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— Nelson E. Welch
— Dean B. Dahlstrom
— Kramer D. Powley

Wound Ballistics Misconceptions

— Duncan MacPherson
INFORMATION FOR 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 be given to authors of rejected papers and will be made available upon request to anyone.

Articles are accepted only for exclusive publication in IWBA, and when published, the articles and illustrations become the property of IWBA.

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).

In submitting original work, the manuscript and one copy are required; one set of high quality illustrations is required; black and white is preferred. Author's name must be clearly identified on the title page with addresses 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 or Microsoft Word are preferred. (Please convert files to WordPerfect 5.1 or 6.0, or to Word for Windows 3.0--6.0.) PLEASE DO NOT PROVIDE COMPUTER TEXT WITH SPECIAL FONTS OR LAYOUTS. PLAIN, SIMPLE TEXT WITHOUT INDENTS, TABS, LINES OR GRAPHERICS. Any graphs, tables, charts, etc. should be supplied as separate files and/or with a clean, high quality paper copy. Legends for all illustrations should be listed in order, double-spaced. An abstract of the article. Page numbers must be given in books, cited as references.

REFERENCES are to be numbered sequentially within the text and appear in the order cited at the conclusion of the article. Page numbers must be given in books, cited as references.

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The International Wound Ballistics Association (IWBA) is an IRS 501(c)(3) non-profit scientific, educational, and public benefit California corporation with federal ID#94-3136817.
The IWBA is devoted to the medical and scientific study of wound ballistics, including evaluation of literature in the field as well as encouraging and promoting new work.
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Volume 2, Number 3

WOUND BALLISTICS REVIEW
JOURNAL OF THE INTERNATIONAL WOUND BALLISTICS ASSOCIATION

EDITORIAL

Martin L. Fackler, MD

BULLET PENETRATION TESTING
In this issue we are proud to include the article describing the bullet testing program set up by Firearms Examiners Dahlstrom and Powley of the Royal Canadian Mounted Police (RCMP) Forensic Laboratory. The IWBA is justly proud of this test program, having helped with its inception, at the IWBA meeting at Sacramento in 1994. Kramer Powley attended and learned from the gelatin testing that was done. This article includes the complete text of their report, the data summary, and the photographs of recovered bullets from the various tests. The original report has 170 data sheets, of necessity, we have included only illustrative examples of these. Their complete report (about 120 pages) includes all their data sheets and photographs; the interested reader can obtain a complete copy of this research report (TR-01-95), at no cost, by simply telephoning (613) 998-6343 and asking for it.

Dean Dahlstrom gave a presentation on the RCMP bullet testing program at the recent 1995 Association of Firearm and Toolmark Examiners (AFTE) Training Seminar in San Diego. He mentioned a problem that is not included in their report but might prove useful to anybody who anticipates putting animal parts in gelatin for testing. The first time they put pig ribs in their gelatin, it did not harden and had to be thrown out. They then trimmed off the excess flesh and fat from the ribs (they did not remove the muscles between the ribs) and blotted them dry of tissue fluid before placing them in the gelatin. This time the gelatin hardened well. I have no idea why tissue fluid from these ribs would have this effect, but it did. I hope that printing this might save future wound ballistics researchers some time and effort. Also, we would welcome a letter from any reader who might be able to shed some light on the reason for the gelatin’s failure to harden.

The shots reported by Dahlstrom and Powley through the pig rib cage imbedded just inside the surface of the gelatin are unique. Their results have finally documented in the literature what has been the strong impression of researchers, including myself and colleagues, and experienced forensic pathologists who have considered the question — that striking a rib generally affects the penetration and the wounding potential of handgun bullets an insignificant amount. A small correction needs to be made: Dahlstrom and Powley were misled by a faulty transcription of the comments I made at the FBI Wound Ballistics Seminar of January 1993. Their paper states “The wound profile method has been validated by Dr. Davis’ colleagues at the Miami-Dade Medical Examiners office who conducted ballistic testing of swine and gelatin and compared findings to that of gunshot victims at autopsy.” Actually, the ballistic testing on anesthetized swine and in gelatin was done at the Wound Ballistics Laboratory of the Letterman Army Institute of Research. A significant portion, however, of the validation of the Wound Profile by comparison with findings in human gunshot wounds at autopsy was done in collaboration with Dr. Davis and his colleagues at the Metro-Dade Medical Examiners Office, and two of these cases were reported in "The Wound Profile & The Human Body: Damage Pattern Correlations" (Wound Ballistics Review 1(6):12-19, 1994.
In addition to the reporting of the calibration BB velocity and penetration data, as needed for scientific validity, Dahlstrom and Powley are to be congratulated for refraining from redundancy in their testing and for reporting their results clearly and simply. Good work!

GELATIN
We would also like to congratulate the US Fish and Wildlife Service Forensic Laboratory at Ashland, Oregon: they have become the newest member of the wound ballistics community using ordnance gelatin as a research tool. Speaking of gelatin, several IWBA members have reported to us difficulty in ordering or obtaining gelatin powder directly from Kind & Knox. We are happy to recommend Mr. George Kass (who obtains the gelatin for the RCMP Forensic Laboratory) as a reliable source for ordnance gelatin. His address and phone number are:
Mr. George Kass
Forensic Ammunition
4512 Nakoma Drive
Okemos, Michigan 48864
Phone: (517) 349-9362

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MEMBER QUESTIONS & COMMENTS

One of the purposes of the IWBA is to provide information to the members. Questions sent in by members that are of general interest will be answered in the Wound Ballistics Review in a format like this. Members are encouraged to submit any questions that they may have or any comments they wish to make to the IWBA office address.

QUESTION: What effect and to what extent does the trailing angle off the bullet’s meplat contribute to tissue displacement? What is the relative contribution of various impact velocities to any differences in the volume of tissue displacement in conjunction with the influence of the meplat’s crossectional area?

George Bredsten

ANSWER: Meplat is a French word and in ballistics refers to the flat area on a bullet’s nose, it is often used for tip of a semi-wadcutter bullet, but in principle could refer to the total nose area of a full wadcutter. This question really has meaning only for bullets that do not deform or overturn in soft tissue, and so is not related to modern rifle bullets or to JHP handgung bullets. Soft tissue displacement due to bullet passage depends somewhat on the soft tissue being penetrated, but the question obviously refers to effects in the absence of variation in tissue properties and this is assumed in the answer.

The tissue displacement depends on the lateral tissue velocity caused by the bullet passage, which in turn depends on the impact velocity on the tissue (which is the same as the force the tissue exerts on the bullet). This force is modeled in the literature of Bullet Penetration - Modeling the Dynamics and the Incapacitation Resulting from Wound Trauma, and at velocities above the cavitation velocity (when tissue displacement is largest) is proportional to the cavitation drag coefficient ($C_D$). Values of $C_D$ were determined for a variety of bullet nose profiles, and are summarized in Table 8-3 (page 206). The cylinder (full wadcutter) and expanded LIP bullet shapes are the most effective, with $C_D$ values of 0.83 and 0.68, respectively; a sphere is least efficient ($C_D<0.355$). All of the other bullet configurations have values of $C_D$ between 0.52 and 0.57, indicating very little difference in force (and tissue displacement) for a wide range of non-deforming bullet configurations (illustrated in Figure 8-10). This strongly suggests that small changes in bullet configuration (meplat or otherwise) will have only a secondary effect on the drag force and resulting tissue displacement.

