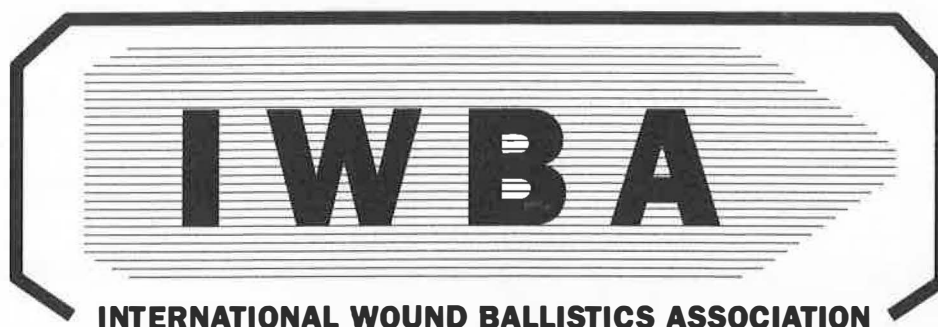


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WOUND BALLISTICS REVIEW

JOURNAL OF THE INTERNATIONAL WOUND BALLISTICS ASSOCIATION

The Physiological Effects of Handgun Bullets

— Ken Newgard, MD

Wound Ballistics Research of the Past Twenty Years: A Giant Step Backwards

— Martin L. Fackler, MD

The Advanced Combat Rifle Program: Weapons & Wound Ballistics

— Alexander Jason

An Inexpensive Downrange Chronograph System

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Police Handgun Ammunition Selection

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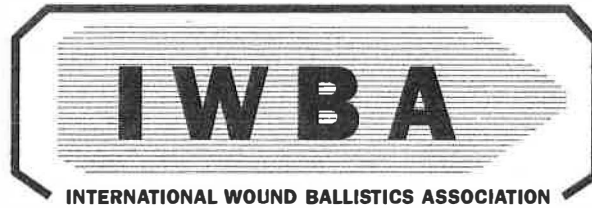
The Effect of Bullet Nose Shape on Expansion

— Gus Cotey, Jr.

VOLUME 1

NUMBER 3

FALL 1992



INTERNATIONAL WOUND BALLISTICS ASSOCIATION

STATEMENT OF PURPOSE

The widespread misinformation and lack of understanding concerning ballistic injury are well known to anyone who understands the subject and keeps up with the literature.

The effects of penetrating projectiles on the body is of vital concern to trauma surgeons, weapon designers and users, and those involved with the forensic aspects of ballistic trauma. Yet, we know of no organization that deals with the subject exclusively and in depth. Papers containing ballistic injury data appear in widely scattered sources, since many groups include projectile effects peripherally in their interests. However, in each source, these comprise a very small percentage of the total papers — most containing numerous errors. Wound ballistics expertise is sparse, and human inertia being what it is, once in print, errors are likely to go uncorrected. Even when discredited by letters to the editor, these substandard papers remain in the literature to mislead the unwary.

Effects of the persistently poor understanding of ballistic injury range from substandard gunshot wound treatment to lessened law enforcement effectiveness.

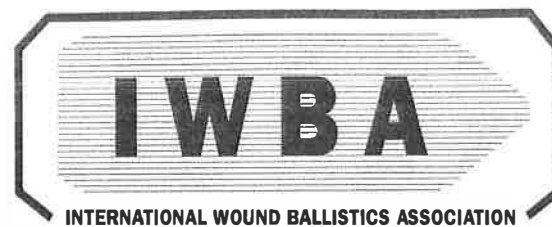
What needs to be done? First, the valid literature needs to be identified. This will give the interested reader the scientific background material on which to

build a solid understanding of the subject. Next, an ongoing periodic critical review of the wound ballistics literature needs to be initiated. Finally, an easily accessible source of wound ballistics expertise needs to be established. When a need exists with no ready and recognized source of expertise, mythology fills the gap.

The International Wound Ballistics Association has been founded to fill these needs. The IWBA is comprised of members possessing verified expertise in one or more aspects of wound ballistics and the IWBA publishes a journal, the *Wound Ballistics Review*. By focusing its expertise upon the literature relating to wound ballistics, the IWBA hopes to stimulate an increased awareness among editors, writers, and readers and to help minimize future inaccuracies. Additionally, the International Wound Ballistics Association is prepared to offer expertise to assist any publication concerned with avoiding error and maintaining technical accuracy.

The IWBA encourages and demands skepticism. We are convinced that only by encouraging active questioning, reevaluation and verification of views, data and cherished beliefs, etc. in the open literature can wound ballistics be delivered from the chaos of its "dark ages" to assume its full potential as a science.

Martin L. Fackler, MD, FACS
President, IWBA



WOUND BALLISTICS REVIEW

JOURNAL OF THE INTERNATIONAL WOUND BALLISTICS ASSOCIATION

VOLUME 1

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JOURNAL OF THE INTERNATIONAL WOUND BALLISTICS ASSOCIATION

Literature Review & Comment

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— Martin L. Fackler, MD

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INSTRUCTIONS TO AUTHORS

The **Wound Ballistics Review** welcomes manuscripts, articles, short notes and letters to the editor that contribute to the science of wound ballistics. Publication preference will lean strongly toward pertinent papers with clear practical applications. We invite cogent reviews of articles, books, news items, etc. Our goal is to commend good documentation as well as to point out the errors in the wound ballistics literature. The **Wound Ballistics Review** especially requests our readers' help in submitting short reviews which correct errors noted in the literature.

The review of all manuscripts reporting original work will be open; the names of reviewers will either appear with the paper when published or will be made available upon request.

Articles are accepted only for exclusive publication in **IWBA**, and when published, the articles and illustrations become the property of **IWBA**. When an article is selected for publication, the author(s) will be required to sign a copyright transmittal which also attests to the originality of the material submitted.

The experiment described in any paper must represent good scientific method. Complete methodology must be presented so that the reader can duplicate the experiment exactly.

Work must be based on basic solid understanding of projectile-tissue interaction. Results must be reported completely to permit meaningful comparison. In experimental animal wounds, for example, a clear and thorough quantitative description of the observed damage must be included; i.e., was the bone fractured? Were major vessels disrupted? How big was the entrance? The exit? What is the appearance of the projectile path (penetration depth, size and morphology of damage to organs, etc.)? This information is mandatory to allow meaningful correlation of the wound reported to military as well as civilian wounds.

The entire paper must be expressed in language understandable to the layman.

SUBMISSION INSTRUCTIONS

1. If submitting a letter or review which refutes or points out errors in another work, please provide the address of the source (please include a copy of the article reviewed--these will be returned if requested); **IWBA** will notify the editor of the source, pending correction, inviting a rebuttal to be published with the review if one is submitted.

2. In submitting original work, the manuscript and one copy are requested; one set of glossy illustrations is required; black & white is preferred. Author's name must be clearly identified on the title page with address and telephone number. Manuscript must be double-spaced with ample margins (at least one inch on all sides) on standard (8 1/2" x 11") paper. NOTE: THE PREFERRED MANUSCRIPT FORM IS THE 3 1/2" (1.44 Meg or 720K) or 5 1/4" (1.2 Meg) PC FLOPPY DISK WITH A PAPER COPY. Most major PC word processors are acceptable but WordPerfect 5.0 or 5.1 is preferred. (Do not send data in Samna or Ami Pro format: please convert to WordPerfect or ASCII format.) MacIntosh floppies are also acceptable with text in ASCII format. PLEASE DO NOT PROVIDE COMPUTER TEXT WITH SPECIAL FONTS OR LAYOUTS: PLAIN, SIMPLE TEXT WITHOUT INDENTS, TABS, LINES OR GRAPHICS. Any graphs, tables, charts, etc should be supplied as separate files and/or with a clean, high-quality paper copy.

3. References are to be numbered sequentially within the text and appear in the order cited at the conclusion of the article. Examples:

Book: Black KE, Jederberg WW. *Athymic nude mice and human skin grafting*. Maibach HI, Lowe JN, eds. **Models in Dermatology**: vol 1. Basel: S Karger, 1984;226-239.

Article in periodical: Fackler ML, Surinchak JS, Malinowski JA, et al. *Bullet fragmentation: A major cause of tissue disruption*. **J Trauma** 1984;24:263-266.

4. Legends for all illustrations should be listed in order, double-spaced.

5. An abstract of 150 words or less should precede the text.

Association News

*"Adequate Ammunition List:"
A Proposed New Journal
Feature*

One of the most common requests we receive from law enforcement concern the performance of a particular type of ammunition -- especially new brands or models. We recognize that there is a need for objective evaluation of ammunition and while we encourage users to test the performance of their own ammunition, we plan to begin a new feature in this Journal -- the "Adequate Ammunition List" (AAL) which will provide basic performance data on ammunition which has been properly tested.

Our intention is to provide a page or two in each issue which will list law enforcement handgun ammunition which has been found to be "adequate." We will not be rating ammunition with relative point values as the gun magazines and certain federal entities like to do. We believe that -- in regard to wound ballistics -- the important features of ammunition are:

• **Penetration** -- In order to be effective in worst case scenarios, a bullet should be capable of penetrating at least 12" of tissue.

• **Expansion** -- A bullet designed to expand in tissue should do so. While this requirement may appear obvious, there are a surprising number of hollow-point or soft-point bullets on the market which do not expand in tissue.

• **Over-Penetration** -- A handgun bullet for law enforcement use should not penetrate beyond 20" of tissue. Allowing for penetration of 20" should provide a sufficient safety margin tak-

ing into account a worst-case scenario in which a bullet has to penetrate several bones and a large amount of soft tissue.

Ammunition which has been tested in calibrated tissue simulant by IWBA members or others knowledgeable in testing methodology and analysis will be included in the list. The testing for inclusion on the list will be relatively simple and will not require the penetration of wood, metal, glass, etc. as in the FBI ammunition testing -- only tissue simulant. Although our proposed criteria are less stringent, we intend the list to be regarded as a general guideline to effective ammunition, not as a definitive evaluation.

Because ammunition manufacturers often make un-announced modifications to their products, we intend to include a warning stating that the AAL cannot be applied to all lots and variants of a particular model of ammunition.

At present, we do not plan to include a list of "Inadequate Ammunition."

We invite comment and suggestions on this proposal from our members. If you have any ideas on the merits or weaknesses of the Adequate Ammunition List, please let us know.

DON'T FORGET:

Your "one year"
subscription is good for
four issues of the
Journal.

(No matter how long it takes us to get four issues out.)

Reader's Forum

To The Editor

I found your last issue (No.2) very valuable. I am with a large law enforcement agency in the Midwest and I find that there is a lot of misconception and conflicting opinions on what is the best ammunition to use in different situations. I think your journal is the only source of good information on the subject and I would hope to see more articles on which ammo is best and why.

I have been following the body armor standards you discussed in the first issue and I would very much appreciate being kept informed of whatever is happening. The people in our department who are responsible for purchasing body armor really don't understand the technical details of the testing and the certification process. They have admitted to me that while they know that there are big problems with the current NIJ standard, they are just afraid to purchase armor which does not meet the NIJ standard. Their feeling is that if they specify that all armor tested must meet NIJ specs, then they have covered themselves.

As someone who has to wear a vest on a daily basis, I know that the NIJ standard is really meaningless and most of the officers I work with wear non-NIJ certified armor as it is much more practical. What we need is some documentation we can use to convince our purchasing people to disregard the NIJ spec's and just buy good armor.

Please don't print my name and department. I don't need the grief.

Name Withheld

Response

We thank you for your letter and in regard to your request about ammunition selection; our next issue will include a section listing law enforcement handgun ammunition which we believe is likely to perform adequately. We recognize the problem that exists with most of the information available about ammunition performance coming from gun magazine writers who are often paid by ammunition manufacturers to write the "reviews;" from anecdotal "war stories;" "secret" data collections and other such unreliable sources. One of the prime reasons for the founding of the IWBA was to provide an objective, scientific source of data on ammunition performance and related topics.

On the body armor standards:

The U.S. Congress' Office of Technology Assessment (OTA) has completed its study of the issue and has concluded that the National Institute of Justice's body armor standard is flawed and in need of revision. An editorial discussing this is featured in this issue of the Journal.

AJ

**Send us
YOUR comments!**

Wound Ballistics Review
welcomes comments
and suggestions from
our readers.

IMPORTANT

The IWBA address has changed.

The new address is:

**IWBA
P.O. BOX 634
PINOLE, CA 94564**

(The telephone: 510-273-9596

and FAX: 510-724-0733 numbers have not changed.)

tant as this requirement severely affects the comfort of a vest. The OTA commented,

*"In summary, there is an apparently small but unquantified risk that non-wet-tested armor might be wetted enough to be degraded and then shot. However, wet-tested armor might be worn less often than non-wet-tested armor. There is no compelling evidence that requiring wet-testing costs more lives than it saves, but neither is there a compelling rationale for continuing to require armor to be tested wet, as the current standard does. Revising the NIJ standard to allow armor to be tested wet or dry would allow purchasers to choose armor that they believe offers the most protection, considering wear rate as well as ballistic resistance, and considering local and personal factors, such as climate and type of duty."*¹³ (emphasis added.)

NEED FOR LEGISLATION:

One of the most important issues addressed by the OTA was the NIJ's attempt to pass legislation which would give the NIJ the authority to enforce their standards by federal law. The OTA could not offer recommendations on such matters; it could only present "options" discussing the benefits and drawbacks of the proposed law. Although striving to be neutral, the OTA concluded,

*"Authorizing legislation should consider possible conflicts of jurisdiction . . ." with other federal agencies and that "Enacting H.R.322 would not settle the standards controversy and might exacerbate it. We do not know whether the Act would save more lives than the current regime of voluntary compliance with the NIJ standard."*¹⁴

The OTA also pointed out that there was no real need for the legislation,

*"Enacting H.R. 322 is not necessary to assure consumers that production units . . . conform to . . . certification or have acceptable ballistic resistance. A voluntary quality control program would suffice for that."*¹⁵

THE REAL PROBLEM

To completely revise the flawed NIJ standard, more research will need to be performed. But in order to avoid repeating the errors of the past, it is important to understand how these errors occurred and were allowed to remain uncorrected:

The Body Armor Standards program began with admirable goals and, in the early stages, it did the best with the data and resources available. But as the years passed and bureaucratic fiefdoms and hierarchies were created, the program's basic goal of protecting law enforcement officers was overtaken by a bureaucratic passion to resist

any and all criticism. "We Never Make Mistakes" became the NIJ's operational motto as the program administrators reacted with hostility to even the most benign suggestions that there were flaws in their procedures or that new data might be worthy of consideration.

