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# Rifle Wounds from High Velocity, Center-Fire Hunting Ammunition

Wounds from high velocity, center-fire rifles are relatively uncommon. Such wounds are markedly different from those caused by handguns or .22 rim-fire rifles. Injuries from pistol or .22 rim-fire rifle bullets are confined to tissue and organs directly in the wound track. In contrast, high velocity rifle bullets can injure structures without actually contacting them. Discussion of rifle wounds in the medical literature is concerned almost exclusively with injuries from military ammunition [*1-3*]. Wounds encountered by medical examiners, however, almost always involve hunting ammunition, whose design and construction is radically different from that of military ammunition. Because of these differences, the wounds produced by hunting ammunition are much more devastating.

This paper will discuss the wounding mechanism of high velocity, center-fire rifle bullets as well as the specific characteristics of hunting ammunition and the wounds produced by it. For the purpose of this paper, a high velocity, center-fire rifle cartridge is defined as any cartridge with a centrally located primer, intended to be fired in a rifle of caliber .17 or greater, whose bullet is propelled at a velocity of more than 2000 ft/s (610 m/s).

## Theories of Wounding

Research by the military in the field of wound ballistics has revealed that the severity and extent of a wound is directly proportional to the amount of kinetic energy lost by a bullet in tissue [*1*]. All bullets, by virtue of their mass and velocity, possess kinetic energy. This energy can be expressed by the equation $KE = WV^2/2g$, where $W$ equals weight, $V$ equals velocity, and $g$ equals gravity.

Rifle bullets, by virtue of high velocities, possess considerably more kinetic energy than pistol bullets. This can be readily appreciated by examining the kinetic energy formula. This formula states that while the kinetic energy possessed by a bullet varies directly with the weight of the bullet, this energy varies with the square of the velocity. Thus, doubling the weight of the bullet doubles its kinetic energy, while doubling its velocity quadruples its kinetic energy. Table 1 illustrates the muzzle velocities and kinetic energies possessed by some typical pistol and rifle bullets. The marked contrast in the kinetic energy possessed by rifle bullets in comparison to pistol bullets is evident.

The severity and extent of a wound, however, is not determined by the amount of kinetic energy possessed by a bullet; rather, it is the amount of this energy that is lost in

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TABLE 1—*Muzzle velocities and kinetic energies of typical pistol and rifle bullets.*

| Caliber | Bullet Weight, grains | Muzzle Velocity, ft/s | Muzzle Kinetic Energy, ft-lbs |
|---|---|---|---|
| | Handguns | | |
| .32 ACP | 71 | 960 | 145 |
| .38 Special | 158 | 790 | 220 |
| .357 Mag | 158 | 1190 | 490 |
| .45 Auto | 230 | 850 | 370 |
| | Rifles | | |
| 5.56 (.223) | 55 | 3240 | 1282 |
| 30-30 | 150 | 2390 | 1902 |
| 30-06 | 150 | 2910 | 2820 |

1 grain = 64.79 mg
1 ft = 0.30 m
1 ft-lb = 1.35 J

the tissue. The major determinants of the amount of kinetic energy lost by a bullet in the body are the mass and velocity of the bullet (its kinetic energy at time of impact with the body); the shape of the bullet; any change in the presented area of the bullet in its passage through the body; the construction of the bullet; and the histological characteristics of the tissues through which the bullet passes.

By virtue of the high velocities and thus higher kinetic energies, rifle bullets have the potential to produce extremely severe wounds. In military ammunition, velocity is the most important determinant of the severity of the wounds produced. This is because the full metal jacket required in such ammunition prevents deformation of the bullet. In contrast, bullet construction plays an extremely important role in the extent and severity of the wound produced by hunting ammunition. This is because a hunting bullet is designed to deform in its passage through the body, producing an increase in its presenting area. This plus a tendency to fragment result in greater kinetic energy loss and thus greater tissue injury.

Two types of wound tracks are produced when a bullet passes through tissue [*1–3*]. The first is the permanent wound track seen at autopsy or surgery. The diameter of this wound track is approximately that of the missile. The second wound tract is a temporary cavity present during and immediately after passage of the bullet. As the bullet moves through the body, tissue adjacent to the bullet's path is flung away in a radial manner, creating a temporary cavity. The size of the cavity is directly related to the amount of kinetic energy absorbed by the tissue. This cavity may be as much as 6 in. (15 cm) in diameter for high velocity rifle bullets [*3*]. The cavity undulates for 5 to 10 ms before it comes to rest as the permanent wound track. The pressure in the temporary cavity in the case of high velocity rifle bullets can be tremendous, with shock waves of up to 200 atmospheres (20 MPa) [*4*]. Organs struck by these bullets may undergo partial or complete disintegration. The pressures generated are sufficient to fracture bone and rupture vessels adjacent to the permanent wound track but not directly struck by the bullet [*3*].

