

APPLIED WOUND BALLISTICS: WHAT'S NEW AND WHAT'S TRUE

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APPLICATION

The widespread misconception that projectiles possessing "high-velocity" or "high-energy" invariably cause extensive damage^{17,18} has been addressed recently^{5,6}. The critical reviews that have questioned this concept in the past have gone relatively unheeded^{11,15}. Interestingly, those who have questioned the "high-velocity/high-energy" concept of wounding (Lindsey, Hampton, Fackler) have all had extensive combat surgery experience.

Let us consider the most common penetrating injuries of the battlefield. Multiple penetrations by fragments from explosive devices are probably the most common injury seen in most armed conflicts. Figure 1 shows the trunk of a soldier who has suffered multiple fragment wounds from an explosive device. These fragments generally penetrate no more than 15 cm in human soft-tissue; they cause a punctate entrance wound consistent with their size and the tissue surrounding their track appears healthy. The wound profile in Figure 2 can be used to demonstrate this tissue disruption in its last 15 cm of projectile penetration where there is no significant temporary cavitation. Military rifle bullets cause the same type of wound with negligible cavitation in the first part of their path through tissue, before the bullet yaws. Figure 3 shows wound profiles produced by two common military rifle bullets compared with those produced by projectiles of lesser velocity. Note that the disruption produced in the first part of their path, the only part that is involved in most extremity wounds, does not differ significantly from that pro-

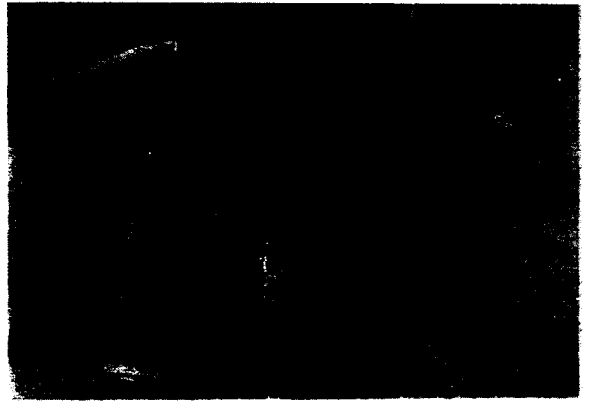


Fig. 1. All of the fragments that caused these entrance wounds remained in the body.

duced by the far lower velocity bullets. Thousands of these simple perforations of the extremity (Figure 4) are seen each year in our larger city civilian hospitals; the great majority of these wounds are treated with systemic antibiotics but no surgery — they heal well¹¹.

Before the frenzy of wound ballistics "research" that followed the Vietnam conflict, uncomplicated wounds caused by the military rifle (and small fragment wounds for the most part) were also treated with little or no surgery — they healed well. Compare Stevenson's advice in 1897²⁰ against surgical interference with the bullet path in uncomplicated rifle wounds, with Theodor Kocher's observations from

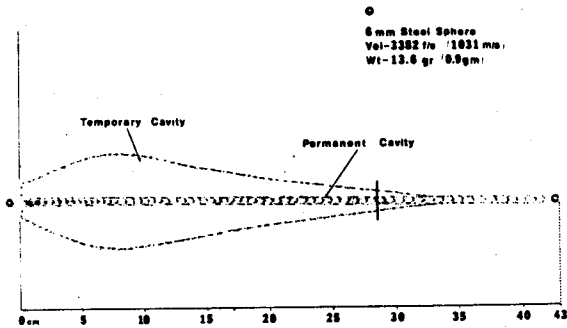


Fig. 2. Observe that little or no cavitation occurs in the last 15 cm of penetration. This last part of the sphere's path corresponds to what is observed in battlefield casualties, yet most wound ballistics researchers who use this projectile concentrate exclusively on the initial part of the path. We admit, the first part is more dramatic, but it is not a valid model for application to the wounded combat casualty.

World War I⁴; that the minimal damage produced by the rifle bullet allowed the wounds ("...wie Verletzungen ohne hautwunde ausheilen.") to heal so well that it appeared as if they had no skin wounds.