Another Federal agency which contributed greatly to the problem through its own technical incompetence and steadfast refusal to admit error was the National Institute of Standards and Technology's (NIST) Law Enforcement Standards Laboratory (LESL). The LESL is the agency which created standards for police handguns and shotguns and then announced that each and every brand and model of firearm they tested failed its new standards. Both the law enforcement community and the firearm manufacturers have since completely ignored LESL.

The NIJ's technical errors and flaws could be forgiven and forgotten but what should not be is the NIJ

"The NIJ was the cause of the problem; it is not likely to contribute constructively to the solution."

program managers' refusal to accept criticism and to make the changes required to restore confidence and validity in their body armor standards. The OTA's year and a half long, \$200,000 study itself is clear evidence of the NIJ's mis-management.

A competent, responsive management would have solved this dispute long ago by taking note of the many inconsistencies and flaws and making the corrections themselves -- instead of stonewalling all attempts at improvements and trying to quash critics by seeking criminal penalties for anyone not following their directives. The resultant frustration and lack of confidence in the NIJ by the law enforcement community is what brought the OTA into this controversy. There are many technical disputes among manufacturers, users, and regulatory agencies yet very, very few become subjects of an OTA study.

Although the OTA was free to study and comment on all scientific and technical aspects of the controversy, it is a governmental entity which must operate within political constraints. Specifically, the OTA can not comment on the competence of other federal entities nor can it suggest that the authority to supervise a Congressionally mandated project be withdrawn. This is regrettable because although the OTA performed a valuable service by identifying many problems within NIJ's body armor standards, it was unable to address the root cause of the faulty standards and the resultant controversy: the inability of NIJ management to effectively administer the program.

WHAT HAPPENS NEXT?

The OTA is a branch of Congress; the NIJ, part of the Executive branch under the Department of Justice. This means that the OTA's findings are only suggestions and options for legislators; not directives. The Executive Branch, from the President to the Attorney General to the Director of the NIJ can choose to ignore the OTA or it can decide to utilize the findings to make the needed revisions.

The Senate Judiciary Committee has issued a statement calling for the armor industry and the Justice Department to "form a team to undertake an effort to fully resolve the standards and testing."¹⁶ This

"team" has not yet been organized but we are hopeful that it will lead to a new, scientifically valid standard but only if it can be lead and staffed by people more interested in making improvements than in pretending that there never was a problem.

The NIJ will, no doubt, attempt to somehow put a positive spin on the OTA report and use the OTA's recommendations for more research as a means of increasing its budget and authority. But it must not be forgotten that the NIJ's original position was that there was no need to make *any* changes in its standard. NIJ management (and the National Institute of Standards and Technology's (NIST) Law Enforcement Standards Laboratory) has demonstrated its inability to competently administer the body armor standards program; it is highly unlikely that it will be able to correct the deficiencies it consistently refused to recognize.

We believe the law enforcement community deserves a more able, responsive, and technically enlightened management of its body armor standards. The NIJ was the cause of the problem; it is not likely to contribute constructively to the solution.

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THE PHYSIOLOGICAL EFFECTS OF HANDGUN BULLETS

The Mechanisms of Wounding and Incapacitation

Ken Newgard, M.D.

An examination of the effect of handgun bullets upon the human body shows that immediate incapacitation cannot be reliably expected even after disruption of vital organs.

When a law enforcement officer shoots a suspect, it is his or her purpose to stop the current activity of the suspect in order to prevent death or severe bodily harm to himself or other innocent persons. How many shots should an officer fire to achieve this objective?

There is a large disparity in what is taught relative to this question in police academies, training schools, and military units. The range varies from one shot to the maximum cartridge capacity of the firearm. This paper attempts to answer this question using a physiological approach, and incorporating what is known about bullet wound trauma.

Although much of this information applies to all types of weapons, I am referring here to handgun bullets because these are the most common weapons in use by police today.

A discussion of physiological effects of bullets would not be complete without a cursory review of terminal wound ballistics — although this discussion

will be common knowledge to many readers of this Journal. I will then discuss the physiology of blood loss and shock and finally review the literature on length of survival times of fatal gunshot wounds.

TERMINAL BALLISTICS

A bullet causes injury primarily by crushing tissue as it penetrates.^{1,2} The space once occupied by the crushed tissue is called the permanent cavity. Injury of tissue may be augmented by bullet expansion -- or

bullet yaw in non-expanding bullets.^{3,4} These variables of projectile terminal performance expand the size of the permanent cavity.

Another cause of injury is by the radial stretching of tissue around the bullet path producing a temporary cavity.¹ Because of tissue elasticity within the body, much of the temporary cavity

potential for damage will be nullified by the stretching of the elastic fibers and will not contribute to tissue injury. Most often the temporary cavity of handgun bullets is too small to significantly contribute to the wounding mechanism. Certain organ tissue within the body are more susceptible to damage from the tempo-

"How many shots should an officer fire?"

rary cavity due to their inelasticity lacking elastic tissue. These include the brain, spleen, liver and bones.³ Nevertheless, damage from the temporary cavity to these organs is limited.

TWO PHYSIOLOGICAL TYPES OF WOUNDS

The only method of reliably stopping a human with handgun bullets is to decrease the functioning capability of the central nervous system (C.N.S.) and specifically, the brain or cervical spinal cord. There are two ways in which to accomplish this goal: 1) direct trauma to the C.N.S. tissue resulting in tissue destruction and 2) lack of oxygen to the brain caused by bleeding and loss of blood pressure.

Bullet wounds to the brain are commonly thought to cause instant cessation of activity. Although this is true much of the time, there are cases where bullet wounds to the brain have not incapacitated the subject.

In the experience of the author these usually involve injuries to the brain's frontal lobe which controls the body's non-critical functions such as memory, analytical thinking, etc. The only wounds which result in immediate cessation of activity are those that cause destruction of essential brain matter such as the brain stem or the cervical spinal cord which control the basic survival functions such as breathing and heart beat rhythm.

Non-central nervous system wounds are far more commonly seen and are variable in the amount of incapacitation they produce. Here, the disruption of blood vessels and organ tissue causes blood loss. The blood loss in turn leads to a lowering of blood pressure (hypotension) and when the blood flow is insufficient to deliver adequate amounts of oxygen to the brain, unconsciousness results. The rate of bleed-

ing will depend on the size and shape of the wound, the number of vascular structures damaged, the size of the damaged vessel, the blood pressure within the vessel and the effects of surrounding tissue structures.

Instantaneous neutralization is impossible with non-central nervous system wounds. Even when bullets strike the heart or major blood vessels, the adversary may not be affected for many seconds or even minutes. Studies of civilian populations demonstrate that most persons with gunshot wounds to the heart survive if they reach a hospital in a reasonable amount of time.^{5,6} Table 1 shows the mortality rate in a civilian population of gunshot and knife wounds to the heart. A gunshot wound to the thoracic aorta

would cause the greatest sudden blood loss and a relatively fast incapacitation. However, because the thoracic aorta is a long but very narrow target it, is not often hit and therefore has a low rate of injury, less than 10% in most studies.⁷

How is a person able to survive wounds of major vessels or the heart? Controlled blood loss is only one half of the story. The other half is A phenomenon called "physiologic compensation."

COMPENSATORY MECHANISMS IN HEMORRHAGIC SHOCK

In 1895 Warren described hemorrhagic shock as "a momentary pause in the act of death."⁸ Shock, he wrote, is "a clinical syndrome involving widespread cellular dysfunction as a result of the inadequate delivery and use of oxygen, yielding the subsequent release of pharmacologically active cell metabolites."⁹ Shock is not an all-or-nothing phenomenon but occurs over time with a progressive degree of detriment to the individual. For our purposes we are looking at the effect

TABLE 1

PENETRATING WOUNDS OF THE HEART

Houston, Texas, 1951 to 1971

	NUMBER OF PATIENTS	NUMBER OF DEATHS	MORTALITY RATE (Percent)
STAB WOUNDS	192	40	21%
GUNSHOT WOUNDS	77	27	35%

Data from Beall, A.C., et al: Penetrating Wounds of the Heart. J. Trauma, 1972;12:468

of hemorrhagic shock to the brain since this is the organ most sensitive to a reduction in oxygen supply.

There are a number of compensatory mechanisms that occur with the initiation of blood loss. The initial response and is by blood pressure sensors (baroreceptors) in the heart and great vessels. This results in an increase of two hormones: norepinephrine and epinephrine (adrenaline) in the bloodstream. The release of these hormones results in a faster heart beat and an increase in the heart muscle's contractive force which causes an increase in cardiac output. The low volume of blood is detected by sensors in the carotid vessels (which carry blood to the brain,) and by sensors in the heart which send signals through the nervous system to initiate compensatory action. This action — the release of the two hormones into the blood stream — results in a constriction (narrowing) of the venous system. Since 60% of the circulating blood volume resides in the venous system (10), constriction of the veins will compensate for the mild blood loss without causing other changes in the body.

Because Cardiac Output (C.O.) equals Mean Arterial Pressure (M.A.P.) minus Central Venous Pressure (C.V.P.) divided by Total Peripheral Resistance (T.P.R.),

$$C.O. = M.A.P. - C.V.P. / T.P.R.$$

and;

Total Peripheral Resistance equals Mean Arterial Pressure minus Central Venous Pressure divided by Cardiac Output,

$$T.P.R. = M.A.P. - C.V.P. / C.O.$$

as T.P.R. increases, M.A.P. can be maintained by decreasing C.O. Maintenance of blood flow to the heart and brain is also protected by selective, sympathetic nervous system activity which constricts and reduces blood flow in vessels supplying the extremi-

ties and the non-critical (in terms of immediate survival) organs such as the liver, spleen, and bowels.

The forces governing fluid movement across peripheral capillary membranes were initially described by Starling.¹² When bleeding causes blood pressure to fall, body fluid enters the capillaries from the surrounding tissue and replenishes the vascular volume. The amount of fluid transferred from tissue into the vascular system is proportional to the volume deficit and is significant.¹³ In Viet Nam, injured soldiers were shown to demonstrate transcapillary refill rates well in excess of 1000 ml/hr.¹⁴

HUMAN TOLERANCE OF BLOOD LOSS

Because of the described mechanisms, the body can compensate for some blood loss. Healthy young persons can tolerate a sudden loss of approximately 25% of their blood volume blood loss in the supine (flat on the back) position without significant effect¹⁵ and without permanent injury. However with blood loss greater than 25% (which is about 1 liter) of total volume, the compensation mechanism described above will not be adequate to keep the brain and heart supplied with sufficient oxygen. The progression of this condition will lead to irreversible shock and death.

There are differences in the blood pressure requirements for a person laying flat and for a person in a standing position. In the standing position, a greater blood pressure is required for the blood to reach the brain and therefore a smaller amount of blood loss will be tolerated by a standing person. The exact quantity of blood loss that a person can tolerate before collapsing is difficult to determine and is dependent on age, health, activity, presence or absence of drugs and alcohol, and psychological state. However, testing of healthy, young persons by means of laying them on a flat board and then varying the tilt from horizontal to vertical has determined that symptoms and signs of hemorrhage are unpredictable until 1000 c.c.s of blood are lost.¹⁶ With this quantity of blood loss, a change in heart rate greater than 30 beats per minute or significant symptoms were observed when patients were

tilted back to the upright position. Fig 1 and table 2 demonstrate that adequate blood pressure can be maintained with minimal symptoms until a 20% blood volume deficit was reached.¹⁷

For an average 70 kg male the cardiac output will be 5.5 L. per minute. His blood volume will be 60 c.c.s per kg or 4200 cc. Assuming that his cardiac output can double under stress (as his heart beats faster and with greater force), his aortic blood flow can reach 11 l. per minute. If one assumes a wound that totally severs the thoracic aorta, then it would take 4.6 seconds to lose 20% of his blood volume. This is the minimum time in which a person could lose 20% of his blood volume from one point of injury. How many shots could be fired in this 4.6 seconds? A

marginally trained person can aim and fire at a rate of two shots per second. (unpublished data) In 4.6 seconds there could easily be nine shots of return fire before the assailant's activity is neutralized. This analysis does not account for oxygen contained in the blood already perfusing the brain, that will keep the brain functioning for an even longer period of time.

Most wounds will not bleed at this rate because: 1) bullets usually do not transect (completely sever) blood vessels, 2) as blood pressure falls, the bleeding slows, 3) surrounding tissue acts as a barrier to blood loss, 4) the bullet may only penetrate smaller blood vessels, 5) bullets can disrupt tissue without hitting any major blood vessel resulting in a slow ooze rather than rapid bleeding, and 6) the above mentioned physiologic compensatory mechanisms.

Although the amount of time it takes for incapaci-

tation to occur is difficult to predict, one point is perfectly clear, with wounds which do not disrupt the central nervous system, significant amounts of time can elapse between receiving the wound and unconsciousness. This correlates with what we observe in a trauma unit.

SURVIVAL TIMES OF FATAL GUNSHOT WOUNDS*

Survival time of fatal gunshot victims is difficult to determine with extreme accuracy due to the number of uncontrolled variables involved and the inherent observation inaccuracies of random events occurring in the field. For our purposes extreme accuracy is not needed. We only wish to determine if the person who was shot had enough time to shoot back. Two studies address this issue.

Levy¹⁸ looks at the activity of the gunshot and knife victims who eventually died in Dade County in 1983. This obviously selects for the more severe injuries since only persons who died from their wounds were included in the study. The data in Table 3 shows the percentage of persons who survived longer than five minutes after being shot. The percentage of gunshot victims who survived five minutes or more after receiving ultimately fatal injuries was 64% with chest and abdominal injuries and 36% with head and neck injuries. In addition, they present individual cases of persons with severe injuries, including bullet wounds of the heart, undertaking strenuous physical activity before dying.

*Survival time relates only to persons who received fatal gunshot wounds; it should not be confused with gunshot victims who consciously fall down, faint, or otherwise surrender. Those reactions are based on psychological factors, not the physiological factors discussed in this article.

