World J Surg (2015) 39:1840–1847
DOI 10.1007/s00268-015-3004-x

ORIGINAL SCIENTIFIC REPORT

Myths and Misinformation About Gunshot Wounds may Adversely Affect Proper Treatment

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Published online: 10 February 2015

Abstract

Background Poorly designed experiments and popular media have led to multiple myths about wound ballistics. Some of these myths have been incorporated into the trauma literature as fact and are included in Advanced Trauma Life Support (ATLS). We hypothesized that these erroneous beliefs would be prevalent, even among those providing care for patients with gunshot wounds (GSWs), but could be addressed through education.

Methods ATLS course content was reviewed. Several myths involving wound ballistics were identified. Clinically relevant myths were chosen including wounding mechanism, lead poisoning, debridement, and antibiotic use. Subsequently, surgery and emergency medicine services at three different trauma centers were studied. All three sites were busy, urban trauma centers with a significant amount of penetrating trauma. A pre-test was administered prior to a lecture on wound ballistics followed by a post-test. Pre- and post-test scores were compared and correlated with demographic data including ATLS course completion, firearm/ballistics experience, and years of post-graduate medical experience (PGME).

Results One-hundred and fifteen clinicians participated in the study. A mean pre-test score of 34 % improved to 78 % on the post-test with associated improvements in all areas of knowledge ($p < 0.001$). Years of PGME correlated with higher pre-test score ($p = 0.021$); however, ATLS status did not ($p = 0.774$).

Conclusions Erroneous beliefs involving wound ballistics are prevalent even among clinicians who frequently treat victims of GSWs and could lead to inappropriate treatment. Focused education markedly improved knowledge. The ATLS course and manual promulgate some of these myths and should be revised.

Introduction

Poorly designed ballistics experiments as well as popular media have led to a number of incorrect ideas about wound ballistics and gunshot wound (GSW) care. Webster defines myth as "an idea or story that is believed by many people but that is not true" [1]. Some of these myths have been incorporated into the trauma literature, are accepted as fact,

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and are also included in the Advanced Trauma Life Support (ATLS) course. Since ATLS serves as a common basis of trauma knowledge and initial trauma management, care based on these ideas has the potential to be either inadequate or overly aggressive. We hypothesized that these erroneous beliefs would be prevalent among those frequently providing care for patients with GSWs but could be addressed by education.

Materials and methods

The ATLS course was reviewed, and a number of myths involving wound ballistics were identified. Subsequently, a directed review of the literature revealed clinically relevant myths and evidence to refute these misconceptions (Table 1) [2–24].

The study was created using a pre- and post-intervention design addressing seven different topics relating to GSWs. Individual questions testing the same concept relating to the specific topics were constructed for both the pre- and post-test by the authors with knowledge of weapons and ballistics (SCH, JWD) (Appendix). The study was performed at three academic trauma centers: UCSF Fresno, UC San Diego, and UCSF East Bay (Oakland). UCSF Fresno is a 633 bed ACS verified Level I trauma center with approximately 2,600 annual trauma admissions and 15 % penetrating trauma. UC San Diego is a 365 bed ACS verified Level I trauma center with approximately 3,200 annual trauma admissions and 12 % penetrating trauma. UCSF East Bay is a 220 bed level II Trauma center with approximately 1,100 annual trauma admissions and 30 % penetrating trauma. All three institutions have residencies in surgery and emergency medicine.

Education consisted of a 40 min lecture on the topic of GSWs and relevant wound ballistics. The lecture was given to each of the study groups by the same presenter. The pre-test was administered prior to the lecture with approximately 5–10 min allowed to complete the pre-test. At the completion of the lecture, another 5–10 min were allotted for post-test completion. Test results were completely anonymous. Participation was voluntary and included providers on the trauma and emergency medicine services with almost all choosing to participate.

Subjects' pre- and post-test scores were compared using the Wilcoxon signed-rank test. Pre-test scores were compared among institutions with ANOVA. Demographic data including ATLS course completion, firearm/ballistics experience, and years of post-graduate medical experience (PGME) were collected and correlated with pre- and post-test scores using the Pearson r correlation coefficient. Using a Likert 5 point scale, subjects were also queried if their understanding of wound ballistics had improved, and whether the lecture would alter their management of GSWs.

