An Unusual Feature of Graze Gunshot Wounds

Michael M. Heninger

ABSTRACT

All graze wounds that occurred in the jurisdiction of the Fulton County Medical Examiners Center over a ten-year period (2005-2014) were inspected. Of a total of 227 graze wounds, 31 (14%) exhibited a previously not well-described feature. At one end of the graze wound, two small, subtle, parallel abrasions separated by a band of spared skin extended away from the wound. This finding occurred more often at the proximal corner (16 times) than the distal corner (seven times) when a direction was able to be determined. The mechanism of this feature does not appear to be related to jacketed ammunition expected to deform into petals. Possible mechanisms for the creation of this feature are random irregularities in skin resistance along with slight wobble (yaw) of the bullet or pressure waves generated by the bullet that causes buckling of the skin. *Acad Forensic Pathol.* 2016 6(2): 291-300

AUTHOR

Michael M. Heninger MD, Fulton County - Medical Examiner's Office

Roles: Project conception and/or design, data acquisition, analysis and/or interpretation, manuscript creation and/or revision, approved final version for publication, accountable for all aspects of the work, principal investigator of the current study, principal investigator of a related study listed in the citations.

CORRESPONDENCE

Michael M. Heninger MD, 430 Pryor Street SW, Atlanta GA 30312, michael.heninger@fultoncountyga.gov

ETHICAL APPROVAL

As per Journal Policies, ethical approval was not required for this manuscript

STATEMENT OF HUMAN AND ANIMAL RIGHTS

This article does not contain any studies conducted with animals or on living human subjects

STATEMENT OF INFORMED CONSENT

No identifiable personal data were presented in this manuscript

DISCLOSURES & DECLARATION OF CONFLICTS OF INTEREST

The author, reviewers, editors, and publication staff do not report any relevant conflicts of interest

FINANCIAL DISCLOSURE

The author has indicated that he does not have financial relationships to disclose that are relevant to this manuscript

KEYWORDS

Forensic pathology, Death investigation, Gunshot wounds, Graze wounds

INFORMATION

ACADEMIC FORENSIC PATHOLOGY: THE OFFICIAL PUBLICATION OF THE NATIONAL ASSOCIATION OF MEDICAL EXAMINERS

©2017 Academic Forensic Pathology International • (ISSN: 1925-3621) • <https://doi.org/10.23907/2016.030>

Submitted for consideration on 9 Feb 2016. Accepted for publication on 8 Mar 2016

INTRODUCTION

Gunshot wounds are the most common type of homicide in the jurisdiction of the Fulton County Medical Examiners Center (FCMEC) and firearm homicide accounted for 11 068 of the 16 238 homicide deaths nationally in the U.S. in 2011 (1). Multiple gunshot wounds are common. Graze wounds seldom cause death but are often encountered by the medical examiner because of the company they keep, that being fatal gunshot wounds. Their direction often is important in the evaluation of circumstances surrounding the shooting. Graze wounds are studied closely to determine the direction of travel; features that distinguish entrance, exit, and graze wounds are well-described (2, 3).

The common appearance of a graze wound consists of an elliptical furrow in the skin of variable depth. The initial point of contact or the proximal corner of a graze wound may have a partially round or crescentic margin of abrasion resembling a portion of a typical entrance wound margin of abrasion. This can be help-

ful in distinguishing a graze wound from a laceration and in determining direction. The edges of the graze wound may have small diagonal lacerations. Because the kinetic energy of the projectile is dissipated away in every direction, the lacerations tend to radiate away from the initial point of contact. These small lacerations create corresponding diagonal skin tags that point back in the direction from which the projectile came. The distal corner is variable in appearance, often irregular, and lacerations may be present (**Figure 1**).

This study describes an unusual feature noted on a few graze wounds that is not described in the standard texts or medical literature searched (4-10). This unusual feature consists of a pair of parallel abrasions, roughly the same size and shape, extending away from either the proximal or, less commonly, the distal corner of the graze wound in the same direction of travel as the graze wound. The parallel abrasions demarcate a central area of sparing of the skin that is slightly higher in relation to the abrasions on either side of it (**Figure 2**).

Figure 1: Typical graze wound. Drawn under contract with professional medical illustrator Diana Kryski.