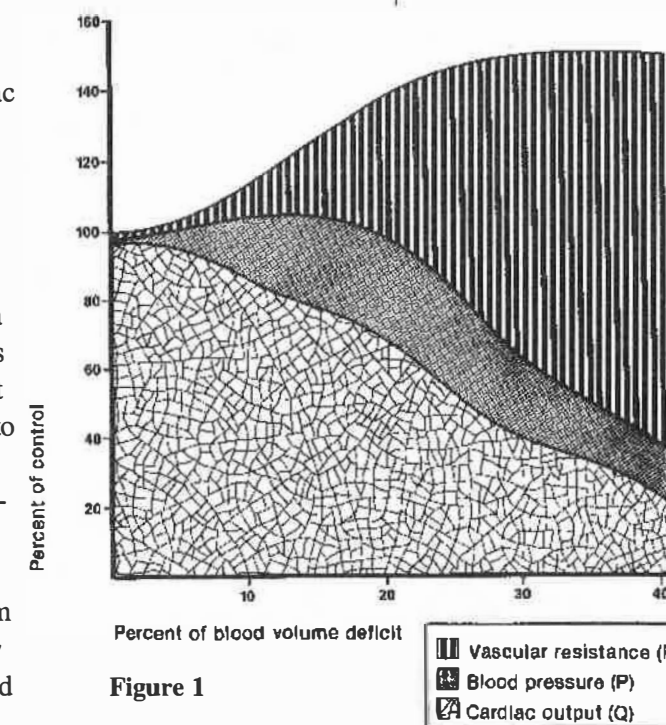


Figure 1

TABLE 2

Changes Seen in Acute Hemorrhage

Blood Loss	Vascular Response	Endocrine Response	Signs and Symptomatology
Mild (0% to 20%)	Contraction of capacitance system	Minimal	Narrowing of pulse pressure Hypotension (90 to 100) Fast heart rate Sweating
Moderate (20% to 30%)	Arteriolar constriction Narrowed pulse pressure Reduced cardiac output	Aldosterone Antidiuretic hormone Catecholamines (Epinephrine and Norepinephrine)	Decreased urine output Anxiety Hypotension (app. 60 mm Hg) Cool, clammy skin Obtundation
Severe (> 30%)	Hypotension Drastic reduction of cardiac output	Marked liberation of catecholamines	Shortness of breath Coma Death

Reprinted from *Emergency Medicine: A Comprehensive Review* by T.C. Kravis et al. p.74, with permission of Aspen Publications, Inc., 1983

TABLE 3

Survival Time of More Than 5 Minutes

	With chest and/or abdominal injuries	With head and/or neck injuries
Stab wound victims	6 (50%)	6 (50%)
Gunshot victims	53 (64%)	30 (36%)

Reprinted with permission from Levy, V. et al: Survival Time in Gunshot and Stab Wound Victims. *The American Journal of Forensic Medicine and Pathology*, 1988;9(3): 215-217.

Similar cases were presented by Spitz.¹⁹ Again, for a person to succumb from non central nervous system gunshot wounds takes a considerable length of time relative to the time it takes an assailant to return fire multiple times.

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CONCLUSION

Instantaneous incapacitation is not possible with non central nervous system wounds and does not always occur with central nervous system wounds. The intrinsic physiologic compensatory mechanisms of humans makes it difficult to inhibit a determined, aggressive person's activities until he has lost enough blood to cause hemorrhagic shock. The body's compensatory mechanisms designed to save a person's life after sustaining a bleeding wound, allow a person to

continue to be a threat after receiving an eventually fatal wound, thus necessitating more rounds being fired in order to incapacitate or stop the assailant.

How many times is it necessary to shoot an assailant before he is incapacitated? Although shooting situations vary tremendously, the correct answer is clearly to continue shooting as long as an officer believes he is still threatened by his adversary. An officer in a life threatening situation he should aim and fire as many rounds as tactically feasible. No absolute limit can be set since the officer has no way of knowing what organ tissue his rounds are disrupting and if compensatory mechanisms will allow the assailant to continue fighting. The officer has no way of determining if an assailant is about to immediately collapse or to continue his actions for 4, 5, 10 or more seconds. The only indicator he can use is the assailant's response: as long as he continues to be a threat, the officer should continue to fire until he can perceive that the assailant is no longer capable of continuing his life-threatening actions.

The implications of the above information are not trivial. Persons writing police department policies on the use of lethal force, firearm instructors, forensic scientists, lawyers litigating shooting cases, police investigators, expert witnesses in criminal and civil cases and the news media must take the physiological response to bullet wounds into consideration when performing their respective duties or drawing judgmental conclusions. Also, a summary of this information should be part of every police officer's education.

ACKNOWLEDGMENT

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WOUND BALLISTICS RESEARCH OF THE PAST TWENTY YEARS: A GIANT STEP BACKWARDS

Martin L. Fackler, M.D.

A review of the wound ballistics literature shows the source of many misconceptions and invalid assumptions regarding both ballistic effects and medical treatment of gunshot wounds.

Wound ballistics research is supposed to aid the surgeon in providing optimal care for the wounded. Twenty years ago, wounds from penetrating projectiles were likely to be treated in a rational and effective manner; today many surgeons are likely to remove excessive amounts of tissue in treating wounds caused by what they suppose to be "high-velocity" projectiles.

The most common battlefield wound has a simple punctate entrance with tissue disruption limited to a diameter no larger than the wounding projectile. The military rifle wound of the extremity, where the bullet has not yet yawed, and virtually all individual wounds from explosive device fragments fall into this category. Historically, this type of wound has healed well, despite little or no treatment -- even in pre-antibiotic days.

Since the Vietnam era, the majority of wound ballistics "research" has been politically motivated. It has used flawed methods to exaggerate wounding effects, seriously confusing current doctrine.

The amount, type, and location of tissue disruption, determined objectively, and *not* the supposed velocity of the projectile, is the critical information that should be used by the battlefield surgeon to determine treatment.

INTRODUCTION

The widespread misconception that "high-velocity" or "high-energy" projectiles invariably cause extensive damage ^{1,2} has been addressed recently ^{3,4}. The critical reviews that have questioned this concept in the past have gone relatively unheeded ^{5,6}. Interestingly, those who have questioned the "high-velocity/high-energy" concept of wounding (Lindsey, Hampton, Fackler) have all had extensive combat surgery experience.

Multiple penetrations by fragments from explosive devices are a common injury in most armed conflicts. Figure 1 shows a soldier who has suffered multiple fragment wounds. Fragments generally penetrate less than 15 cm in human soft-tissue; they cause a punctate entrance wound and track consistent with their size. Tissue surrounding their track is uninjured. Figure 2 shows the wounding pattern produced by a steel sphere; fragments from explosive devices produce similar wounding patterns, with the maximum disruption near the entrance where the projectile velocity is the highest. **The last 15 cm of projectile penetration** shown in Figure 2, produces no significant temporary cavitation because the velocity is much lower. This last portion of the projectile path illustrates the typical battlefield fragment wound. Military rifle bullets cause this 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 produced by the far lower velocity bullets**. Thousands of these simple perforations of the extremity (Fig. 4) are seen each year in our larger city civilian hospitals; the great majority of these wounds are treated with systemic antibiotics but little or no surgery -- they heal well ⁵.

HISTORICAL REVIEW

Before the wound ballistics research that followed the Vietnam conflict, uncomplicated military rifle wounds (and small fragment wounds for the most part) were also treated with little or no surgery -- they healed well. Compare Stevenson's advice in 1897 ⁷ Against surgical interference with the bullet path in rifle wounds, with Theodor Kocher's observations from World War I ⁸, that the minimal damage produced by the rifle bullet allowed the wounds ("...wie Verletzungen ohne hautwunde ausheilten.") to heal so well that it appeared as if they had no skin wounds.

Jolly, in 1941 ⁹, noted "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 1942 ¹⁰, advised that the "...seton* wound is innocuous, it should be left alone." Ferguson et al. ¹¹, Slesinger ¹², Crile ¹³, and Cope ¹⁴ made similar observations, and Ogilvie ¹⁵, 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. He wrote, "The majority of these with rest and sulfonamide heal rapidly and leave no disability; operation means loss of time and loss of function."

King ¹⁶, 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 author of this paper served in one of the busiest hospitals in South Vietnam (US Naval Support Activity Hospital, DaNang) during the most active period of the Vietnam conflict (December 1967 to December 1968). Immediately thereafter he served

* "Seton" or "en seton" is a medical term use to describe a punctate, perforating or "through and through" wound.



Fig. 1. All of the fragments that caused these entrance wounds remained in the body, as is the case almost without exception. This indicates that the striking velocity was probably not over 1000 ft/s (305 m/s).

three years at the US Naval Hospital, Yokosuka, Japan, caring for the combat casualties from South Vietnam who were transported there by air soon after their initial surgery. He was a delegate at the last two Tri-Service War Surgery Conferences (1970, 1971)¹⁷. The amount, type, and location of tissue disruption, determined by physical examination and appropriate x-ray studies was the information on which this author and his colleagues based their treatment of penetrating war wounds¹⁷.

ORIGINS OF CURRENT MISCONCEPTIONS

If we didn't have any trouble treating the gunshot wounds of the Vietnam War why has this field regressed so badly since then? In 1967, one small series of wounds caused by the then new M-16 assault rifle was reported^{18,19}. These wounds were described using such emotionally charged terms such as "massively destructive"¹⁸ and "devastating wounding power...tremendous wounding and killing power"¹⁹ rather than reporting wound dimensions and/or includ-

ing measuring scales on photographs to give the reader an objective means of comparing these wounds with those caused by other weapons.

Remembering the political climate of that time, and the fact that the Swedish government, as a part of its anti-war stance, was actively encouraging desertion by American soldiers and providing them refuge, it is not surprising that Swedish interests saw in these reports an opportunity to be exploited. They began a program attempting to have the M-16 declared "inhuman" and outlawed by international convention. The "research" done to support this program used methods that could easily be misinterpreted to make wounding effects produced by the M-16 bullet appear worse than those produced by other small-arms projectiles. For example, shooting projectiles through small (14 cm) blocks of tissue simulant, or the legs of 20 kg pigs in which the tissue path is even shorter, gives results that can mislead. The photos in Berlin, et al (20) show a 15 cm stellate exit wound caused by a 5.56 mm bullet compared to one of only about 1 cm caused by a 7.62 mm bullet, making the smaller bullet appear to have a

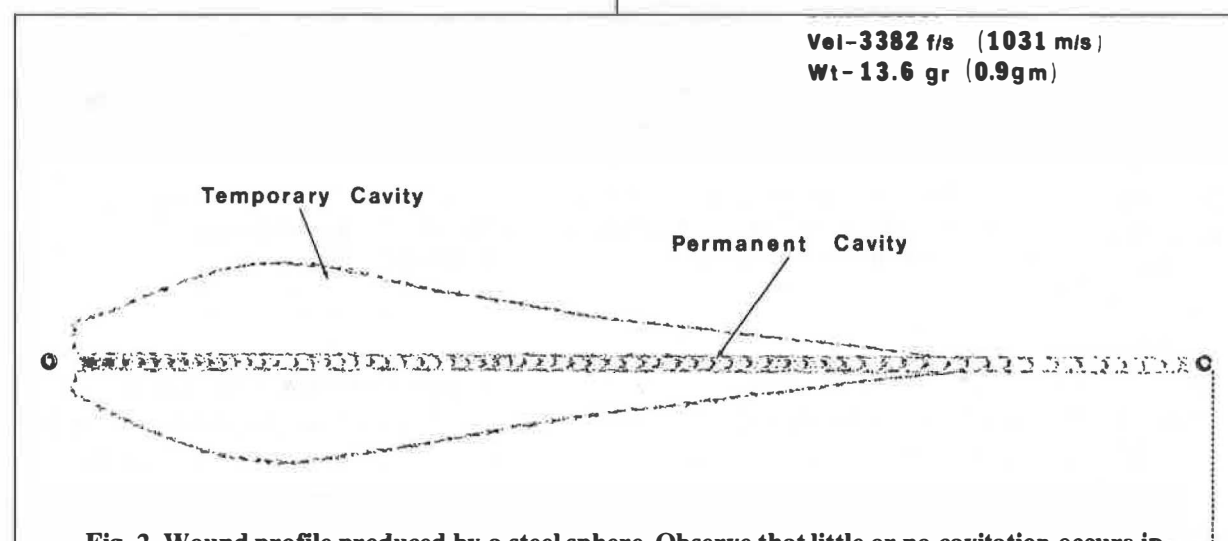


Fig. 2. Wound profile produced by a steel sphere. Observe that little or no cavitation occurs in the last 15 cm of penetration. This last part of the sphere's path corresponds to what is observed in battlefield casualty, yet most wound ballistics researchers who use this projectile concentrate exclusively on the initial part of the path. The cavitation effects of the first part of the projectile path are not seen in fragment wounds of the wounded combat casualty and the cavitation effects produced by rifle bullets occur at a deeper depth of penetration. Although the sphere does produce easily repeatable results, unfortunately these results do not reproduce battlefield type wounds.

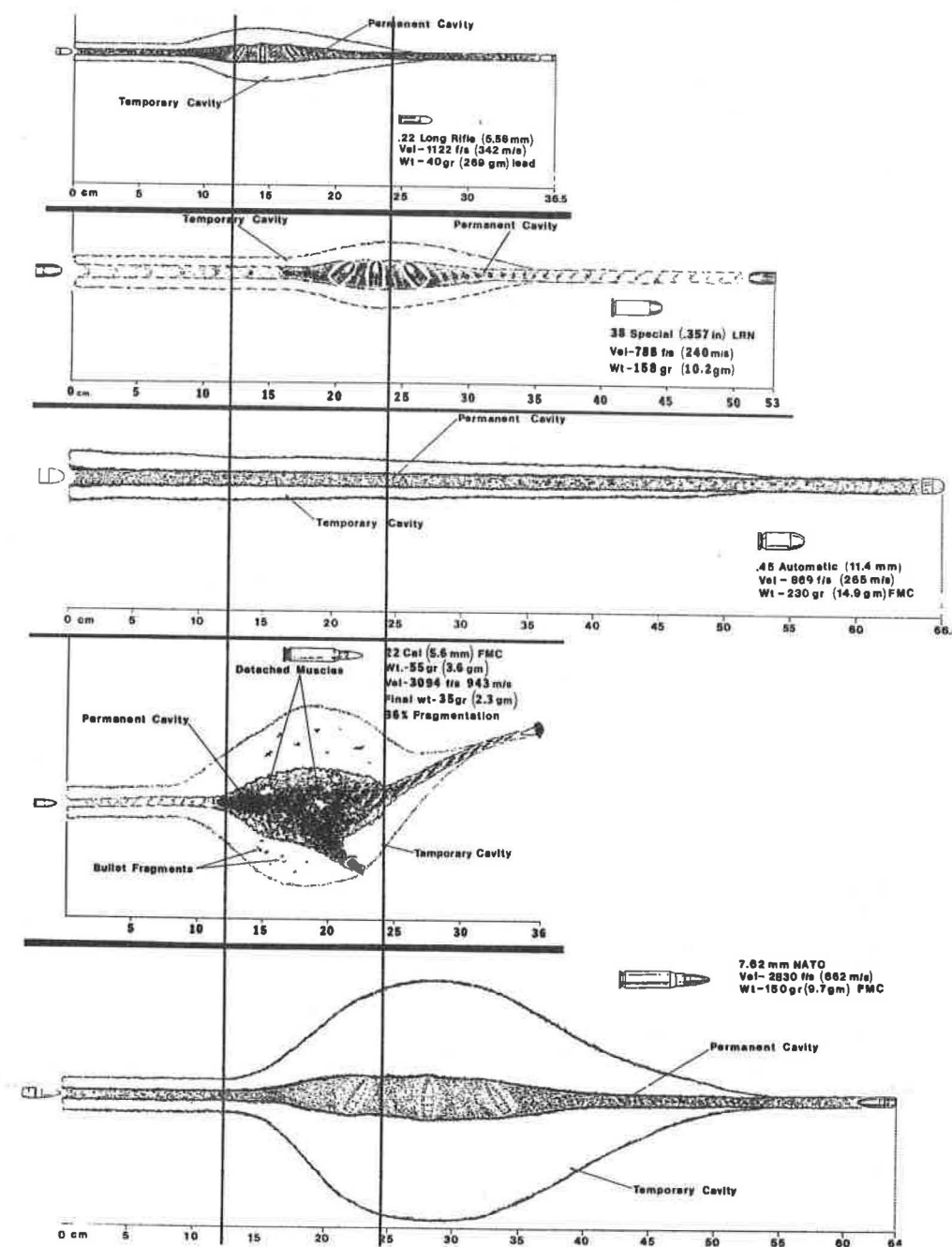


Fig. 3. Comparison of the first 12 cm of the projectile path in the five wound profiles pictured shows why the wounds from "high-velocity" rifle bullets may be no more disruptive than many simple extremity wounds caused by lowest velocity handgun bullet.

far greater wounding capacity.