The drag force for any bullet shape (i.e., at a fixed value of $C_D$) is proportional to the square of the bullet velocity. The total volume of the tissue displacement (the volume of the temporary cavity) is approximate proportional to the bullet kinetic energy ($km^2$). The bullet shape and size are parameters in the drag force on the penetrating bullet, but do not have any other significant dynamic effect (including the volume of the temporary cavity). The physical reasons for the proportionality of temporary cavity volume and bullet kinetic energy are described on pages 59-60 of Bullet Penetration and the detailed physics of the penetration are described in Chapter 6.

The total bullet configuration (including any meplat) determines the bullet stability during tissue penetration. A bullet that overturns (as many FBI military rifle bullets do) is much more effective in wounding at rifle velocities, so the most important effect of bullet configuration is often the effect on bullet stability during tissue penetration. Bullet stability during tissue penetration cannot be determined analytically and so must be investigated by testing, but a flat area on the bullet nose generally tends to be stabilizing and so minimizes bullet yaw.

Duncan MacPherson

QUESTION: Is there an IWBA membership directory? It would be useful to call or write other members.

C. Rodney James

ANSWER: The membership office has a membership data base, but this has never been made available to anyone despite occasional requests. The issue here is the privacy of the membership, because making the membership records available would inevitably mean that someone would sell it to one or more unknown parties for commercial or other purposes. Few if any of our members have anything to hide, but we think most prefer not to have this exposure.

Dr. Martin Fackler

QUESTION: The article Matching Bullet - Past, Present, and Future in the Vol. 2, No. 2 issue of the IWBR describes drilling a 0.055" hole in the newer Matching bullets. How deep should this hole be drilled?

Bud Briner

ANSWER: The hole only goes through the copper jacket, the lead is not touched because it does not fill the bullet nose.

Dr. Martin Fackler
QUESTIONS:

One aspect of the Lattimer article that I question, in the sense that I would like an explanation of the dynamics involved, is the statement on p. 29 re the head bullet, that it "hit the hard bone of the back of the skull and broke up." To many lay readers such explanations and tests as those illustrated in the article, raises the question: Why will a bullet that can plow through two feet of hard wood such as elm or oak and retain its integrity to a great extent, breakup and fragment rather badly upon passing through two quarter inch (approximately) pieces of bone? Was this caused by the bullet becoming destabilized? I assume that the fragmentation was in part an artifact of its movement at a very high velocity.

C. Rodney James

ANSWER:
The basic answer to this question is that the bone of the back of the skull is much harder than wood. When a bullet hits another material either the bullet, or the material, or both, are deformed. The allocation of deformation depends on the bullet construction and the material hit; the object that presents the least resistance to deformation undergoes most, but usually not all, of the deformation (this is why a JHP bullet can expand in water). A bullet that hits bone usually deforms to create a larger frontal area than is created by hitting wood (independent of thickness); this is the key to the fragmentation.

As implied in the question, the bullet breakup is not necessarily complete after bone penetration. The contact with the hard bone deforms the bullet to create a large frontal area, which greatly increases the forces on it during penetration of subsequent material. At velocities at or above the 2000 ft/sec range, a deformed bullet often breaks up in a couple of inches of soft tissue penetrated. This is so rapid that it is easy to improperly ascribe all the breakup to bone contact.

Duncan MacPherson

COMMENT:
The excellent and informative article by Lattimer, et al. entitled The Frangible or Plastic Bullet Theory Disproved which appeared in Vol. 2, No. 1, 1995 of the Wound Ballistics Review, contained an error on page 27 regarding the muzzle velocity of the new obsolete 22 Short frangible "gallery" loadings, which was listed as 350 ft per second.

The two principal U.S. manufacturers of these 22 Short frangible bullet loads were Remington and Winchester, which produced such cartridges in 15 grain and 29 grain loadings. Remington and Winchester 15 grain loads had respective nominal velocities of rifle length barrels of 1690 and 1710 ft/sec. Nominal muzzle velocity for both manufacturers' 29 grain frangible loadings was 1045 ft/sec; the same velocity is listed for their 29 grain conventional homogeneous lead alloy 'Standard Velocity' 22 Shorts.

Mr. Gus Cotey, Jr.

RESPONSE: This is a letter of admiration and appreciation to Mr. Cotey, for picking up my error in listing the muzzle velocity of the 22 caliber frangible round as 350 fps, when it should have been 1100 fps.

It is reassuring (and impressive) that our journal is read so carefully by our members. It is a tribute to the quality of our organization.

John K. Lattimer, M.D., Sc.D.

COMMENT: I am writing just to straighten out one thing you wrote about the JHP/Spitzer bullet in the JWBDA 1996 Fall, Vol. 2, No. 2. You stated in the Editorial section that you thought the Secret Service was still using the same bullet type that was responsible for the loss of the FBI Agent in Miami. The Secret Service changed from the 9mm Winchester Silver Tip to the Remington 9mm +P+ about 1 1/2 or 2 years ago. I loved the articles on the JFK assassination and so did the other men I work with.

George E. Morris, U.S. Secret Service

RESPONSE: Thank you for pointing out the recent change in 9mm ammunition by Secret Service. Although the change may have been mentioned more than a year ago, the Secret Service field office I called had just received their first shipment of the Remington ammo. They confirmed that it was a +P+ load — as you mentioned — and also that it was a 115 grain hollow point bullet, which you neglected to mention.

Perhaps my meaning was unclear: by "same bullet type" I was referring to the too-light and too-fast 115 grain 9mm hollow point bullets — proven (in Miami and elsewhere) to be inadequate because they penetrate only eight inches in flesh. The Secret Service changed bullet manufactured, but did not change bullet type. By changing to a faster +P+ bullet they have, in fact, increased the danger to their agents, and those they protect, by providing a bullet that penetrates to an even shallower depth than did its predecessor.

The persons responsible for the choice of bullets at the Secret Service need to ponder the points in Gus Cotey's letter in the Literature Review in this issue and also study Duncan MacPherson's book Bullet Penetration. It is unfortunate that, when it comes to such things a bullet choice, decisions are often left to those who lack qualifications and knowledge on the subject and are thus easily influenced by the firearm mythology and pseudoscience presented in the popular gun press.

Dr. Martin Fackler

WOUND BALLISTICS REVIEW
JOURNAL OF THE INTERNATIONAL WOUND BALLISTICS ASSOCIATION

QUESTIONS:

Some of you may have noticed the tendency for the local K-Mart and bought a .30-30 Marlin with a 4X Weaver scope wouldn't be poorly armed against the ordinary police or Federal swat team. This was confirmed by your revelation that the .22-250 and go for head shots-messy but a sure stopper.

John C. Schaefer

RESPONSE: Thank you for pointing out the recent change in 9mm ammunition by Secret Service. Although the change may have been mentioned more than a year ago, the Secret Service field office I called had just received their first shipment of the Remington ammo. They confirmed that it was a +P+ load — as you mentioned — and also that it was a 115 grain hollow point bullet, which you neglected to mention.

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Dr. Martin Fackler

COMMENT: I read with some amusement the article on the performance of the Federal .308 Winchester load with the 168 grain Sierra Match King bullet as it is clearly a case of what in the computer industry is called RFPN (Read The F. Manual).

The Sierra reloading manual states that this bullet is not intended to expand. The hollow-point design is used for uniformity of manufacturing and not for expansion. The Sierra manual further states that if expansion is desired that the 165 grain hollow-point Game King (which has a big hollow-point) should be used. It looks like either Federal has fallen down on the job of warning people about this particular bullet or those folks who are rolling their own for "official use" never read the manual.

Of course, with the current political climate of being "human" to criminals perhaps expansion is not desired since we all know that those (gasp!) hollow-point bullets are terrible nasty things and are responsible for all of the evil in the world.

But then, for most law enforcement work the .308 is probably overkill. Most of the folks that I have worked with use the 22-250 and go for head shots — messy but a sure stopper.