Jolly, in 1941¹², noted that "Many high-velocity bullet wounds of soft parts have small punctured wounds of entrance and exit. Often such wounds do not require operation; and if operation is performed, nothing more than excision of the orifices of the track to provide better drainage need be undertaken. Such wounds usually heal spontaneously within ten days. The high velocity bullet, unlike other projectiles, does not usually carry foreign matter into the tissues and tends to leave an aseptic track."

Bailey, in 1942¹, advised that the "...seton wound is innocuous, it should be left alone." Ferguson et al¹⁰, Slesinger⁹, Crile⁴, and Cope³ made similar

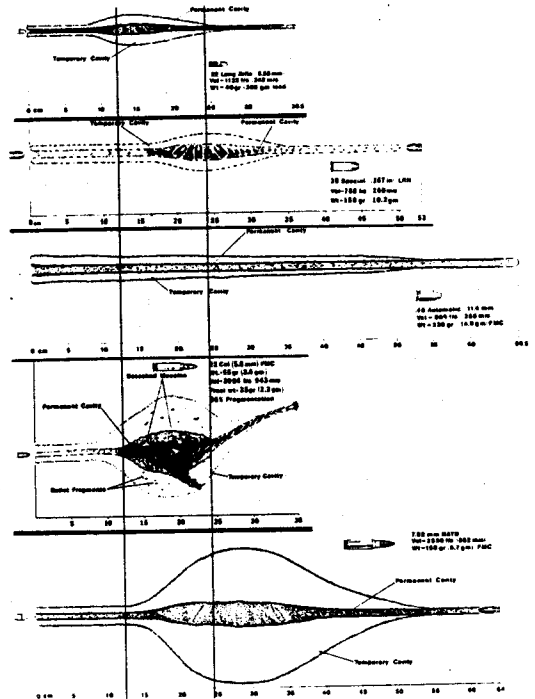


Fig. 3. Comparison of the first 12 cm of the projectile path in the five wound profiles pictured shows why the wounds from "high-velocity" rifle bullets may be no more disruptive or dramatic than many simple extremity wounds caused by lowest velocity handgun bullet.

observations, and Ogilvie¹⁶, consultant surgeon to British forces in World War II, listed as his first "sin" of war surgery the unnecessary operations on through and through bullet wounds of the soft parts, stating that "The majority of these with rest and sulfonamide heal rapidly and leave no disability; operation means loss of time and loss of function."

King¹³, reporting on war wounds from South Vietnam, wrote that "Uncomplicated perforating soft-tissue wounds were the most common bullet wounds of the extremities; they showed small entry and exit wounds and a clean soft-tissue track with little or no devitalisation of tissue. They usually healed if left alone."

The first author of this paper served in one of the busiest US Military hospitals in South Vietnam (Naval Support Activity Hospital, DaNang) during



Fig. 4. This through and through wound of the plantar surface of the foot was caused by an M-16 rifle bullet at close range. The tissue disruption was minimal.

the most active period of the Vietnam conflict (December 1967 to December 1968). Immediately thereafter he served three years at the US Naval Hospital, Yokosuka, Japan, caring for the combat casualties from South Vietnam who were transported there by air as soon as they could be moved after their primary surgery. He was also a delegate to the last two Tri-Service War Surgery Conferences (1970, 1971)². The amount, type, and location of tissue disruption, determined objectively by physical examination and appropriate roentgenographic studies was the information on which this author and his colleagues based their treatment of penetrating war wounds².

Should not the battlefield experience guide wound ballistics research? The Vietnam war surgery conferences did not identify any special problems

associated with "high-velocity" projectile wounds. The last conference listed "Topics suggested for further study", but no need to study penetrating projectiles (wound ballistics) was mentioned². Despite this, extensive wound ballistics study programs were inaugurated, including the six International Wound Ballistics Symposia. It appears that the motivation for these studies was something other than improving the care of the battlefield wounded. Speculating on motives at this point is probably not fruitful, but the applications of the resulting studies—the effects of this research—need no speculation. They are clear. Most wounds seen on the battlefield are simple and have been treated by simple means with good results for the past hundred years^{1,4,10-14,16-20}. In recommending unnecessarily radical excision of tissue for all "high-velocity" projectile wounds, and assuming that all battlefield wounds fall into this category the overall effect of the past twenty years of wound ballistics research can only be considered a giant step backwards.