The study was approved by the Institutional Review Board of UCSF/Fresno and Community Regional Medical Centers, Fresno, CA and qualified for waiver of consent.

Table 1 Brief description of the myth with corresponding references to refute the myth

Myth	Reference number
Shotguns are only lethal at close range	[6], [7], [22]
Antibiotics are not necessary	[2], [3], [4], [5], [8], [9], [10]
Initial reaction exaggeration	[4], [19], [24]
Cavitation occurs at 30–100X	[3], [18], [19], [23]
Wounding mechanism = energy transfer	[2], [3], [4], [5], [17], [18]
Over importance of debridement	[3], [4], [19], [21]
Bullet removal/lead poisoning	[11], [12], [13], [14], [15], [16]

Results

A total of 115 clinicians participated in the study (UCSF/Fresno 50, UCSD 17, UCSF/East Bay 48). The mean pre-test scores for individual topics ranged from 5 to 81 % correct with a mean of 34 % (Table 2). Pre-test scores suggested that myths relating to lack of need for antibiotics (21 %), kinetic energy transfer wholly explaining wounding mechanism (5 %), and shotguns being lethal only at close range (25 %) were the most prevalent. Initial reaction of the victim was the only topic where over 75 % of the participants answered the pre-test question correctly. There was no significant difference in pre-test scores between the institutions ($p = 0.764$) and post-test scores improved significantly ($p < 0.001$) with an average score of 78 %. Statistically significant improvement occurred for each of the covered topics on the post-test (Table 2). Wounding mechanism was the only topic on the post-test with less than 75 % correct.

Demographic data were collected and compared with pre-test results using Pearson's r correlation. Years of PGME correlated with higher pre-test score ($p = 0.021$) suggesting that knowledge was gained from experience and/or education (Table 3). Despite this, even the most experienced providers had a mean pre-test score of only 40 %. Although only 50 % of test subjects were currently certified in ATLS, ATLS status did not correlate with higher pre-test scores ($p = 0.774$) (Table 4). Only 16 % of subjects felt comfortable using a firearm, and previous firearm/wound ballistics experience did not correlate with higher pre-test scores.

Table 2 Topics for specific questions are listed with their associated average pre- and post-test scores. The corresponding *p* values show a statistical difference between the pre- and post-test values

Question topic	Pre-test (%)	Post-test (%)	*p* value
Shotguns	25	93	<0.001
Antibiotics	21	86	<0.001
Initial reaction	81	97	<0.001
Cavitation	12	86	<0.001
Wounding mechanism	5	22	<0.001
Importance of debridement	57	88	<0.001
Lead poisoning	32	75	<0.001
Overall average	34	78	<0.001

After the intervention, the vast majority of subjects (94 %) indicated that they had a better understanding of wound ballistics. In addition to improved understanding, the majority (68 %) indicated that they would alter their management of GSWs.

Discussion

Erroneous beliefs about GSW and wound ballistics are common and have been perpetuated in the trauma literature [20, 23]. Many of the misconceptions on wound ballistics are a result of errors in previous experimental design [3, 19]. Tissue simulants lack the complex structure of the human body and are thus devoid of skin and strong fascial planes which greatly alter the wound profile [5]. The use of non-elastic tissue simulants (e.g., clay) preserves the maximum wound cavity and does not accurately represent the amount of damage in the elastic tissues of the human body [3]. Elastic tissue simulants, like gelatin, may be improperly mixed and not appropriately calibrated with actual tissue, leading to falsely exaggerated penetration and cavitation [3, 4, 20]. Several studies used spheres to represent the bullet; however, this is misleading since the shape and construction of the bullet greatly alter the wound [3]. To further complicate matters, many studies assumed small animals (10–20 kg) were valid models for humans. However, small animals have less tissue/mass around the bullet path thereby decreasing the energy necessary to move the tissue outward from the bullet path, thus, over exaggerating the temporary cavity [3].

Some of the prevalent myths about wound ballistics including those relating to shotgun wounds, cavitation, and wound care were examined in this study. Shotgun injuries are described in the ATLS manual as "lethal at close range, but (its) destructive potential rapidly dissipates as distance increases" [2, p. 406]. There is significant variability in shotgun rounds; the generalization that shotgun injuries are only lethal at close range is misleading and could potentially cause clinicians to underestimate the injuries in patients with moderate to long distance shotgun wounds. A single shotgun "slug" is larger than most rifle rounds (12 gage is .730 caliber), "OO (double ought) buckshot" is the equivalent of multiple 9 mm handgun projectiles, and "birdshot" consists of hundreds of small lead pellets less than 0.147 inches in diameter. The ATLS statement is accurate for birdshot; however, buckshot or slug rounds can be lethal at over 150 yards [6, 7, 22].

