*Michael E. Ward,*[1] *M.D. and Kurt B. Nolte,*[2] *M.D.*

# Ballistic Characterization of the Remington Premier® Copper Solid™ Sabot Shotgun Slug*†

**REFERENCE:** Ward ME, Nolte KB. Ballistic characterization of the Remington Premier® Copper Solid™ sabot shotgun slug. J Forensic Sci 2000;45(6):1259–1266.

**ABSTRACT:** We evaluated the impact and penetration characteristics of the Remington® Copper Solid™ sabot shotgun slug with standardized ballistic tests and used this information to predict tissue wounding patterns. This unique ammunition, first distributed in 1993, is composed of a solid copper, hollow-point slug with longitudinal slots cut into the nose. The slug is fitted into a hard plastic sabot with 8 finger-like projections and loaded into a shotgun shell with two plastic wads separating it from the underlying gunpowder charge. The ammunition was fired through a 12-gage shotgun using a rifled barrel, a smooth-bore barrel with rifled choke, and a smooth-bore barrel with a smooth modified choke into targets consisting of poster board and 10% ballistic gelatin at a variety of distances.

The copper slug and plastic sabot created single 8-fingered asterisk-shaped defects in the poster board when fired at distances of less than 7 to 9 ft (~2 to 3 m). All three barrel types performed similarly. At greater distances, the sabot impacted the targets separately from the slugs and created variably shaped defects that reflected base-first, nose-first, and side-first impacts. Increasing muzzle-to-target distances generally increased the impact distances between the slug and sabot. There was no predictable relationship between the sabot and slug impact points for any of the three barrel types. With each barrel tested, the wads created separate defects from the slug at distances greater than 5 ft (1.5 m). The distances between the slug and the wad impact points increased with increasing muzzle-to-target distances up to 40 ft (12 m), after which the wads generally no longer struck the targets. The slug created atypical defects at distances between 7 and 150 ft (~2 to 45 m), probably due to yawing or tumbling.

When the slug impacted the gelatin block in a nose-first orientation, the slotted nose portion tended to fragment and radially deposit pieces in the gelatin that were visible on radiographs. When the slug struck the gelatin target in a side-first orientation, it passed through the gelatin intact.

The slug, sabot, and wads of this unique projectile separate and create independent impact points in a stereotypical manner independent of barrel type. This pattern of separation allows estimates to be made of ranges of fire. Wounds created in human tissues by this ammunition would likely have similar asterisk-shaped configurations, and nose fragments may be deposited in tissues and seen radiographically. Rectangular wounds created by the tumbling or yawing slug might be mistaken for intermediate target wounds.

**KEYWORDS:** forensic science, forensic pathology, wound ballistics, shotgun slugs, sabot

Each year, new ammunition is introduced into the commercial market. Some of these ammunitions create characteristic wounds or radiographic findings related to their unique construction and deformation/fragmentation patterns. Some handgun examples include the Glaser safety slug (1), Hydra-shok bullet (2), tubular "cookie cutter" bullet (3), and shotshell ammunition (4). Shotgun ammunition, such as the Brenneke slug, can also be uniquely constructed so that "signature" patterns are created in wounds (5).

In 1993, the Remington Premier® Copper Solid™ sabot shotgun slug was marketed for commercial use. Available in 12 and 20 gage, this hollow-point, solid copper slug is machined at the nose to create four longitudinal slots, all designed to control deformation (Fig. 1*a*). A plastic 8-fingered sabot surrounds the smaller-diameter copper slug and engages the grooves of a rifled shotgun barrel or a rifled shotgun choke (Fig. 1*b*). A sabot (sabo'_, sab'_o) is a thrust-transmitting, lightweight carrier in which a subcaliber projectile is centered (6). It prevents the escape of gas ahead of the missile. The plastic sabot allows the copper slug to be fired through larger-diameter shotgun barrels. In addition to the slug and sabot, each round contains two plastic wads, each weighing less than 2 g (Fig. 1*c*). A gray disk-shaped wad sits below the sabot and a green, concave, disk-shaped wad is positioned above the powder charge. Each wad is the diameter of the sabot. The gray wad is twice the weight and ⅔ the thickness of the green wad. The 12-gage round has a muzzle velocity of 1450 ft/s (442 m/s) and a muzzle energy of over 2000 ft-lb. The manufacturer claims the round has improved accuracy due to rotation of the slug as the sabot engages the rifled shotgun barrel or rifled choke (7).

Because the Remington® Copper Solid™ shotgun slug is an unusually constructed projectile, we predicted that it would create atypical wound patterns if it struck a human target. To evaluate this hypothesis we characterized the potential wounding patterns of this projectile using standardized ballistic tests.

## Materials and Methods

This project was divided into two basic components. The first component evaluated the surface impact characteristics of the projectile, including the dynamics of sabot-slug separation. Foam core boards served as a proxy for human skin. The second component evaluated the penetration characteristics of the projectile including fragmentation patterns and radiographic appearances. Gelatin blocks served as a proxy for human tissue. Shooting was conducted outdoors on calm to slightly breezy days.

[1] Chief Medical Examiner, Greenville County Pathology Associates of Greenville, Greenville, SC.

[2] Office of the Medical Investigator, University of New Mexico School of Medicine, Albuquerque, NM.

* This study was supported in whole by funds from the American Academy of Forensic Sciences, Pathology/Biology Research Committee.

† Presented at the 50th Annual Meeting, American Academy of Forensic Sciences, San Francisco, CA, February 1998.