METHODS

An extensive database has been maintained by the FCMEC for many years. The digital database of autopsy reports was searched over the same ten-year time frame when digital photographs were also available, which spanned the interval from Jan 1, 2005 to December 31, 2014. All autopsy reports including the partial word “graze” were identified and all wounds from gunfire of the external surface of the body described as a graze wound were evaluated. If “graze” did not appear in the autopsy report, the wound was not included in the study. Only one graze wound in this decade was not photographed and could not be included in the study.

The total number of gunshot wounds evaluated over this ten-year time period could not be counted accurately. Many cases had a small, manageable number of gunshot wounds. Some cases exhibited dozens of gunshot wounds, to the point that the pathologist was unable to tally them all accurately. The number of homicides attributed to gunshot wounds over the ten-year period was 1464. Injuries described as graze wounds of internal organs such as heart and liver were not included, although they are well-described and demonstrate similar features (11).

The photographs of each graze wound archived in the database were carefully inspected retrospectively and the presence of this unusual finding of parallel abrasions with a central area of sparing was determined. Characteristics of the wounds with this unusual feature obtained from the photographs included length of spared area between the parallel abrasions, anatomic location, and related ammunition. This information was confirmed or determined from the autopsy report when not clear. All of the graze wounds in the study were photographed, often many times, and these pictures included a ruler as a matter of course. The length of the spared area was measured with a ruler in the photograph to the nearest 1/16 of an inch.

The autopsy reports were used to determine demographic information of the victims (age, sex, race) and location, whether on the proximal or distal corner, and to confirm other features in the photographs. The direction of many of the graze wounds (23 of 31) with this unusual feature was described at the time of autopsy and determined based on the observations of the pathologists looking at the wound at autopsy while considering all of the other information in context with the circumstances. The direction of the 31 graze wounds was not independently determined by the author through inspection of the images during

Figure 2: Graze wound with unusual feature. Drawn under contract with professional medical illustrator Diana Kryski.

this study, although no cases where it appeared to be obviously incorrect were encountered. The direction determined by the pathologist at autopsy was used in the description of this data.

Next the frequency of types of projectiles encountered in association with these unusual wounds was evaluated with the potential mechanism in mind. This frequency was compared to the frequency of types of projectiles encountered in the general population of all homicides in this jurisdiction in order to evaluate the probability that the mechanism was reasonable. A total of only three years overlapping the most recent portion of the ten years of data was deemed adequate for comparison, and it included 279 of the total 1464 homicides in the study.

The appearance of the projectiles associated with the unusual pair of parallel abrasions with a central spared area (ten years of data) and the projectiles from the general population of homicides (three years of data) were classified into four categories based on their proposed likelihood of causing the unusual finding:

1. Semi-jacketed bullets with partial unfolding of the metal flaps to form a “floral” pattern, similar in distance from each other as the parallel abrasions.
2. Fragmented bullets with pieces of both jacket and lead core possibly capable of forming a floral pattern when more intact as might be expected in a graze wound, in contrast to a wound going through tissue.
3. Not deformed or only mildly deformed, whether fully jacketed or not jacketed bullets; expected to not likely cause the unusual finding.
4. No bullets recovered and hence bullet type not known.

RESULTS

The unusual finding of parallel abrasions extending from the corner of a graze wound with central sparing was observed in 31 of the 227 (13.7%) graze wounds

examined over a ten-year span. In many cases ($n=18$), only a small hint of this finding (1/16 of an inch) was identified. Representative examples of five of them of various sizes are included (**Images 1- 5**).

Several of the 227 cases had more than one graze wound, and those that did usually had two or three. One exceptional case had 17 identifiable graze wounds and too many total gunshot wounds to be accurately counted. None of these 17 graze wounds demonstrated this unusual feature. Three victims demonstrated two separate graze wounds with this unusual finding, resulting in 28 victims with the 31 wounds included in this study.

All of the graze wounds in this study occurred in homicides attributed to gunfire, although graze wounds are reported to occur rarely in suicides (12). In this series of cases, none of the few graze wounds in suicides, or the even fewer graze wounds in deaths classified as accidents or undetermined, demonstrated this unusual finding. In one case, a small amount of stippling was associated with the unusual graze wound but the rest were of distant/indeterminate/nonspecific range of fire.