Table 3 Pre-test scores are shown stratified by post-graduate year

PGY category	Number of subjects	Average pre-test score
less than 2	40	0.33
2–3	35	0.27
4–5	18	0.36
5–10	9	0.46
10 plus	13	0.40

Cavitation is defined as the temporary cavity that is created as the bullet travels through tissue. This phenomenon has been significantly exaggerated in the literature, suggesting that it can be 30–100 times the diameter of the projectile [2, p. 405, 3]. Cavitation has also been falsely associated with only high-velocity projectiles [3]. However, cavitation occurs with both high and low velocity projectiles [3, 18, 19]. The temporary cavity generated tends to occur to a greater degree with higher velocity projectiles; however, even with high powered rifle rounds traveling as fast as 1,031 m/s, the maximal temporary cavity is only 12.5 diameters of the projectile [3, 18, 19]. The temporary cavity should chiefly be considered as tissue stretch which affects solid organs like the liver significantly more than hollow organs or muscle [3, 18]. If cavitation created significant tissue damage at 30–100 times the diameter of the projectile, a GSW to the abdomen would require resection of the majority of abdominal viscera (Fig. 1), and an extremity GSW would require amputation [23].

The need for debridement of GSWs is another concept that has been overemphasized [19, 23]. Removal of devitalized tissue to prevent wound infection is important. However, this concept has been erroneously expanded to include recommendations to excise the entire wound tract. Excising viable tissue that has only been stretched by temporary cavitation is not beneficial and only leads to a larger, more disfiguring wound [3, 4]. According to Owen-Smith, cell death extends up to 20 cm beyond the edge of the wound [21]. If this was true, essentially every GSW to the abdomen would be lethal [3].

Antibiotic therapy has been dismissed as nonessential by some texts and is not mentioned in others [2, 3, 5]. Another common misconception is that bullets are sterile because of

Table 4 ATLS and firearm/ballistics experience demographic data are reported by institution

Demographic	Oakland *n* (%)	Fresno *n* (%)	San Diego *n* (%)	Overall *n* (%)
ATLS status				
Never taken course	33 (69)	12 (24)	5 (29)	50 (43)
Currently certified	12 (25)	34 (68)	11 (65)	57 (50)
Expired ATLS	3 (6)	4 (8)	1 (6)	8 (7)
Firearms/ballistics experience				
None	19 (40)	20 (40)	8 (47)	47 (41)
Minimal	24 (50)	19 (38)	6 (35)	49 (43)
Some	5 (10)	11 (22)	3 (18)	19 (17)
Expert	0(0)	0 (0)	0 (0)	0(0)

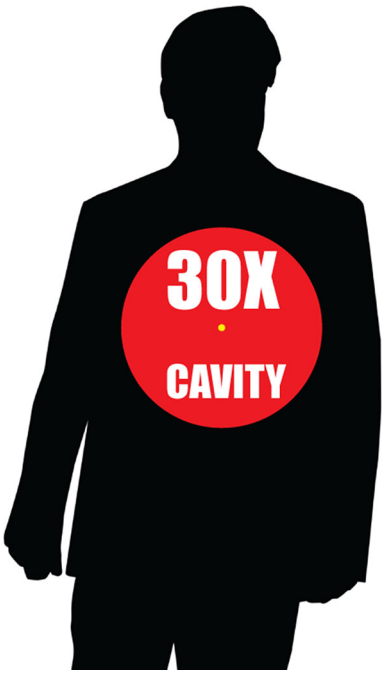

Fig. 1 Representative human silhouette showing a 9 mm or .38 caliber projectile surrounded by a cavity 30 times the diameter