Military bullets begin their tissue path traveling point forward. They yaw (turn sideways in relation to their line of flight) at under 10 cm to over 20 cm penetration depth, depending on the bullet. Even in groups of shots using the same type of bullet, variations in the penetration depth at which the bullet yaws can easily vary 25% from the average²¹. This means that in any group of shots with a given bullet there are likely to be some that yaw within these small targets; these will show large exit wounds. There will be others that have not yet yawed; these will show minimal wounds. Those with an interest in "proving" one bullet less "humane" than another need only to photograph the appropriate exit wound. This variation also explains apparent inconsistencies in bullet effects. Nordstrand, et al²², showed comparative microsecond x-ray pictures comparing the same type bullets that Berlin, et al.'s study²⁰ had indicated an apparently far greater wounding effect for the 5.56 mm bullet. In this study²² **both bullets yawed and broke apart at the same depth of penetration in a soap block, and the 7.62 mm bullet's disruptive effects were far greater.**

By using enough tissue/tissue simulant to catch the entire projectile path, the **entire** potential of the projectile can be determined²³; nothing is hidden. Only presentation of the projectile's disruption pattern along its entire tissue path allows meaningful comparison of wounding potential between various projectiles.

Apparently overzealous in his attempt to justify the Swedish efforts; Berlin wrote, "During the 1960's injuries of much greater severity were reported due to a new generation of small firearms."²⁴ Those who wish to check will find that only two of the seven citations Berlin gives to support that statement do, in fact, support it; these two are by the same author¹⁸. In fact, it appears that all the furor over the M-16, repeated and amplified in many papers, originated from this one source.¹⁸

OBJECTIVE OBSERVERS SAW NO MORE SEVERE WOUNDS FROM THE M-16 THAN FROM OTHER SMALL-ARMS

The five Tri-Service Vietnam war surgery conferences did not identify any special problems associated with "high-velocity" projectile wounds. The last conference¹⁷ listed "Topics suggested for further study," but no need to study penetrating projectiles (wound ballistics) was mentioned.

Scott²⁵, in a superbly comprehensive study which combined an outstanding historical review, comparative shots into tissue simulant and in live animals at ranges up to 600m, and case reports of 70 shootings with the new 5.56 mm caliber, concluded, "The experimental observations which I have made under widely varying circumstances do not indicate that light weight rifle bullets inflict more severe wounds than those caused by rifles in use since the early part of this century. My experience in the field supports this conclusion."

Albrecht, et al.²⁶ did an extensive study shooting various military rifle bullets through the tied-together thighs of 59-66 kg swine in order to study bullet effects in a more realistic tissue thickness (25 cm) than was used in the Swedish studies. Their findings were clear; the 7.62 NATO bullet caused more damage than the 5.56 mm M-16 bullet.

Bellamy²⁷ recently reviewed the information collected on approximately 1400 gunshot wound casualties by the Wound Data and Munitions Effectiveness Team (WDMET) in Vietnam. Wounds caused by the M-16 rifle comprised about one fourth of these cases and Bellamy states unequivocally that they did **not** cause more severe wounding than other small arms used in this conflict.

SCOPE OF THE MISINFORMATION

Five International Wound Ballistics Symposia have been sponsored by the Swedish research group. The proceedings of these symposia have been published, and many readers assume that the information is valid scientific literature, selected by peer review. It is not. Papers submitted to these symposia are accepted and published without critical review. The

major emphasis appears to be on attracting participation and interest in the symposia; this has resulted in greatly increasing the volume of data **with no regard for the quality of this data**. Serious contradictions in this work have gone unaddressed, e.g., two papers by Swedish researchers concluded that the amount of nonviable tissue around a projectile wound increases with time^{28,29}; three papers from other countries³⁰⁻³² reported contradictory findings.

The degree of exaggeration to be found is well illustrated by recommendations given by Rybeck³³.

He wrote that "...the clinical experience [is] that tissues which have been subjected to the formation of the temporary cavity after a high velocity missile will not survive.", and "...the temporary cavity, especially after missiles traveling at high velocities, is very large (30 times the diameter of the

projectile)...". Using this to calculate extent of the tissue excision recommended for the wound shown in Figure 4, for example (5.56 mm M-16 bullet diameter, multiplied by 30), we find a diameter of 16.68 cm (over 6 inches). Compare this with the experience of King, cited above¹⁶, that this type of wound "...usually healed if left alone." The reader can judge for himself which treatment recommendation appears to be the more reasonable.

Rather than striving for a rational synthesis, correcting and striving to replace flawed data with more valid work, those in control of the symposia have attempted to suppress contrary information. For example, the printed Proceedings of the 5th Sympo-

sium (held in 1985 but not published until 1988); omitted a panel discussion in which data very critical of Swedish research methods was presented; additionally, none of the comments made from the floor on the papers presented (many of them critical of methods, conclusions, etc.) were included³⁴.

CONCLUSION

Scientific work demands hard choices, separating the valid from the unsound, the significant from the trivial, and the common from the rare. When this is

not done the flawed works pile up, greatly outnumbering the valid ones; repetition compounds the problem and many are misled. The sad legacy of the misguided studies of the past twenty years can be found in the faulty understanding of wounding mechanisms and irrational treat-



Fig. 4. This through and through wound of the plantar surface of the foot was caused by an M-16 rifle bullet. Despite the "high-velocity", tissue disruption was minimal; almost indistinguishable from a .22 long rifle wound.

ment recommendations in recent surgical textbooks³⁵⁻³⁸. The detrimental effects 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^{5, 7-17}. Since it has resulted in recommendations for unnecessarily radical explorations and excision of tissue for all "high-velocity" projectile wounds, and assumptions 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. It is hoped that this documentation of the problem will stimulate corrective measures.

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The Advanced Combat Rifle Program: Weapons & Wound Ballistics

Alexander Jason

The U.S. Defense Department has terminated its unsuccessful attempt to develop a superior replacement for the M16A2 rifle but their enthusiasm for the inadequate flechette projectile continues.

The "Advanced Combat Rifle" (ACR) program was a ten year effort of sponsored research, development, and testing of new rifle models to provide "significant improvements" in rifle technology; specifically in hit probability while maintaining or improving the wounding potential of the M16A2 firing the standard M855 cartridge. The manufacturers of each of the four final candidate weapons (see Fig. 1) also developed new ammunition cartridges in an attempt to increase their weapon's hit probability. They included duplex (two bullets in one cartridge) ammunition, flechettes, and caseless cartridges.

THE ACR WEAPONS

The Colt ACR rifle used both the standard M855 cartridge and a new duplex (two bullets in one case) cartridge. The duplex round featured a 35 grain bullet above a nested 30 grain bullet. The idea is that the first bullet will hit at the point of aim and the second, rear bullet will disperse slightly from the first thereby increasing the chance of at least one bullet hitting the target.

The Heckler & Koch rifle used a unique caseless "cartridge" with a 4.9mm, 51 gr bullet located within a solid propellant body. Two potential advantages of ammunition which does not require a relatively heavy metal (usually brass) case are: a substantial reduction in carry load of the soldier and a reduction in logistic tonnage for the supply system. Also, a weapon firing

caseless ammunition does not require an extractor or extraction cycle. The H&K rifle made good use of this feature to provide a three-round burst mode at a cyclic rate of 2,000 rounds per minute (33 rounds per second) -- which is almost three times the full auto cyclic rate of the M16A2 or any other common service rifle -- and so fast that all three bullets will exit the muzzle before the rifle moves appreciably in recoil.

The Steyr rifle used a sabot, 9.85 grain fin-stabilized flechette in a plastic case which traveled at a very high velocity of about 4,900 f/s.

The AAI rifle fired the same flechette projectile as the Steyr but from a brass case which (oddly) weighed less than the Steyr plastic cased round. Muzzle velocity of the AAI flechette is about 4,600 f/s.

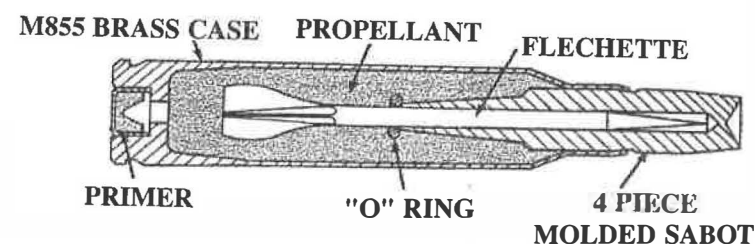
There were problems with the caseless and particularly with the sabot flechette cartridge which -- in spite of the light weight of the flechette itself -- weighed more than the standard M855 cartridge. The flechette was also less accurate than the M855 bullet and there was a problem with the fact that the sabot which -- after transporting the flechette down the barrel -- separates from the flechette and becomes a hazard to nearby friendly troops in front of the shooter. One important point which will likely affect any consideration of their use is that both the caseless and the flechette rounds require more production steps and more precision in manufacturing and therefore more expense per round than conventional ammunition.

The decision to terminate the program resulted from the failure of all the newly developed weapons in field tests. Soldiers received training on the new weapons and then fired them at targets from 50 to 300 meters distant. The results of the tests demonstrated

Candidate ACR's

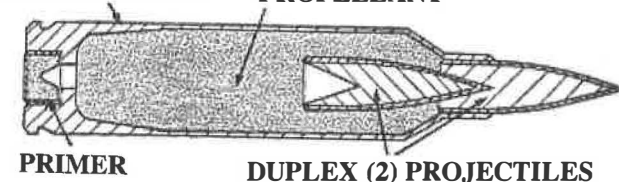


AAI

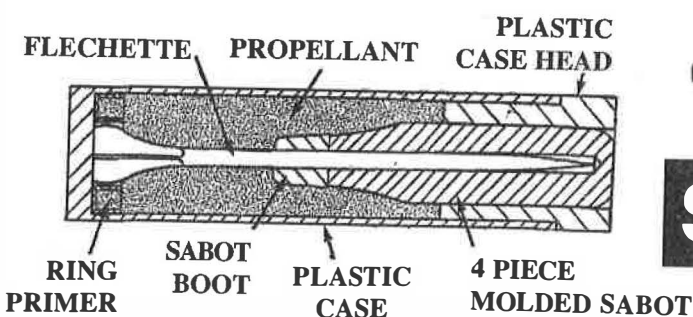
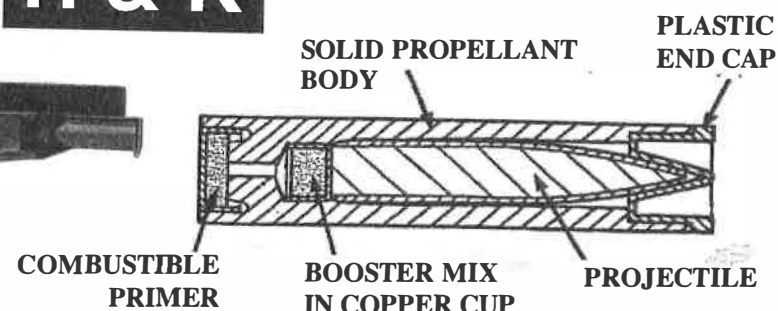


COLT

M855 BRASS CASE PROPELLANT



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STEYR



that soldiers firing the new rifles and new ammunition were not able to hit more targets than were the soldiers firing the current M16A2 rifle. As the candidate weapons failed to meet a primary program goal of providing a significant improvement in hit probability, the program was terminated.

While the program's criteria and methodology for evaluating the rifles' ability to get rounds on targets appear to have been innovative, practical, and worthwhile; the program's evaluation of the "lethality" or wounding effects of the candidate weapon's ammunition was based on flawed assumptions and have provided the DoD with data which are likely to lead to serious errors in future weapons development.

The official DoD and ACR program position is that although the ACR program did not result in the development and production of a better service rifle, the program was a "success" as, "significant advances in the state-of-the-art in rifle technology have been made"² and in the establishment of a more valid database on hit probability. Although the program does appear to have collected valuable data on caseless ammunition and hit probability, it is disturbing to find that the program evaluators came to the absurd conclusion that the flechette projectiles (used by two candidate rifles) were equal in wounding effect to the conventional M855 bullet used in the M16A2.

Attempts to use flechettes as rifle projectiles is not a new idea as there have been several Army programs since the 1950's -- most notably the Special Purpose Individual Weapon (SPIW) program -- which attempted to develop a flechette-firing service rifle. The continuing allure of flechettes is based on the understandable desire to field a service rifle which can use very lightweight ammunition (thereby allowing a soldier to carry more rounds.) A flechette can, because of its highly aerodynamic shape, travel in a flat trajectory (which makes long range shooting easier) and due to its very high length over diameter ratio, the flechette is also capable of considerable penetration into hard material.

The flechette does possess these characteristics but a factor often overlooked in the past and misunderstood in the recent ACR program is the flechette's wounding characteristics: what the flechette does to

tissue. In many instances the long, thin, fin-stabilized flechette will simply perforate a human torso; going in one side and exiting out the other with minimal tissue disruption. A wound of this type is not likely to cause rapid or eventual incapacitation or even a wound of any tactical significance. One of the top engineers evaluating flechettes in an early project study recognized this and reported that after being hit with a flechette, "... a person might hardly know he's been shot."³

The ACR program did attempt to evaluate the wounding capability of the flechette projectiles by firing into tissue simulant. The lethality testing was performed by U.S. Army's Ballistic Research Lab (BRL) at Aberdeen, MD and although the flechette's propensity to "zip through" tissue without significant wounding effect was recognized as a flaw, BRL believed there was a mechanism by which the flechette's performance could "... exhibit lethality characteristics similar to bullets." BRL found a flechette penetrating tissue at sufficiently high velocities (the exact "critical velocity" is classified but is believed to be about 3,000 f/s), will (usually) yaw, and deform into a "C" shape and stop -- thereby satisfying the most fervent longing of all ballistic engineers: a complete transfer of kinetic energy from projectile to target.

