FMJ) and hollow point (HP) bullets were utilized in testing in order to assess the effect of this variable on the degree of wound contamination (**Figure 4**). In order to collect the HP bullets we developed a novel technique. Each gel examined in this phase of the experiment was maintained on the shooting stand and an article of clothing was placed over the front. Immediately behind the gel was the backdrop of a bullet proof vest. This ensured that the specimen would not get excess residual fiber types in the bullet due to both an entrance and exit wound. After firing into the gel, the bullet projectile was stopped by the bullet proof vest and collected for visual examination of any fiber accumulation. A police forensic photographer took all photographs.

Wound contamination was calculated by measuring the particle debris track with a ruler (**Figure 5**). The individual measurements of the particles were recorded. A total of 32 specimens were examined. Each caliber handgun was fired a minimum of 5 times into a gel with different clothing with standard FMJ and HP bullets. A standard FMJ bullet is either ball or flat faced as opposed to a HP bullet that contains a cavity and is designed to expand through the cavity upon impact. Descriptive statistics were utilized to report on the wound classification among the various bullet types.

Figure 4. Gel shot with .22 caliber bullet cut in half along projectile pathway demonstrating gross contamination with denim.

Results

Regardless of bullet caliber there was gross contamination seen in 100% of specimens in all scenarios and for all fiber types (**Table, Figure 3**). We also found that the FMJ bullet casing did not alter the degree of contamination. Furthermore, as would be expected, the degree of contamination appeared to increase as the size of the bullet increased (**Figures 4-8**).

When examining wounds with larger caliber projectiles such as the 9 mm, .45, and .38 caliber bullets, the size of the particles as well as the total amount of contamination increased as the caliber size increased.

Of note, most gels shot with HP bullets were completely fractionated and the pieces were unable to be assembled for photography. This occurred most commonly with the larger .45 caliber HP bullets. However there was gross contamination noted in the dispersed pieces of gel.

When we examined the HP bullets to see how much debris was retained in the hollow portion of the bullet, we confirmed that the cloth changed the dynamics of the bullet. Additionally, we found that the HP was full of fiber material and thus did not expand as a HP would be expected. Each bullet fired demonstrated varying degrees of retained debris (**Figure 9**). This finding demonstrates that a large amount of contaminated foreign material would be introduced if the HP bullet were to be retained within the patient.

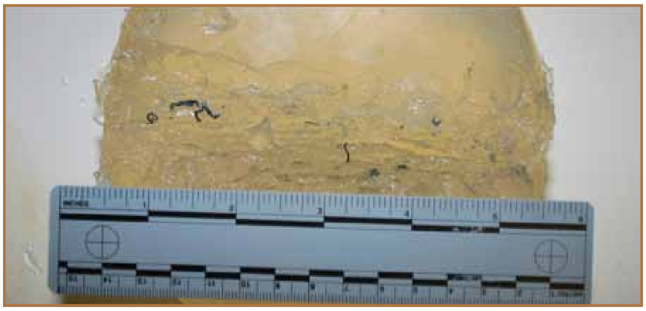

Figure 5. Overview of a gel shot with .38 caliber bullet demonstrating gross contamination with denim throughout entire pathway as well as entrance and exit wound.

Discussion

In order to assess the degree of contamination that occurs following low velocity GSW trauma, we used a model to simulate real world conditions that a patient might experience when sustaining this type of injury. We found that regardless of bullet size or jacket type, 100% of the wounds were grossly contaminated throughout the length of the bullet tract. We also found that when a HP bullet is shot through denim and

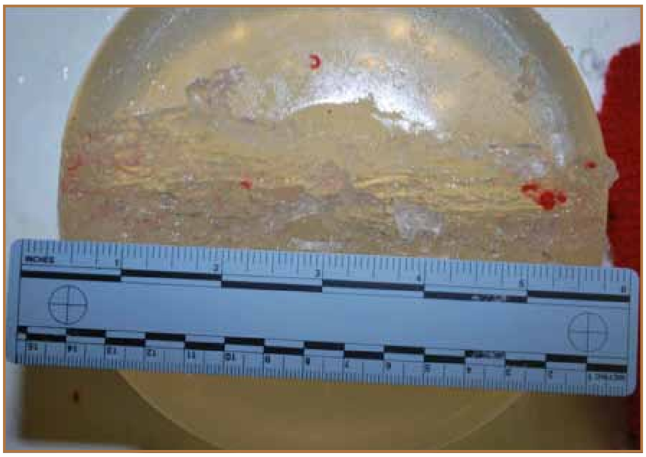

Figure 6. Gel shot with .38 caliber bullet demonstrating large collection of wool bunched at the exit wound and a wide dispersal of individual fibers at the entrance wound.

Figure 7. Gel shot with a .45 caliber bullet with denim contamination.

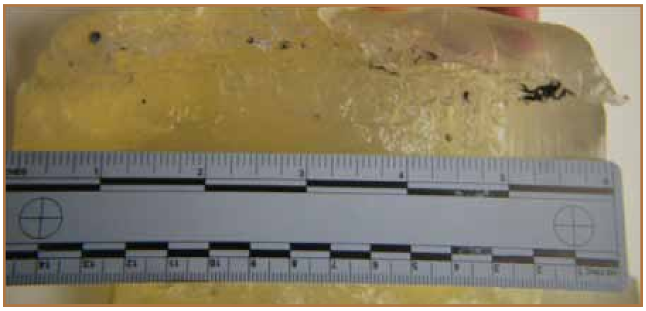

Figure 8. Gel shot with 9 mm full metal jacket bullet cut in half demonstrating cotton sweatshirt gross contamination along the entire course of the bullet pathway.

retained within the body there is a great possibility that there will be retained denim within the bullet. This study used clear ballistics gel, which helps visualize the contamination that is dragged into the wound. The photographs document contamination that could easily be missed in a bloody surgical field.

