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Radiography of Perforating Centerfire Rifle Wounds of the Trunk*

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ABSTRACT: All deaths resulting from perforating centerfire rifle wounds of the chest and abdomen, investigated by the Office of the Chief Medical Examiner for the Province of Alberta from 1988 to 1995, were reviewed retrospectively to determine whether the radiographic distribution of bullet fragments in such cases is a useful predictor of bullet trajectory. Study cases were limited to single gunshot wounds without surgical intervention or intermediate targets, and for which adequate radiography was available. Three pathologists individually viewed the radiographs on two separate occasions; wound locations were provided for the second viewing (Group 2). Differences in opinion regarding direction of fire were resolved by consensus review. A trauma radiologist independently made two sets of interpretations in the same way. Comparisons of these groups of interpretations were made with the actual bullet direction determined at autopsy. Of 21 cases included in the study, only three (14.3%) did not require consensus resolution in either group. Accuracy of pathologists' interpretation improved from 38.1% (8/21) to 76.2% (16/21) with provision of wound locations ($p = 0.012$). The radiologist achieved similar improvement, from 28.6% (6/21) to 47.6% (10/21). The rate of agreement between radiologist and pathologists increased from 42.9% (9/21) to 61.9% (13/21) between Groups 1 and 2. Both the pathologists and radiologist interpreted several cases the same way in both groups; of those cases interpreted differently, the second interpretation was occasionally incorrect after correct interpretation in Group 1. We conclude that bullet direction for perforating centerfire rifle wounds cannot be accurately determined from postmortem radiographs. When wound location is known, the ability to predict bullet direction improves but is still subject to error, including a lack of consistency between observers.

KEYWORDS: forensic science, forensic pathology, postmortem radiography, centerfire rifle, ammunition, wounds, bullet direction

Determining the direction and path of the bullet is a crucial component of the autopsy examination in any death caused by a firearm. In a perforating gunshot wound, this generally involves examination of the skin wounds, and clothing defects, in order to establish the entrance and exit wounds. In some cases, however, the distinguishing features of these wounds may be altered by decomposition, postmortem animal activity, or other postmortem changes which render the gross or microscopic examination and interpretation of the wounds extremely difficult. The forensic pathologist is then faced with having to use any other available evidence to establish the bullet direction.

When dealing with perforating centerfire rifle injuries, it has been said that postmortem radiographs of the body can be of some assistance in establishing the direction of the projectile (1). Centerfire rifle cartridges have a centrally located primer over the cartridge base, are of caliber .17 or greater, and are fired from a rifle with muzzle velocities in excess of 2000 ft/s (610 m/s). As a result of this velocity, the bullet possesses enormous kinetic energy. A metal jacket of copper-nickel alloy, or other gilding metal, is required to prevent the soft lead of the projectile from being stripped away by the rifling grooves of the barrel. The metal jacket can cover the entire bullet (a so-called full metal jacket), or it can leave the soft lead core tip of the bullet exposed (a partial metal jacket), thus facilitating expansion of the round in the soft tissues of its target with the resultant increased transfer of kinetic energy. Partially jacketed centerfire cartridges are most commonly used for hunting larger animals. As this type of round passes through soft tissues, expands, and deforms, small portions of its lead core break off and are hurled into the tissues surrounding the main bullet track. The radiographic picture of multiple tiny radio-opaque fragments distributed along a centerfire bullet wound track has been referred to as a "lead snowstorm" (Fig. 1) (1–3). This radiographic appearance is quite characteristic of partially jacketed centerfire rifle rounds. It is an energy-dependent (and thus velocity-dependent) phenomenon. The lead fragments are said to form a triangular or cone-shaped pattern, with the apex of the cone located at, or close to, the point of entry, such that examination of a radiograph should allow one to determine the direction in which the bullet was traveling.

The purpose of this study was to document whether or not the postmortem radiographic distribution of lead fragments from perforating centerfire injuries of the trunk can, in fact, be used to reliably establish the direction of the bullet.