Received 18 June 1999; and in revised form 30 Sept., 30 Nov. 1999; accepted 6 Dec. 1999.

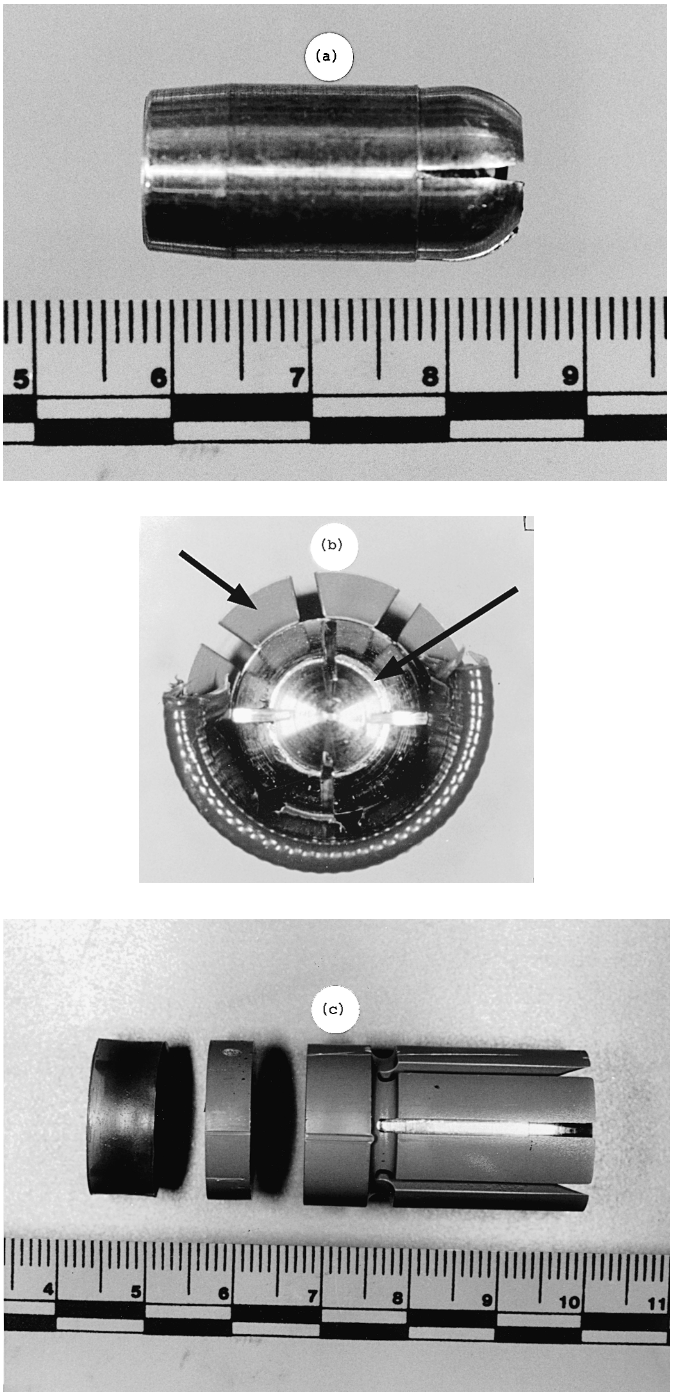



FIG. 1—(a) *Side view of the Remington Premier® Copper Solid™ slug showing the longitudinal slits cut into the hollow point nose.* (b) *Partial cutaway end view of Remington sabot shotgun slug ammunition demonstrating hollow-point copper slug (long arrow) with machined nose placed within the 8-fingered plastic sabot (short arrow).* (c) *Side view of the relationship of the two plastic wads and sabot. The wad to the left is positioned above the gunpowder charge. Scales in centimeters.*

*Evaluation of Surface Impact*

For the surface impact evaluation, foam core poster boards, ⅜-in. thick, were used as targets. Remington Premier® Copper Solid™ sabot 12-gage ammunition, with a shell length of 2¾ in., a slug weight of 1 oz (27.5 g), and a sabot weight of 4.3 g, were fired through a 12-gage Remington 870 Express shotgun. Interchangeable barrels included a rifled bore, a smooth bore with a rifled choke, and a smooth bore with a smooth modified choke. Three rounds from each barrel were fired at 6 in. and 1, 2, 3, 5, 7, 9, 11, 15, 20, 30, 40, 50, 60, 75, and 100 ft (15, 30, 60, and 90 cm and 1.5, 2.1, 2.7, 3.3, 4.5, 6, 9, 12, 15, 18, 23, and 30 m). Five rounds from each barrel were fired at 150 ft (45 m). The following observations were recorded for each distance: description of defect in target board when the sabot and missile struck together; gunshot residue patterns; unique patterns created by the deforming plastic sabot; muzzle-to-target distance at which sabot and slug created separate defects; the location and distance of the defect created by the plastic sabot (using a clock-face orientation relative to the slug entrance); and the muzzle-to-target distance at which the plastic sabot no longer impacted the target. Target sizes of $42 \times 28$ in. ($106 \times 71$ cm) were used for shorter firing distances and of $40 \times 60$ in. ($100 \times 150$ cm) were used for greater firing distances.