WHAT'S NEW

Many suppose that one must have expensive and sophisticated equipment to do useful and valid work in wound ballistics. We suggest that a chronograph, available for just a few hundred dollars, and some tissue simulant in which bullet deformation and penetration depth reflect that observed in living animal tissue, are all that is really needed to determine the wounding potential of penetrating projectiles.

Ordnance gelatin, provided it is made and stored properly⁷, and shot while at a constant and uniform known temperature, gives the most information. Projectile penetration depth, projectile deformation, projectile fragmentation pattern, and temporary cavity configuration can be determined for each shot⁸. Soap can be used to determine all of these except fragmentation pattern; the partial persistence of the temporary cavity distorts the pattern of fragments as compared to that seen in animal tissue.

Tissue simulants such as clay and ductseal should be avoided because they cause far greater projectile deformation⁹ and much less penetration depth than seen in animal tissue (Figure 5). Water can be used

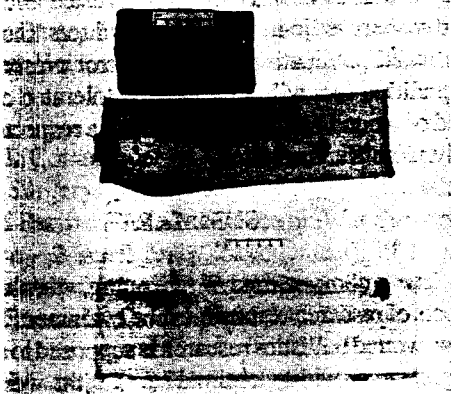


Fig. 5. Shots from a 45 ACP handgun with Winchester Silvertip bullets are shown in three materials. The top block is clay and was shot at 20 degrees C; the bullet expanded to a diameter of 22 mm and penetrated 8.6 cm. The center block is Swedish soap and was shot at 20 degrees C; the bullet expanded to a diameter of 20 mm and penetrated 20 cm. The bottom block is 10% ordnance gelatin and was shot at 4 degrees C; the bullet expanded to a diameter of 20 mm and penetrated to a depth of 26 cm

as a tissue simulant and causes just slightly more bullet deformation than gelatin or soap; the Firearms Training Unit of US Federal Bureau of Investigation uses it as a screening medium to decide which bullets expand well enough to merit further scrutiny?

Penetration calibration studies, done recently at the Letterman Army Institute of Research, in which 4.3 mm (0.17 inch) copper-plated steel spheres, weighing 0.34 gm (5.3 grains), were shot at 593 ± 13 ft/s (181 ± 4 m/s), gave the following penetration depths:

Leg of freshly killed (<15 min) 40 kg pig.....	8.8 ± 1.6 cm	(n-10)
10% ordnance gelatin at 4 degrees C.....	8.5 ± 0.4 cm	(n-30)
20% ordnance gelatin at 4 degrees C.....	4.4 ± 0.2 cm	(n-5)
20% ordnance gelatin at 20 degrees C.....	8.0 ± 0.2 cm	(n-5)
Swedish soap at 4 degrees C.....	4.2 ± 0.3 cm	(n-5)
Swedish soap at 20 degrees C.....	5.8 ± 0.4 cm	(n-5)

As can be seen from these results, ordnance

gelatin changes its characteristics considerably with temperature; penetration depth increases 82% as the block temperature increases from 4 to 20 degrees C. Soap also changes with temperature; penetration depth increases 38% over this same 4 to 20 degree temperature range. It is mandatory to report the block temperature in any study using gelatin and strongly recommended when using soap. We must not forget that the purpose of scientific communication is to learn from the comparison of data; sufficient detail must be given so that others can accurately reproduce the experiment in order to have valid comparisons.