Kinetic energy (KE) -- which is one half of the product of mass times energy squared -- is perhaps the most misunderstood, misused, and misleading concept in wound ballistics. There are many who believe that a bullet's effectiveness is directly related to its kinetic energy and BRL has been a primary source for this erroneous theory. In addition, virtually all ammunition manufacturers provide brochures with lists of their various loadings showing kinetic energy levels at differing velocities. Civilian gun magazines invariably discuss the kinetic energy of new hunting and defense cartridges.

Although widespread and popular, the mistaken belief in the correlation between KE and wounding effect has been around for many years and it is likely to have resulted from an attempt by engineers to apply numerical values to wound ballistics. As someone who has worked in the field for many years, I understand and sympathize with the desire for an ordered,

linear system for predicting the effect of projectiles on humans. Being able to accurately and simply measure (or predict) the effectiveness of a bullet by only having to know its weight and velocity would make wound ballistics research and evaluation much easier. But the fact is that the interaction of projectiles and living creatures (humans included) is much too complex a subject to allow a simple, linear systems of evaluation to be valid.

Using the KE theory of wounding, a projectile is fired at a target (tissue or tissue simulant.) The velocity of the projectile is measured just before it penetrates into the target and then upon exiting (if it goes completely through the target.) The greater the difference between the entrance and exit velocities, the more KE "deposited" or transferred to the target and therefore -- by KE theory -- the more "lethal" the projectile. A projectile which did not exit the target (thereby transferring all its KE to the target) would be considered more "effective" than a projectile which did exit the target. While this approach may have some validity when applied to armor and other materials, it is not generally applicable to wound ballistics.

The KE "energy transfer" theory of wounding was further developed to evaluate bullets by the speed with which they decelerate: i.e., how quickly a bullet comes to a stop. The idea is that a fast transfer of energy is somehow more "lethal" or disruptive than a slower transfer. When applied to actual use, this concept results in higher lethality values being given to bullets with extremely shallow tissue penetrations than to bullets which penetrate to greater depths.

The National Institute of Justice (NIJ) and the National Institute of Standards and Technology (formerly the National Bureau of Standards) have utilized this method for almost 20 years to evaluate handgun bullets for law enforcement. Its published "Relative Incapacitation Index" (RII)⁴ of handgun ammunition is now widely ignored and generally recognized to be worthless.

As an example of the fallacy of utilizing KE to evaluate bullets consider:

Two bullets have the same weight and velocity. Bullet 1 strikes an animal and stops. Bullet 2 strikes an identical animal and perforates through its body.

Using KE deposit theory to evaluate effectiveness, Bullet 1 would be superior. But if Bullet 1 was stopped in fat and muscle without disrupting major organs or vessels and Bullet 2 went into and through the animal's brain before exiting, which bullet was really more effective?

Living human and animal systems are not homogeneous objects:

Wounding, incapacitation, or lethality is not a function of the quantity of energy applied or transferred but of the quality (or importance) of the tissue being disrupted.

With flechettes, the quantity of KE produced is similar to the quantities produced by handgun bullets -- not rifles. This means that the amount of temporary cavitation in tissue caused by a flechette when it does deform and stop will not be sufficient to stretch most tissue beyond its break point and is therefore unlikely to produce significant tissue disruption.

THE FUTURE OF THE FLECHETTE

The ACR program has ended and with the substantial cutbacks in future military expenditures it is not likely that a new program will begin soon. But without a reevaluation of DoD/BRL's basic assumptions regarding the mechanisms of wounding, it is likely that the future will find the flechette resurrected yet again as a "Wonder Bullet." In terms of effective wound ballistics, the ACR program termination can be considered fortunate; but it is disturbing to realize that the continued acceptance of the KE deposit wounding myth may -- someday in the future -- result in our troops being equipped with lighter, faster, and less effective ammunition.

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An Inexpensive Downrange Chronograph System

Lucien C. Haag

This article describes the construction and use of an inexpensive device for protecting small portable chronographs from damage errant bullets, bullet fragments, and/or ejected fragments of intermediate targets positioned close to such chronographs.

In cases involving certain exterior and terminal ballistic issues it is often desirable to measure velocity loss over substantial distances so that the ballistic coefficient of the particular bullet can be calculated. In other cases the velocity loss experienced a particular type of bullet during passage through some intervening object is of forensic importance. In the past this writer has used sets of matched chronographs for these purposes with one unit positioned uprange and one or more units downrange. Whether located a few feet beyond an intervening object or 50 to 100 yards downrange for an unobstructed shot the down range chronographs are in jeopardy of being struck with potentially catastrophic results. A device has therefore been constructed which offers good protection for small portable chronographs like the Chrony Quartz-Lok or the ProTach. This device uses a 3/8 inch thick steel plate mounted at an angle on a framework to shield the downrange chronograph(s). An adjustable arrangement of protected mirrors allows any velocity readings displayed on the chronograph(s) to be observed through a spotting scope or an optical sight on the test firearm when the device is positioned at distances of 50 to 150 yards. The unit is capable of being mounted on a telescoping, adjustable stand borrowed from a portable shop lighting system.

Materials and specifications of the materials necessary to construct this device are listed below. Some of the key dimensions and specifications of the unit are shown in the line drawing and described below.

- 3/8" steel plate - 6.5x14 inches.
- 3/8" plywood, 2 pieces - 14x18 inches and 4.5x14 inches.
- 1/8" thick "angle iron" (right angle sections of mild steel) 1.5 inch sides, three (3) 4 ft. lengths.
- 1/8" thick 1.5 inch wide flat plate steel strips; two (2) 12 inch pieces.
- 1/8" thick glass mirror, 2 pieces 4.5 x 14 inches ea.
- 1" thick soft urethane foam, 4.5 x 14 inches.
- One 14 x 18 inch section of pile carpeting.
- Right angle brackets (4).
- 3/4" square Velcro fasteners (8 pairs).
- Miscellaneous small screws, nuts and wingnuts.

Nearly all of the foregoing materials are obtainable from hardware store or home building supply stores. The steel plate was obtained from a metals fabrication company. Velcro fasteners can be found in department stores or fabric stores.

ASSEMBLY

Two of the 4' lengths of the 1.5" wide angle iron were cut to form a rectangular framework with inside dimension of 14" x 24". Two 14" long pieces of 1.5" angle iron were mounted back to back with their vertical elements 1.5 inches in from the front of the unit. This arrangement provides triangulated support for the 6.5" x 14" section of 3/8" thick steel plate which is

welded in at an approximate angle of 55 degrees to the plane of the framework. A nominal 14" x 18" plywood floor was attached to the framework with small screws and nuts leaving a 4" opening at the forward end of the unit. A 4.5" x 14" piece of 1" thick urethane foam was glued to the backside of the steel plate as a shock absorber. Velcro fasteners were glued to the four exposed corners of the piece of foam. Corresponding Velcro fasteners were glued to the backside corners of a 4.5" x 14" section of 1/8" mirror which can then be attached or removed as desired from the shock absorbing foam on the back of the deflection shield.

This arrangement also allows for easy replacement in the event the mirror becomes cracked or broken.

Once the unit's approximate center of gravity is located four (4" right angle brackets were used to attach a one (1) foot section of 1" square tubing. This telescopes into a stand borrowed from a portable shop light system manufactured by Grandrich).

Two 12" long flat steel straps were attached with screws and wingnuts through holes drilled 6 inches back from the front of the unit. A 3/8" thick, 4.5" x 14" piece of plywood was affixed at the bottom of these two metal straps with a single wood screw on each side. Another section of mirror of the same dimension as before was secured to the front-facing side of this piece of plywood. The upper wingnuts and the lower screws are

left sufficiently loose so that adjustments may be made to allow remote viewing of the chronograph's display. The lower mirror system can either be re-

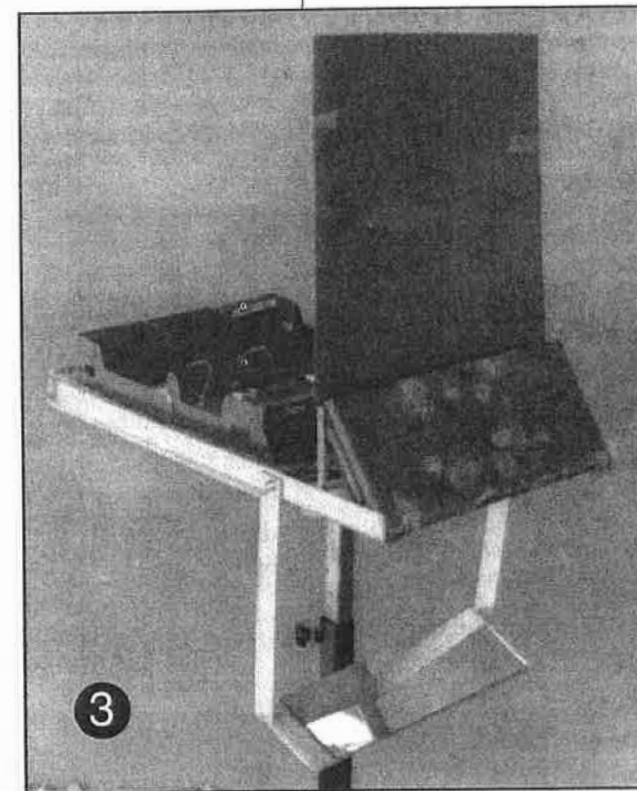
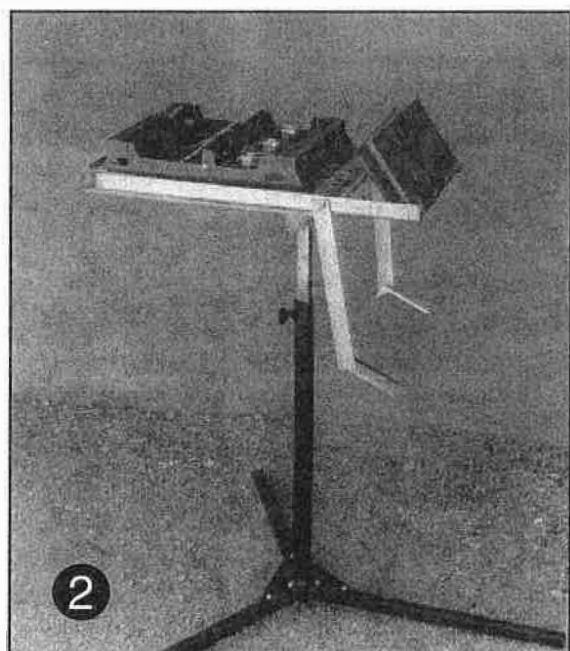
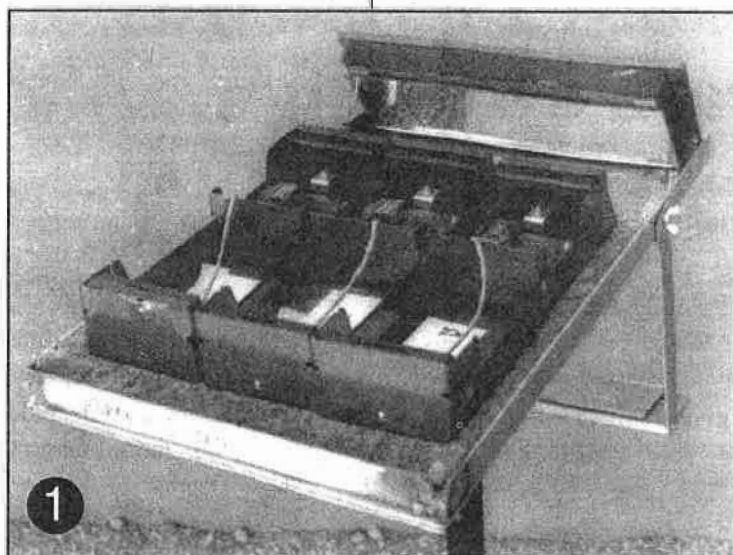
moved when not in use or simply rotated forward up over and onto the carpeted floor of the unit for storage and transportation. A profile view of this device is shown in the diagram. The three photographs show the actual unit from several angles with three (3) Chrony brand portable chronographs situated side-by-side in the protected area. Photograph

3 also shows the addition of a simple cardstock witness panel mounted on two 5/16" diameter wooden dowel rods inserted in two empty 357 magnum cartridge cases which have been epoxy-glued to the inside of the framework.

USES AND APPLICATIONS

For long distance chronographic measurements, this system can be positioned in front of and approximately 1 foot below a grouping of shots on some form of sighting target. Three chronographs are used instead of one to increase the overall zone of detection. Subsequent shots which pass over the protected chronographs in the correct height zone can be seen and recorded through the use of a spotting scope. The cardstock witness

panel on the deflection device can also be of assistance in making small sighting corrections to bring subsequent shots into the proper zone for detection by the



chronograph(s). The cardstock witness panel is also useful when measuring the exit velocities of bullets that have passed through certain types of intervening objects. Small particles or other debris ejected from materials such as glass, sheetrock or particleboard will frequently confuse nearby downrange chronographs and give erroneous velocity readings. A cardstock panel mounted at the front of the deflection device will substantially reduce these bogus readings by filtering out the ejected debris from the bullet's passage through the intervening object.