Methods

All cases of perforating centerfire rifle wounds, investigated by the Office of the Chief Medical Examiner for the Province of Alberta in Canada from 1988 to 1995, were retrospectively reviewed. Cases with perforating injuries of only the head, neck, or extremities were excluded, as the dispersal of metal fragments in these areas is limited by the relatively short intracorporeal distance traveled by the projectile. Multiple gunshot wounds were excluded due to the interpretation difficulties caused by overlapping bullet frag-

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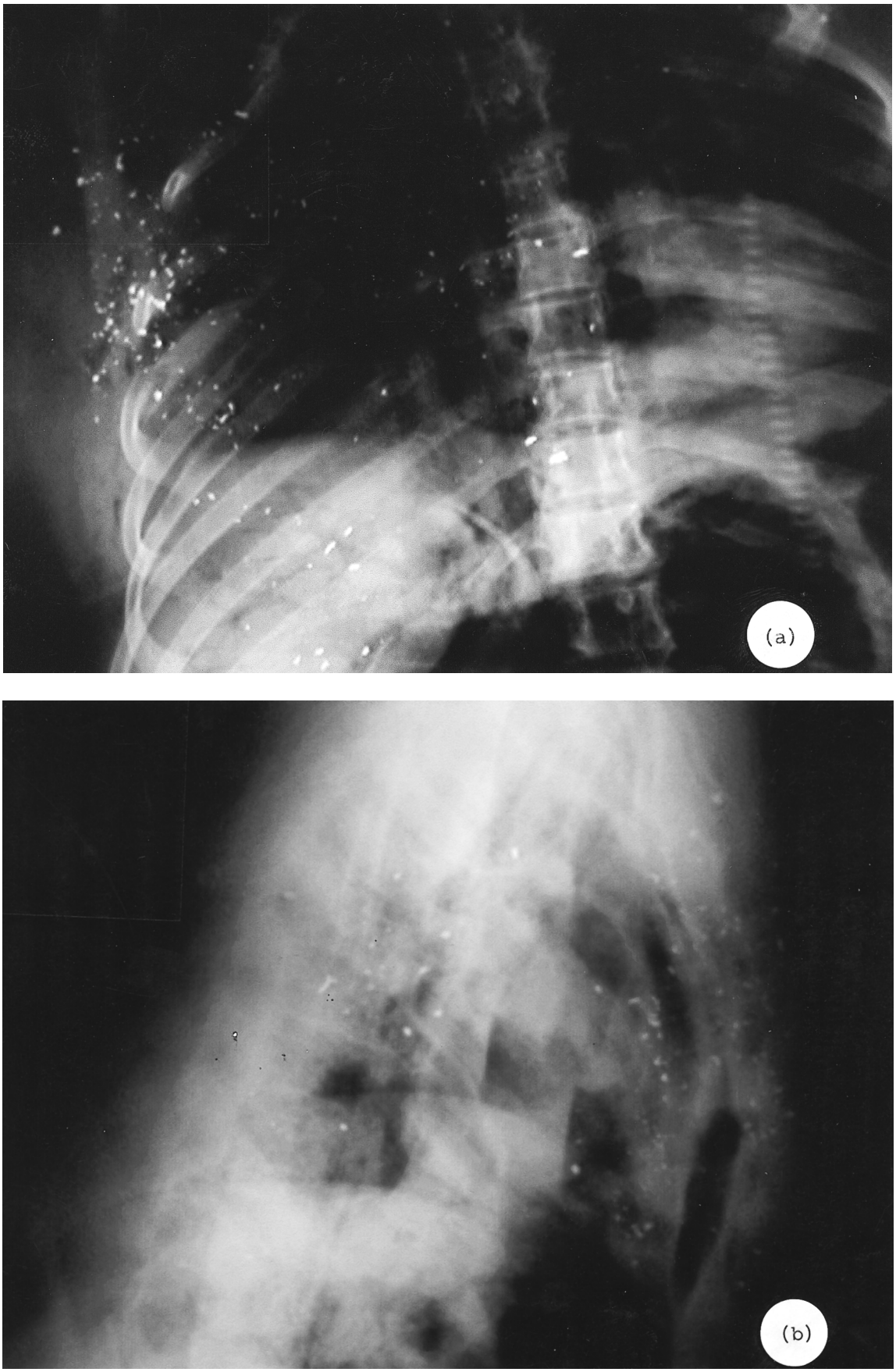