*Evaluation of Penetration*

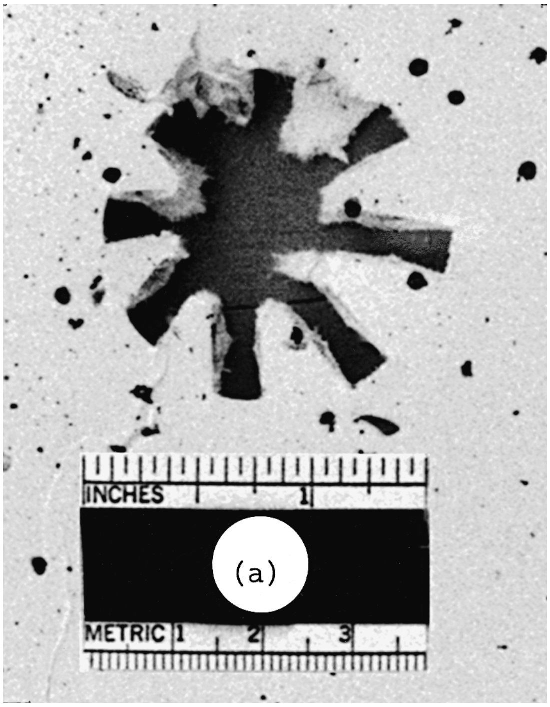
For the evaluation of penetration, ballistic gelatin powder purchased from Knox and Knox, Inc., was mixed according to the procedure described by Thompson (8) to a 10% gelatin concentration and was molded into $7.5 \times 7.5 \times 11$ in. ($19 \times 19 \times 28$ cm) blocks that had average weights of approximately 21 lb (9.5 kg) each. Gelatin block temperatures were maintained at 4 to 6°C. Three rounds were fired from each barrel into the gelatin at muzzle-to-target distances before and after the sabot separation point. A distance of 3 ft (0.9 m) was chosen as the "before separation" distance. The blast effect at closer distances tended to disrupt the gelatin. "After separation" distances were 30 and 60 ft (9 and 18 m). Three rounds were fired at 150 ft (45 m) through the rifled barrel. Both the outer surfaces of the gelatin block and a longitudinal section through the missile track were photographed to demonstrate cavity formation and missile fragmentation. Front and side radiographs of the gelatin blocks were taken. The radiographic patterns were recorded and photographed.

Pearson correlation coefficients were used to describe linear relationships between muzzle-to-target distances and ballistic measurements. Repeated measures of analysis of variance were used to test for mean differences between the three barrel types.

## Results

*Evaluation of Surface Impact*

When the plastic sabot impacted the target, it created unique defects. Separate sabot and slug defects were created at distances beginning at 7 ft (2.1 m) with the rifled barrel and the smooth barrel with a smooth modified choke, and 9 ft (2.7 m) with the smooth barrel with the rifled choke. The distance between the two defects increased as the muzzle-to-target distance increased. The projectile and sabot created a single defect at closer muzzle-to-target distances. Prior to separation, the sabot defect often had the shape of an asterisk with 8 prongs (Fig. 2*a*) or some variation of this shape. The sabot also created partially rounded defects with a varying number of prongs reflecting some degree of side-first impact (Fig. 2*b*). Following separation, the sabot could impact the target with any presentation and generally created an elongated rectangular defect when the side impacted first (Fig. 2*c*). The 8 plastic prongs opened to varying degrees, giving the defect a round to fan-like appearance. Occasionally, a prong broke off from the sabot prior to impact and created a separate irregular defect (Fig. 2*c*); and the prong sometimes penetrated adjacent wooden target supports.



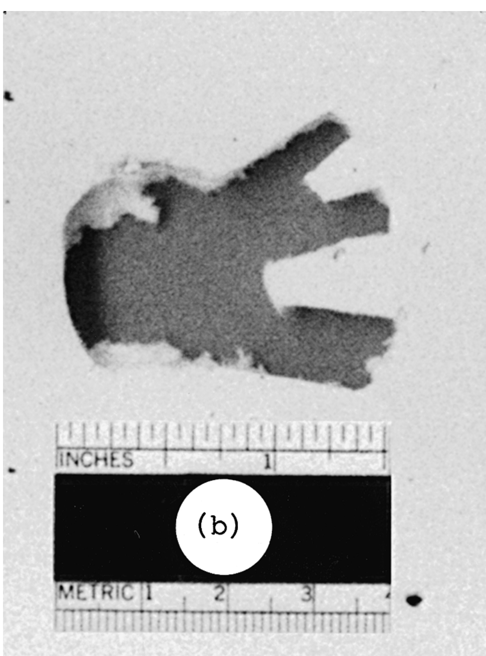




FIG. 2—*Surface impact defects in foam core targets demonstrating* (a) *asterisk-shaped defect from nose-first combined slug-sabot impact, target distance 3 ft (0.9 m);* (b) *elongated defect with varying numbers of prongs, formed when the sabot impacts the target with side-first orientation, target distance 5 ft (1.5 m); and* (c) *multiple defects at 9 ft (2.7 m) target distance; sabot defect (arrow 1), side-impacting slug defect (arrow 2), circular defects from impacting wads (arrows 3 and 4), and rectangular defect created by separately impacting sabot prongs (arrows 5 and 6).*