John C. Schaefer

RESPONSE: No question about the .308 being unnecessary (and counterproductive with most .308 bullet types) for most law enforcement work. The 22-250 will certainly do the job for most police purposes — but so will the .223.

Dr. Martin Fackler

QUESTION:

While the Feds are basically law clerks who occasionally get in a fight, the situation isn't a lot better with a lot of valuable cops — now offered at your local gun shop are bargain police trade-ins, 9mm weapons sold to finance the faddish stampede toward .40 S&W. By proper selection of ammo, these pistols could stay in service another thirty years, but nobody is reading the fine print.

Leon Day

RESPONSE: Leon has stated his views strongly. Some may feel that this position is over stated, but most would agree that there is a lot of merit in most of his points.

Dr. Martin Fackler

COMMENT: I would read with some amusement the article on the performance of the Federal .308 Winchester load with the 168 grain Sierra Match King bullet as it is clearly a case of what in the computer industry is called RFPN (Read The F. Manual).

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John C. Schaefer
COMPARATIVE PERFORMANCE OF 9 mm PARABELLUM, .38 SPECIAL AND .40 SMITH & WESSON AMMUNITION IN BALLISTIC GELATIN

Dean B. Dahlstrom, Kramer D. Powley
Firearms Section, Forensic Laboratory, Royal Canadian Mounted Police, Regina, Saskatchewan, Canada

Executive Summary

Currently the trend in police issue sidearms is the adoption of a high capacity pistol, in Caliber 9 mm Parabellum or .40 Smith and Wesson. The purpose of this paper is to compare terminal ballistic performance of commercially manufactured 9 mm Parabellum and .40 Smith and Wesson ammunition with the current Royal Canadian Mounted Police issue 38 Special 158 grain semi-wadcutter hollow-point (SWCHP) cartridge.

Ammunition supplied by various commercial manufacturers was chronographed and fired into 10% ordnance gelatin blocks under three conditions at distances of three metres and twenty-five or fifty metres, depending upon the barrel length of the firearm utilized as dictated by R.C.M. Police training standards. At each distance, 5 rounds of each type of ammunition were fired into 2.5 cm gelatin, gelatin covered with clothing, and gelatin with pigs' ribs embedded one to two inches under the entrance surface.

The ability of a projectile discharged from a handgun, to incapacitate a human is a subject of crucial importance to law enforcement agencies, since the handgun is usually the law enforcement agent's primary weapon of defense. Based on previous research, it is generally accepted that at handgun velocities temporary cavitation produced by a projectile is a minimal wounding agent, particularly in the case of torso shots. In such cases, the expansion of the bullet must be relied upon to physiologically incapacitate an individual. There must be sufficient blood loss to effectively disrupt the central nervous system, since physiological incapacitation is unpredictable. To achieve this, a projectile should reach vital organs within the body and damage as much tissue as possible.

In 1982, Dr. M. Fackler of the Wound Ballistics Laboratory of the Letterman Army Institute of Research developed a scientific approach to the study of wound profiles based on an understanding of the effects of projectiles on body soft tissues. The procedure for the RCMP study was developed on the basis of Dr. Fackler's research with some additional modifications that more closely simulate actual field conditions.

The terminal performance of Calibres 9 mm Parabellum and .40 Smith and Wesson ammunition was measured with respect to penetration depth, expansion, weight retention, and percent weight retention. Results were recorded and compared to similar tests conducted for Calibre .38 Special 158 grain semi-wadcutter hollow-point ammunition. An easily interpreted tabular form of the resulting data was developed to assist law enforcement agencies in the selection of a suitable calibre and ammunition type for police use.

From the limited ammunition types tested, there are both Calibre 9 mm Parabellum and .40 Smith and Wesson ammunition which are comparable or exceed the terminal performance of the R.C.M. Police issue Calibre .38 Spl. 158 grain SWCHP ammunition. The significance of the performance difference is an issue which may only be determined by those agencies involved in the selection of a suitable firearm ammunition combination for law enforcement use. This selection process must be based upon individual force protocol and may rely upon factors outside the listed test events such as shooting through intermediary targets.

Introduction

Handguns have historically been the primary source of defense for regular duty law enforcement officers. Because it is the duty sidearm which is generally used in confrontational situations, the firearm ammunition combination must be relied upon to incapacitate a human aggressor. In handgun projectile wounds, incapacitation is caused by two factors: 1) Psychological incapacitation and 2) Physiological incapacitation.

Psychological incapacitation is non-predictable and thus a model of reaction to being shot cannot be developed. Psychological incapacitation is completely independent of any inherent characteristics of a specific bullet and is totally unrelated to the potential for any given bullet to cause physiological incapacitation. 1, 2, 3

Physiological incapacitation has been well documented and is the result of the mechanical effects of the projectile producing physical damage to the human body. As a handgun bullet enters the human body it must first crush and destroy tissue. The space once occupied by this tissue is called the permanent cavity. 4

Temporary cavity is "the lateral transient dispersion of tissue from the wound track" and at handgun velocities the tissue generally does not stretch beyond its elastic limits and there is no significant contribution to the wounding mechanism. 1, 3

Certain organs within the body including the brain, spleen, liver, and bones are more susceptible to damage from the temporary cavity due to their malleability; however, damage to these is limited. 1 Overall, it is generally recognized that at handgun velocities temporary cavity is not a reliable wounding mechanism.

The only reliable method of stopping a human with a handgun bullet is to "decrease functioning capability of the central nervous system". 2, 5

This may be done in one of two ways: Type I is direct disruption of the central nervous system by bullet penetration. Type II is by lack of oxygen to the brain caused by bleeding. The only wounds which result in immediate incapacitation are those which damage the essential brain matter such as the brain stem or cervical spinal cord. 3

Because the central nervous system occupies such limited space within the human body, it is not feasible to expect or train for direct CNS shots, particularly in confrontational situations.

In non-direct central nervous system bullet injuries, the size and location of the wound are important. Wolberg states "The rate of incapacitation is directly proportional to the rate of blood flow and the organs or structures hit." 4, 5

Bullet must be able to penetrate deeply enough in order to disrupt major organs and blood vessels within the human torso to cause hemorrhaging which results in incapacitation. However, an individual who has been shot in the heart or major blood vessels may not be affected for many seconds or even minutes. Therefore, the expectation that a bullet striking a vital organ aside from the brain will cause immediate incapacitation is a dangerous misconception.

The exact quantity of blood loss a person can tolerate before collapsing is difficult to determine because it is dependant upon age, health, activity, presence of drugs or alcohol and psychological state. McKenney, however, states 2000 mL is the point at which "serious incapacitation" takes place. 6 Newgard states that for blood loss greater than 25% of total volume, compensation will not adequately keep the brain and heart supplied with sufficient oxygen and progression of this condition will lead to irreversible shock and death. 7

Vital anatomical structures are located deep within the body protected by various layers of tissue. The average thickness of an adult human torso is 4". The major blood vessels in the torso are located approximately 4" from the ventral skin surface. From oblique and transverse angles the heart and major blood vessels of the torso can be over 7" deep. Bullets must be able to penetrate the "minimal depth necessary to ensure disruption of the major organs and blood vessels in the torso from any angle and despite intermediate obstacles." 8, 9 Bullets that penetrate beyond 18" are wasting tissue disruption potential which could be used to make a larger wound or in the ideal 12 to 15" range of penetration required for handgun bullets. 10