A significant body of previous literature exists which examines wounds associated with gunshot injuries in relation to high-velocity gunshot injuries, typically those associated with military-style weapons in the setting of war or close-range shotgun injuries. Low-velocity gunshot injuries, occurring among the civilian population in an urban setting, differ in that there is minimal tissue destruction when compared with high-velocity gunshot injuries as a result of less cavitation and shock-wave damage. Although strong evidence exists for current treatment strategies involving high-velocity gunshot injuries, the treatment of low-velocity gunshot injuries is less clear. The current theory and practice is to administer antibiotics when there is obvious gross contamination. However, the duration, bacterial coverage, mode of administration, and even the indication for is debatable.[9,17,18,26] The absolute indications for formal surgical irrigation and debridement include neurovascular injury, gastrointestinal tract or joint involvement, fracture, tendinous injury, compartment syndrome, massive soft-tissue injury, or obvious wound contamination.[4] The timing of surgical irrigation and debridement, or operative repair, after the initial GSW is also debatable.

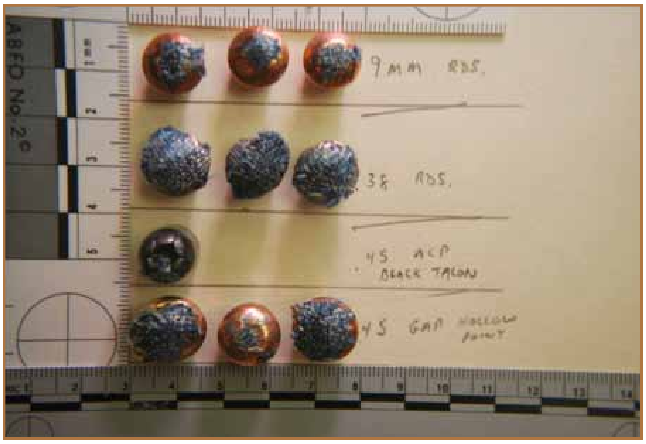

Figure 9. Photograph demonstrating 4 types of bullets that were shot through ballistics gels with denim material only covering the entrance wound. The bullets were stopped by Kevlar bulletproof vests and collected for visual examination. The top row shows three 9 mm full metal jacketed bullets. The second row shows three .38 caliber bullets. The third row shows a .45 mm black talon bullet. The last row shows three .45 mm hollow point bullets. All bullets collected had retained denim fibers.

The limitations of this study include the fact that our shooting trajectory was not identical for each gel. This was due to different shooters with differing shooting styles of investigators. Differences in composition and casing of bullets from different manufacturers, which could have affected wound contamination. Differences in bullet composite and casing may be influential in the injury patterns and contamination that occurs. We only investigated 4 types of handguns, thus our results only apply to those tested. Furthermore, the number of gels per bullet type could have been increased to show even more reproducibility, although there is no evidence that a "clean through and through" wound is possible. While these data demonstrated a significant amount of contamination with a low velocity GSW, our model does not account for any effect the skin might have in diminishing penetration or minimizing bacterial contamination. Finally, while every bullet track may be contaminated, there has been no clinical evidence to date that there is a threshold amount of contamination that leads to an infected wound.

This study calls into question the practice of "benign neglect" in the treatment of low velocity GSWs. It is clear that bullet wounds such as these pose a concern for future infection at the injury site. A thorough firearms history should be obtained from the patient or police if possible. It would seem, based upon our results consideration for formal debridement of low velocity GSW tracks is indicated in some cases, particularly in those where the bullet first penetrated garments worn by the wounded.

Further clinical investigation should focus on the degree to which debridement should be taken and improving follow-up in patients who sustain these injuries to account for any possible complications. In the future an in vivo randomized control study would be of significant help in order to properly define

Table. Results of Ballistics Contamination

Gel	Bullet type	clothing type	contamination
1	.22 caliber	blue denim	Class 2
2	.22 caliber	blue denim	Class 2
3	.22 caliber	blue denim	Class 2
4	.22 caliber	blue denim	Class 2
5	.22 caliber	red wool	Class 2
6	.22 caliber	red wool	Class 2
7	.22 caliber	polyester	Class 2
8	.22 caliber	cotton	Class 2
9	9 mm FMJ	blue denim	Class 2
10	9 mm FMJ	blue denim	Class 2
11	9 mm FMJ	red wool	Class 2
12	9 mm FMJ	cotton	Class 2
13	9 mm FMJ	polyester	Class 2
14	9 mm HP	blue denim	Class 2
15	9 mm HP	blue denim	Class 2
16	9 mm HP	red wool	Class 2
17	9 mm HP	red wool	Class 2
18	9 mm HP	cotton	Class 2
19	.38 HP	blue denim	Class 2
20	.38 HP	blue denim	Class 2
21	.38 HP	red wool	Class 2
22	.38 HP	cotton	Class 2
23	.38 caliber	blue denim	Class 2
24	.38 caliber	blue denim	Class 2
25	.38 caliber	red wool	Class 2
26	.38 caliber	cotton	Class 2
27	.38 caliber	polyester	Class 2
28	.45 mm GAP	blue denim	Class 2
29	.45 mm GAP	red wool	Class 2
30	.45 mm GAP HP	blue denim	Class 2
31	.45 mm GAP HP	blue denim	Class 2
32	.45 mm GAP HP	red wool	Class 2

Further clinical investigation should focus on the degree to which debridement should be taken.

operative indication. Of note, the senior author has been operatively debriding these bullet wounds in the past. It is felt by him that the results of this paper support this continued practice.

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