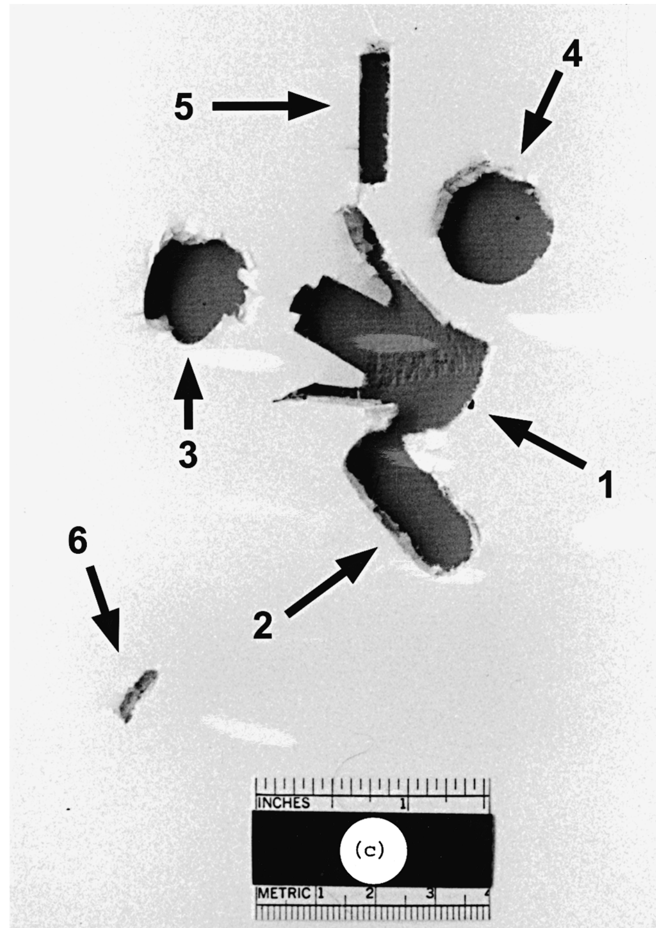



FIG. 2—*(Continued)*

Plotting the distance between the slug and sabot defects against the muzzle-to-target distance for all barrels types demonstrated a positive linear relationship (Fig. 3; $r = 0.77$; $p = 0.0001$). However, as the muzzle-to-target distance increased, measurements of slug and sabot separation became more variable. At greater than 30

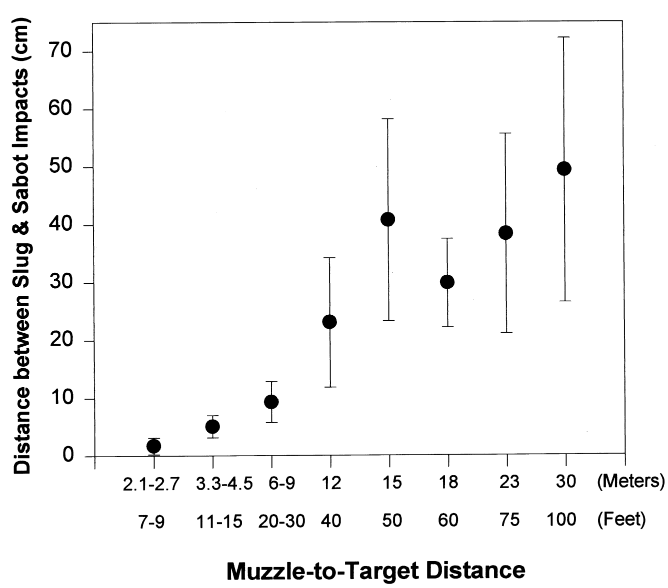



FIG. 3—*Mean of sabot separation distance (cm)* ± *standard deviation, by distance from muzzle to target, all barrel types,* r = *0.77.*

ft (9 m), measurements of the slug and sabot separation were most varied (i.e., large standard deviation). The sabot consistently impacted and perforated the target at distances up to 75 ft (23 m) and consistently impacted but rarely perforated the target at distances of 100 ft (30 m). No sabot impacted the core target at 150 ft (45 m). Comparison demonstrated no significant differences in mean separation distances between the three barrel types.

Relative to the slug, the sabot impacted the target in all four quadrants without significant variation between barrel types. When impacts from all barrel types were combined and grouped by muzzle-to-target distance, certain patterns became apparent. At muzzle-to-target distances of less than 5 to 7 ft (1.5 to 2.1 m) the sabot impacted at the slug defect, and at 9 to 11 ft (2.7 to 3.3 m) there was near equal distribution in all quadrants. At muzzle-to-target distances greater than 15 ft (4.5 m), 70% of the sabot impacts were to the left of the slug. At shorter muzzle-to-target distances, the sabot tended to impact above the slug, but as distance increased to 50 ft (15 m) and greater, the majority impacted below the slug.

In addition to the sabot and slug, the two separate plastic wads also impacted the targets. In all three barrels, the wads began to separate at a muzzle-to-target distance of 5 ft (1.5 m), slightly earlier than the sabot, and the wads created two round-to-elongate defects in the target (Fig. 2*c*). Although they separated from the slug/sabot sooner, the lightweight wads rarely impacted the target at distances greater than 40 ft (12 m). The gray wad, which was more dense, tended to travel 10 to 20 ft (3 to 6 m) farther than the green wad.

Measurements of the distance of the farthest wad impact (regardless of type) from the slug defect demonstrated a positive linear relationship with the range of fire (Fig. 4; $r = 0.96$; $p = 0.0001$). There was no significant difference in mean distance between the three barrel types ($p = 0.50$).

A measurement of overall pattern size was made for all shots and a positive linear relationship existed from 3 to 30 ft (0.9 to 9 m) (Fig. 5; $r = 0.98$; $p = 0.0001$). After 40 ft (12 m), the wad components of the shell often did not reach the target. The maximum size of the overall pattern differed by range of fire ($p = 0.0001$); and no difference was noted between the three barrel types ($p = 0.44$).