The average age of the 28 victims was 30.6 years old with a standard deviation of 10.3 years (95% CI 26-34.2 years old) and a range of 17 to 54 years old. Twenty-five victims were male (89.3%) and three were female (10.7%); 24 were black (85.7%), two (7.1%) were white, and two (7.1%) were Hispanic. This corresponds closely to the demographic features of the gunshot wound homicides generally in this jurisdiction over the same period. (Average age of 31.8 years; males 89.2% and females 10.8%; black 89.9%, white 6.1%, Hispanic 2.5%, and Asian 1.5%).

The 31 graze wounds were sorted by the length of the spared area between their parallel abrasions (**Table 1**).

The unusual pair of parallel abrasions and central spared area occurred at the proximal corner 16 of 23 times and at the distal corner seven of 23 times. The direction was ambiguous or not determined in the remaining eight cases by the pathologist at autopsy. This

Image 1: Thought to be on the proximal corner at autopsy.

Image 2: Thought to be on the proximal corner at autopsy.

Image 3: Proximal corner with faint stippling indicating close range of fire.

Image 4: Thought to be on proximal corner at autopsy (subtle).

unusual feature occurred with enough frequency on either the proximal or the distal corners, and in cases with an ambiguous direction, to not be definitive in determining direction and cannot be used to establish the direction of travel based on the data in this study.

The graze wounds with central sparing longer than 1/16 of an inch were distributed between the proximal and distal corners (six versus four). The two with the greatest length (5/16 and 4/16 inch) were from a proximal corner and a distal corner respectively (**Table 2**).

Table 1: Lengths of the Central Spared Area

Length of the Central Spared Area	Number of Unusual Graze Wounds
1/16 inch	18
2/16 inch	8
3/16 inch	3
4/16 inch	1
5/16 inch	1

The anatomic distribution of the 31 graze wounds in this study was recorded and compared to the anatomic distribution of the other 196 graze wounds without this unusual feature (total of 227 graze wounds in the study) (**Table 3**).

In the 28 cases of 31 wounds with this unusual feature, the associated ammunition recovered was summarized (**Table 4**). The formation of the floral expansion of recovered ammunition turned out to be exactly as likely in the group of all homicides by gunfire as in the smaller group of graze wounds with this unusual finding. The suspected type of ammunition was found with no greater or lesser frequency than in the general population of homicides.

DISCUSSION

“The eye does not see what the mind does not know” (Attributed to D.H. Lawrence, 19th century English novelist and many others). The unusual feature of graze wounds described here could easily be missed in many cases. Although often subtle, this finding was surprisingly common once it was looked for carefully

Image 5: Thought to be on the distal corner at autopsy (ambiguous).

and specifically. The parallel abrasions defining this unusual finding were usually small (1/16 of an inch) as observed in 18 of the 31 identified wounds (58%). But rarely they were fairly obvious (3/16 to 5/16 of an inch), as observed in five of 31 identified wounds (16%). Among all of the 227 graze wounds examined in a decade at a moderately busy medical examiner's office, a wound with this unusual feature > 3/16 of an inch might only be expected to occur approximately five times in ten years or in this setting in 2.2% of the graze wounds (5/227).

A mechanism for forming the unusual parallel abrasions likely related to ammunition used was considered and abandoned. Certain types of ammunition, specifically, partially jacketed projectiles, are designed for the jacket to unfold into several protruding wings

of metal that will catch in tissue. Then they will be less likely to perforate all the way through a body. In a few of the more obvious cases of this unusual finding, projectiles with jackets that had unfolded out into a floral pattern are observed. The unfolding of petals scraping along the surface of the skin is considered as an explanation for the parallel abrasions. Other more speculative mechanisms are also considered.

