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Characteristics of Shored Exit Wounds

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ABSTRACT: Experimentally produced shored exit wounds are examined primarily with respect to the elements of wound appearance and secondarily to the effects of weapon caliber, kinetic energy of the round, type of shoring material, and shoring pressure on wound characteristics.

KEYWORDS: pathology and biology, wound ballistics, ballistics

Among forensic pathologists, the shored exit is a recognized entity [*1-3*]. Its appearance differs significantly from the typical exit wound, which is irregular, slit-like or stellate, and has margins free of abrasion. By contrast, an exit wound supported or shored by a firm material pressed against the skin (Fig. 1) may have the characteristics of an entrance wound, specifically a circular defect with an abraded margin; these similarities may lead to confusion and misinterpretation as to direction of fire.

The nature of the shoring material may vary widely [*1,3*]. Articles of clothing with constrictive portions such as the waistband of trousers or elastic brassiere straps may support the skin at the exit, where there may be a patterned abrasion of the cloth weave. Personal effects, such as a wooden crutch pressing on the axillary skin of an amputee, have accounted for atypical, shored exits. Another part of the body pressed against the site of exit may be responsible for these unusual wounds. Virtually any firm material against which the skin is pressed may cause shored exits, such as when a person is shot while lying on the floor. Two actual shored exit wounds are shown in Figs. 2 and 3.

A search of the scientific literature revealed no articles addressing the characteristics of shored exit wounds and the influence on wound configuration of weapon caliber, type of shoring material, and pressure of the skin against the supporting substance. An experimental model was designed to produce a number of known shored exit wounds for examination.

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The experiments reported herein were conducted according to the principles described in "Guide for the Care and Use of Laboratory Animals" of the Institute of Laboratory Animal Resources, National Research Council, Department of Health, Education and Welfare Publication (NIH) 78-23, revised 1978.

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Materials and Methods

The weapons and ammunition selected for this study are given in Table 1. The animals used to receive the shored exit wounds were male, mixed breed "mini-pigs," each weighing approximately 23 to 34 kg (50 to 75 lb). Surgical anesthesia was achieved by intravenous administration of sodium pentobarbital (approximately 30 mg/kg body weight) by means of an indwelling "butterfly" cannula in a lateral ear vein. The animals were washed and lightly clipped without damage to the skin.

On the ballistic firing range, the animals were placed in a wooden frame designed to hold the skin at the exit wound pressed against various shoring materials at differing pressures. The shoring materials included 0.48-mm (0.019-in.) aluminum sheet metal, 6-mm (¼-in.) plywood, 13-mm (½-in.) plasterboard, 6-mm (¼-in.) clear Plexiglas®, 6-mm (¼-in.) plate glass, and concrete blocks; in addition, shored exit wounds were produced in areas of skin tightly wrapped with cloth, specifically sheeting material. Four control wounds, one for each weapon used, were also produced without the use of shoring material.

The pressure of the skin against the shoring materials was controlled by a smaller square wooden frame situated on the side of the animal away from the supporting material. Connected to two opposite sides of the frame with eye hooks was a loop of wire that passed under the animal and shoring material as well as over them; pressure was exerted by a 4.5 or 18-kg (10- or 40-lb) weight suspended from the wire loop.

The larger wooden frame was connected to a stainless steel cart with four C clamps. Weapons were individually attached to a remote control firing stand and were discharged with a push button located outside the firing range. The range of fire was approximately 0.3 m (1 ft) for the rifle and 0.6 m (2 ft) for the handguns.

During weapon firing, every attempt was made to ensure the uniformity of the procedure in the following respects: shots were fired as nearly perpendicular to the shoring material as possible. Impact with bone, which would have altered missile behavior unpredictably, was avoided by firing weapons only into the abdomen and away from the vertebral column. Pigs of similar size and with similar skin thickness on rough gross examination were chosen for the study. In addition, the distance from the muzzle of each weapon to the skin surface of each pig and the thickness of tissue traversed by the projectile (abdominal diameter of approximately 0.3 m [1 ft]) were kept constant.

The experimental, shored exit wounds were visually examined, photographed, completely excised with underlying subcutaneous tissue, and studied under dissecting and light microscopes. Three exit wounds, shored by concrete, plate glass, and aluminum, were chosen for examination with a scanning electron microscope on the basis of visible particulate matter on the skin surface. Elemental analysis of these wounds was performed by the technique of energy dispersive analysis of X-rays (EDAX).