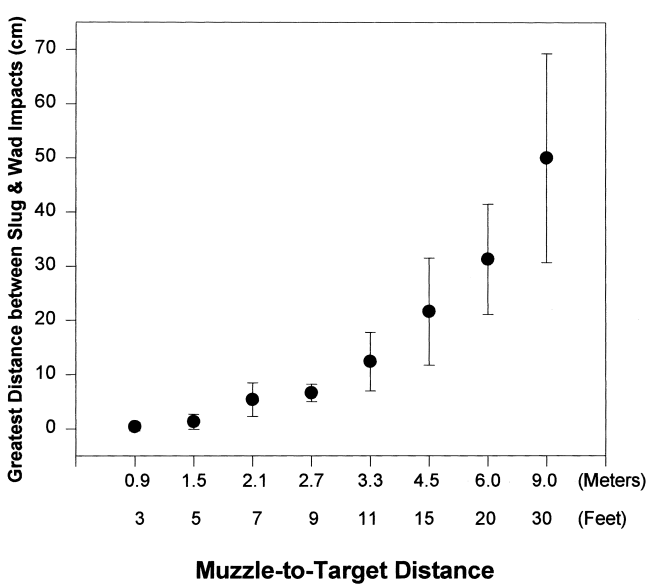



FIG. 4—*Mean of greatest wad separation distance (cm) ± standard deviation, by distance from muzzle to target, all barrel types,* r *= 0.96.*

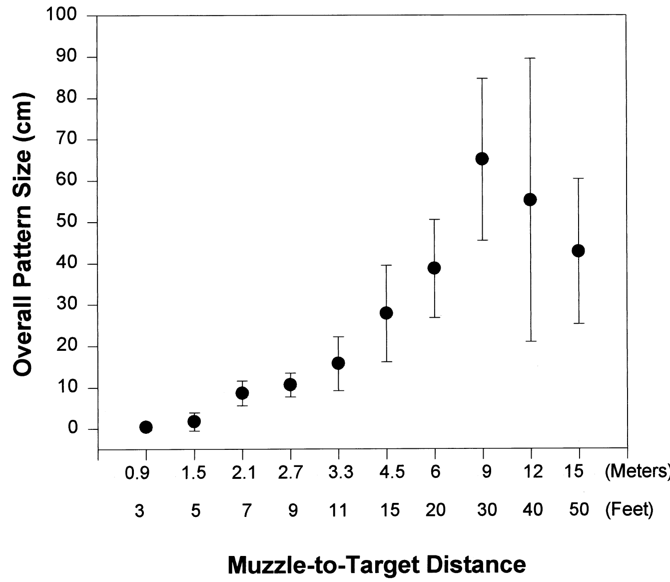



FIG. 5—*Mean overall pattern size (cm) ± standard deviation, by distance from muzzle to target, all barrel types,* r *= 0.98 up to 30 ft (9 m).*

Unlike bullets fired from handguns or rifles, the copper solid slug frequently did not maintain ballistic flight, regardless of barrel type. At distances of 5 and 7 ft (1.5 and 2.1 m), all slugs that impacted separately from the sabot created a round defect. However, at 9 and 11 ft (2.7 and 3.3 m) only 67% of the slugs created round defects. The remainder of the defects were irregular. An irregular defect was considered to be one not round, but instead elliptical to elongate in appearance (Fig. 6). No specific length-to-width ratio was employed. At 15 and 20 ft (4.5 and 6 m), 67% of the impacts were irregular; at 30 and 40 ft (9 and 12 m), 22% were irregular; and at distances of 50 ft (15 m) and greater, 61% of the slug defects were irregular. Of the rounds fired at 150 ft (45 m), 2 of 5 were irregular from the rifled barrel, 3 of 5 were irregular from the smooth barrel with a smooth modified choke, and 5 of 5 were irregular from the smooth barrel with a rifled choke.

Gunshot residue was deposited on the surface of foam core targets at distances from 6 in. to 5 ft (15 cm to 1.5 m) and was inconsistently deposited on targets at 7 and 9 ft (2.1 to 2.7 m). Gunshot residue consisted of soot, which disappeared at a distance of 1 ft (30 cm), and disk-shaped unburned gunpowder, which created punctate defects in the foam core. Unburned gunpowder penetrated along the missile track for a distance of 8 to 10 in. (20 to 25 cm) into the gelatin blocks at muzzle-to-target distances of 3 ft (0.9 m). Measurements of gunshot residue from all barrel types at 6 in. to 5 ft (15 cm to 1.5 m) demonstrated a positive linear relationship between the mean gunshot residue diameter and the muzzle-to-target distance ($r = 0.85$). The gunshot residue diameter differed by range of fire ($p = 0.00001$); however, the gunshot residue diameter did not differ between barrel types ($p = 0.39$).