A graze wound seldom has a projectile conclusively related to it since, by definition, the projectile continues to travel away from the body where it is more difficult to recover and not likely by the medical examiner, if at all. However, many of these deaths with graze wounds had multiple gunshot wounds with projectiles recovered at autopsy from the other simultaneous wounds. An assumption was made: the projectiles

Table 2: Location of Unusual Finding on the Graze Wound Versus Length of the Central Spared Area

Size	Proximal Corner	Distal Corner	Ambiguous Direction	Total
Smaller than 1/16 inch	10	3	5	18
Larger than 1/16 inch	6	4	3	13
All	16	7	8	31

Table 3: Anatomic Location of the Graze Wounds

Graze Wounds with Unusual Feature (n=31)			All Other Graze Wounds (n=196)		
Head	7	22.6%	Head	38	16.7%
Torso	8	25.8%	Torso	61	26.9%
Extremities	16	51.6%	Extremities	97	42.7%
Total	31		Total	196	

Table 4: Comparison of the Associated Ammunition of Graze Wounds with the Unusual Finding and Ammunition From the General Population of All Gunshot Wound Homicides (2011-2013)

	"Floral"	Fragments	Intact	None	Total
Unusual Graze Wounds	8	11	10	6	35*
%	25.8%	35.5%	32.5%	19.4	
Gunshot Wound Homicides (2011-2013)	73	53	78	79	283*
%	25.8%	18.7%	27.6%	27.9%	

* Some cases had multiple kinds of associated ammunition.

that created these graze wounds often resembled the projectiles recovered because the same ammunition is often (not always) used in multiple gunshot wounds. In a few of the cases with a greater length of this unusual feature, it was noticed that the associated projectiles expanded out in a “floral” pattern to form petals, with two of them on one side being approximately a similar distance apart as the parallel abrasions noted at the corner of the graze wound. These were semi-jacketed, copper-coated projectiles. The similar, associated fragmented projectiles causing these graze wounds might have been more intact and might have resembled the projectiles with the floral appearance. In other cases, either no projectile was recovered or intact projectiles without significant deformities were recovered.

Our limited data did not support the unfolding of metal into a “floral” pattern as the primary mechanism of these unusual graze wounds with two parallel abrasions, but in a couple of these unusual cases, it seemed to be strongly suggested anecdotally.

Another inconsistency of this mechanism is the observation that most (16 of 23) of the parallel abrasions were noted in the proximal corner of the graze wound where the projectile first comes into contact with the skin before it has a chance to be deformed by contact with the skin and open up. This is indirectly related to the underlying problem that determining the direction of graze wounds was not always possible.

In this study, the direction of travel of the projectile was ambiguous or not able to be determined at autopsy in eight of the 31 (25.8%) wounds examined. Although defining another characteristic of graze wounds helpful in determining direction would be valuable, this unusual pair of parallel abrasions described in this paper does not measure up. In the more subtle cases, it was difficult to confirm the direction by inspection of photographs. No well-photographed example where this unusual finding was clearly and convincingly at the distal corner was found in the six cases where it was indicated to be at the distal corner at autopsy. The best example was in the last photograph (**Image 5**).

A mechanism not able to be tested by the design of this simple retrospective study was considered. A combination of random irregularities in skin resistance along dermatome lines along with slight wobble (yaw) of the bullet in flight might also explain this finding, especially when it occurred at the proximal corner of the graze wound. Subtle variations related to dermatome lines in the resistance of the skin to damage may not be great enough to matter in most cases of gunshot injury. But this, coupled with random wobble of the projectile that coincidentally happens in such a way that it corresponds with or resonates with the subtle areas of resistance, might account for a band of sparing of the skin to injury between two areas of abrasion. Another alternate mechanism might be pressure waves generated by the bullet at the proximal or distal edges of the wound causing buckling of the skin and creating the features described above.

While searching for the graze wounds in the FCMEC photograph archives, a few entrance wounds with the appearance of tangential injury of the skin creating furrows resembling graze wounds were also noticed to demonstrate this unusual finding. They were not further studied at this time. Coincidentally, a picture of an entrance wound in one of the textbooks reviewed demonstrates this finding (*Gunshot Wounds* by DiMaio, figure 4-18b on page 69) (13). The caption of this picture states: “two entrance wounds with markedly different abrasion rings, though trajectory of bullets through body was identical” (13). No mention was made in the text of the small pair of parallel abrasions at the inferior corner of one wound that were 2 mm in length (almost 2/16 inch in length). One of the earlier articles describing the features of graze wounds by Dixon in 1980 showed a schematic diagram of a graze wound (Figure 9 of his article) and the drawing included a small pair of abrasions extending from the proximal corner, but it is not further mentioned or described (2). This finding apparently has been encountered with some frequency in the past but not specifically described or commented upon.