the immense heat and pressure generated with firing [5]. However, when bullets are fired into a sterile medium, the medium becomes inoculated with bacteria from the bullet [5]. Similarly, bullets inoculated with *Staphylococcus aureus* and fired into sterilized sand resulted in universally positive cultures from the retrieved bullet [8]. Furthermore, skin and clothing, neither of which are sterile, can be carried deep into the wound by the bullet [5]. Fackler noted that streptococcal bacteremia was the most common cause of death for victims of battlefield related missile wounds in the preantibiotic era [4]. He further described a decrease in wound infection, associated with GSW, from 5 % in WWI to 0.7 % in WWII and 0.08 % in the Korean War. During this time period, recommended wound debridement did not change, but the antibiotic use increased significantly [3]. More recently, a retrospective study of penetrating combat injuries in Iraq showed a significant reduction in wound infection rates in subjects who received systemic antibiotic prophylaxis. The number needed to treat to prevent one wound infection was only three patients (95 % confidence interval of 2–14) [9]. To date, there have been no large prospective randomized controlled studies delineating the optimal duration of antibiotics for the treatment of GSWs. Current recommendations are for a short duration of antibiotic prophylaxis unless significant soft-tissue disruption, contamination from hollow viscera, or involvement of joint, bone, or CNS has occurred [10].

Popular media has also contributed to the sensationalization of GSWs. The Black Talon round was hyped up by the news media to be a "super bullet"; however, its wound characteristics are similar to any hollow-point bullet [4, 19]. Hollywood movies depict actors being knocked off their feet, dying instantly, and/or wounds spurting blood immediately after being shot. Fackler notes that bullets lack the kinetic energy to knock people off their feet and that by Newton's third law, the person firing the weapon would also have to be knocked off their feet. Even victims with fatal GSWs to the head may walk several yards prior to incapacitation [24]. Interviews conducted with police officers involved in shootings revealed that the gunshot victim's most common initial reaction was nothing at all [4].

The importance of removing the bullet or fragments is another prevalent myth that has been extensively portrayed in motion pictures. However, bullet removal is often unnecessary [11, 12]. Lead poisoning is generally only considered a potential concern, if the projectile is in contact with synovial fluid or within an intervertebral disk [13]. Other indications to remove retained bullets exist, related to the risk of thromboembolism of bullets within a blood vessel or the myocardium [14–16].

The energy contained in a moving projectile is defined by the equation for kinetic energy: $E = 1/2\ mv^2$. In this

equation, velocity is clearly the most important variable in calculating the energy of the projectile; however, this does not directly translate into the degree of damage [3, 17, 18]. The greatest increase in velocity of projectiles occurred with the invention of the copper-jacketed bullet, but this increase in bullet velocity was also associated with a large decrease in the amount of soft-tissue disruption [3, 23]. Many high-velocity rounds enter a victim and exit without hitting much, continuing at almost the same velocity. In these instances, there is little kinetic energy transfer, $E = 1/2\ m(v_1 - v_2)^2$ [2, 5, 17]. The concept of kinetic energy transfer in wounding ("the more energy transferred, the greater the damage") also fails to explain the wounding mechanism [3, 17, 23]. Kinetic energy transfer alone does not take into consideration the interaction between the projectile and tissue as well as the type of tissue disruption [23]. For example, a 4 g (62 grain) bullet traveling 940 m/s, from an M16 assault weapon, results in 1,767 J of kinetic energy. The energy transfer from a 100 kg linebacker moving at 9.83 m/s is 4,831 J, almost three times more than the M16; however, the injuries sustained from the bullet will be substantially worse. This has to do with the rate of energy transfer and the area over which the energy is transferred. The energy transferred from the projectile generally falls into one of two forms: tissue crush, leaving a permanent cavity or tissue stretch causing a temporary cavity [3, 4, 18, 23]. Tissue stretch is generally fairly well tolerated by many parts of the body, and the energy is dissipated without much damage [3–5, 18]. The wound can be greatly altered by bullet fragmentation. Fragmentation of the bullet leads to multiple small sharp pieces of the bullet which lead to multiple small lacerations within the tissue. When these lacerated areas are further stretched during cavitation, it results in more damage and a larger permanent cavity [3, 5, 18].

The low pre-test scores in this study suggest a high prevalence of misinformation among medical providers, even at busy urban trauma centers with significant experience with penetrating trauma. These myths persist either due to a lack of education or incorrect information in the literature. This misinformation has the potential to cause patient harm either through overly aggressive or inadequate treatment [19]. The significant improvement on the post-test after the focused educational intervention suggests the positive benefits of targeted education.