Results

Examination with the Dissecting Microscope

Each experimentally produced wound was studied under an American Optical stereooptic microscope for details of wound configuration. The wounds were analyzed with attention to the following: shape of skin defect, degree of abrasion and contusion, relative amount and type of particulate matter, maximum wound diameter, including abraded margin, and maximum width of abrasion ring. Of the 48 experimentally produced shored exit wounds, the number and the percentage of the total number demonstrating these features are given in Table 2.

The four control wounds are representative of typical exit wounds and have a true stellate configuration, virtually no abraded margin, and no particulate matter on the skin surface.

The most common finding in the shored exit wounds—a round or ovoid defect with a pro-

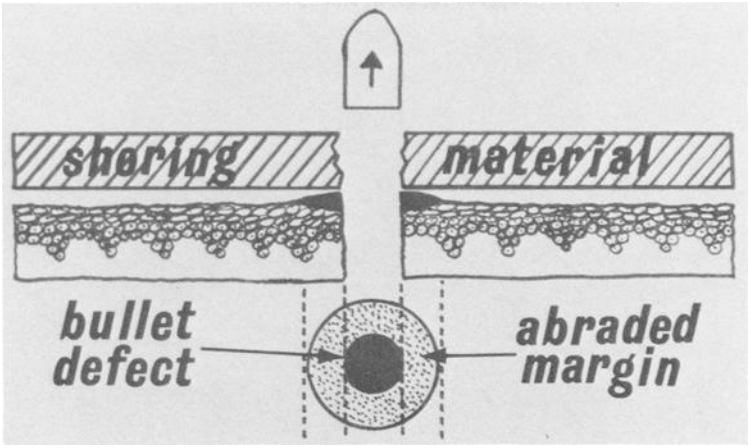

FIG. 1—*Schematic view of formation of shored exit wound with skin pressed against shoring material. Black portion of skin surface represents tissue lost through abrasion by supporting material. Resulting circular defect with abraded margin is shown at bottom.*

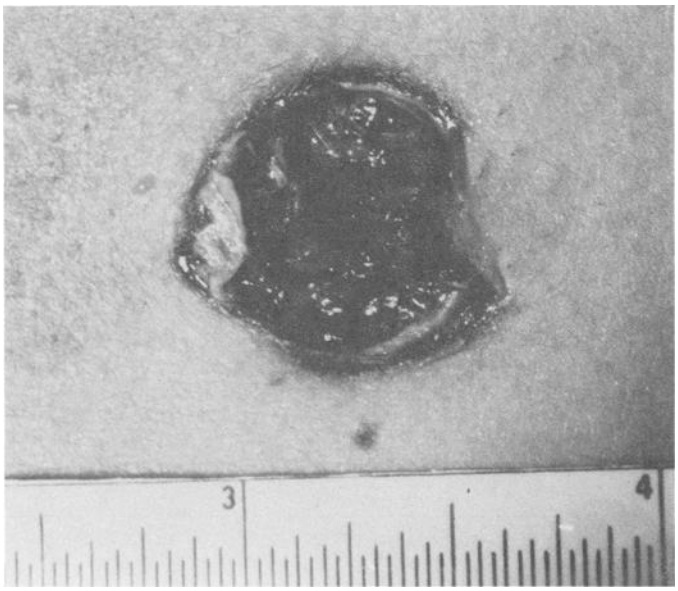

FIG. 2—*Shored exit wound of left chest of a man shot during a bank robbery with a .38-caliber weapon while lying facedown on a stone floor. The corresponding entrance wound was typical in appearance (Case 80-12-973).*

minent abrasion margin—represents the most frequent description [*1-3*] of a shored exit wound. Examples of typical experimental shored exit wounds are shown in Figs. 4 and 5.

Lacerations of varying sizes radiating from the central defect were noted in many wounds (33%). Most of the lacerations were a minor aspect of wound configuration, but, in several wounds, they were prominent and suggestive of a close-range entrance wound.