Currently, at the Letterman Army Institute of Research, we are using a one-half microsecond duration flash system to study bullet yaw behavior in ordnance gelatin. This equipment also allows us to visualize temporary cavitation (Figure 6). Advantages of this system over high-speed cine include its cost (each flash apparatus costs only about \$3500) and the time saved in its use. By exposing a polaroid camera simultaneously with a standard film camera it is possible to find out in just a minute if the desired result has been obtained from a shot. With cine equipment one must wait for the film to be developed and then return another day for additional shots if the result is not ideal. The one-half microsecond flash also allows us to freeze rifle bullet images of shots in

air. This most useful feature permits the use of this

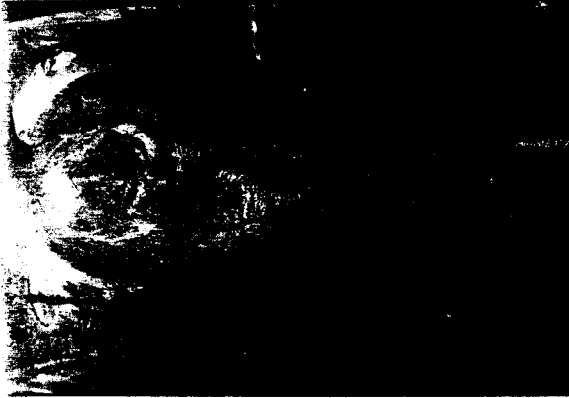


Fig. 6. A 45 ACP Winchester Silvertip bullet fired into 10% ordnance gelatin at 4 degrees C is shown with the maximum temporary cavity captured with a one-half microsecond flash. The bullet expanded to 20 mm. Using a calipers the maximum temporary cavity diameter (11.9 cm) can be measured from this film by using the bullet as a scale. There should be no parallax error since the bullet is the same distance from the film plane as the cavity.

equipment to study bullet yaw in air whereas during the longer exposure time of the high-speed cine most rifle bullets move 5 to 10 cm in air and appear on the film only as a blur.

WHAT'S TRUE

We suggest that the interested reader doesn't need us to tell him "what's true" (and what's not) in wound ballistics. We suggest that he take a long, hard, and critical look at the literature himself. Compare results. Hard physical data measured from shots into suitable tissue simulants and photos of shots into animals (including battlefield and civilian wounded) will provide a sound basis for validating findings or detecting inconsistencies. The historical and critical review papers given as references will provide a further resource and a basis to compare from a historical perspective.

The reader who takes this suggestion will be well prepared to recognize error when it is published. Only if sufficient numbers of interested and informed readers let journal and book editors know that continued publication of blatant error presented as unqualified fact will no longer be tolerated can the field of wound ballistics evolve into a respected and truly scientific discipline.

SUMMARY

There comes a time of reckoning, when overall effects of research results must be evaluated. In our view, wound ballistics research is supposed to aid the surgeon in providing optimal care for the wounded. Unfortunately, in the past twenty years, most of the work in this field has been counterproductive to this objective. As a result, today many surgeons are likely to do unnecessarily radical or crippling excisions of tissue if the word "high-velocity" is mentioned in connection with the wound they are treating.

The most common battlefield wound has a simple punctate entrance with tissue disruption limited to a diameter no larger than the wounding projectile. The rifle wound of the extremity, in which the tissue path is limited to that initial portion of the wound profile where the bullet has not yet yawed, and virtually all individual wounds from explosive device fragments fall into this category. The tissue disruption observed with this kind of wound is no greater than that seen in most handgun wounds. Viewed from the historical perspective, this type of rifle wound has been singled out in the literature because of its propensity to heal well despite little or no treatment — even in preantibiotic days.

The amount, type, and location of tissue disruption, determined objectively by physical examination and appropriate roentgenographic studies, remains today, as it has throughout history, the critical information that should be used by the battlefield surgeon to determine treatment.

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