FIG. 1—*The "lead snowstorm" observed as a result of fragmentation of a centerfire rifle bullet within the body;* (a) *anteroposterior view,* (b) *lateral view.*

mentation patterns on radiographs. All cases in which there was evidence of an intermediate target, with the exception of clothing, were excluded, as intermediate targets will often cause fragmentation of the bullet prior to its entry into soft tissues. Those cases in which there were attempts at surgical repair of the wound were excluded, simply because the distribution of metal fragments within the soft tissues can be altered by surgical intervention. Finally, only those cases in which both anteroposterior and lateral postmortem radiographs were available for review were considered for further study. Information regarding the caliber of the weapon and the range of fire was extracted from each case file in order to assess the possible contributions that these factors might have on the radiographic fragmentation pattern.

Three forensic pathologists independently reviewed the radiographs from each of the remaining cases on two separate occasions. The pathologists were asked to determine the bullet direction, in three planes, using the distribution of the metal fragments visible in the radiographs as their only guide. On the first occasion, the pathologists were not provided with any information about the cases at all (Group 1). Their opinions were recorded, and any discrepancies in opinions between the three were discussed and resolved by consensus review. Approximately four weeks later the films were viewed again. On this occasion the pathologists were told the location of wounds on the trunk, but were not told which wound was entrance or exit (Group 2). Again, any discrepancies in interpretation were later resolved by consensus review. A radiologist with experience in gunshot wound radiography (AJW) independently made two sets of interpretations in the same way, but with no consensus review of his results. The final opinions rendered for Group 1 and Group 2 were then compared to the conclusions about bullet direction, based upon examination of the skin and clothing defects, provided in the autopsy report of each case.

TABLE 1—*Number of cases excluded by specific criteria.*

Criterion	Number of Cases Excluded (Total Number of Cases = 56*)
Inadequate radiography	18
Multiple bullets	8
Nonperforating wound	4
Intermediate target	3
Surgical intervention	1
Inadequate number of fragments	1

* Cases remaining and available for study: 21.

Results

There were 56 deaths due to centerfire perforating rifle injury of the trunk investigated by the Alberta Medical Examiner's Office between 1988 and 1995. Twenty-two of these cases met the criteria for inclusion in this study. Inadequate radiography (i.e., only one view, anteroposterior or lateral, available) was the most common exclusionary criterion (Table 1). In one of the remaining 22 cases, that of a skeletonized body, there were insufficient numbers of bullet fragments visible on postmortem radiographs to allow for any useful interpretation of bullet direction. This case was therefore excluded, leaving 21 cases available for study.

Table 2 summarizes each case with respect to caliber of weapon, range of fire, and accuracy of bullet direction (as predicted by the three pathologists for Groups 1 and 2), and the number of times the pathologists were unanimous in predicting bullet direction. In four cases, the actual caliber of the weapon was unknown, although it was known that the weapon was a centerfire rifle in each case. The

TABLE 2—*Summary of case information and pathologist interpretation data.*

			Group 1†		Group 2†	
Case	Caliber*	Range*	Accurate‡	Agreements§	Accurate‡	Agreement§
1	.303	DISTANT	N	CONSENSUS	Y	CONSENSUS
2	.264	CONTACT	N	CONSENSUS	Y	CONSENSUS
3	Undet.	DISTANT	N	Y	N	CONSENSUS
4	.303	CONTACT	N	CONSENSUS	Y	CONSENSUS
5	7 mm	CONTACT	N	CONSENSUS	Y	CONSENSUS
6	.303	DISTANT	N	CONSENSUS	Y	Y
7	7 mm	CONTACT	Y	CONSENSUS	Y	Y
8	.358	DISTANT	Y	CONSENSUS	Y	CONSENSUS
9	.30–30	Undet.	N	Y	N	Y
10	.30–06	CONTACT	N	Y	Y	CONSENSUS
11	Undet.	Undet.	Y	CONSENSUS	N	Y
12	.30–30	CONTACT	Y	Y	Y	Y
13	.30–30	CONTACT	N	CONSENSUS	Y	CONSENSUS
14	.32–20	MEDIUM	Y	CONSENSUS	Y	CONSENSUS
15	.303	Undet.	N	Y	Y	CONSENSUS
16	.30–06	CONTACT	Y	CONSENSUS	Y	Y
17	.303	CONTACT	Y	Y	Y	CONSENSUS
18	7 mm	CONTACT	N	Y	N	Y
19	.25–06	DISTANT	Y	CONSENSUS	Y	Y
20	Undet.	MEDIUM	N	Y	Y	CONSENSUS
21	Undet.	Undet.	N	CONSENSUS	N	CONSENSUS

* CONTACT = presence of soot in or around wound, or on clothing; MEDIUM = presence of stipple abrasions, but no soot; DISTANT = no soot, no stipple abrasions; Undet. = Undetermined (range or caliber not determinable).