Another frequent observation was that contusion around the wound was present in 63% of

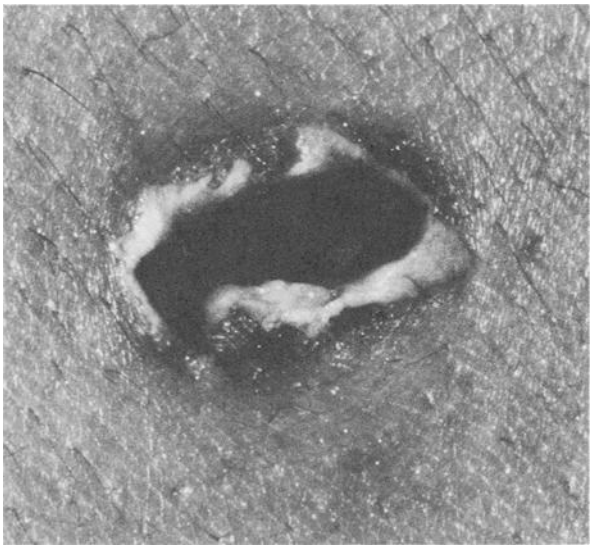

FIG. 3—*Shored exit wound of the back of a woman at the level of a brassiere. She was shot in the upper right chest at close range with a .38-caliber weapon; the entrance wound determination was confirmed by the presence of powder on the skin (Case 80-05-360). The defect measured 1.3 by 0.6 cm.*

TABLE 1—*Weapons and ammunition used in the study.*

Weapon	Ammunition
Remington .22-caliber Long Rifle, Commercial Training Grade M13 rifle	Remington high velocity .22 Long Rifle 40-grain solid point, muzzle velocity 382 m/s (1255 ft/s), kinetic energy at muzzle tip 189 J (140 ft·lbf) [*4*]
Ruger .357 Magnum revolver, "Ruger Security Six"	Remington .357 Magnum 158-grain lead, muzzle velocity 376 m/s (1235 ft/s), kinetic energy at muzzle tip 722 J (535 ft·lbf) [*4*]
Colt .38-caliber Special revolver, "Police Positive Special"	Remington .38 Special 158-grain lead, muzzle velocity 230 m/s (755 ft/s), kinetic energy at muzzle tip 270 J (200 ft·lbf) [*4*]
Remington .45-caliber M1911 A1 U.S. Army semiautomatic pistol	Remington .45 automatic 230-grain full metal case, muzzle velocity 247 m/s (810 ft/s), kinetic energy at muzzle tip 452 J (335 ft·lbf) [*4*]

TABLE 2—*Number and percentage of wounds demonstrating different features of wound configuration.*

Feature	Wounds	
	n	%
Round or ovoid defect	44	92
Radiating lacerations	16	33
Partial circumferential abrasion	48	100
Complete circumferential abrasion	29	60
Contusion around wound	30	63
Particulate matter grossly	11	23
Particulate matter microscopically	12	25

FIG. 4—*Shored exit wound produced by a .357-caliber weapon with Plexiglas shoring at 176 N (40 lbf) of force (AFIP Negative 79-10205). The extensive light area around the defect is the dermis underlying abraded pigmented epidermis. The diameter of the wound defect was 0.8 cm; the abrasion margin measured 0.6 cm in greatest width.*

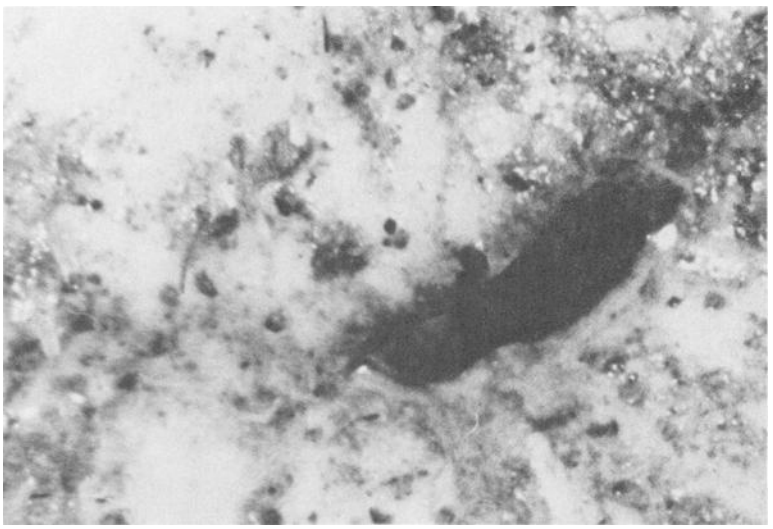

FIG. 5—*Shored exit wound produced by a .38-caliber weapon with concrete shoring at 44 N (10 lbf) of force (AFIP Negative 79-10212). Note particulate matter suggestive of powder stippling. The diameter of the wound defect was 0.6 cm; the abrasion margin measured 1.0 cm in greatest width.*

the injuries and was greatest in situations where the kinetic energy of the round was highest (.357 Magnum) and where the shoring material was least flexible (Plexiglas, glass, and concrete).

