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Wounding Characteristics of .38 Caliber Revolver Cartridges

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ABSTRACT: Injury patterns in both artificial media and animal tissues were analyzed, and the results were then correlated with autopsy findings in subjects who died from gunshot wounds to determine the wounding characteristics of bullets from two standard .38 caliber revolver cartridges. The 150-grain round nose bullet, in comparison with a 110-grain semi-jacketed controlled-expansion round (hollowpoint bullet), was found to have greater penetration and a greater tendency to deviate from its flight path. The controlled expansion round was found to produce a wider bullet track with greater deformation and bullet fragmentation than the round nose ammunition in artificial media and animal tissue. Autopsy study of shooting victims indicated more through-and-through wounds with round nose bullets than with hollowpoint rounds, and overall survival in shooting victims was greater with round-nose bullets, but was modified by site of injury and availability of prompt medical treatment. Neither round appeared to differ in inherent "knockdown" power. Though distinct differences in wounding patterns can be demonstrated in artificial and animal media, the differences between round nose and controlled expansion round bullets are not marked in actual human subjects with gunshot wounds.

KEYWORDS: criminalistics, wound ballistics, ballistics

The selection of ammunition for use by law enforcement agencies has been the subject of considerable debate, but few experimental studies have addressed the issues involved. Public officials, the public at large, and news media, as well as law enforcement officers, have become involved in the debate. One of the primary issues of the debate concerns the use of the controlled-expansion round (CER), commonly known as the "hollow-point" bullet, by officers instead of the round nose (RN) bullet that has been the mainstay of many law enforcement agencies for years [*1*].

This issue centers on the potential wounding capabilities of these two bullet types and the consequent potential injury patterns to subjects who sustain gunshot wounds [*2*]. Related to wounding are both survival of subjects sustaining injuries and long-term disabilities as sequelae of these wounds. One opinion suggests that the CER bullet, by

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its expansile nature, inflicts more severe wounds that decrease survival and increase disability. Another opinion holds that the RN bullet, by its ballistic properties, is more likely either to penetrate to vital structures or to exit a subject without producing significant wounding or "knockdown" to stop the subject. By producing through-and-through wounds, the RN bullet is thought by some to create a greater potential hazard to bystanders.

Previous reports [*3–7*] have discussed general principles of ballistic injury. We addressed specifically the issue of wounding pattern of revolver cartridges by a study analyzing both CER and RN revolver cartridges in respective use by two law enforcement agencies. The wounding patterns of these rounds were compared by use of artificial media (Duxseal® and ordnance gelatin) simulating skeletal muscle and bone. The rounds were also compared in an experiment with animal tissues. Finally, the case records of subjects at autopsy who sustained gunshot wounds by the two law enforcement agencies were analyzed for wounding patterns and survival times.

Materials and Methods

The standard issue revolver cartridges of two law enforcement agencies in Los Angeles County, California, were studied. Agency A (Los Angeles Police Department) used the .38 caliber Winchester special cartridge with 150-grain (9.72-g) nonjacketed RN bullet of manufacturer's stated muzzle velocity of 860 ft/s (262 m/s). Agency B (Los Angeles County Sheriff's Department) used the .38 caliber Federal special cartridge with 110-grain (7.13-g) semi-jacketed CER with manufacturer's stated muzzle velocity of 1100 ft/s (335 m/s). Standard shooting conditions employed for all experiments included the use of a single chamber of a single Smith and Wesson .38 caliber special service revolver with 4-in. (10.2-cm) barrel. Rounds were fired at a target distance of 15 ft (4.6 m) by a single marksman.

Tests in Artificial Media

Two types of artificial media were used to demonstrate basic wounding patterns: Duxseal and ordnance gelatin. On an arbitray scale of 0 to 1000 as measured by computerized tomography (130 kV, 50 mA, 4-s scanning time, 25-cm scan circle diameter, filter setting 1, 10-mm slice thickness), with 0 representing the density of water, 20 to 40 the density of human muscle, and 1000 the density of bone, Duxseal was found to have a density of 794 and ordnance gelatin 18.

Rounds were fired into the center of the long axis of ten cylindrical blocks of each artificial test media. Each block measured 3.5 in. (8.9 cm) in diameter by 8 in. (20.3 cm) in length. Five of the blocks of each media had CER ammunition and five had RN rounds fired into them. After firing, the blocks were analyzed by conventional roentgenography and by computerized tomography. Views were made and photographed in two planes at 90° to each other along the length of the bullet track. Bullet track permanent cavity volume was measured by filling the cavities with water and then pouring the water into a graduated cylinder.