Of the bullets which attain desired penetration depth, those of larger diameter are the most effective, crushing more tissue and the penetration of the bullet can also be an important factor. Cutting is a variation of the crush factor and is far more efficient in disrupting tissue than is stretching. 11 Expanded bullets which are sharp edged are more likely to cut tissue along the wound track compared to blunt edges which...
tend to stretch tissue aside during their passage. If handgun bullets fragment, wound severity is generally not increased since the bullet fragments are usually found within 1 cm of the main permanent cavity formed by the bullet path.14

The wound profile method for measuring the damage caused by penetrating projectiles was developed by the Wound Ballistics Laboratory of the Letterman Army Institute of Research in 1982. Its purpose was to clarify the interaction of penetrating projectiles with body soft tissues and establish a quantitative predictive model for human wounds.15 This method was based upon shooting projectiles into 10% ordnance gelatin at 4 °C and recording the projectiles' penetration depth, its yaw pattern, its deformation (including fragmentation, and the size and location of the temporary cavity it produced). The wound ballistic profile method has been validated by Dr. Davis' colleagues at the Miami-Dade Medical Examiners office who conducted ballistic testing of swine tissue and gelatin and compared findings to that of gunshot victims at autopsy.16 Wolberg testing 147 gram Subsonic Winchester 9 mm stated "this gelatin can be a useful predictor of this bullet's penetration and expansion characteristics in shots in the human torso."17

Although 10% gelatin has many proponents, and Dr. M. Fackler's wound profile is currently used by many researchers and police agencies, there are also critics.18 Dr. Ragsdale in a letter to the editor of the Journal of American Medical Association states "Gelatin is in fact a very misleading tissue simulant, since a gelatin block, since the latter cannot be compared to the complex regional density differences within the body."19

Ragsdale further states, "The simple expedient of injecting epoxy glue into permanent cavities in gelatin blocks details the structural complexity of radial fissures. They are actually an overlapping series of fissure calculations and actual temporary cavities. They are actually an overlapping series of fissure calculations and actual temporary cavities. The wound profile method of Fackler is basically the creation of a comparative series of sketches of the permanent cavities created in 10% gelatin with superimposed outlines of the temporary cavity, as inferred by mathematical calculations in view of the demonstrated lack of correlation between fissure calculations and actual temporary cavities, the Wound Profile diagrams cannot be taken as accurately showing likely cavitation effects in gelatin, let alone tissue."14

Since the pioneering work by Dr. Fackler's wound profile method by inserting bones or organs into 10% gelatin blocks, Dr. Lane and Ted Hallabough, Firearms Training Unit FBI, have conducted tests inserting swine femur into 10% ballistic gelatin blocks, advising swine bone is similar to human bone.20

Lewis, Clark and O'Connell stated, "The placement of organs in gelatin is of great value in studying the effects of missile trauma on various organs and tissues and produces a model which more closely simulates the human body."

"The symmetrical damage revealed in homogeneous translucent gelatin can be expected to be substantially modified if the incoming missile is destabilized by an intermediate target or strikes bone early in its penetration. Also, the complex structure of the human body has layers of variable density (skin, fat, muscle, fascia), and irregularly shaped viscera and visci variously filled with air and fluid. This complexity means there will be an almost infinite array of possible wound channel configurations, unlike the homogeneous tissue simulator."

"Gelatin/bone target probably has more relevance to human wound than a plain gelatin block, since the latter cannot be compared to the complex regional density differences within the body."

Ragsdale states, "Simple direct shots in the human body traverse various tissues, we would expect the wound profiles to vary somewhat, depending on the tissue traversed. However, the only radical departure has been found to occur when the projectile strikes bone: this produces a cavity more than soft tissue, reducing its overall penetration depth, and sometimes altering the angle of the projectiles course. Shots traversing only soft tissue in humans have shown damage patterns of remarkably close approximation to the wound profiles."

Kinetic energy and tissue trauma has been a subject debated in the modern concept of terminal wound ballistics. Duncan MacPherson in a paper presented at the Wound Ballistic seminar at the FBI Academy in 1/19-22/93 stated there is a lack of correlation between kinetic energy and damage in some physical processes. The reason for this is that physical damage is the result of stress (force per unit area), not energy. Higher kinetic energy usually increases the induced stress, but this stress only creates damage if it produces strains above the elastic limit. Most body tissues have a relatively high elastic strain limit, well above the level produced by handgun bullet temporary cavities. Since much of the kinetic energy of a bullet is associated with producing the temporary cavity volume, there is a lack of correlation between handgun bullet kinetic energy and wound trauma.21

Ragsdale states, "The severity of a wound is directly related to the amount of kinetic energy lost by the bullet in the body, because the kinetic energy of a missile is dissipated in bullet deformation and tissue damage. Nineteen millimetre pistol wounds of the abdomen create haemorrhagic lesions on the intestinal walls that may look innocent but may develop into dangerous intestinal perforations if they are left untreated. For a given aim point, the bullet producing the largest temporary cavity at the proper depth, defined by the location of vital organs, should have the greatest likelihood of producing incapacitation."

In the spring of 1994 it was determined that the Royal Canadian Mounted Police should adopt a new sidearm and ammunition combination, based upon the expectation noted by the Firearms Training Unit FBI, that the Royal Canadian Mounted Police Armourers did an exhaustive series of tests of submitted commercial semi-auto pistols in Calibers 9 mm and .38 Spl. During testing, a short list of firearms were submitted to the Firearms Section of Forensic Laboratory Regina for ammunition testing. Previous research in the field of ammunition testing and terminal wound ballistic studies suggested that the wound profile method for measuring damage caused by penetrating projectiles should be followed with very few exceptions. Perhaps the most notable exception to this profile was the addition of pigs' ribs into the gelatin as one of the test procedures. The reason it was felt this was necessary was based upon RCMP protocol. Members of the RCMP who encounter situations where the use of "deadly force" is warranted are trained to shoot for the "critical centre of mass." In order for the bullet to penetrate to the desired vital organs, it is apparent from previous examined shootings within the Firearms Section, Forensic Laboratory Regina, that the projectile must pass through not only soft tissue but a combination of rib, muscle, and cartilage.

The addition of the pigs' ribs used in testing, although similar in diameter to human ribs measured at autopsies and with connective tissue still present, was not meant to simulate human bone necessarily but to add a medium of different density that the bullet would likley strike in order to achieve desired outcome. The ribs were introduced during this test to determine and accentuate any undesirable attributes that a specific ammunition type may display during impact with a structure of different density, i.e. fragmentation, core jacket separation, non-expansion.

Based upon previous research and discrepancies in measuring temporary cavities, it was decided that no form of measurement for the temporary cavity would be included in this research.

Three tests were conducted with each firearm ammunition combination at two distances. Distances of 3 m and 30 m were chosen based upon RCMP firearms training protocol. Three metres is the minimum distance at which an RCMP recruit must instictively be able to hit critical centre of mass of their intended target, and 50 m is the maximum distance at which trainees are still expected and required to hit the centre of mass. The media used for the three test events were:

Test 1: bare 10% ballistic gelatin
Test 2: 10% ballistic gelatin covered with a layer of cotton undershirt material, 1 layer of shirt material and a heavy RCMP stormcoat. Conditions which one would expect to encounter outdoors during a typical Canadian winter.
Test 3: 10% ballistic gelatin with marble containing pigs' ribs and connective tissue embedded to 2" behind the entrance side of the gelatin block.