These properties of rifle bullets are not possessed by pistol or .22 rim-fire rifle bullets. The low velocity of such ammunition with resultant low kinetic energy imparted to the tissue result in small temporary cavities, thereby preventing the remote severe wounds and the disintegration of organs. Even the new high velocity pistol bullets, now in general use, injure only tissue and organs directly in the wound track. This is because such high velocity bullets are in reality low velocity projectiles. It is not until the velocity of a projectile approaches 2000 ft/s (610 m/s) that the massive wounds seen in high velocity, center-fire rifle bullets appear.

In conclusion, we can say that any bullet, no matter what its velocity, can inflict a serious or fatal wound. While pistol bullets have to strike vital organs to cause death, center-fire rifle bullets can cause devastating injuries to these organs without directly striking them.

## High Velocity Rifle Bullets: Construction and Design

High velocity, center-fire rifle bullets differ in construction from handgun bullets in that rifle bullets have to have either full or partial metal jackets. Such jacketing is required because of the high velocities at which rifle bullets are propelled down a barrel. If the bullets were lead or lead alloy, these high velocities would result in the lead being stripped from the surface of the bullet by the rifling grooves.

Rifle bullets can be divided into four general categories on the basis of their configuration and construction. The first are the full metal-jacketed bullets. This is the standard form of ammunition used by the military. This bullet has a lead or steel core, covered by an outside jacket of cupronickel or gilding metal. This metal jacket completely encloses the tip of the bullet, preventing it from expanding when it reaches its target.

Soft-point bullets have a lead core and a partial metal jacketing closed at the base. The lead core is exposed at the tip to facilitate expansion when the bullet strikes. The tip of the soft-point bullet may be either tapered to a point or have a rounded, blunt end. Expansion of soft-point bullets can be further facilitated by scalloping the mouth of the jacket or cutting five or six notches around the jacket mouth (Fig. 1). The modifications allow uniform peel-back of the jacket when the bullet strikes the target. Soft-point bullets are the most widely used form of hunting ammunition.

FIG. 1—(Left to right) *Soft-point, Silver-tip, and hollow point .30 caliber hunting bullets.*

Hollow-point bullets are a variant of soft-point bullets. They are partially metal-jacketed hunting bullets that have a cavity at the tip of the lead core to facilitate expansion when the bullet strikes game (Fig. 1).

The fourth category of rifle bullets is a miscellaneous one of controlled expansion projectiles. This group includes Silver-tip® ammunition by Winchester and the Bronze-point® by Remington. The Silver-tip bullet is in reality a soft-point bullet whose lead core tip is protected by a thin jacket of aluminum alloy (Fig. 1). This aluminum sheath extends back under the jacket almost to the cannula. The purpose of the aluminum jacket is to protect the exposed lead core and to slightly delay expansion. The Remington Bronze-point has a pointed, wedge-shaped nose in the forward part of the jacket, so that the lead core is not exposed. A small cavity underlies this wedge. When the bullet strikes the target, the wedge is driven back into the bullet, expanding it.

From the preceding discussion, it can be seen that hunting bullets differ from military ammunition in that the former are designed to expand and therefore more efficiently transfer energy to the target and more effectively kill game. Ammunition manufacturers control the rate and extent of expansion by controlling the bullet velocity and the physical characteristics of the bullet. Thus, the degree of expansion of hunting ammunition can be controlled by the thickness of the jacket, the hardness of the jacket, the location of the bullet cannula, the amount of lead exposed, the shape of the bullet, the composition of the core, and the design characteristics of the bullet (hollow-point, Silver-tip, and so forth).

## Case Material

A review of the files of the Southwestern Institute of Forensic Sciences over a five-year period revealed a total of 30 well-documented deaths caused by high velocity, center-fire rifle cartridges. Twenty-seven of the 30 individuals were shot once, two twice, and one three times. Hunting ammunition was used to inflict all the wounds. The most common caliber in our series was the 30–30 (17 cases). Of the total of 34 high velocity rifle wounds, in all but seven instances the bullet exited. Thus, even with expanding ammunition, high velocity rifle bullets generally exit.

Table 2 lists all the cases in which there was a rifle wound of the head; Table 3 those cases in which there were wounds of the trunk and extremities. Two individuals in Table 2 are also represented in Table 3.