Tests in Animal Media

The hog was selected for experimental use based upon previous studies [*8*]. Eight hog right hindquarters, each weighing approximately 35 lb (15.9 kg), were obtained from a slaughterhouse. Each was suspended, foot down, from a wooden frame. Using a standard embalming machine (Sawyer Hevi-Duty Injector, Model F), the femoral artery of four hindquarters were cannulated and the vascular system was infused with India ink (5%

in 0.9% sodium chloride solution) at 60-psi (42.2-kPa) pressure, with pulsating cycle, for a time sufficient to fill the major veins during the test. Seepage was controlled by clamping off the larger veins. Standard shooting conditions were used as described above for the artificial media. Two hindquarters were shot, once each, with RN ammunition, and two were shot, once each, with CER cartridges, with a bullet path through the skin and into muscle 8 in. (20.3 cm) thick. Pressurization was stopped 15 s after bullet impact, and all clamps were removed. Dissections were performed using cross sections at 1-in. (2.5-cm) intervals serially along the bullet tracks.

The remaining four hindquarters were not cannulated. Under the standard shooting conditions, two were shot with CER and two with RN cartridges using a bullet path through skin that traversed 12 in. (30.5 cm) of hog muscle. Each bullet track was then examined by computerized tomography (130 kV, 75 mA, 2-s scanning time, 40-cm scan circle diameter, filter setting 1, 10-mm slice thickness, 10-mm intervals). Following this, each of the bullet tracks was injected with a radiopaque contrast material (Hypaque®) and examined by conventional roentgenography.

Two whole freshly slaughtered 200-lb (90.8-kg) hogs were obtained with carotids cut and blood drained. They were suspended from a metal bar by front legs. Using the previously described standard shooting conditions, each animal was shot once through each lung in an anteroposterior direction, twice in the abdominal cavity (once laterally at mid-abdomen and once anteroposterior at the level of the liver), once in subcutaneous tissue of abdomen parallel to ventral body surface, once laterally into right femur, once laterally into right hip joint, and once dorsoventrally into cervical vertebrae. One animal was shot with RN and one with CER ammunition. Autopsies with roentgenography were then performed to assess tissue damage.

Four hog hindquarters, minus the lower leg, weighing approximately 17 lb (7.7 kg) each, were used to test forces of acceleration and pressure transmitted to tissues by bullets. A single-axis piezoresistive shock accelerometer (Endevco model 2264-2000) and a piezoresistive pressure transducer (Endevco model 8510) were calibrated on a shaker table with pressure tank and then mounted on the posterior side of the femur with the major recording axes parallel with the path of the bullet. Sampling rate was 1000 samples per second at Society of Automotive Engineers (SAE) filter class 1000. With standard shooting conditions as described above, two hindquarters were shot with CER bullets and two with RN bullets through skin and into muscle 7 in. (17.8 cm) in thickness.

Subjects of Shooting Incidents

Reports in the files of two law enforcement agencies and autopsy reports in the files of the Los Angeles County Medical Examiner-Coroner's office were examined and cases with gunshot wounds produced by .38 caliber RN or CER ammunition in shooting victims with full documentation of number of wounds, location, and description of wounds and survival times were recovered from the files over a two-year period. Cases in which deaths occurred were selected when a complete autopsy had been performed.

Results

Artificial Media

By radiographic measurement, the length of the RN bullet tracks in Duxseal was found to average 7 in. (17.8 cm), with a mean maximum width of 0.5 in. (1.3 cm). The long axes of resting bullets randomly deviated from the long axis of the flight path in all cases. Bullet noses were only slightly flattened, and no fragmentation occurred. The CER rounds penetrated to a mean length of 2.75 in. (7.1 cm), with a mean width of 1.0 in. (2.5 cm)

with expansile deformity of all rounds along with fragmentation along the margins of the bullet track. Cavity volume averaged 75 cm^3 for RN rounds and 93 cm^3 for CER rounds.

In ordnance gelatin blocks, all RN bullets penetrated completely through and were not recovered. Diameters of bullet tracks were equivalent to bullet diameter, which did not expand. CER rounds penetrated a mean distance of 6.75 in. (17.1 cm) and expanded to a mean 0.75 in. (1.9 cm) in diameter. Neither bullet exhibited fragmentation in this media.

Animal Media

In the cannulated hog hindquarters, India ink surrounded the bullet tracks as a result of the tracks' course through perfused areas near the vascular tree. In one case shot with CER ammunition, the India ink surrounded the bullet track in the manner of antemortem vascular hemorrhage. The width of the RN bullet tracks was 0.25 to 0.375 in. (0.6 to 1 cm) and that of the CER tracks 1.0 to 1.5 in. (2.5 to 3.8 cm). The wound tracks of the CER bullets reached maximum diameter in the first inch of tissue and remained of fairly constant diameter throughout. All the bullets exited the media and were not recovered.