The 10% gelatin blocks were produced in molds 21" x 19" x 16" with each mold weighing approximately 130 lbs, to more closely simulate an
Methods and Materials:

Two potential service pistols were submitted for testing by the Royal Canadian Mounted Police Armourer's Shop: 1) A Smith and Wesson Model 5943, Calibre 9 mm Parabellum with a four-inch barrel, Serial No. VAC1271 and a Smith and Wesson Model 4046, Calibre. 40 Smith and Wesson with a four-inch barrel, Serial No. VAA3369. A Beretta 82 Centurion and compact variation of the forementioned Smith pistols were also submitted for testing by the Royal Canadian Mounted Police Armourer's Shop: 2) A Smith and Wesson: .40 Smith & Wesson: 155 grain Winchester Silvertip 155 grain Federal Hydraulok 155 grain Speer Gold Dot 165 grain Federal Hydraulok 180 grain Winchester Ranger SXT 180 grain Winchester Full Metal Jacket 180 grain Winchester Subsonic 180 grain PMC Starfire .40 Smith & Wesson 180 grain Speer Gold Dot

In Calibre 38 Spl., the RCMP's adopted service round 158 grain Federal Semi-Wadcutter hollow-point ammunition was used for all tests. Kind and Knox 250A ordnance gelatin Lot 30 was used as the tissue simulant for all tests. Dr. M. Fackler's recipe for manufacturing 10% ordnance gelatin as outlined by S. Post20 and E. Thompson21 was followed. The gelatin powder was mixed with cold water (7 - 10° C) in the ratio of 1000 g to 9000 mL. The mixture was gently agitated and allowed to hydrate for two hours at room temperature. The ordnance gelatin was heated in an Escan molds, measuring 21" x 19" x 16" which had previously been sprayed with vegetable oil to act as a release agent. The approximate weight of each completed mold was one hundred and thirty pounds. Propionic acid was initially used in solution to prevent bacterial growth, however, because the molds were used within a five-day period, the addition of acid was eliminated and no bacterial growth was recorded as was initially reported by Lucien Haag22.

Once the solution was poured into the molds, any foam on the surface was skimmed off and the molds were placed in a walk-in cooler and stored at 5° C. Temperatures of the gelatin blocks were recorded prior to test firing were no further testing. Temperatures were taken only prior to test firing. Upon completion of test events into each block (20 rounds), gelatin was removed in layers from the top surface using a fixed blade knife, so the bullet paths could be more easily observed. Bullet penetration depths were measured from the exterior of the entrance surface to the furthest point of the bullet, or in some situations to where the bullet path ended, the bullet having rebounded slightly within the gelatin. Permanent cavity diameter was measured using a Mitutoyo Digimatic Caliper. This measurement, although recorded, was not presented for this particular research. The bullets orientation at rest was recorded as well as fragmentation or core jacket separation. Bullet penetration through the pigs' ribs was measured using a rod of known length to project into the bullet path. To determine what the bullet came into contact with when shooting through ribs, a finger was inserted into the block of gelatin to differentiate between tissue, muscle, or bone fragmentation. Measurements of the rib diameter was recorded for each test containing the racks of pigs' ribs. When the bullets were removed from the gelatin, maximum and minimum expansions were measured using a Mitutoyo Digimatic Caliper. This measurement, although recorded, was not presented for this particular research. The bullets orientation at rest was recorded as well as fragmentation or core jacket separation. Bullet penetration through the pigs' ribs was measured using a rod of known length to project into the bullet path. To determine what the bullet came into contact with when shooting through ribs, a finger was inserted into the block of gelatin to differentiate between tissue, muscle, or bone fragmentation. Measurements of the rib diameter was recorded for each test containing the racks of pigs' ribs. When the bullets were removed from the gelatin, maximum and minimum expansions were measured using a Mitutoyo Digimatic Caliper. This measurement, although recorded, was not presented for this particular research. The bullets orientation at rest was recorded as well as fragmentation or core jacket separation. Bullet penetration through the pigs' ribs was measured using a rod of known length to project into the bullet path. To determine what the bullet came into contact with when shooting through ribs, a finger was inserted into the block of gelatin to differentiate between tissue, muscle, or bone fragmentation. Measurements of the rib diameter was recorded for each test containing the racks of pigs' ribs. When the bullets were removed from the gelatin, maximum and minimum expansions were measured using a Mitutoyo Digimatic Caliper. This measurement, although recorded, was not presented for this particular research. The bullets orientation at rest was recorded as well as fragmentation or core jacket separation. Bullet penetration through the pigs' ribs was measured using a rod of known length to project into the bullet path. To determine what the bullet came into contact with when shooting through ribs, a finger was inserted into the block of gelatin to differentiate between tissue, muscle, or bone fragmentation. Measurements of the rib diameter was recorded for each test containing the racks of pigs' ribs. When the bullets were removed from the gelatin, maximum and minimum expansions were covered after an initial cooldown period.
recorded along with the remaining bullet length. Any protruding jacket fragments were included in these measurements. Black Talon bullets were measured from the tip of each protruding point for maximum expansion values.

Remaining length measurements of Hydrashok bullets were taken from the tip of the post to the base of the bullet or any portion of the jacket protruding beyond the base. All recovered bullets were weighed after removing as much foreign material as possible. Those bullets which still weighed more than the reported weight were recorded as 100% weight retention. When bullets fragmented, the largest remaining fragment was measured and weighed.

Data:
The following data are presented in tabular form, Appendices 1 through 17. Photographs appearing in Appendices 172 through 182 depict examples of fired and unfired bullets of all ammunition types under all test events. Appendix 183 contains two photographs depicting 10% ordnance gelatin before and after a test event.

Ammunition Comparison

Ammunition Comparison

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Although they do not pertain directly to the data recorded for this research, they may be significant to law enforcement agencies in the selection of a suitable duty sidearm ammunition combination.

The 158 grain SWCHP bullet fired from the S & W Calibre .38 Spl. with a 2 ¾" barrel over-penetrates 10% ordnance gelatin and gelatin covered with layers of clothing; however, when ribs were embedded into the gelatin medium, both adequate penetration and expansion result. Although accuracy was not one of the test events in measuring ammunition's terminal performance, it is obvious that a bullet must have an intended target to achieve the desired result. For those test events at 50 m shooting the gelatin blocks from a sandwich rest using Calibre 9 mm Parabellum, 124 grain PMC Starfire ammunition was a challenge and a 200 round supply of ammunition was depleted prior to finishing the test events.

Conclusion:

For their significant technical support we also thank Mrs. Nancy Wilson, Mr. Ed Perreault, Mr. Alan Laughalin, Mr. Brent Ostrum, and S/Sgt Dave Hepworth.

Ammunition Comparison

Ammunition Comparison

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References:


5. Fackler, M. L., M.D., Summary of Remarks to the Wound Ballistic Seminar, FBI Academy, Quantico, Virginia, 1/19/203.


7. McMenemy, M. G., M.D., Summary of Remarks to the Wound Ballistic Seminar, FBI Academy, Quantico, Virginia, 1/19/2293.


15. Lane, E., Dr., Summary of Remarks to the Wound Ballistic Seminar, FBI Academy, Quantico, Virginia, 1/19/2293.


17. Ragsdale, B.D. and Sohn, S.S. Comparison of the Terminal Ballistics of Full Metal Jacket 762 mm M80 (NATO) and 5.56 mm M193 Military Bullets. A Study in Ordnance Gelatin. Reprint from...
The penetration data can be corrected using Figure 10-10 on page 257 of the book. The correction of the data on Appendix page 165 to standard conditions will be described here for illustrative purposes.

The first measured bullet penetration on Appendix page 165 is 14.00 inches; entering this curve on Figure 10-10 at a calibration of 9.4 cm gives a point on the vertical axis that appears to be about -0.27 cm, but this is rounded to -0.3 (always round to the nearest 0.1 cm). The corrected first BB penetration is then 10.0-.3=9.7 cm. Similarly, the correction to the second BB calibration is -0.2 cm, and the corrected second BB calibration is 9.4 cm. Combining these results gives an average BB calibration of 9.55 cm, which can be called 9.6 cm. (The reason that this doesn’t matter is shown below.) Note that making two BB calibration measurements that are consistent gives confidence that no error has been made in measurement or recording, and also provides some confidence that the gelatin block does not have anomalous inhomogeneities (through temperature effects or otherwise). This good practice should be followed by all experimenters.