TABLE 2—*Center-fire rifle wounds of head.*

| Age/Race/Sex | Manner of Death | Range | Entrance | Caliber of Weapon |
|---|---|---|---|---|
| 54/w/m | suicide | contact | right mastoid | 30–30 |
| 33/w/f | suicide | contact | right temple | .303 |
| 58/w/m | suicide | contact | mouth | 30–30 |
| 32/w/m | suicide | contact | mouth | 30–30 |
| 48/w/m | suicide | contact | temple | .270 |
| 44/w/m | homicide | intermediate | left forehead | .243 |
| 13/b/f | homicide | intermediate | midline of forehead | 30–30 |
| 36/w/m | homicide | distant | center of right ear | 30–30 |
| 53/w/m | homicide | distant | left cheek | .32 |
| 19/w/f | homicide | distant | back of head | .270[a] |
| 14/w/m | homicide | distant | left orbit | 30–06 |

[a] Bullet did not exit.

The eleven rifle wounds of the head were contact in five instances, intermediate in two, and distant in four. All but one were through-and-through wounds. The single exception involved a case in which a .270 rifle bullet went through a car panel before striking the victim.

Contact wounds of the head are extremely devastating. Large pieces of the skull and brain are "blown out" with pulpefaction of the brain. The skull shows extensive comminuted fractures. Such wounding effects are due primarily to the large quantities of gas

TABLE 3—*Center-fire rifle wounds of chest and abdomen.*

| Age/Race/Sex | Manner of Death | Range | Entrance | Exit | Caliber of Weapon |
|---|---|---|---|---|---|
| 29/w/m | suicide | contact | abdomen | back | 30-06 |
| 19/w/m | suicide | contact | abdomen | back | 30-30 |
| 21/w/m | suicide | contact | chest | back | 30-30 |
| 28/w/m | suicide | contact | chest | back | .270 |
| 42/w/m | suicide | contact | chest | back | 30-30 |
| 53/w/m | suicide | contact | chest | left axilla | 30-30 |
| 32/w/m | homicide | intermediate | abdomen | back | 30-30 |
| 30/w/m | homicide | distant | chest | chest | 30-30 |
| 43/w/m | homicide | distant | chest | chest | 30-06 |
| 43/w/f | homicide | distant | chest | back | 30-30 |
| 36/w/m[a] | homicide | distant | chest | back | 30-30 |
| 53/w/m[a] | homicide | distant | abdomen | no exit | .32 Winchester |
| | | | abdomen | shoulder | .32 Winchester |
| 25/w/m | homicide | distant | chest | no exit | 30-30 |
| 52/w/f | homicide | distant | chest | back | 30-06 |
| 42/w/m | homicide | distant | chest | axilla | 30-06 |
| 30/w/m | homicide | distant | chest | chest | 8 mm |
| 29/w/f | homicide | distant | chest | back | .32 Winchester |
| 32/w/m | homicide | distant | chest | no exit | 30-30 |
| 64/w/m | homicide | distant | chest | back | 30-30 |
| 34/b/m | homicide | distant | arm | no exit | 30-30 |
| | | | chest | no exit | 30-30 |
| 47/w/m | homicide | distant | abdomen | no exit | 30-30 |

[a] Listed in Table 2.

produced by combustion of the propellant. The gas begins to expand as soon as it emerges from the muzzle of the weapon. If the gun is held in contact with the head, this gas follows the bullet into the cranial cavity, where the gas expands. The high pressure generated by the expanding gas, as well as that caused by the temporary cavity, all in the unyielding boney framework of the cranial cavity, produce an effect that can only be described as "explosive."

Intermediate range gunshot wounds (those in which powder tattooing is present) and distant wounds accounted for the other six cases involving wounds of the head. These rifle wounds can be just as devastating as contact wounds. As the hunting bullet rapidly expands, large quantities of kinetic energy are lost in the cranial cavity. This produces a large temporary cavity with resultant high pressure, all within the rigid framework of the skull. The pressure developed produces extensive fractures of the skull, large lacerations of the scalp, and ejection of fragments of bone and brain tissue. Differentiation of entrance from exit wounds may require extensive reconstruction of the skull with careful realignment of the edges of the scalp.