### *Evaluation of Penetration*

When the slug was fired 3 ft (0.9 m) from the gelatin, an asterisk-shaped defect was created by the impacting sabot (Fig. 7*a*). At this distance the slug impacted the gelatin in a nose-first orientation. The hollow point expanded, and the nose pieces fragmented from the slug base and extended away from the main slug track in

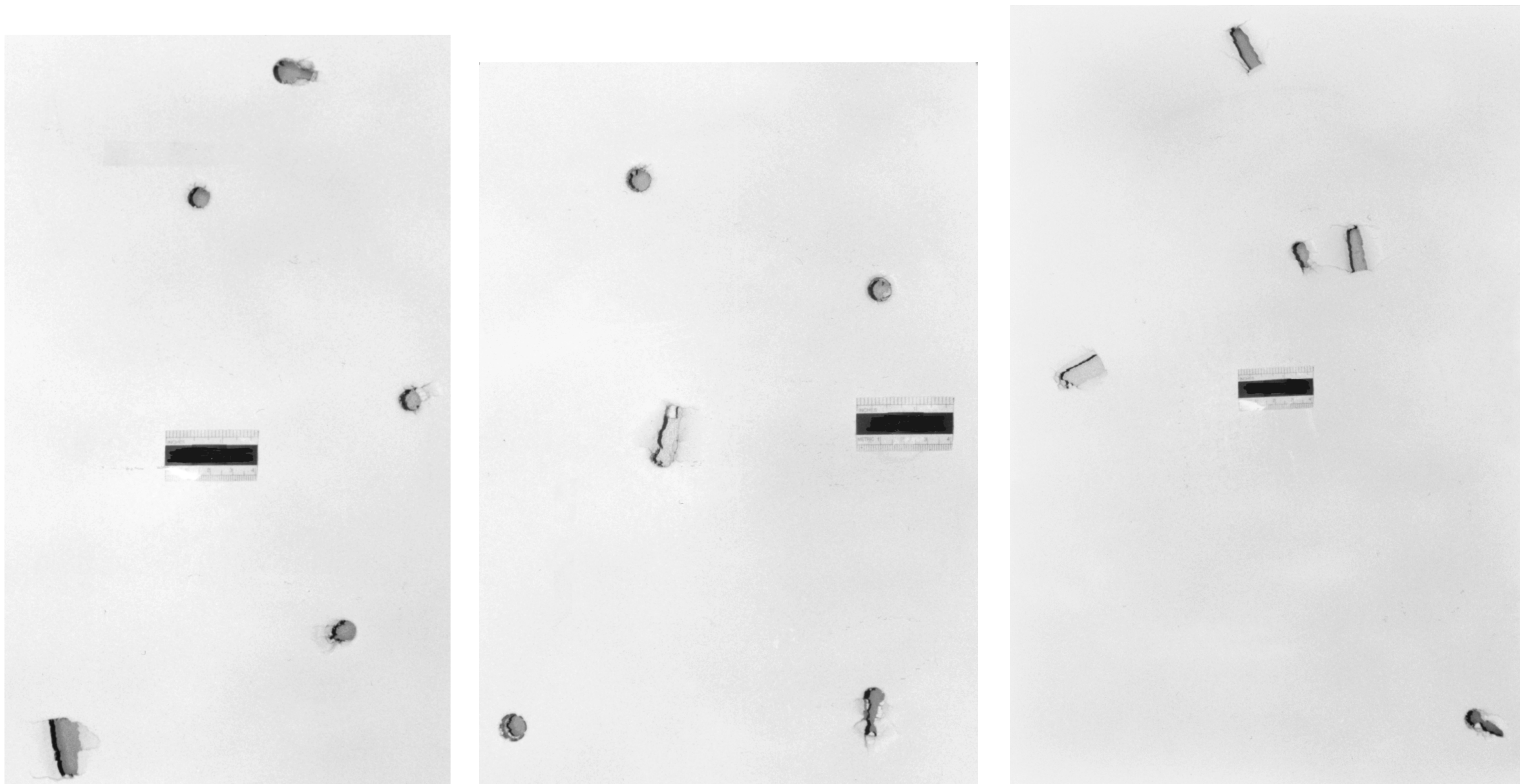


FIG. 6—*Slug surface impact defects in foam core targets at 150 ft (45 m) showing both irregular and round shapes. The irregular defects are likely the result of tumbling or yawing during flight. The ammunition was fired through a rifled barrel* (left), *smooth barrel with smooth modified choke* (middle), *and smooth barrel with rifled choke* (right) *[scale marker = 1.6 in. (4.1 cm)].*