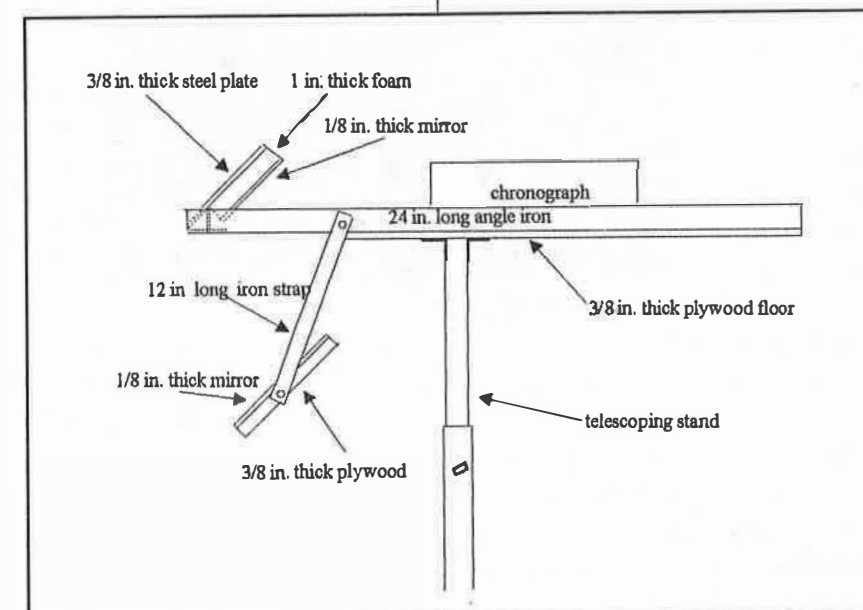
SUMMARY

The construction and uses of an inexpensive device for the shielding of downrange chronographs has been de-

scribed. This unit will protect chronographs from impact damage from direct gunfire as well as fragments from disintegrating bullets and ejected debris from intermediate targets located immediately in front of the unit containing the downrange chronograph(s). This unit also provides a detachable viewing system which will allow one to record distant chronographic measurements through the optical sights of a rifle or through a spotting scope thereby obviating the need to travel downrange after each shot to record any velocity values.

ACKNOWLEDGMENT

Special thanks are extended to IWBA member William H. Morris, Jr. of the Arizona Department of Public Safety Crime Laboratory for the application of his forensic welding skills during the construction of this device.



Police Handgun Ammunition Selection

Martin L. Fackler, M.D.

A discussion of the basic facts which should be considered in the selection of police handgun ammunition; and a review of the most common misconceptions concerning bullet effectiveness.

Nothing is sadder than the unnecessary loss of police lives from equipment failure. FBI Special Agent Dove did his part in the "Miami Shootout" of April 1986: his aim was perfect; his bullet was heading directly for the heart of a heavily armed and experienced killer. However, that bullet failed to reach the heart because of inadequate penetration (see Fig. One): it passed through the criminal's upper arm before continuing into his chest (not an uncommon situation: many at whom one shoots have one or more arms in front of their torso -- holding their gun). Two FBI agents died as a result of this bullet failure. This was by no means the first or the only instance in which police officers have lost their lives due to failures of bullets designed to place high on the infamous National Institute of Justice (NIJ) "Relative Incapacitation Index (RII)." The autopsy of the criminal (who later died from several head shots) revealed that the bullet which perforated his arm and entered his chest stopped only about an inch from his heart. This incident proved the danger of inadequate bullet penetration: a fault common to bullets rated high on the RII.

The "Miami Shootout" attracted a lot of attention since two FBI agents lost their lives and five were

wounded. The investigation revealed the problem: the FBI faced it squarely and corrected it. Most law enforcement agencies learned from the FBI's experience and adopted bullets with adequate penetration: a notable exception is the U. S. Secret Service -- it appears that interagency rivalry or excess pride won't allow them to learn from anyone else, they will need their own disaster.

The purpose of this article is to provide basic facts about handgun bullet effects on the human body for those who choose police bullets to use as a guide through the minefield of misinformation to which they are subjected in the popular gun press and bullet manufacturers' advertisements.

The facts needed to make the critical bullet-choice decisions are simple and easy to understand:

• THE ONLY RELIABLE WAY TO STOP THE AGGRESSION OF A

FEARLESS ASSAILANT IS TO DISRUPT HIS VITAL BODY STRUCTURES. This fact has proven itself both on the military and urban battlefields. It should come as no surprise to any experienced hunter.

• **THE HEART, MAJOR BLOOD VESSELS, AND UPPER PART OF THE SPINE ARE THE VITAL STRUCTURES OF THE TORSO.** These can be over ten inches deep from some angles in some people.

"The facts needed to make the critical bullet-choice decisions are simple and easy to understand."

• **BULLETS PENETRATE BY CRUSHING THE TISSUE THEY HIT.** Crush by direct bullet contact (also called the permanent cavity), is the only disruption mechanism the handgun user can rely upon. The other mechanism, transient radial displacement of tissue surrounding the bullet path (the temporary cavity), is too small when caused by the expanding handgun bullet to have a reliable effect in the adult human. The stretch of the first part the bullet hole to about the diameter of an orange (see Fig. One) is easily absorbed by the elasticity of the tissues in most parts of the human torso. These flexible tissues act much like a shock absorber. The effect of the handgun produced temporary cavity stretch is at best variable and erratic. The effect of permanent cavity crush is certain and reliable.

• **IDEAL BULLET PENETRATION DEPTH IN THE BODY IS BETWEEN 12 AND 20 INCHES.** Penetration beyond 20 inches is preferable to penetration under 12 inches but it wastes bullet potential (something one cannot afford to do given the limited potency of the handgun) as well as creating an unnecessary hazard to bystanders.

• **THOSE BULLETS WITH THE LARGEST EXPANDED DIAMETER ARE THE MOST EFFECTIVE** (Provided that they reach the necessary penetration depth with sufficient potential to disrupt what they hit.)

However, there is more to consider here than just diameter: shape and configuration of the expanded

bullet can also be an important factor. Hatcher ascribed to various bullet shapes a "disruptive factor" (*Textbook of Pistols and Revolvers*, p. 410). He

rated highest the full-wadcutter: full-wadcutters cut a sharp round hole in the target (rather than the fuzzy, folded-back hole made by the round-nosed bullet). Cutting is a variation of the crush mechanism and is far more efficient in disrupting tissue than is stretching by temporary cavitation (largely a waste of energy in the handgun). Consider the broadhead hunting arrow: it has been used to kill every species of big game on this planet -- including the elephant -- and it possesses about the same amount of kinetic energy as a .22 Short. It disrupts tissue by cutting.

Consider the average expanded hollow-point handgun bullet: the soft lead of the expanded forward edge is rounded-off and smooth. When striking a large blood vessel within a few inches of the end of its tissue path it will push the vessel aside. However, if the bullet has leaves of the copper jacket still attached to it and exposed (see Fig. Two) they can act like little knives, slicing blood vessels rather than just pushing them aside. This cutting action by a 147 gr. Winchester OSM subsonic bullet was described by forensic pathologist Dr. Richard

Mason in an autopsy he did last year in Santa Cruz, CA: the wall of the thoracic aorta was cut by this bullet. This OSM bullet was the only one among the many bullets I tested at the Wound Ballistics Laboratory at the Letterman Army Institute of Research in which the recovered bullets consistently had these ex-

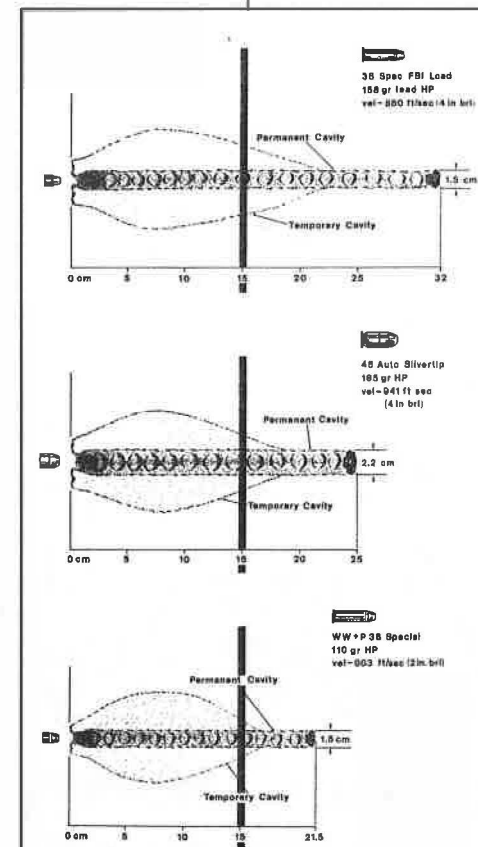


Figure One -- The black line on the three wound profiles indicates a penetration depth of 6 inches (15 cm). This is the minimum depth at which the major blood vessels are located (from the front of the torso) in a small slender adult. Heavy build, angled shots, or having to perforate an arm first can easily double that distance. The wound profile of the bullet used by FBI SA Dove in the FBI shootout, the 9mm 115 grain WW Silvertip, is similar to the bottom profile shown.

posed knife-edge jacket leaves. Alan Corzine, an ordnance engineer at Winchester, recognized the importance of this cutting mechanism and designed a bullet based upon it. This bullet (Fig Three), the "Black Talon," after expansion has six sharp pointed copper hooks around the circumference of the mushroomed lead. In my view this "Black Talon" bullet is the most significant advance in handgun bullet technology since the invention of the expanding bullet. Recently, three Black Talon bullets (two 9mms and one 45) were shot through the lower abdomen of a freshly killed, 100 lb pig. All three bullets were recovered and showed expansion identical to shots done previously into gelatin (see Fig Three for a typical example). Autopsy showed four distinct cuts in loops of small bowel that were made by the cutting hooks on the expanded bullets: these were pieces of bowel that would have been simply pushed aside by bullets without the cutting mechanism of the "Black Talon."

• **BULLETS HITS IN THE TORSO CANNOT BE COUNTED UPON TO CAUSE A PERSON TO IMMEDIATELY CEASE HIS**

ACTIONS. Even a total cessation of blood flow to the brain can allow 10 seconds of purposeful action -- more than enough time to empty a whole magazine.

The false expectation that a bullet striking a vital part of the body will cause immediate incapacitation is a common and dangerous misconception. Officers involved in shootings usually express surprise at the lack of any visible reaction to bullet hits on their adversary. Again, this will come as no surprise to the experienced hunter: even when a center-fire rifle bullet has just disintegrated his heart, a deer will commonly run off showing no sign of being hit -- only to be found dead within 30 to 50 yards.

Many will collapse immediately when hit by a bullet (as will some who were missed but **think** they

have been hit). They do so for **psychological reasons**. However, the most dangerous opponents, those under the influence of drugs, psychotics, and the determined, well-trained and fearless; are far less likely to stop. **The psychologic stop is extremely variable and erratic -- you cannot count on it.**

This concept is not new: Hatcher described it well in 1935 in his **Handbook of Pistols and Revolvers**, pp. 428-430. New examples of the danger posed by these tough-to-stop individuals have been brought up in every seminar I have given to law enforcement groups. However, the "magic bullet boys," the self-proclaimed experts at work pushing their pet theories and favorite bullets, don't talk much about it. They would rather ascribe the psychological stops to some miraculous property of the bullet they are currently hawking.

• **LUCK IS A FACTOR THAT CANNOT BE IGNORED: SOMETIMES AN APPARENTLY WELL-PLACED BULLET WILL JUST MISS EVERY IMPORTANT STRUCTURE YOU THINK IT SHOULD HIT.** Just below the heart, for example, it is possible for a bullet to pass between the

aorta and the vena cava without hitting either of these large blood vessels. Several well-placed hits is the only way to get around the luck problem.

When you are in a gunfight and know that you have just put two or three bullets into the center of the chest of the bad guy what should you expect? Any expectation other than that he will keep shooting back at you can get you killed. Hope for the best, but plan for the worst.

These are the major points for the police administrator to use as a guide to selecting appropriate bullets and for the policeman on the street to use as a guide to his survival. Good bullet placement is critical, but must be coupled with bullets that can be relied upon to reach and disrupt vital structures.

"Immediate incapacitation is a common and dangerous misconception."

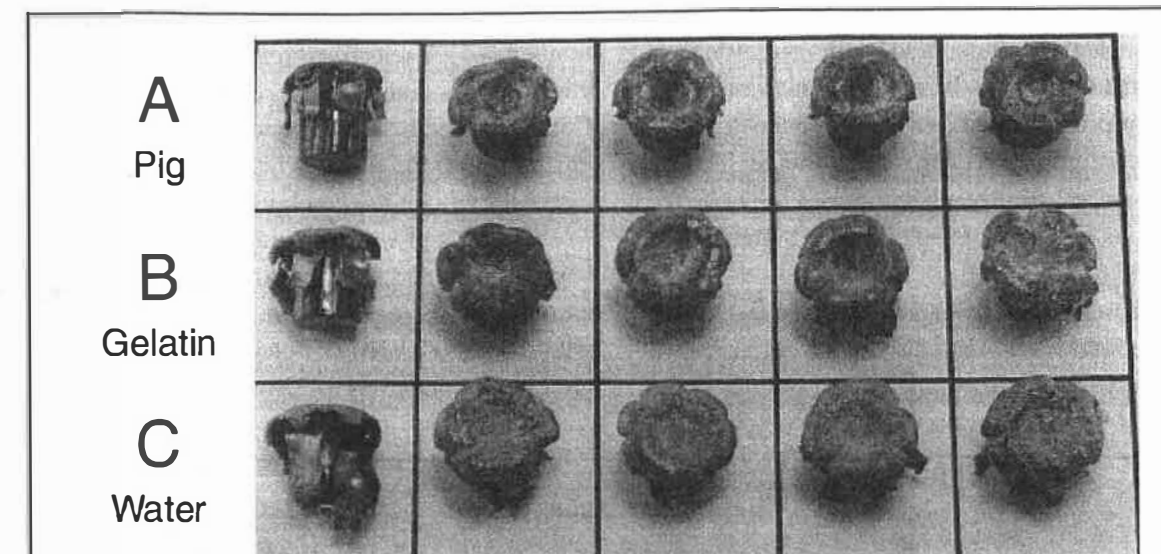


Figure Two -- The bullets in group A were recovered from shots into the abdomens of anesthetized pigs. Group B were recovered from 10% ordnance gelatin. Group C were recovered from shots into water. Note the knife-like leaves of folded-back copper jacket. The wound profile of this bullet is similar to the top one shown in Figure One except that it penetrates an inch or two more deeply than the one shown on that profile.

POTPOURRI OF FALLACIES

THE RII -- This whole fiasco could have been prevented: if only someone (highly placed enough to make a difference) had taken the time to apply a little common sense and think through the seriously flawed RII theories. These hold that the temporary cavity size determines the incapacitation produced in the human by a handgun bullet. The NIJ adopted this theory from the Ballistics Research Laboratory of Aberdeen Proving Grounds which used it as a basic precept in determining "lethality" of all penetrating projectiles (unfortunately, it is apparently still being used). Most parts of the human body are quite elastic: they can stretch and expand to absorb most handgun produced temporary cavities while suffering little or no damage. To accurately determine penetrating projectile effects on the human body one must understand the human body: a trauma surgeon or forensic pathologist (who has experience with and interest in gunshot wounds) must be closely involved in any such effort to avoid such blunders as the RII.