Particulate matter around the wound exit defect, presumably from the shoring material, was seen grossly in 23% of the wounds, especially in those shored by metal, glass, and concrete. The wounds shored by glass had a fine gray powder surrounding them, paralleling the finding of Stahl et al [5] in an entrance wound with glass as an intermediate target. The wounds supported by concrete were stippled by a gray, gritty material. The latter appearance is shown in Fig. 5.

Examination with the Light Microscope

All wounds were studied under a light microscope after formalin fixation and standard processing for histologic sections. Surprisingly, black particulate matter suggestive of gunpowder was noted in the depths of almost all of the exit wound tracks. In addition, true stippling of the epidermal surface by embedded particulate matter was noted microscopically in 25% of exit wounds, primarily those shored by metal, Plexiglas, glass, and concrete.

Other Examinations

Specimens chosen for electron microscopy on the basis of large amounts of particulate matter were examined with an Advanced Metals Research Scanning Electron Microscope Model 1000. By energy dispersive analysis of X-rays, examination of particles for identification as to specific elements was achieved with an EDAX instrument (Model 711B). The results of this examination are shown in Table 3. The particulate matter in an exit wound shored by concrete contains a range of elements quite similar to the concrete control. The wound shored by glass had high levels of silicon, as would be expected; a glass control was not examined. Attempts to document aluminum in a wound shored by sheet metal were fruitless.

Discussion

Analysis of wound configuration showed that 92% of the typical shored exit wounds had a round or ovoid defect. All of them had some part of the circumference abraded, and in 60% there was abrasion of the entire circumference. Both of the characteristics may lead to confusion of a shored exit wound with the typical distant entrance.

The greatest degree of abrasion was seen in many wounds produced by the rounds impart-

TABLE 3—*Results of EDAX examination of selected exit wounds and concrete control.*

Shoring Material	Weapon Caliber	Shoring Pressure		Elements Detected
		lbf	N	
Concrete (control)	...	...	...	calcium, silicon, aluminum, potassium, sulfur, magnesium, iron
Concrete	.357	40	176	calcium, silicon, aluminum, potassium, sulfur, iron
Glass	.357	40	176	calcium, silicon, aluminum, potassium, iron

ing the most kinetic energy from the round to the skin (.38-, .45-, and .357-caliber rounds) in conjunction with the most rigid or brittle shoring materials (glass and concrete). (For the purposes of these studies, a high degree of rigidity is indicated by the likelihood that a particular shoring substance will shatter when perforated by a projectile.) The relationship between degree of abrasion and shoring pressure is not clear from the data developed by this study.

In addition, many of the wounds (33%) had lacerations radiating outward from the central defect; this finding may be misinterpreted as an indication that the apparent stellate wound is a hard contact entrance wound.

Even more confusing was the presence of particulate matter appearing as apparent powder stippling around the skin defect in 25% of the wounds. Elemental analysis by EDAX revealed that in those wounds studied the material on the skin surface was consistent with glass or concrete and not gunpowder. Such surface particulate matter was seen in wounds shored with metal, Plexiglas, glass, and concrete.

Another feature of wound configuration was the presence of contusion in 63% of shored exits. This finding also is related to the kinetic energy of the round and to the rigidity or brittleness of the shoring material.

Conclusions

Shored exit wounds may be readily confused with entrance wounds, whether distant, close range, or contact, on the basis of a round or ovoid defect with an abraded margin, contusion and particulate matter from the shoring material mimicking powder stippling, and a stellate configuration, respectively. The degree of abrasion and contusion is directly proportional to the rigidity or brittleness of the shoring material and to the kinetic energy of the round. The effects of the shoring pressure cannot be evaluated from the results of this study. All of these factors must be considered to prevent misinterpretation of shored exit wounds as entry wounds.

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