The noncannulated hindquarters were traversed by the RN bullets, which were not recovered. Computerized tomographic scans showed minimal splitting of tissue planes near the proximal wound track and mild side-to-side undulation of the tracks, which averaged 0.4 in. (1 cm) in diameter. The CER bullets came to rest 6.75 to 8 in. (17.1 to 20.3 cm) into hog muscle with greatest damage in the first 4 in. (10.2 cm). The average track width was 0.5 in. (1.3 cm). There was considerable dispersion of contrast material with extensive splitting of tissue planes.

Examination of injury patterns in lung in the whole-hog specimens revealed that both CER bullets caused a cylindrical defect approximately the same diameter as the expanded round, 0.625 and 0.69 in. (1.6 and 1.8 cm) and were recovered in subcutaneous tissue. RN bullets were deflected by ribs, causing grazing wounds to lateral lung surfaces, but were recovered in subcutaneous tissue. Shots into the abdomen with CER ammunition created extensive multiple bowel and mesentery lacerations, with both bullets expanded to 0.625 in. (1.6 cm) and remaining in the abdominal cavity. One RN bullet caused one laceration of mesentery and grazing wound of a single loop of bowel, while the abdominal anteroposterior shot stayed in subcutaneous tissue without entering the abdominal cavity. The CER bullets fired into abdominal subcutaneous tissue expanded to 0.69 in. (1.8 cm), creating a cavity of equal diameter and did not exit; RN bullets created a cavity equal to bullet diameter and exited the specimen.

The RN bullet fired at femur produced a fracture, whereas the CER bullet did not. Neither the CER nor the RN bullet damaged the hip joint as assessed by roentgenography. Both bullet types produced fracture of cervical vertebrae, but the RN bullet remained intact and penetrated into the cranial vault, whereas the CER bullet fragmented into four pieces.

Examination of recordings from accelerometer and pressure transducer in hog hindquarters showed that both measurements were much higher for CER ammunition. All test bullets penetrated completely through the tissues. Pressures averaged 7 psi (4.9 kPa) for RN and 17.7 psi (12.5 kPa) for CER bullets, with pressure waves lasting 4 ms for RN and 7 for CER. Accelerations in tissue averaged 130 Gs for RN and 270 Gs for CER bullets with duration of tissue acceleration averaging 11 ms for RN and 15 ms for CER bullets. Shock wave diameters around bullet tracks were estimated at 1 to 2 in. (2.5 to 5.1 cm) in hog muscle for RN and 6 to 7 in. (15.2 to 17.8 cm) for CER bullets.

Subjects of Shooting Incidents

Table 1 summarizes the information gathered over the two-year study period. Law enforcement Agency A using the RN bullets was involved with 32 cases that met study

TABLE 1—*Rounds fired and wounds inflicted by law-enforcement agencies.*

Agency	Subjects	Total Rounds Fired	Fatal Wounds	Gunshot Wounds per Subject	Rounds Fired per Officer
Agency A (RN)	32	103	55	3.1	1.6
Agency B (CER)	28	94	47	3.2	1.7

criteria, and these subjects sustained an average 3.1 gunshot wounds each, with 1.6 rounds fired per officer and 3.2 total rounds fired per subject. Of these wounds, 55 (53.4%) were designated as fatal. Law enforcement Agency B, using the CER bullets, was involved with 28 cases in this study, and these subjects sustained on average 3.2 gunshot wounds from 3.7 total rounds fired with, 1.7 rounds per officer. Half of 94 total gunshot wounds in this group were designated as fatal. None of the records indicated that any of the rounds fired by officers of either law enforcement agency struck other human subjects as secondary targets.

When the wounds were examined at autopsy to determine those that were through and through (exiting the body) versus those that penetrated only (Table 2), it was found that the RN bullets exited in 63% of all wounds (64% fatal versus 63% nonfatal), while the CER bullets exited in only 43% of all wounds (38% fatal versus 47% nonfatal). When the wounds were compared by body region most susceptible to fatal wounding (head, neck, or torso versus extremities, Table 3), it was found that 58 (59%) of wounds inflicted by Agency A were to these regions, compared to 63 (67%) by Agency B. When survival times of subjects were compared for both rounds, Agency A was found to have 13 subjects (41%) survive for 1 h or more, while eight subjects (28%) with wounds inflicted by Agency B's officers survived that long. The mean depth of penetration at

TABLE 2—*Comparison of penetrating versus through-and-through wounds by law enforcement agency.*

Fatal, through-and-through	35	18
Fatal, penetrating	20	29
Non-fatal, through-and-through	27	22
Non-fatal, penetrating	16	25

TABLE 3—*Composite entry wounds by body site and law enforcement agency.*

	Site			
	Front	Back	Lateral	Combined
		Agency A (RN)		
Head and neck	8	6	4	18
Torso	19	20	1	40
Extremities	18	19	3	40
		Agency B (CER)		
Head and neck	8	1	5	14
Torso	28	19	2	49
Extremities	17	11	3	31

autopsy for both fatal and nonfatal RN bullets was 9.2 in. (23.4 cm) compared with 8.2 in. (20.8 cm) for CER bullets. The range, 1.5 to 21 in. (3.8 to 53.3 cm), was similar for both bullet types.