THE "DEFINITIVE FALLACY" OF "HANDGUN STOPPING POWER"

I have had several calls from law enforcement officers who are concerned that some of their less perceptive colleagues might endanger their lives by believing material presented in a recent book that claims to be "the definitive study" of handgun stopping power. This book's authors claim to have collected information on thousands of shootings; and that this "data base" shows just about everything I have written in this article to be wrong -- that the RII was right -- that there is "magic" in temporary cavitation -- that there are "magic bullets" that cause immediate incapacitation up to 97% of the time **from a shot anywhere in the torso**. Even if the data had been collected as claimed, it would be meaningless for the following reasons:

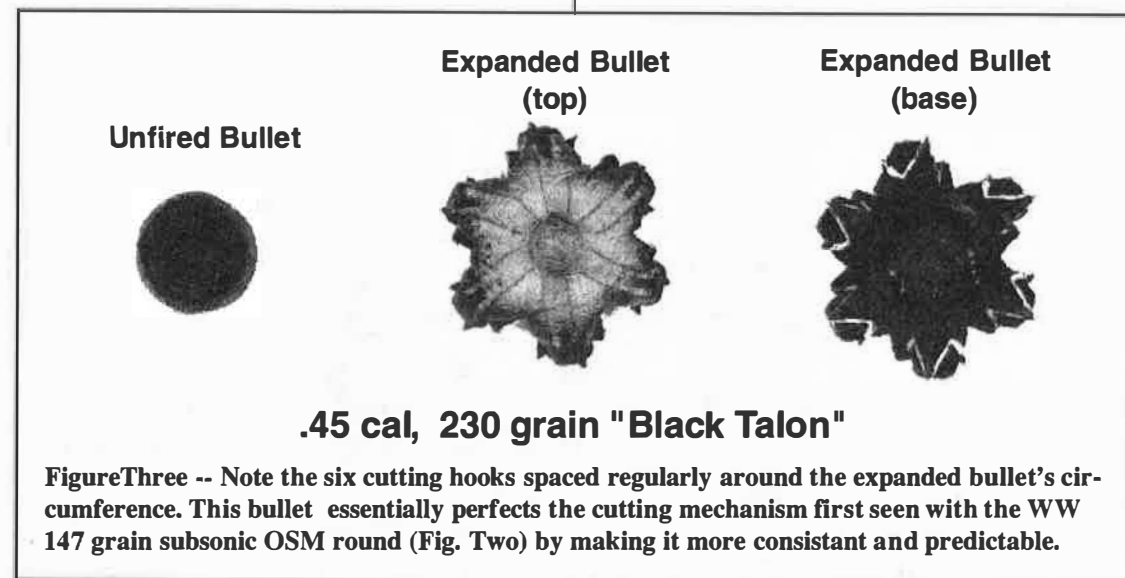
No well-trained officer is going to shoot once and then stand there and wait to see if his adversary is going to stop shooting back at him. Instead, the intelligent officer will put several shots in the **center**

of the torso of his adversary. As soon as the second shot hits, the incident is not counted in this purported "one-shot stop data base." To be rational, any multiple hit incident should be counted as a failure in the "one-shot stop" calculations rather than being ignored. This purported "data base" thus disregards most of the shooting incidents from which we can learn something (like the FBI shootout).

It ignores the most basic of scientific investigative procedures -- the search for the reason a shot or shots didn't have the expected effect (analysis of failures is

The "catch-as-catch-can" method of data collection allows for selective omissions, by which an unscrupulous author can "prove" anything he wishes. Couple this with two authors whose bias can be demonstrated at trade shows where they can be found representing commercial bullet companies.

The lack of scatter in the "one-shot-stop data base" casts the most serious doubt on its veracity. The extreme regularity of their numbers contradicts the whole body of Forensic Science in which the large variation in reactions following gunshot wounds has



basic to everything from airplane accidents to washing machine stoppages). Unless we search for and analyze reasons we don't learn from experiences.

Many, who might be fully capable of continuing their aggression, stop for a variety of reasons after being hit: the assumption that these people were **unable** to continue is a crucial error.

As mentioned above, immediate cessation of aggressive acts should not be expected from any shot in the torso: the officer who does expect it puts his life in jeopardy. Only the person who stops for psychological reasons is likely to stop immediately -- and this is extremely variable, erratic, and unpredictable: to use "one-shot-stops" as a basis for estimating bullet effectiveness is absurd.

been repeatedly described by reliable scientists. The final proof that puts this "data base" in the realm of voodoo rather than science is the authors' hiding behind the claim of "secrecy" when asked to identify their sources so they could be verified. The nonsense in this book appeals to what many want to believe, (and what many bullet makers want them to believe): that some bullets have such miraculous powers that a single hit **anywhere in the torso** will cause immediate cessation of the threat. Believing this could get a lot of law enforcement officers killed. Few sensible people would buy a car relying only on what the salesman told them. Should they be less sensible when buying bullets upon which their lives might depend?

"KNOCK DOWN POWER"

A hit from a bullet does not knock the human body down, or even drive it significantly backwards. However, we have all seen so many misleading depictions of shootings in the entertainment media that undoubtedly some of it has rubbed off to influence what we envision. When the officer's life is on the line, the more realistic his expectations the better will be his survival chances: you don't need unnecessary surprises when bullets are flying your way. The physics of the bullet's "push" (or lack of push) can be demonstrated easily. Take a sack and fill it with 160 pounds of sand; tie the neck with a rope and suspend it so it can swing freely. Now shoot the sack with a bullet and note the swing imparted (or more accurately, the lack of swing imparted). There is other unequivocal evidence: the author of the video documentary, **"Deadly Effects: Wound Ballistics"**¹ allowed himself to be shot with a full-power 147 grain, 7.62 NATO (.308 Winchester) rifle bullet, while wearing tactical body armor. He is not knocked backwards perceptibly; he repeats it while balancing on one foot with similar results. This is shown on the videotape.

I understand that one self-proclaimed expert advocates shots into the pelvic bones of the lower torso as a means of causing an adversary to fall over. First, a hit in the majority of this large bony complex will merely punch a hole in the bone and do nothing to its structural support: so this idea is based on fallacy. A hit that fractures the mid-shaft of the thigh bone is far more likely to put a person on the ground. However, this does not guarantee that he is incapacitated, he might even shoot more accurately from the prone position.

CONCLUSION

The police administrator has a serious responsibility in choosing the bullets upon which his officers' lives depend. If only his own life was at stake he would be free to base this choice on anything he wished -- advertisements, voodoo, or scientific fact. But when this choice affects the lives of others he is obligated to use only verified and valid data. If he should need additional expert advice it is close at

hand: he need only call on the firearms examiner in his criminalistics lab. It is the firearms examiner's job to know bullets. Many firearm examiners have a background in the exact sciences and this makes him the police administrator's best advisor on difficult bullet choice decisions. The administrator should also have the firearms examiner test any bullets that are furnished as a duty round.

Many crime labs are already set up to test bullets in 10% ordnance gelatin, but even if they are not they all have a water tank and shooting into water is a good screening test to insure that the bullets you bought expand as they should (see Fig. Two). A return to the old fashioned "show me" attitude -- some call it skepticism -- some call it common sense -- others know it as scientific method -- is the key to making the correct bullet choice decisions needed to protect police lives.

REFERENCES

1. Jason, A., "Deadly Effects: Wound Ballistics," 1987; video documentary, ANITE Productions, Pinole, CA

Special thanks to the publishers of *Law & Order* magazine for allowing the reprinting of this article.

"One-shot-stops as a basis for estimating bullet effectiveness is absurd."

THE EFFECT OF BULLET NOSE SHAPE ON EXPANSION

Gus Cotey, Jr.

An experiment demonstrates that bullet expansion or deformation is affected by the shape of the projectile point.

At impact velocities of approximately 1200 f/s (the round nosed soft lead alloy bullet of the 22 Long Rifle cartridge does not normally expand in soft tissue or in calibrated soft tissue simulant. The Thompson/Center 54 caliber cast, lead Maxi-Ball muzzle loading rifle projectile normally exhibits no more than only slight expansion at these velocities. By cutting back the rounded tip of the 22 Long Rifle bullet to form a noticeable meplat (frontal flat surface) and increasing the meplat diameter of the Maxi-Ball by either cutting back the nose or by simply loading it base forward, it is possible to cause these minimally expansion-prone bullets to expand significantly in a calibrated soft tissue testing medium.

PROCEDURE

TEST MEDIUM

The terminal ballistic test medium used in these experiments was water-filled 2-quart milk and juice cartons with their spout openings manually pinched shut, but not sealed. The cartons were arranged in a single-file row of up to 18 with all cartons in the row firmly touching each other. Each carton in the row was numbered with a wax marker, with the carton closest to the shooter being #1. For each test shot the carton row was shot lengthwise and the number of the carton

containing the fired bullet was recorded. After each shot, all damaged cartons were replaced. Note that in the United States, the thickness of the polyethylene-treated bleached sulphite cardboard used to manufacture 2-quart cartons is standardized which insures consistent results regardless of carton make or original product contained therein.

Previous experiments performed by this writer have demonstrated that bullets impacting water-filled 2-quart cartons deform and/or fragment in a similar manner as impacts with Type 250 A ordnance gelatin at 4°C (39.2°F) which has been calibrated to live swine muscle tissue.

One of the disadvantages of using water-filled 2-quart cartons as test media is that their narrow profile sometimes allows a bullet to escape from the carton row before it comes to rest. During the middle of the test shooting for this article, it was discovered that covering the carton row with a 2-ply furniture moving blanket can be quite useful in catching test bullets that would otherwise be lost as they exit from a carton's sidewall or back edge.

VELOCITY MEASUREMENT

An Oehler Model 33 chronograph was used to measure the velocities of the test shots with all readings expressed in feet per second (f/s). Sky screen spacing was 4 feet and the distance from the second skyscreen to carton #1 was approximately 12 inches. The range from the test weapon muzzle to carton #1 was approximately 10 feet. In cases where the chronograph failed to record the velocity for a given shot, the

number recorded was the average for 10 shots with the particular load used with this number being preceded by the symbol .

EXPANSION MEASUREMENT

The expanded diameter (ED) of each recovered test bullet exhibiting expansion was determined by taking the average of 3 roughly equally spaced diameter readings taken with a digital caliper and expressed in inches to the nearest 3rd decimal place. Recovered length (RL) was also measured with a digital caliper.

22 LONG RIFLE TESTS

All test shots in this test series, except for one, were fired from a Browning T-Bolt (T-2) straight-pull bolt action rifle with a 24-inch barrel. The one exception was fired from a Beretta Model 70S semiautomatic pistol with a 3.5-inch barrel .

The 22 Long Rifle High Velocity ammunition tested was Winchester "Super-X" and Federal "Lightning." Both ammunition types featured a soft lead alloy round nosed bullet with a nominal weight of 40 grains. The bullets of the Winchester ammunition were plated with a copper alloy, while those of the Federal cartridges were not plated.

There were 2 test shots fired for each brand of ammunition with the bullet noses left in their original state. Velocities ran from 1235 f/s to 1323 f/s. In no instance did any of these bullets expand. The only deformation evident was a slight blunting of the bullets' noses and an inward bending on one side of the relatively fragile circumferential perimeter of their concave bases. The distortion to the bullets' bases was most likely caused by impact with carton walls as these projectiles yawed to 180 degrees.








The 2 test shots from the Federal cartridges were recovered from carton #7, while both the Winchester test shots exited from the far left edge of carton #6 and were stopped by the furniture moving blanket surrounding the carton row. Considering the severe dents these bullets made as they grazed the near left edge of carton #7, they would have probably managed to enter the 7th carton if they were more centered.

Next, test shots were fired with samples of both the Winchester and Federal cartridges that had their bullet noses filed flat with a Nicholson flat smooth 4-inch file and with a Hanned Precision (P.O. Box 2888-R, Sacramento, CA 95812) SGB (Small Game Bullet) trim die used as a guide. The SGB tool is a

hollow steel cylinder with an inside diameter just large enough to permit a 22 Long Rifle round to freely drop in until the forward ledge of the case rim stops its forward motion and hardened to withstand file abrasion as the protruding bullet tip is filed flush. The SGB trim die used in these tests measured .8995 inches in length and the meplats

filed onto the bullets of the test cartridges were approximately .145 inches in diameter. Bullet weight loss from the filing process was approximately 1 grain.

For each make of ammunition 3 test shots were fired from the 24-inch barreled rifle. The recorded velocities for the Winchester cartridges from highest to lowest were 1257, 1233, and 1192 f/s. Expanded diameters (ED) were .329, .322, and .276 inches respectively, while their recovered lengths were (RL) were .306, .318, and .366 respectively. Recorded velocities for the Federal loads were 1320, 1265, and 1260 f/s. Respective ED's were .345, .312, and .299 inches and respective RL's were .300, .317, and .326 inches. With the exception of the Winchester 1192 f/s, .276 inch ED test shot, which was recovered from car-

			FEDERAL "LIGHTNING" 22 LR, 40 gr, lead round nose	
UNMODIFIED ROUND	1323 FPS ED NO EXP RL .418	1261 FPS ED NO EXP RL .430		
				Modified by filing tip of bullet nose
MODIFIED ROUND	1320 FPS ED .345 RL .300	1265 FPS ED .312 RL .317	1260 FPS ED .299 RL .326	

ton #5, all test shots with the Hanned SGB tool-modified rounds fired from the 24-inch barreled rifle were recovered from carton #4.

One Hanned SGB tool-modified Winchester Super-X round was fired from a 3.5-inch barreled Beretta Model 70S. Recorded velocity was 897 f/s and the bullet, which did not expand, was recovered from carton #8. The probable reason that penetration for this shot was greater than for the non-expanding unmodified bullets traveling at an average of more than 370 f/s faster was the fact that flat nosed bullets generally exhibit less of a tendency to yaw than round nosed bullets. Naturally, to properly assess the penetration characteristics of any

load would require more than just 1 test shot.

54 CALIBER MAXI-BALL TESTS

The test weapon used in this series was a Thompson/Center 54 caliber Hawken percussion lock muzzle loading rifle with a 28-inch barrel rifled for conical projectiles. The propellant used was Goex FFg black powder. Propellant charges were measured volumetrically using a Thompson/Center adjustable black powder measure with charge weights varying from approximately 110 grains down to approximately 20 grains. Powder charges were ignited by CCI #11 percussion caps. Maxi-Ball projectiles were cast from pure lead with a Thompson/Center 54 caliber single-cavity Maxi-Ball mold and had an average as-cast weight of 406 grains. Average front band diameter measured .545 inches and average base diameter measured .538 inches. Prior to firing, all Maxi-Balls had their lubrication grooves filled with Crisco (partially hydrogenated vegetable shortening).