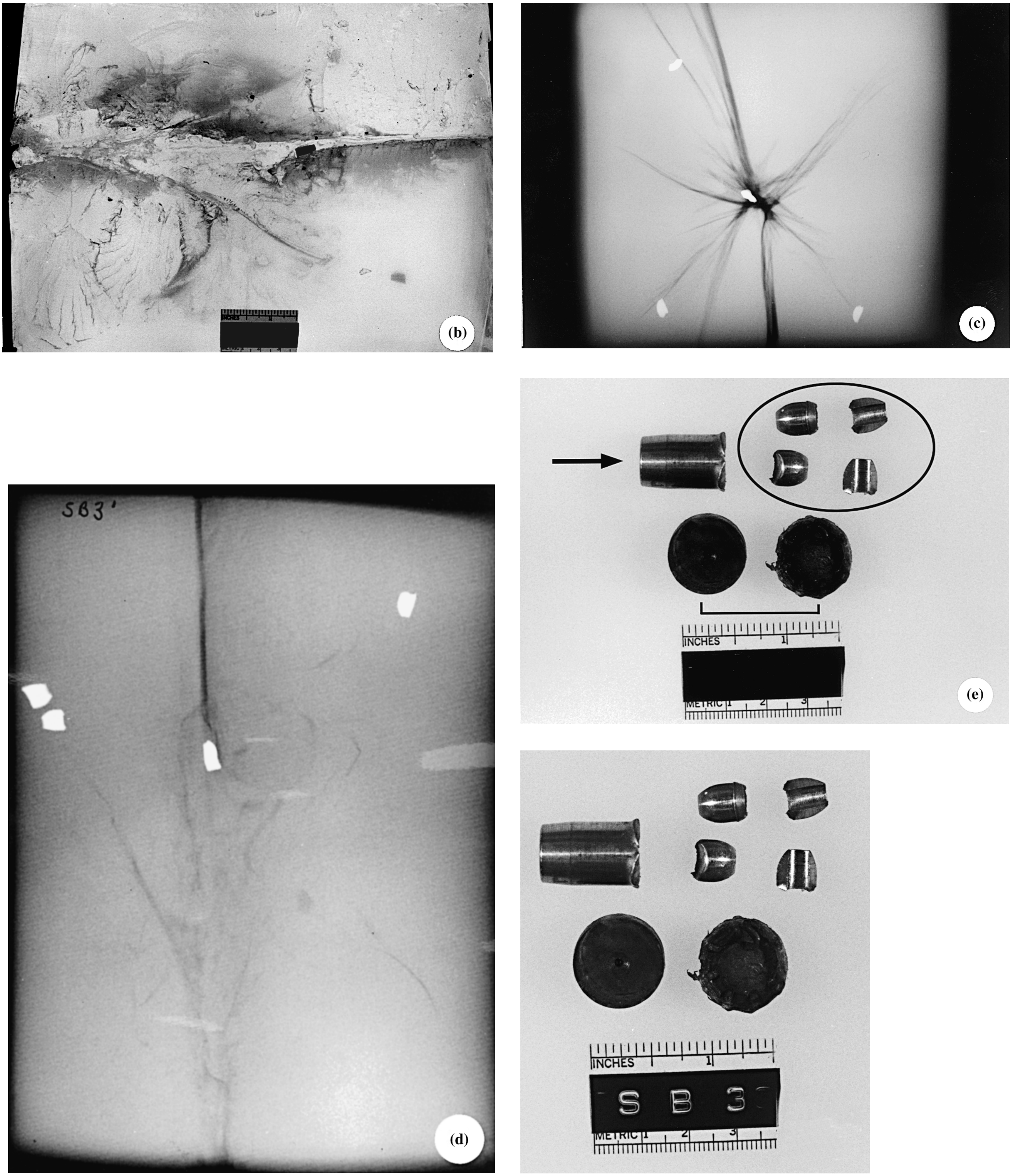



FIG. 7—*Penetration of ballistic gelatin blocks at 3 ft (0.9 m) muzzle-to-target distance, showing* (a) *asterisk-shaped defect created by impacting sabot;* (b) *gelatin block bisected along slug track, demonstrating cavitation and radial extension of the slug nose fragments (arrows);* (c) *and* (d) *anterior-posterior and lateral radiographs of gelatin block demonstrating cavity and deposition of radiodense slug nose piece fragments in a radial fashion; and* (e) *projectile components recovered after firing, including four nose-piece fragments* (upper right) *from gelatin block, and slug base* (upper left) *and wads* (lower) *recovered from backstop.*

a radial fashion (Fig. 7*b*). The nose piece fragments were visible on radiographs (Figs. 7*c* and 7*d*). The slug base, sabot, and wads all passed through the gelatin at this distance and were recovered from an adjacent backstop (Fig. 7*e*).

At 30 and 60 ft (9 and 18 m), all slugs impacted with a side-first presentation and passed through the gelatin with minimal deformation to the slug. There was no expansion of the nose and no fragmentation. The sabot and wads either impacted separately and penetrated a short distance into the gelatin, or did not strike the gelatin surface at all. All three of the slugs fired through the rifled bore at 150 ft (45 m) impacted the gelatin in the nose-first orientation and created a round defect in the gelatin surface. The noses fragmented and the fragments remained in the gelatin as the main slug bases exited.

## Discussion

The uniquely constructed Remington® Copper Solid™ sabot shotgun slug creates characteristic patterns when it is test fired into target boards and gelatin. Because this projectile has several components (slug, sabot, and wads), differing impact patterns are generated as functions of the degree of the components' separation at different firing distances. At muzzle-to-target distances of less than 3 to 5 ft (0.9 to 1.5 m) all components of this ammunition perforate the target through a single defect that tends, depending on the sabot impact orientation, to be some variation of a unique 8-pronged asterisk. The wads consistently begin to separate at distances greater than 5 ft (1.5 m) and create round-to-elongate defects. The separation distance of the wads from the slug occurs in a linear fashion out to a muzzle-to-target distance of 40 ft (12 m). The more consistent expansion of the wads when compared to the sabot is likely due to the lack of variability in shape of the wads versus the sabot. At muzzle-to-target distances greater than 7 to 9 ft (2.1 to 2.7 m) the slug and sabot impact the target separately, and at muzzle-to-target distances between 7 to 9 ft and 40 ft (2.1 to 2.7 m and 12 m), at least four separate impact points are present in the target. There is marked variability in the shape of the sabot impact defects and at greater than 30 ft (9 m), a large standard deviation exists in measurements of the distance between slug and sabot impacts. This large standard deviation may be due to the effect of air resistance on the variable presenting surfaces of the lightweight plastic sabot. Less resistance would be expected when the sabot travels base first rather than with prongs forward. A linear relationship exists between the muzzle-to-target distance, and (1) the distance between the sabot defect and the slug defect, (2) the wad defects and the slug defect, and (3) the overall pattern size out to a distance of 30 ft (9 m) independent of barrel type. The separation pattern of the projectile components should allow forensic pathologists to make crude estimates of range of fire in fatal shootings associated with this ammunition.