Discussion

General principles of ballistic injury have been previously reported [*3–7*]. Mattoo et al. [*9*] have also experimentally addressed the issue of shot penetration, while Barach et al. [*10*] have discussed pathophysiology of wounding. Significant differences exist between high-velocity rifle bullets and low-velocity handgun (revolver) bullets [*11*]. We analyzed the data from several experiments to determine specifically the characteristics of the wounding patterns for both CER and RN revolver bullets and to determine, if possible, the relationship of bullet type to injury in subjects sustaining gunshot wounds. It was not possible, from the reports available, to determine long-term sequelae of injuries in subjects who survived gunshot wounds, so no conclusions concerning disability could be made.

In artificial media with a density by computerized tomography approaching that of human bone (Duxseal), the RN bullets showed greater penetration and a greater tendency to deviate from the long axis of the flight path. The CER bullets produced a track approximately twice the diameter of the RN track with significant deformation of the CER bullet. The CER bullet also produced greater cavitation than RN ammunition. Metallic fragments were left in the track of CER bullets, but not RN bullets. In artificial media with a density similar to human muscle (ordnance gelatin), RN bullets were found to penetrate further than CER bullets, though both types maintained a straight path with minimal deviation from the flight path. Neither bullet left metallic fragments in the track.

In the cannulated hog hindquarters with pulsatile vascular pressurization, the CER bullets produced more tissue damage than the RN bullets, though both were capable of penetrating through skin and 7 in. (17.8 cm) of muscle tissue. The wound track of the CER ammunition was three to six times the size of the track produced by the RN bullets. In hog hindquarters that were studied by roentgenography and contrast media, the RN bullets showed greater penetration but had a wound track only two thirds the size of CER bullets. CER bullets showed deformation with fragmentation and greater tissue damage than RN bullets, which did not deform or fragment.

Analysis of shooting patterns in the intact whole hogs showed that CER bullets were less likely to deflect upon striking bone, less likely to fracture bone, and less likely to produce through-and-through wounds than RN bullets, but were more likely to fragment upon striking bone. The CER ammunition produced more damage to bowel and mesentery. The CER bullets expanded fairly uniformly to 0.625 in. (1.6 cm).

The data from measurement of pressures and acclerations of hog muscle indicate that both these parameters were more than double for CER bullets compared to RN bullets, but the forces produced by both bullets acted over a short duration. These data suggest that a human perforated through soft tissue by either a CER or RN bullet might not perceive the injury as much as that from the blow of a blunt object. For through-and-through wounds, this suggests that there is no inherent "knockdown" power in either bullet. However, the force of the RN bullet is fairly localized, compared to the CER, so that the perception of injury may be greater with the CER bullet.

When actual subjects of gunshot wounds from CER and RN ammunition were studied at autopsy, we found that there were more through-and-through wounds from RN bullets (Table 2). Depth of penetration was only slightly greater for the RN bullets, and both types had an equivalent range of penetration. When data from investigative reports of the shooting incidents were correlated with the tissue findings, we found that there were slight differences in survival times and number of fatal wounds between the two law

enforcement agencies using CER and RN bullets. The slightly greater survival times with the RN bullets used by Agency A may have reflected the smaller proportion of gunshot wounds to head, neck, and torso or the larger size of the CER wounds (Table 3). Hemodynamic alterations, which we did not study, may also have played a role [*12*]. No through-and-through wounds were associated with injury to bystanders, according to the reports studied. The number of rounds fired per officer (Table 1) suggests that there was no real or perceived difference in "knockdown" power under real-life conditions.

Conclusion

Although controlled experimental studies in artificial or animal models show differences in wounding patterns between CER and RN bullets, these differences in subjects of gunshot wounds inflicted by law enforcement agencies are not pronounced. For forensic pathologists investigating gunshot wounds at autopsy, the greater tendency to fragment or deform, or both, but lesser tendency to deflect or produce through-and-through wounds may be useful parameters to help differentiate CER wounds from those of RN bullets, which are less likely to have such characteristics. Our studies of through-and-through wounds and the numbers of rounds fired per officer suggest that there is no significant actual or perceived "knockdown" power in either bullet and, in terms of total energy imparted from the bullets to the subjects, both appear to be equally disabling. Our studies did not include any measure of "nerve shock" to victims by the bullets, though further studies might be able to show whether or not the greater tissue destruction by the CER bullets produces such an effect. Site of injury, number of wounds, the condition of tissues in relation to the subject's health or age, and availability of trauma care may also influence survival.

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