The penetration data can be corrected using Figure 10-10 on page 257 of Bullet Penetration (the bullet velocity is close enough to the 1000 ft/sec limit). The first measured bullet penetration on Appendix page 165 is 14.00 inches; entering this curve on Figure 10-10 at a calibration penetration depth of either 9.5 or 9.6 cm gives a penetration correction of about -0.7 inch. There is no point in calculating the correction more accurately than to the nearest tenth of an inch; this is why the BB calibration penetration can be rounded to the nearest tenth of a centimeter. The corrected bullet penetration is then 14.0-.7 = 13.3 inches. This same procedure can be followed for the other 4 penetrations on Appendix page 165, all of these have corrections of -0.6 or -0.7 inch.

The penetration depth correction described in the previous paragraph can also be made using the approach described in the article A Simplified Penetration Depth Correction for Data Taken in Non-Standard Gelatin that appeared in the Vol. 2, #2 issue of the Wound Ballistics Review. The first measured bullet penetration on Appendix page 165 has an average expanded diameter of .653 inch; this is approximately 16.6 mm (multiply by 25.4 to change inches to millimeters, 653x25.4=16.6). From Figure 1 of (the article), a JHP bullet having Ø =16.6 gives $d = 97$ (the value can be read more accurately as .673, but this added precision is not needed). From Figure 2, the value of $\gamma = 0.12$ is determined for $X_{	ext{avg}}$ = 9.6 (or 0.11 for $X_{	ext{avg}}$ = 9.5, either is satisfactory). The parameter $S$ is calculated from the formula given as $S = 15.65(0.18/10.6)^2 = 10.8$. The value $C_{\text{avg}} = 0.68$ is determined from Table 8-3. Then from the formula in the article, $d' = 10.8x.87x.605x.68 = 1.7$ cm = 1.72.54 = 0.7 inch. This correction is subtracted from the measured penetration, and so the two methods give the same result.

This example on Appendix page 165 has a typical correction magnitude because the gelatin used for most of the testing in this report has BB calibration between 9.0 an 10.0 cm. Most of the penetrations in this study will be reduced by one half to one inch by correction to standard gelatin; this modest correction has no significant impact on the study conclusions.
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Ammunition Comparison

Date: 94 APR 25
Bbl. Length: 4" 
Make: .38W
Serial No.: V44-3369
Model: 4546
Ammo Mfg.: SPEER
Bbl Type: 190 grain Gold Dot
Lot No.: D19V23

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Notes:

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2. Sideways
3. Sideways
4. Sideways
5. Sideways

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Appendix page 165

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APPENDIX 174: BARE GELATIN (9 mm Parabellum)

3 metres 50 metres

9 MM Parabellum fired from S&W 5943:

115 grain Winchester Silvertip

115 grain Federal Jacketed Hollowpoint

124 grain PMC Starfire

147 grain Federal Hydrashok

147 grain Remington Golden Saber

147 grain Winchester Black Talon

147 grain Speer Gold Dot

147 grain Winchester Full Metal Jacket

APPENDIX 175: HEAVY CLOTHING (9 mm Parabellum)

3 metres 50 metres

9 MM Parabellum fired from S&W 5943:

115 grain Winchester Silvertip

115 grain Federal Jacketed Hollowpoint

124 grain PMC Starfire

147 grain Federal Hydrashok

147 grain Remington Golden Saber

147 grain Winchester Black Talon

147 grain Speer Gold Dot

147 grain Winchester Full Metal Jacket
APPENDIX 176: PIGS RIBS (9 mm Parabellum)

9 MM Parabellum fired from S&W 5943:

- 115 grain Winchester Silvertip
- 115 grain Federal Jacketed Hollowpoint
- 124 grain PMC Starfire
- 147 grain Federal Hydrashok

3 metres 50 metres

147 grain Remington Golden Saber
147 grain Winchester Black Talon
147 grain Speer Gold Dot
147 grain Winchester Full Metal Jacket

APPENDIX 177: BARE GELATIN (9 mm Parabellum)

---

.38 SPECIAL fired from S&W 10-5 5" BBL:

9 MM Parabellum fired from H&K MP5:

- 115 grain Winchester Silvertip
- 115 grain Federal Jacketed Hollowpoint
- 124 grain PMC Starfire
- 147 grain Federal Hydrashok

3 metres 50 metres

147 grain Remington Golden Saber
147 grain Winchester Black Talon
147 grain Speer Gold Dot
147 grain Winchester Full Metal Jacket
.38 SPECIAL fired from S&W 10-5 5" BBL:
158 grain Federal Semi-wadcutter

9 MM Parabellum fired from H&K MP5:
115 grain Winchester Silvertip
115 grain Federal Jacketed Hollowpoint
124 grain PMC Starfire
147 grain Federal Hydrashok

.38 SPECIAL fired from S&W 10-5 5" BBL:
158 grain Federal Semi-wadcutter

9 MM Parabellum fired from H&K MP5:
115 grain Winchester Silvertip
115 grain Federal Jacketed Hollowpoint
124 grain PMC Starfire
147 grain Federal Hydrashok

APPENDIX 178: HEAVY CLOTHING (9 mm Parabellum)

APPENDIX 179: PIGS RIBS (9 mm Parabellum)
.38 SPECIAL fired from S&W 10-5 5" BBL:
158 grain Federal Semi-wadcutter

.40 SMITH & WESSON fired from S&W 4046:
155 grain Federal Hydrashok
155 grain Winchester Silvertip
155 grain Speer Gold Dot
165 grain Federal Hydrashok

APPENDIX 180: BARE GELATIN (.40 Smith & Wesson) SCALE:

.38 SPECIAL fired from S&W 10-5 5" BBL:
158 grain Federal Semi-wadcutter

.40 SMITH & WESSON fired from S&W 4046:
155 grain Federal Hydrashok
155 grain Winchester Silvertip
155 grain Speer Gold Dot
165 grain Federal Hydrashok

APPENDIX 181: HEAVY CLOTHING (.40 Smith & Wesson) SCALE:
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MONICA DUNN'S SUICIDE INVESTIGATION: A STUDY IN TUNNEL VISION

Martin L. Fackler MD, and Nelson E. Welch MS

"...learning how to not fool ourselves -- of having utter scientific integrity -- is, I'm sorry to say, something that we haven't specifically included in any particular course that I know of. We just hope you've caught on by osmosis.

The first principle is that you must not fool yourself -- and you are the easiest person to fool ...I'm talking about a specific, extra type of integrity that is, bending over backwards to show how you're maybe wrong, that you ought to have when acting as a scientist. And this is our responsibility as scientists, certainly to other scientists, and I think to laymen."

Surely You're Joking Mr. Feynman
Feynman RP, New York, WW Norton, 1985, pp. 342-343

ABSTRACT

PURPOSE - To recount how apparently focusing on a single shotgun petal abrasion caused several investigators to become so convinced that a shotgun wound was made from a distance of two feet (and was, thus, a murder), that they overlooked overwhelming contradictory evidence and needlessly caused an innocent police officer to spend eight months in jail awaiting trial. To show the unique finding of greater omentum protruding from the exit wound of the back, forced there by the pressure of powder gas in the abdominal cavity.

METHOD - Each item of misinterpreted and overlooked evidence is described, analyzed, and related to the distance of fire.