CONCLUSION

Of a total of 227 graze wounds occurring during a ten-year period, 31 (14%) exhibited a previously not well-described feature. This consisted of a pair of parallel abrasions roughly the same size and shape extending away from either the proximal or distal corner of the graze wound in the same axis of travel as the graze wound. Most of the examples identified were small; 18 of 31 were 1/16th of an inch, but a few were longer. The five longer ones, 3/16 of an inch or greater, were encountered in 2.2% of graze wounds in this study.

This unusual feature was found to favor the proximal corner (16 of 23 wounds where direction was determined at autopsy). This feature should not be relied upon to determine direction of travel. A larger, more statistically powerful study might demonstrate a significant trend that might allow this unusual feature to be used to help indicate the direction of travel of projectiles causing graze wounds.

A mechanism of forming this feature, the unfolding of the petals of a semi-jacketed projectile, was considered. The ammunition that would be expected to cause this injury was associated with the graze wound with the unusual feature neither more nor less commonly than with the general population of homicide victims. Other mechanisms not demonstrable in this study were considered although not proven. The unusual finding might be related to random irregularities in skin resistance along with slight wobble (yaw) of the bullet in flight. It might also be explained by pressure waves generated by the bullet causing buckling of the skin. Further study is needed to demonstrate the validity of these mechanisms.

REFERENCES

- Centers for Disease Control and Prevention [Internet]. Atlanta: U.S. Department of Health & Human Services; c2014. FastStats: Assault or homicide; 2013 May 30 [cited 2014 Oct 23]. Available from: <http://www.cdc.gov/nchs/fastats/homicide.htm>.
- Dixon DS. Determination of direction of fire from graze gunshot wounds. *J Forensic Sci.* 1980 Apr; 25(2):272-9. PMID: 7391789. <http://dx.doi.org/10.1520/jfs12122j>.
- Denton JS, Segovia A, Filkins JA. Practical pathology of gunshot wounds. *Arch Pathol Lab Med.* 2006 Sep; 130(9):1283-9. PMID: 16948512.
- Spitz WU. Spitz and Fisher's medicolegal investigation of death. 4th ed. Springfield (IL): Charles C. Thomas; c2006. Chapter XII, Part 1, Injury by gunfire; p. 607-705.
- Graze wounds. In: Dolinak D, Matshes E, Lew E, editors. Forensic pathology: principles and practice. Burlington (MA): Elsevier Academic Press; 2005. p. 171-2.
- Wright RK. Forensic science: an introduction to scientific and investigative techniques. 2nd ed. Boca Raton: CRC Press; c2005: Chapter 4, Investigation of traumatic deaths; p. 43-60.
- Wetli CV, Mittleman RE, Rao VJ. An atlas of forensic pathology. Chicago: ASCP Press; c1999. Chapter 4, Firearms injuries; p. 79-87.
- Knight B. Forensic Pathology. 2nd ed. New York: Oxford University Press; c1996. Chapter 8, Gunshot wound and explosion deaths; p. 243-70.
- DiMaio VJM. Atypical entrance wounds. In: Gunshot wounds: practical aspects of firearms, ballistics, and forensic techniques. New York: Elsevier Science; 1985. p. 77-8.
- Adelson L. The pathology of homicide: a vade mecum for pathologist, prosecutor and defense counsel. Springfield (IL): Charles C Thomas; c1974. Chapter V, Homicide by firearms; p. 188-290.
- Dixon DS. Determination of direction of fire from graze gunshot wounds of internal organs. *J Forensic Sci.* 1984 Jan; 29(1):331-5. PMID: 6699600. <http://dx.doi.org/10.1520/jfs11669j>.
- Perdekamp MG, Faller-Marquardt M, Kleck A, Pollak S. [Suicide with multiple graze shots]. *Arch Kriminol.* 2005 Nov-Dec; 216(5-6):150-9. PMID: 16430052. German.
- DiMaio VJM. Gunshot wounds: practical aspects of firearms, ballistics, and forensic techniques. New York: Elsevier Science; c1985. Figure 4-18 (B); p69.