There is no predictable difference between the rifled barrel, rifled choke, and smooth choke when looking at the location of the sabot impact in the target board in relation to the slug. At shorter ranges of fire, the majority of sabot impacts occurred above the slug. As expected, at greater distances the sabot tends to impact below the slug as it reaches the downward arc of its trajectory. These findings are similar to those in studies of the Remington .30-06 Accelerator® round (9). At muzzle-to-target distances greater than 15 ft (4.5 m), roughly 70% of sabot impacts occurred to the left of the slug. The reason for the left-sided dominance of sabot impact distribution is uncertain. A possible explanation for this occurrence is the effect of wind on the lightweight plastic sabot.

The variable shape of the slug defect in the target board at distances of 7 to 150 ft (2.1 to 45 m), indicates that the projectile tumbles or yaws during flight independent of the barrel type or choke rifling. This finding has also been observed in casual test firing of Copper Solid™ ammunition through a smooth bore shotgun (10). It should be noted that the round defects created by the slug in the foam core targets could result from both nose-first and tail-first impacts. However, the three shots fired at 150 ft (45 m) into gelatin resulted in fragmentation of the nose portion of the slug, indicating a nose-first impact orientation. If similar rectangular defects are created in human skin by side-first impacts due to nonballistic flight, they could be misinterpreted as being a consequence of the projectile striking an intermediate target.

Some unusual types of ammunition have a unique radiographic appearance that is caused by construction characteristics. For example, the tubular "cookie cutter" bullet can appear as a radiodense circle if viewed on end (3). The Glaser Safety Slug™ appears on X-ray with characteristic shot pellets and a radiodense enveloping cup (1). Similarly, a characteristic radiographic pattern is created when copper solid slugs are test fired into ballistic gelatin blocks. When the copper slug impacts in a nose-first orientation, the nose portion expands and fragments. These fragmented pieces extend radially from the central track of the slug base and are present on X-rays as similarly-sized, irregularly-shaped radiodense fragments dispersed around the centrally located bullet track. At distances between 7 and 150 ft (2.1 and 45 m) nearly two-thirds of the slugs are likely to impact in a side-first orientation and will not expand or deform the nose pieces. One would expect radiographs of retained copper solid slugs that strike in this orientation to reflect an undeformed shape. Because the sabot and wads are radiolucent, recognition of the radiographic pattern of the slug should prompt forensic pathologists to search for the evidentiary sabot and wads.

It is unclear if the sabot and wads can perforate human skin independent of the slug. However, at a range of fire less than 5 to 7 ft (1.5 to 2.1 m), all components of the shell are likely to enter the body through a single defect. The copper slug may exit, and as the plastic sabot and wads are radiolucent, recognition of the signature asterisk-shaped entrance wound should alert the forensic pathologist to search for these components. At greater distances, the wads and sabot will separate from the slug prior to contact and can impact a body independently, possibly creating a signature patterned abrasion on the skin near the entrance wound. The presence of odd defects and abrasions created by the slug, sabot, and wads could cause confusion in interpreting wounds generated by this unusual projectile that could lead to the misinterpretation of an intermediate target.

If the sabot and wads can perforate human skin, puzzling situations may arise. For example, there may be two or more entrance holes, no exit hole, and only one projectile on a radiograph. If a body is struck by more than one shot, reconciling the number and types of wounds with the radiographs could be even more confusing. When confronted by seemingly irreconcilable wound patterns, the forensic pathologist should consider the Copper Solid™ sabot ammunition as a possible cause. Surface wound patterns and radiographs may provide clues.

### *Acknowledgments*

The authors wish to thank research biostatistician Dawn Blackhurst, MS, and medical editor Nancy Taylor, Ph.D, of the Division of Academic Services, Greenville Hospital System, and Sergeant Steve Johnson of the Greenville County Sheriff's Office for their tremendous assistance with this project. Thanks also to Drs. Jim Luke and Ross Zumwalt for editorial assistance.

## References

1. Jones AM, Reyna M Jr., Sperry K, Hock D. Suicidal contact gunshot wounds to the head with .38 special Glaser Safety Slug ammunition. J Forensic Sci 1987;32:1604–21.
2. Sperry K, Sweeney ES. Terminal ballistic characteristics of Hydra-Shok ammunition: A description of three cases. J Forensic Sci 1988;33:42–8.
3. Nolte KB. The Tubular "Cookie Cutter" bullet: A unique projectile. J Forensic Sci 1990;35:1461–7.
4. Zumwalt RE, Campbell B, Balraj E, Adelson L, Fransioli M. Wounding characteristics of "Shotshell" ammunition: A report of three cases. J Forensic Sci 1981;26:198–205.
5. Rao VJ, Rao GS. A unique missile in a homicide victim: The Brenneke shotgun slug. J Forensic Sci 1987;32:1435–9.
6. National Rifle Association. NRA Firearms Fact Book. 3rd ed. Washington, DC: National Rifle Association of America, 1989;312.
7. Remington Arms Co. Inc. Remington Firearms, Ammunition, Clothing and Accessories Catalog. Remington Arms Company, Inc., 1993.
8. Thompson E. Ordnance gelatin testing procedures. AFTE Journal 1993; 25:87–8.
9. Thompson RL, Gluba BM, Johnson AC. Forensic science problems associated with the Accelerator® cartridge. J Forensic Sci 1984;29:162–8.
10. Fackler ML. [untitled letter] J International Wound Ballistics Assoc 1994;1:6.

Additional information and reprint requests:
Michael E. Ward, M.D.
Office of the Medical Examiner
301 University Ridge, Suite 5950
Greenville, South Carolina 29601