ATLS course completion did not have a positive effect on pre-test scores. The information in the ATLS course is limited to a short section on GSW and wound ballistics with a number of erroneous statements including: temporary cavitation is associated solely with high-velocity bullets, cavitation occurs up to 30 times the diameter of the bullet, shotguns can be lethal at close range but generally not as distances increase, and that it is important to determine whether a wound is an entrance or an exit wound [2]. The overall valuable educational experience of the ATLS course would be enhanced by the correction of the misinformation.

This study has several potential limitations. The pre- and post-tests have not been independently validated; however, the questions were all based on evidence from the literature. The potential for selection bias exists because of the voluntary basis of the study. However, there is little reason to believe that the wound ballistics knowledge or ability to learn would be significantly different in those who chose not to participate. The potential for bias is significantly limited by the multi-institutional nature of the study, although a potential for a regional bias exists as all participating institutions were within California.

Erroneous beliefs involving wound ballistics are prevalent, even among clinicians who frequently treat patients with GSWs, which have the possibility to lead to patient harm. Focused education markedly improved knowledge and has the potential to improve patient care. The current ATLS course and manual promulgate some of these myths and should be revised. Future study is indicated to determine if improved understanding of wound ballistics will improve patient outcomes.

Acknowledgment IRB approval was obtained from the UCSF Fresno/Community Medical Centers Institutional Review Board; this study qualified for waiver of consent.

Conflict of interest None.

Appendix

Ballistics in Medicine

Pretest

1. Have you taken ATLS (Advanced Trauma Life Support) and if so within how many years
   (a) No, I have not taken ATLS.
   (b) Yes, I have had ATLS within the last 1–4 years.
   (c) Yes, but was more than 4 years ago.
2. Please rate your firearms/ballistics experience
   (a) None (never used a firearm).
   (b) Minimal experience (limited experience with firearms).
   (c) Some experience (understand and feel comfortable using a firearm).
   (d) Expert (performed research with firearms or on wound ballistics).

3. Please chose answer that corresponds to your years of post-graduate medical experience

   (a) 1 year
   (b) 2–3 years
   (c) 4–5 years
   (d) 5–10 years
   (e) 10+ years

4. Shotguns are typically only lethal at a range of

   (a) 20 yards or less.
   (b) 40 yards or less.
   (c) 60 yards or less.
   (d) Can be lethal over 100 yards.

5. A 24-year-old male presents to the ED with a gunshot to his right thigh from an assault rifle. Last tetanus shot was 7 years ago. After a primary and secondary surveys which demonstrate intact sensation, movement, and pulses to the affected extremity, initial management should consist of

   (a) Tetanus booster alone.
   (b) X-ray of the thigh and arterial pressure indices.
   (c) X-ray of the thigh, arterial pressure indices, and tetanus booster.
   (d) X-ray of the thigh, arterial pressure indices, tetanus booster, and IV antibiotics.
   (e) CT angiogram of the thigh and tetanus booster.

6. You see a police officer fires a gun at an assailant; the bullet hits him in the chest

   (a) When the bullet hits him in the chest, it will knock him off his feet.
   (b) He will immediately collapse to the ground.
   (c) Blood with spurt from the chest.
   (d) There will be little to no outward sign that he has been shot.

7. A 16-year-old male is dropped off at the emergency department after sustaining a gunshot wound to the right chest. The police say it was from a high-velocity assault rifle. Which of the following statement is most correct

   (a) The patient will likely need extensive debridement beyond the edges of the wound because cavitation can stretch the tissue up to 100 times the diameter of the bullet.
   (b) Cavitation can be up to 30–40 times the diameter of the bullet and can cause injury far from the bullet tract.
   (c) Cavitation type injury to the lung will be more significant than the liver because it is mostly full of air.
   (d) The majority of penetrating chest trauma does not require operative intervention.

8. A 23-year-old male is shot with a gun. Of the following which is the greatest determinant of damage from a ballistic missile

   (a) Kinetic energy transferred to the tissue.
   (b) Type of missile (i.e., hollow point vs. full metal jacket vs. shotgun).
   (c) Bullet caliber.
   (d) None of the above.

9. A 35-year-old female sustains a high-velocity gunshot wound to her right thigh. Debridement is

   (a) Not important.
   (b) Important to remove obviously non-viable tissue.
   (c) Important to remove obviously non-viable tissue and then close the wound to prevent contamination.
   (d) Important to remove tissue beyond areas of obviously non-viable tissue because microscopic cell death occurs far from the edge bullet hole.