A total of 23 high velocity rifle wounds of the chest, abdomen, and extremities were available for study. In all but six instances the bullet exited. Contact wounds of the chest and abdomen do not have the dramatic external appearance of such wounds in the head. There is no tearing of the skin caused by gas. The wound of entrance is typically circular in shape. Usually it will be larger in diameter than those of pistol bullets. The edges of the wound are seared from the effect of the hot gases of combustion. Powder soot is deposited in and around the wound. The amount of soot, however, is less than that seen with most pistols. The imprint of the muzzle of the weapon is commonly present. Such imprints are due to the gas of combustion entering the chest cavities, expanding them, and slamming the chest or abdominal wall onto the muzzle of the weapon. The fact that the whole chest or abdominal wall is flung against the muzzle of the weapon by the gas, rather than the gas passing between the skin and underlying tissue, accounts for the fact that the skin is not torn. In contrast to their benign external appearance, contact high velocity rifle wounds of the chest and abdomen produce massive internal injuries. The severe nature of these wounds, resulting from both the effects of the gas and the temporary cavity, may literally pulpify organs such as the heart and liver.

Intermediate range and distant entrance wounds of the trunk inflicted by high velocity rifle bullets are generally indistinguishable externally from those produced by pistol bullets. The only difference that may be present is that the abrasion ring around the rifle wound of entrance is narrower than that seen in a pistol wound. The internal injuries from a high velocity rifle bullet, however, are extremely devastating with massive destruction and pulpefaction of the organs. They are often as severe as those from contact rifle wounds.

No matter what the range, exit wounds of the chest and abdomen all have the same appearance. They are larger and more irregular than the entrance wound. In 14 exit wounds of the trunk in which accurate measurements were available, one measured 2¾ by 1½ in. (70 by 38 mm), one 2 by 1½ in. (51 by 38 mm), and the rest 1 in. (25 mm) or less in diameter.

**X-Rays**

X-rays of individuals shot with hunting ammunition usually show a characteristic radiological picture, seen almost exclusively with this form of rifle ammunition. This is the so-called lead snowstorm picture. As the expanding bullet moves through the body, fragments of lead break off the lead core and are driven out into the surrounding tissues. Thus, an X-ray shows scores of small, radiopaque bullet fragments scattered along the wound track (the snowstorm) (Fig. 2). Such a picture is not seen with pistol bullets, nor, with one exception, full metal-jacketed rifle bullets. The sole exception in

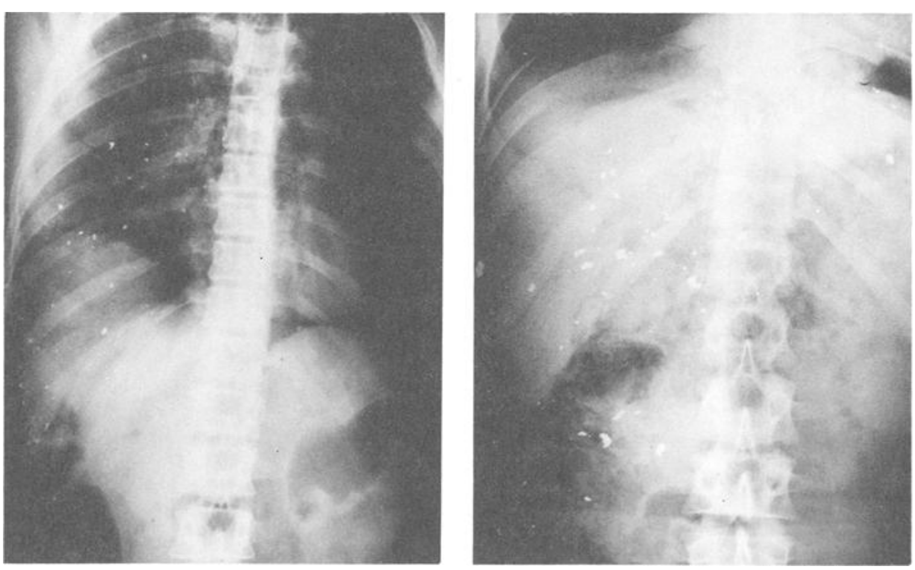

FIG. 2—*X-rays showing lead snowstorm in woman* (left) *and man* (right) *shot with 30-30 soft-point ammunition.*

the military rifle bullets is the 5.56-mm cartridge.[2] On occasion, while passing through the body, this full metal-jacketed bullet will tumble and fragments of lead will be ejected from its open base.

While the snowstorm appearance of an X-ray almost always indicates that the individual was shot with high-velocity-rifle hunting ammunition, absence of such a picture does not absolutely rule out this possibility.

## Powder Tattooing

Most rifle wounds fall into two extremes in regards to muzzle to target distance: contact wounds in suicides and distant wounds in homicides. Intermediate range wounds, that is, those with powder tattooing, are uncommon. The maximum distance to which this powder tattooing occurs from high velocity, center-fire rifles has never been determined. In view of this, an attempt was made experimentally to determine the maximum distance.