RESULTS - Eight points of evidence, any one of which proves beyond a reasonable doubt that the wound was a contact one, were misinterpreted or overlooked. Five other items of evidence each give cause for considerable doubt of Paul Dunn's guilt, although they do not prove his innocence.

CONCLUSIONS - The trap of investigators letting one apparently convincing piece of evidence blind them to all contradictory evidence is discussed, as is the ego trap of refusing to change one's opinion in the face of overwhelming evidence to the contrary.

INTRODUCTION

On 4 April 1994, Monica Dunn, the 31 year old wife of Police Officer Paul Dunn, sat on her water bed, held the barrel of a 12 gauge Remington Model 1100 semiautomatic shotgun, loaded with 00 Buckshot, against her abdomen with her right hand on the barrel, leaned forward and pulled the trigger with her left thumb. The shot perforated her distal aorta, left iliac artery and vena cava. She died rapidly.

At autopsy, a conspicuous radial abrasion, about 3/8 inch (9 mm) long, was noted extending from the entrance wound in the one to two o'clock position. This was interpreted as a shotgun petal slap abrasion and led to the conclusion that the shot must have been made with the muzzle from one to three feet from the skin. The manner of death was therefore declared to be homicide. Because of this, the State of New Mexico prosecuted Officer Paul Dunn for the murder of his wife. He spent eight months in jail before his trial ended in acquittal by a 12 to 0 vote of the jury on their first ballot. That the State of New Mexico prosecuted this case is astounding in view of the following evidence.
Fig 1 - Entrance wound two inches above Monica Dunn's umbilicus.

Fig 2 - Twelve gauge shotgun muzzle with bead sight on a ventilated rib.

Fig 3 - The position of the model shows the approximate position of Monica Dunn when she committed suicide. Each of the buckshot pellets passed through the plasterboard wall and then struck a brick wall about six inches behind the plasterboard. Thus, two points on the trajectory of each pellet could be determined: this allowed for an exact determination of each buckshot's trajectory angle. These angles are demonstrated in the photograph by wooden dowels placed in the holes. This demonstration was intended to show only the upward angle: the model has her right and left hands reversed. The evidence showing that Monica Dunn pulled the trigger with her left thumb had not been recognized at the time this photograph was taken.

UNDENIABLE PHYSICAL EVIDENCE

ENTRANCE WOUND (see Fig. 1)

- The one shotcup petal abrasion was on the skin at the top left side of the wound. There was another mark, on the lower right side of the wound, made by the ventilated rib and front bead sight above the shotgun's muzzle (Fig. 2). As the gas produced from burning of the gunpowder passed into Monica Dunn's abdominal cavity, through the contact entrance wound, it forced her abdominal wall to expand and bulge outward against the shotgun's muzzle, causing the rib and bead sight to mark the right side of the entrance wound. This mark was misinterpreted by state experts as being a second shotcup petal abrasion. The second mark was not 180 degrees opposite the first one — where a second petal abrasion mark would have to be; it was about 40 degrees from that position. It was, however, where the ventilated rib on the shotgun muzzle would be if the shotgun stock was rested on the water bed mattress with the gun's ejection port facing upward (see Fig. 3). The two corners of the ventilated rib marked the skin as did the round bead which appeared midway between these corner marks. The width of the shotgun's rib is 0.31 inches; the interested reader who wishes to measure the width of the two corners of the mark on the left of the wound, using the scale in the photograph, will find that this mark corresponds exactly to the width of ventilated rib on the shotgun barrel. Additionally, the diameter of the bead on the ventilated rib is 0.125 inches, which corresponds exactly to the width of the mark it made on the skin.

The width of the shotcup petal abrasion on the upper left side of the wound is considerably wider than the one made by the rib, and approximates the one-half inch width of the shotcup petals.

- If the distance of fire had been one to three feet, Monica Dunn's dress (which was unbuttoned, but covered the right side of her abdomen — from six to twelve o'clock around the wound) should have had a protective effect on the skin from any shotcup petal that struck on the right. Any such petal should also have marked the fabric of the dress where it struck. There was no indication of a petal mark on her dress. As the several gallons of gas produced by the burning of the gunpowder passed into Monica Dunn's abdominal cavity, and forced her abdominal wall to bulge outward, this expansive bulging most likely pushed her dress away from the wound margin just before the expanding abdominal wall skin was slammed into the shotgun barrel's muzzle, causing the imprint of the ventilated rib and bead front sight on the skin.
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SOOT
• Monica Dunn had unbuttoned her dress (which buttoned up the middle in front) to expose the skin of her abdomen, but the ventilated rib on the shotgun barrel probably caught the right side of her dress; the right half of the muzzle was against her dress and the left half against her skin when the shotgun discharged. There was a semicircular rim of soot just outside where the muzzle pressed against her dress. "Gray soot" was described in the notes regarding Monica Dunn's clothing made by the medical examiner. Concentrated soot is seen in contact wounds, and wounds made at ranges of a few inches: it is not seen at ranges of one to three feet.

• There was a faint shading of soot on the upper part of the skin adjacent to the shotgun muzzle — deposited there by the gunpowder produced gas that leaked by the wadding and preceded the shot out the barrel. This soot was faint but clearly identifiable on the color photograph taken at the autopsy — the jury had no difficulty seeing it. Since the red blood stains show up black in black and white photographs they mask these faint soot deposits and thus it is not possible to show this in a figure with this paper. Color photographs (slides and prints), however, are available which show this faint soot clearly. Ordinarily, faint soot from the powder gasses preceding the shot is not noticed on loose contact or wounds made from a few inches because it is obscured by the much more copious soot contained in the main part of the powder gas. In a hard contact wound, however, where all of the powder gas following the shot column and wadding go into the wound, this copious soot does not appear on the surface. The soot contained in the small amount of powder gas that finds its way past the shot column exits the barrel when there is no hole in the skin, so it should often be identifiable (when not masked by blood) on bare white skin by anybody with the inclination to search closely for it. The presence of this faint soot is undeniable proof of a hard contact wound.

ANGLE
• The upward angle of the buckshot (Fig. 3) which struck a wall three to five feet behind Monica Dunn, who was sitting on a water bed when she committed suicide, made a homicide close to impossible. The stock of the shotgun had to be resting on the lower end of the water bed mattress to account for this angle. It would have been impossible for the gun to be two feet away and still produce the upward angle since the stock would then have had to rest on the bed frame rather than on the water mattress; this would have raised the stock about four inches higher. All nine of the buckshot followed an upward path of between five and fifteen degrees after exiting Monica Dunn's body. These angles are exactly what would be expected with the shotgun stock resting on the water bed mattress with the muzzle just above Monica Dunn's umbilicus. It is nearly impossible to conceive of a homicide (gun held by somebody else) producing this upward angle.

PRESSURE EFFECTS FROM THE POWDER GAS IN THE ABDOMINAL CAVITY
In hard contact wounds, the gas produced by the burning of the gunpowder follows the projectile or projectiles through the hole in the skin. In the typical contact wound of the head with a handgun, for example, the gas flows between the scalp and the skull, often splitting the skin around the wound, usually producing a stellate entrance wound. When the hard contact wound is in the abdominal wall, however, the gas flows into the abdominal cavity. There is space in the abdominal cavity for up to a gallon without stretching things too much, but the 12 gauge shotgun develops three to four gallons of powder gas (estimated from information from the powder manufacturers; using about half of the maximum gas temperature in the barrel to calculate the gas volume using the standard gas laws). This amount of gas increased the pressure in the abdominal cavity greatly and caused the findings listed below.