† Group 1: interpretation without wound information. Group 2: wound information provided.

‡ Assessment of accuracy of interpretation using autopsy report as "gold standard;" N = inaccurate, Y = accurate.

§ CONSENSUS = consensus resolution required (disagreement in pathologists' opinions); Y = unanimous agreement.

range of fire was undetermined in four cases, usually because overlying clothing was not available for examination.

When no information was available to the pathologists regarding the location of wounds on the trunk (Group 1), the accuracy rate for correctly predicting the direction of the bullet from postmortem radiographs was only 38.1% (8/21). Once the location of the wounds was known, the accuracy rate doubled, to 76.2% (16/21) ($p = 0.012$, Fisher's one-tailed exact test). Nine of the 13 cases which were incorrectly interpreted in Group 1 were interpreted correctly in Group 2 (69%). Interestingly, one case, which was originally interpreted correctly in Group 1, was subsequently interpreted incorrectly in Group 2 when wound location was known. Eleven of the 21 cases (57%) were interpreted the same way for both groups; four of these interpretations were incorrect.

The three pathologists were independently unanimous in their interpretation of bullet direction in only 8 of 21 cases (38.1%) for both Groups 1 and 2, but the cases for which a unanimous decision was made were different in the two groups; i.e., only three cases had unanimous agreement in both groups. All other cases (13/21 or 61.9%) required consensus review, with eight cases requiring consensus review both before and after wound location was known.

Table 3 correlates the range of fire with the accuracy of the pathologists' prediction of bullet direction from postmortem radiographs for both Groups 1 and 2. Ten of 17 cases in which the range could be established were contact wounds, with an improvement in accuracy of bullet direction prediction from 40 to 90% between Groups 1 and 2. There were only two medium range wounds and five distant range wounds. Both of these groups showed improvement in accuracy between Groups 1 and 2, though the number of cases was small. Bullet direction was accurately assessed in only 1 of 4 (25%) of the undetermined range wounds for both Group 1 and Group 2. There does not appear to be any significant correlation between accuracy of interpretation and range of fire.

The lone radiologist on the panel, who made interpretations independently of the three pathologists (without benefit of consensus review), achieved an accuracy rate of 28.6% (6/21) for Group 1, which improved to 47.6% (10/21) for Group 2. Correlation of the radiologist's interpretations with the pathologists' consensus results is presented in Table 4. The rate of agreement between pathologists' and radiologist's interpretations seemed to improve marginally after wound information was provided (from 42.9 to 61.9%), although many of these interpretations were incorrect. Of eight cases which the radiologist interpreted the same way in both groups, five were incorrect interpretations. The remaining 13 cases received different interpretations in Group 1 and Group 2. In seven of these cases, the case was reinterpreted correctly; in three cases, neither interpretation was correct. Three cases had been interpreted correctly in Group 1, but were reinterpreted incorrectly in Group 2. As indicated above, this phenomenon of incorrect reinterpretation was also seen in one case in the pathologists' series.