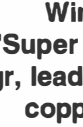
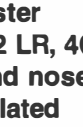
The first part of these tests was conducted with

the unmodified Maxi-Ball fired with a charge measured at 110 grains on the powder measure. Average velocity for this load from the test weapon is 1350 f/s. Initially, the only available board available to rest the carton row upon was only long enough to hold 13 cartons. The first shot at 1361 f/s completely penetrated a row of 12 cartons and was lost, while the second shot at 1331 f/s did likewise to a row of 13 cartons. The deep penetration of these 2 shots, coupled with the similar to pre-fired projectile diameter bullet holes in the carton walls indicated limited expansion at best. After obtaining a suitably long board, a row of 18 cartons was shot and the projectile was recovered from








carton #15. ED was only .620, limited primarily to the front band, and RL was .714. The chronograph failed to record the velocity for this shot so it is listed as 1350. Note that these tests with the unmodified Maxi-Ball were conducted prior to discovering the benefits of covering the carton row with the blanket

These experimen-

tal results indicating limited expansion are consistent with actual field results obtained from killing a 95-pound (field dressed weight) male whitetail deer at a distance of about 100 feet with the test weapon loaded with a Maxi-Ball and 110 grains of FFg. The shot struck the right side of the animal roughly midway between the first and last rib, just below the spine, and exited 1 rib spacing forward. A rib was broken by the bullet during entrance and exit. Total penetration was approximately 8 inches with the round well-defined entrance hole being only slightly smaller than the round well-defined (except for 2 attached skin projections spaced 180° apart) exit hole. The entrance hole in the tanned hide of this animal has a diameter of .68 inches and that of the exit hole measures .72 inches.

Winchester "Super X" 22 LR, 40 gr, lead round nose, copper plated				
UNMODIFIED ROUNDS		Modified by filling tip of bullet nose		
				
1256 FPS ED NO EXP RL .438	1233 FPS ED NO EXP RL .445	1233 FPS ED .322 RL .318	1192 FPS ED .276 RL .358	897 FPS ED NO EXP RL .404
MODIFIED ROUNDS				

.54 CALIBER MAXI-BALL WITH .30 INCH MEPLAT










	Unfired; 394 gr/L=.80
	1134 f/s ED .631 RL .473
	1231 f/s ED .811 RL .473
	1260 f/s ED .717 RL .582
	1299 f/s ED .902 RL .426
	1332 f/s ED .888 RL .424
	1388 f/s ED .924 RL .407

L = LENGTH IN INCHES.

ED = EXPANDED DIAMETER (INCHES)

RL = RECOVERED LENGTH (INCHES)

.54 CALIBER MAXI-BALL FIRED BACKWARDS

	Unfired; 406 gr/L=.895
	611 f/s ED .607 RL .828
	718 f/s ED .644 RL .806
	868 f/s ED .712 RL .753
	921 f/s ED .739 RL .741
	1042 f/s ED .776 RL .686
	1074 f/s ED .796 RL .683
	1228 f/s ED .830 RL .616
	1381 f/s ED .863 RL .569

Book Review

Textbook of Military Medicine, Conventional Warfare, Ballistic, Blast and Burn Injuries.

PART 1, VOLUME 5 ZAJTCHUK, R. (ED).
WASHINGTON, GPO, 1990.

The first of the four part *Textbook of Military Medicine* (TMM) series is entitled "Warfare, Weaponry and the Casualty." This part consists of six volumes. The first five chapters (220 pages) of the fifth volume deal with weaponry and ballistics. These chapters are reviewed below.

Unfortunately, the weaponry and ballistics chapters are filled with inconsistencies, contradictions, and factual errors. The writers of these chapters have a talent for obscuring the obvious with complexity and bulk. Only the most dedicated (or masochistic) reader will wade through the bloated, indecisive and ambiguous pseudoscientific prose. Apparently anything in print is assumed to be true: unsupported theory is repeatedly presented as fact. Only the person already expert in wound ballistics will be able to sort out the reliable from the fallacious. In addition to uninformed speculation and misplaced emphasis, there are over 75 major factual errors in the 200 pages.

The material included in these chapters lacks any sign of thoughtful evaluation and selection by someone expert in wound ballistics: it is more akin to a computer literature search.

PRIMARY CLOSURE FOR WAR WOUNDS IS RECOMMENDED

• Pages 205-209 is an extensive description, by E.H Pool, of the surgical method he used in World War I. The authors write, "From the broadest concepts to seemingly minor details, his [Pool's] treatise on soft-tissue management, excerpts of which follow, remains as valid today as when it was published in 1927." In Pool's description we find:

• Page 205 "...closure of the wound may be carried out by immediate or primary suture..."

• Page 209 under his heading "Primary suture," we find, "If ideal conditions, that is, early and thorough debridement, have been approximated and the [casualties] can be watched for some days, primary suture may be made."

There is no greater lesson from previous wars than to leave wounds open. In the beginnings of every war we have had surgeons who think they can close war wounds primarily -- always they have been wrong and the casualties have suffered as a result.

RECOMMENDATIONS CONCERNING SURGICAL WOUND TREATMENT ARE CONTRADICTORY AND CONFUSING

• Figures 5-30 to 5-32 shows surgical excision of a typical through and through wound, with punctate entrance and exit and minimal tissue disruption. The algorithm in figure 5-27, coupled with figures 5-17,19,20, and 21, recommends "nonoperative treatment" for this type of wound.

By increasing the meplat diameter of the 54 caliber Maxi-Ball from the original of about .150 inches to .30 inches by cutting its nose back by .095 inches on a lathe, it was found that expansion characteristics significantly improved. A test shot at 1388 f/s yielded an ED of .924 inches and RL of .406 inches. At 1332 and 1299 f/s, the ED's ran .888 and .902 inches and RL's were .424 and .426. The average expansion for these 3 shots was .905 inches or 1.66 times the original bullet's major diameter. This increase in expansion led to a decrease in penetration, with the test shots at 1388 and 1299 f/s only making their way to the interior of carton #7 (penetration for the 1332 f/s shot was not recorded).

Curiously, the test shot at 1260 f/s had an ED of only .717 inches while the 1231 f/s shot's ED was .818 inches. The fact that the faster bullet expanded less may be due to possible damage to its meplat by the ramrod during the seating process. Unfortunately, neither time constraints nor carton supply permitted testing this hypothesis with additional test shots. Whatever the cause, the front of the recovered 1260 f/s test bullet expanded eccentrically relative to the base.

At 1134 f/s, expansion for the .30-inch meplat modified Maxi-Ball was only .631 inches. This shot completely penetrated a row of 12 cartons and was recovered by the moving blanket. Note that in this case and that of the aforementioned minimally-expanding 1260 test shot, the area that was formally the meplat became concave after impact.

Experimentation with the 54 caliber Maxi-Ball to investigate the effects of further increasing the meplat diameter was accomplished by the simple expedient of loading the unmodified projectile backwards prior to firing. At 1381 f/s ED was .863 inches, RL was .569 inches, and the recovery carton was #9. The smaller ED of the reversed Maxi-Ball at 1381 f/s relative to the test shot with the .30-inch meplat modified projectile at 1388 f/s was due to the fact that the reversed bullet underwent a pronounced rearward flowing of the mushroom head, leading to a final pronounced dome-shaped profile. This condition, which I refer to as "jellyfishing", is usually a sure sign that a bullet has been driven above the optimum velocity for its design.

The reversed Maxi-Ball exhibited considerable

expansion at impact velocities well below 1000 f/s with the ED's for 921 f/s and 868 f/s running .739 inches and .768 inches respectively. Even at 718 f/s and 611 f/s there was slight expansion, with corresponding ED's measuring .644 inches and .607 inches.

CONCLUSION

Bullet nose shape can be a most significant variable in determining the degree of expansion that a bullet will undergo at a given impact velocity upon striking soft tissue or a valid test medium thereof. The results gathered from these simple experiments seem to indicate that for a bullet of a given caliber and composition, the less aerodynamic the nose profile, the lower the expected expansion threshold velocity will be. This really isn't surprising when one considers that the less streamlined a body's impact profile is when impacting with a given medium at a given speed, the greater the stresses acting against this body will be. Anyone who has ever made a belly-flop dive into a swimming pool should understand this principle rather well.

Knowledge of the fact that normally minimally or non-expanding soft homogeneous low velocity bullets can be made to expand by simple nose profile modification should be of great practical usefulness to designers of small arms ammunition, especially in regard to the design of handgun ammunition. It could also prove useful to forensic pathologists and police firearms examiners in cases where modified ammunition has been used in a crime.

REFERENCE

Cotey G A poor man's ballistics lab. *Rifle* March-April 1990, No. 128 ; pp. 18-21 & 43 (Wolfe Publishing Co., Prescott, AZ)

• On page 93 -- The authors introduce the "four Cs" as they write, "These criteria, which date back to at least World War I, have become known as the four Cs:

color - the tissue is darkish
consistency - the tissue is mushy
contractility - the tissue fails to contract
circulation - the tissue fails to bleed."

How is the young, inexperienced, surgeon to apply the material presented? In treating a wound, is he to cut out all muscle that meets **only one** of the "four Cs"? or must it meet two? Or three? Or perhaps **all four**? The authors of these chapters do not say.

BASIC MISCONCEPTIONS

• Page 117 -- We find, "Bullets have poor stability in tissue." Actually, some bullets, such as the wadcutter (a truncated cylinder shape), are totally stable in tissue, as are some round nosed bullets. Many round nosed bullets, and even a few pointed ones (such as the AK-47) are stable through most soft tissue paths in the human body.

• Page 111 -- 250 f/s is claimed to be the minimum velocity for a **round or pointed** projectile to penetrate human skin. -- DiMaio et al (J Forens Sci Oct 1982) reported, in amputated human extremities, a 38 Special 158 grain lead round nosed bullet penetrated at 166 f/s, another at 191 f/s penetrated 40 mm of muscle after perforating the skin. It takes little insight to recognize that round nosed and pointed projectiles cannot share the same threshold velocity for skin penetration. Also, the thickness of the skin varies greatly at different anatomic locations -- skin of the back is considerably thicker than skin of the anterior torso: no single threshold velocity can be universally valid for all projectile shapes hitting all areas of the body.

• Page 109 -- The Table 4-1 lists the projectile fired by the AK-47 assault rifle as having "poor stability." Dozens of studies agree that this bullet is extremely stable compared to other military rifle bullets -- it has, in fact, more stability in tissue than any military rifle bullet since the first generation of jacketed bullets (30-40 Krag, 6.5 Mannlicher-Carcano, etc.) that were in use at the turn of the century.

• Page 111 -- The authors add an unnecessary and confusing level of abstraction in defining velocity ranges:

"This book is filled with inconsistencies, contradictions, and outright factual errors."

This textbook arbitrarily defines *low velocity* as slower than the speed of sound in air (that is, 334 m/s or 1,100 fps) and *ultrahigh velocity* as the speed of sound in soft tissue (that is, 1,500 m/s or 4,900 fps)....Since the first observations of "explosive" wounds occurred when "high velocity" bullets were fielded in the mid-nineteenth century...this

textbook defines *high velocity* as that at which explosive effects begin to be commonly seen (that is, 600-700 m/s, or 2,000--2,300 fps). Velocities between 1,100 fps and 2,000 fps are known as *intermediate* or *medium*."

To correct the history, the velocities of the heavy (40 to 45 caliber, weighing 300 to 500 grains) cylindro-conoid bullets of the mid-nineteenth century were in the 1100 -- 1400 ft/s range -- far below the book's "high" level. Some of these large, soft lead, bullets, however, despite their "low" to "medium" velocities, did deform on impact and caused temporary cavities ("explosive" effects) as large the fastest modern military rifle bullets.

Why deprive wound ballistics of the scientific precision it might obtain simply by using numbers and numerical ranges in lieu of ambiguous adjectives ("high," "intermediate," "ultrahigh" etc. -- with every author giving his own definitions) to describe projectile velocity?

• Page 152 -- "...projectiles must travel at velocities greater than 200 fps to penetrate bone." This book's repetition of this fallacy illustrates the problems that plague the field of wound ballistics. The fallacy originated in the work of Harvey (Beyer, *Wound Ballistics*, GPO, 1962, page 230):

"...the end of a beef femur was cut and spherical missiles shot into the spongy bone..." [Presumably the first 1/8 inch steel sphere that stuck in the bone marrow, rather than bouncing off, was traveling 200 f/s.]

Once in print, this 200 f/s has been repeated, unqualified, ad infinitum and applied to all parts of all bones struck by any projectile.

• Page 152 -- "...penetration of skin dissipates another 150 fps..." Actually, French and Callender wrote "Even extremely large missiles will lose about 125 f.p.s., of their impact velocity in penetrating the surface of the skin." They cite no source for this data, but we find in the work of Harvey (source for much of what French and Callender reported without citation, on page 229 of Beyer, *Wound Ballistics*, GPO, 1962) a study in which "...several layers of skin..." were perforated by a 3/16 inch steel sphere traveling at 3,030 f/s, and a velocity loss of 225 f/s was reported. No information was given on how many layers were meant by "several," what animal species donated the skin, or from what anatomic part of that animal it came.

Again, once in print, such flawed data is destined to be repeated and universalized to apply to every conceivable situation of any skin penetration by any conceivable projectile. **Reliance on such dubious data has the potential for doing real harm, for instance, if inadvertently applied to the field of forensic wound ballistics.**

• Page 188 -- "...this textbook uses debridement to describe the surgical management of penetrating soft-tissue combat wounds." Thus, everything from incision and drainage to amputation is described with this one word, debridement. This is the antithesis of precision and clarity of meaning: and guaranteed to confuse, rather than enlighten. Because of debridement's unfortunate past -- having its perfectly clear French meaning muddled and confused into a hodgepodge of spurious meanings in English -- it should be dropped from the vocabulary of every thinking surgeon in favor of more precise and meaningful terms such as "incision" and "excision."

Since the writings on wound ballistics form a veritable mine-field of misinformation, those who lack sufficient expertise invariably repeat the errors of others. Unfortunately, the many expensive (printed at taxpayer expense) and impressive looking color plates and the fact that the book was published -- under the auspices

of the Surgeon General of the Army -- by the Government Printing Office gives it an undeserved aura of credibility. These book chapters are an embarrassment to the Army Medical Corps and reflect most adversely on the Center for Excellence at the Walter Reed Army Medical Center where the book originated.

Instead of providing young medical officers with a basic understanding of ballistic injuries, this book will end up thoroughly confusing and misleading them: it constitutes a threat to the care of the wounded in any future conflict.

Martin L. Fackler, MD
Editor-in-Chief

"(This book) constitutes a threat to the care of the wounded in any future conflict."

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- The primary consideration in our decision to invite individuals to become Full Members is that they have a solid understanding of elementary wound ballistics. Full Members must also be (or have been) actively engaged in wound ballistics research and have made contributions to the body of knowledge. Technical Consultants are chosen for their expertise in related areas which will be of value to our Association.
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