A series of tests was carried out on live anesthetized rabbits. The rabbits had to be alive as powder tattooing is a vital reaction and does not occur after death. This has been demonstrated by the authors by firing powder tattoo patterns on dead rabbits [5]. The chest and abdomen of the rabbits were shaved and the remaining hair removed by depilatory cream. The rabbits were then shot in the chest and abdomen at varying distances using a Winchester Model 94 30–30 rifle. Two brands of ammunition were used: Winchester 150-grain Silver-tip and Remington 150-grain soft-point. Two different brands were used because high velocity, center-fire rifle cartridges are loaded with one or the other of two physical forms of smokeless powder. In one form, the grains of powder have the shape of cylinders, while in the other, the grains of powder appear as balls or slightly flattened balls. Previous experiments with handguns have shown that different physical forms of powder in the same weapon produced powder tattooing out to different maximum ranges [5]. In view of this, it was decided to use two different brands of rifle ammunition, each loaded with a different physical form of powder. The Winchester Silver-tip ammunition was loaded with ball powder, while the Remington soft-point was loaded with cylindrical powder.

Table 4 summarizes the results of our tests. These indicate that the maximum ranges at which powder tattooing occurs is different for the two forms of powder. Heavy powder tattooing with deposition of soot was present at a range of 6 in. (15 cm) for the cylindrical powder. By 12 in. (30 cm), only a few scattered powder tattoo marks were present. No tattooing occurred at 18 or 24 in. (46 or 61 cm). Powder tattooing with ball powder extended out to 30 in. (76 cm), at which range it was present in moderate density. At a range of 36 in. (91 cm), ball powder no longer produced any tattooing.

Powder tattooing at greater ranges for ball powder compared to cylindrical powder is probably due to the shape of the powder grains. The sphere has a better aerodynamic form than a cylinder. The ball powder can travel farther with greater velocity enabling it to mark the skin at a greater range.

The skin of rabbits is thinner and more delicate than that of humans. Theoretically, powder tattooing should occur out to greater maximum distances for rabbit skin than for human. Thus, the data obtained in our experiments should be considered only as a guide to the extreme maximum distances at which powder tattooing can occur. In fact, the extent and degree of powder tattooing depends on a number of variables, including the specific weapon used, the barrel length, the caliber, the physical form of propellant, and the nature of the target.

In addition to producing powder tattooing out to different maximum ranges, the different forms of powder produce different-appearing powder tattoo marks [5]. The

[2] Richard T. Mason, M.D., personal communication.

TABLE 4—*Powder tattooing at different ranges for 30-30 rifle.*

| Range, in. | Degree of Powder Tattooing[a] |
|---|---|
| Remington Soft-Point[b] | |
| 6 | + + +[c] |
| 12 | + |
| 18 | 0 |
| 24 | 0 |
| Winchester Silver-tip[d] | |
| 18 | + + + |
| 24 | + + + |
| 30 | + + |
| 36 | 0 |

[a] 0 = none; + = scattered tattooing; + + = moderate; + + + = heavy.
[b] Cylindrical powder.
[c] Soot present as well as tattooing.
[d] Ball powder.

markings from ball powder tend to be small, circular, hemorrhagic, and in great numbers. Tattoo marks produced by cylindrical powder are larger, more irregular in shape and size, and sparse in number. The number of tattoo marks from cylindrical powder at 6 in. (15 cm) was, in fact, less than the number of powder tattoo marks produced at 24 in. (61 cm) by ball powder.

## Summary

Wounds inflicted by high velocity, center-fire rifles firing hunting ammunition are radically different from wounds caused by handguns or .22 rim-fire rifles. Injuries from pistol or .22 rim-fire rifle bullets are confined to tissue and organs directly in the wound track. In contrast, high velocity rifle bullets can injure structures without actually contacting them. This is due to the temporary cavity produced by such missiles with the resultant shock waves having pressures of up to 200 atmospheres (20 MPa). Organs struck by such high velocity rifle bullets may undergo partial or complete disintegration. Hunting ammunition, as it passes through the body, tends to shed fragments of lead from its core, producing a characteristic snowstorm picture on X-ray.

The maximum range at which powder tattooing of the skin occurs from center-fire rifles depends on the physical form of smokeless powder used as propellant. In a test with a 30-30 rifle, cartridges loaded with ball powder produced powder tattooing out to a range of 30 in. (76 cm), while similar cartridges, loaded with the traditional cylindrical powder, produced tattooing out to only 12 in. (30 cm) of range.

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