TABLE 3—*Correlation of pathologist accuracy with range of fire.*

Range of Fire	Accuracy (Group 1)	Accuracy (Group 2)
Contact	4/10 (40%)	9/10 (90%)
Medium	1/2 (50%)	2/2 (100%)
Distant	2/5 (40%)	4/5 (80%)
Undetermined	1/4 (25%)	1/4 (25%)

TABLE 4—*Agreement of pathologist consensus interpretations with radiologist interpretations.*

	Group 1 ($n = 21$)	Group 2 ($n = 21$)
Agree	9 (incorrect interpretations: 7)	13 (incorrect interpretations: 4)
Disagree	12	8

Discussion

Determination of the direction of travel of a bullet or bullets in firearm injuries is an essential part of the postmortem examination. With small-caliber handguns and .22-caliber rifle injuries, the bullet often remains in the body, so the bullet track direction is relatively easy to establish. Larger caliber handguns and centerfire rifles often produce perforating injuries of the body, such that careful examination of the wounds (and any overlying clothing) is necessary to distinguish between entrance and exit wounds. If decomposition, postmortem insect or animal activity, or some other postmortem change has altered the bullet wound defects, determining the direction of fire can become extremely difficult. The partially jacketed projectiles of centerfire rifles are known to produce a very distinctive "lead snowstorm" of tiny metal bullet fragments which is visible on postmortem radiographs. This pattern is not usually seen in handgun injuries. It has been suggested that the metal fragments are distributed in a cone, with the apex of the cone located at or close to the entrance wound (1). If this is the case, it may be possible to establish the direction of fire of a perforating centerfire rifle partially jacketed bullet wound by examination of postmortem radiographs.

Unfortunately, this study has shown that it is extremely difficult to determine the direction of perforating centerfire rifle injuries of the trunk from postmortem radiographs alone. In the 21 cases studied, the pathologists were able to accurately predict the direction of the projectile from radiographs in only eight cases (38.1%) when the location of wounds on the trunk was not known. If the location of the wounds was known, the bullet direction was correctly predicted in 16 cases (76.2%), but there was a considerable degree of inter-observer difference in opinion. Unanimous agreement in opinion between three observers was achieved in only 38.1% of cases, irrespective of whether the location of the wounds was known. A radiologist with experience in interpreting gunshot wound radiography had slightly lower but generally similar rates of accuracy and also showed improvement in the accuracy rate after the provision of wound information. The lower accuracy rate for the radiologist may be explained in part by the independent nature of his interpretations; that is, there was no provision for consensus review. A "decision by majority" may in some cases prove beneficial, but our results show that even this approach is often inaccurate.

The difficulties that arose in trying to establish bullet direction from the shape of the "lead snowstorm" cone from postmortem radiographs were manyfold. In several cases, although a "snowstorm" appearance of small bullet fragments was apparent, there was no visible triangular or cone-shaped pattern of distribution, such that the observers found they were simply guessing at the bullet direction. In those cases where a triangular pattern was indeed apparent, it was impossible to establish which of the three "corners" of the triangle was the apex, if no information was available about the location of wounds. This was reflected in the significant improvement in prediction accuracy achieved when the location of the wounds was known. Establishing the presence or absence of a cone-shaped distribution of bullet fragments was rendered even

more difficult by the fact that a cone is a three-dimensional object, whereas radiographs are two-dimensional. The planar distribution of bullet fragments was particularly difficult to interpret in lateral X-ray projections, where the majority of the fragments were close to the spinal column, even when the entrance wound was located on the back. This posterior location was due to gravity-dependent settling of the thoracic and abdominal viscera, with the decedent lying on his or her back. This effect was compounded by the curvature of the posterior and lateral walls of the trunk. The greater density of fragments posteriorly may give an erroneous impression that the apex of the cone is oriented toward the back. Thus, although a true cone may be formed by lead fragments from a centerfire rifle projectile in a uniform substrate, such as a gelatin block, the same is not always true for a nonuniform substrate, like the human body. This nonuniformity is greatest in the trunk, which has a wide variety of soft tissue, hard tissue, organ, and gas substrates for a bullet to traverse. Many of these substrates are capable of gravity-dependent movement and/or settling.

No definitive relationship was found between the bullet caliber or range of fire and the ability to accurately predict bullet direction from radiographic appearance; however, the number of cases in each caliber and range group was relatively small.

In conclusion, it is extremely difficult, and often inaccurate, to predict the direction of travel of perforating partially jacketed centerfire rifle bullet wounds of the trunk, based solely upon the "lead snowstorm" appearance of postmortem radiographs. Knowledge of the location of wounds on the trunk increases the accuracy significantly, but does not prevent misinterpretation or interobserver differences in opinion. As is the case with so many things in forensic pathology, postmortem radiographs must be used in conjunction with other findings to correctly establish bullet direction.

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