10. A 4-year-old female was shot in the thigh. Of the following statement is most correct

    (a) The majority of bullets made today are not made of lead, hence there is little need to worry about lead poisoning.
    (b) The lead bullet should be removed to prevent lead poisoning because the bullet is large compared to the size of the child.
    (c) Dimercaprol (BAL) should be given as chelation therapy because of the large-sized lead bullet.
    (d) Unless the bullet is in contact with a joint space, there is no need to worry about lead poisoning.

Ballistics in Medicine

Posttest

1. I have a better understanding of wound ballistics

   (a) Strongly disagree.
   (b) Disagree.
   (c) Neutral.
   (d) Agree.
   (e) Strongly agree.

2. This lecture will alter my management of gunshot wounds?

   (a) Strongly disagree.
   (b) Disagree.
   (c) Neutral.
   (d) Agree.
   (e) Strongly agree.

3. A 28-year-old female sustains a gunshot wound to her torso from a 12 gage shotgun firing OO buckshot. There are 5 wounds each about 5–7 inches apart.

   (a) There should be little concern about deep penetration because the pellets are so far apart, and it would be a shotgun wound from a long range.
   (b) Regardless of how far apart the wounds are, they should be treated as separate gunshot wounds (i.e., being shot with a pistol multiple times).
   (c) OO buckshot is a very small projectile unlikely to cause much harm.
   (d) Treatment should consist of antibiotics and tetanus prophylaxis alone.

4. A 34-year-old female presents to the ED with a gunshot to her left upper arm from an assault rifle. Last tetanus shot was 7 years ago. After a primary and secondary surveys which demonstrate intact sensation, movement, and pulses to the affected extremity, initial management should consist of:

   (a) Tetanus booster alone.
   (b) CT angiogram of the thigh and tetanus booster.
   (c) X-ray of the arm and arterial pressure indices.
   (d) X-ray of the arm, arterial pressure indices, and tetanus booster.
   (e) X-ray of the arm, arterial pressure indices, tetanus booster, and IV antibiotics.

5. You witness a shooting in the ED parking lot, a woman is shot in the back. She will most likely

   (a) be knocked off her feet when the bullet strikes her
   (b) immediately collapse to the ground
   (c) have blood spurting from the wound
   (d) continue to stand there with little to no outward sign that she has been shot

6. A 27-year-old male is dropped off at the emergency department after sustaining a gunshot wound to the back. The police say it was from a high-velocity assault rifle with a full metal jacket bullet. Which of the following statement is most correct

   (a) Cavitation should not be considered because it does not occur with full metal jacket bullets.
   (b) Cavitation type injury to the lung will be more significant than the liver because it is mostly full of air.
   (c) Cavitation can be up to 30-40 times the diameter of the bullet and can cause injury far from the bullet tract.
   (d) Temporary cavitation is a phenomenon that occurs with both low- and high-velocity projectiles.

7. A 33-year-old male is brought in by ambulance after being shot with a 357 magnum. Of the following which is the greatest determinant of damage from a ballistic missile

   (a) Muzzle velocity (how fast the bullet is traveling when it leaves the gun).
   (b) Type of missile (i.e., hollow point vs full metal jacket vs. shotgun).
   (c) Kinetic energy transferred to the tissue.
   (d) The fact is was a magnum round.
   (e) None of the above.

8. A 25-year-old male sustains a high-velocity gunshot wound to his left thigh. In regards to the patients care

   (a) Debridement is not important.
   (b) Debridement should be performed if there is obviously non-viable tissue.
   (c) Debridement should be performed if there is obviously non-viable tissue followed by immediate closure of wound to prevent contamination.
   (d) Debridement should be performed to remove tissue beyond areas of obviously non-viable tissue because microscopic cell death occurs far from the edge bullet hole with high-velocity wounds.

9. A 35-year-old female was shot in the right thigh with a civil war era musket firing a 50 caliber lead slug. Of the following statement is most correct

   (a) The majority of bullets made today are not made of lead, hence there is little need to worry about lead poisoning.
   (b) The lead bullet should be removed to prevent lead poisoning.
   (c) Unless the bullet is in contact with a joint space, there is no need to worry about lead poisoning.
   (d) dimercaprol (BAL) should be given as chelation therapy because of the large-sized lead bullet.

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