• Two of the buckshot traveled side-by-side through Monica Dunn's psoas and sacrospinalis muscles (a distance of three or more inches). Protruding from the exit hole these buckshot made in the back was a two inch (length and width) wad of greater omentum (a moveable, apronlike layer of fat covered with a thin, transparent layer of tissue). The only mechanism possible to provide the force needed to push the greater omentum from its normal position in the front part of the abdominal cavity all the way through a three-fourth inch diameter, three inch long hole through muscle, behind the abdominal cavity, to finally protrude two inches out the skin of the back (Fig. 4) was the increased pressure generated in the abdominal cavity by the three to four gallons of powder produced gas.

• Another result of the powder gas pressure was the spattering over the wall three to five feet behind Monica Dunn of her blood, some intestinal fluid, and small pieces of material and threads from her dress (Fig. 5).

• Between the skin of Monica Dunn's back and her dress there were more than one hundred lightweight plastic filler particles (grey) that come packed around the shot in the loaded shell (see Fig. 4). There were none of these on the front of Monica Dunn's dress and fewer on the skin around the entrance wound than around the exit wounds. If the shot had been fired from a distance of two feet, grey particles should have been all over the front of her dress and stuck in the blood all over the front of her abdomen. The amount of this very lightweight filler, however, around her exit wounds can only be explained by all of it being forced into the abdominal cavity with the powder gasses, in a hard contact wound, and then much of it being squirted out the exit wounds with the powder gas. In the absence of the powder gas, at most a few grey particles could be dragged through the wound with each of the nine buckshot pellets.
CIRCUMSTANTIAL EVIDENCE

SUICIDE LETTER

Monica Dunn left a five page suicide letter.

SHOT LOCATION

Paul Dunn had served more than fifteen years as a police officer. He is an intelligent person. It is unimaginable that he would try to kill his wife by shooting her in the abdomen. Most people shot in the abdomen survive if the angle of the shot in Monica Dunn’s abdomen had been twenty degrees to the side from where it was, she could have missed the large blood vessels and survived her wound. A head or heart shot are the only choices for a certain and rapid death — a fact known even to most laymen.

ABSENCE OF STIPPLING

• There was no stippling at all from powder particles around the entrance wound on Monica Dunn (see Fig. 1). The photographs of shotgun petal abrasions shown in forensic pathology books and papers also show considerable stippling around the wounds (1,2).

ABSENCE OF DISRUPTION IN THE CLOTH OF MONICA DUNN’S DRESS

• Test shots were done from two feet: the area of the cloth around the entrance hole in these shots was considerably disrupted by the gray filler. There was no such disruption in the cloth of Monica Dunn’s dress.

FACE OF EVENTS

It is unclear who made the determination that Monica Dunn’s wound was fired from a one to three foot distance rather than being a contact wound. This faulty determination was apparently made, however, either by the state’s firearm examiner or someone in the medical examiner’s office the day of the autopsy or the next day. The initial autopsy report was dated 25 April 1994 and a revised report was done on 27 April 1994. The only difference between the reports was the deletion of the suggestion “that the muzzle of the gun was inside the left side of the fabric” which had gaped open since it had been unbuttoned before the shot. It is interesting that the manner of death was still considered a homicide on the first report, despite the contradictory suggestion — which was then deleted in the revised report.

What is clear is that the state’s medical examiners and the state’s firearms examiner who worked on this case, plus the outside forensic pathologist who the state retained to testify as an expert witness, were all so convinced by a single one-third length shotgun petal abrasion (four full-length petal abrasions would be needed to support their theory) that they ignored or denied all of the contradictory evidence listed above.

It must be noted that all of this contradictory evidence was presented to the state’s attorneys by the authors of this paper before the trial. Despite this mountain of evidence inconsistent with their theory of the case, the state chose to proceed with the trial.

THE SCIENTIFIC FAILINGS

• Autopsy: There was no mention of the protrusion of the greater omentum from the exit wounds (Fig. 4). There was no mention of cutting this protruding omentum off (Fig. 6). There was no mention of the gray soot on Monica Dunn’s clothing in the description of her clothing in the autopsy report, but the handwritten words “gray soot” appear on the notes made. DURING THE AUTOPSY, describing the clothing. Furthermore, under the clothing heading in the autopsy report is “a 1/16 inch wide deposit of gray bullet wipe along this hole.” describing the hole in Monica Dunn’s pants/slip. Since “bullet wipe” is seen around bullet wounds, not those made by shotgun pellets, what was
being described in the autopsy report was clearly soot
(as it was described in the autopsy notes).
In the autopsy report there was no indication that a
biopsy was taken from the margin of Monica Dunn's
entrance wound to determine if microscopic changes
from searing and burning caused by hot power gas (as
happens in contact wounds) were present.

• Failure to test Monica Dunn's dress for powder resi­
due or to search for unburned powder: If the shot had
been made from one to three feet there would have
been powder and powder residue on the dress around
the notch made by the shot. This should have been
searched for directly using a dissecting microscope as
well as testing the front of the dress chemically to de­
tect the nitrates in the powder residue.

CONCLUSIONS

Apparent jumping to an early unwarranted
conclusion in this case led to a failure of scientific
skepticism, and failure to do a thorough investigation of
the evidence. It also apparently caused the oversight of
such a great number of clear and easy to understand
(once they are pointed out) points of evidence that it put
the state's investigators in an extremely embarrassing
position. So rather than honestly accepting this embar­
rassment, they turned a blind eye to the facts and com­
pounded their errors by pushing on with the prosecu­
tion. They hired an outside expert in an attempt to bol­
ster their position. In trying to escape their own embar­
rassment they caused Officer Paul Dunn increased mis­
ery, to say nothing of financial expense.

The discipline of Forensic Science, however, pro­fited (at Paul Dunn's expense) from the unique find­ings in this case:

- The deformation pattern of recovered shot­
cup petals has been found to be at least as reli­able as the abrasions they make on the skin
around the wound in differentiating contact from two foot distant shotgun wounds (see fol­
lowing paper)
- We are unaware of any previous reports of the effects of the pressure from powder gasses
confined in the abdominal cavity (omentum
forced out a wound of the back, gress forced out
wounds of the back, blood and fluids from the
abdominal cavity squirted out the exit wounds
of the back).
- The entrance wound had all the characteristics of a hard contact wound but also had a
cross wound in the form of a cross (2), are commonly used to
separating contact shotgun wounds from those fired
from several feet

METHOD - Test shots were fired into pig skin
draped over 10% ordnance gelatin
RESULTS - All of the shot cup petals recovered
from hard contact shots were conspicuously
depressed, especially at their forward ends. None of
those recovered from test shots made at a distance of
several feet showed deformation of their forward ends.

CONCLUSION - Shotcup petal deformation pattern
appears to be at least as reliable an indicator for
separating contact shotgun wounds from those fired
from two feet as the appearance of the radial skin
abrasions caused by slaps from the petals.

INTRODUCTION

Most readers are familiar with the polyethylene
shot cups found in shotgun shells (Fig. 1). These cups
have four longitudinal slits extending from their open
forward ends to within 3 to 4 mm of their closed bases
(except in the .410 gauge, which has only three slits).
High speed photography has shown that air resistance
causes the shotcup petals to spread apart at distances
from one to three feet from the muzzle, and to be folded
back (with their forward ends pointing backward) as
they pass through the front to three feet. These
outstretched petals typically cause a telltale superficial
abrasion where they slap the skin with their flat
surfaces. These unique marks, regularly spaced and
extending outward from the margins of the entrance
wound in the form of a cross (2), are commonly used to
distinguish contact wounds from wounds made with the
shotgun muzzle one to three feet from the skin. This
often equates to separating suicides (contact) from
homicides (one to three feet distant).

In the hard contact suicide case reported in the
preceding article, the entrance wound had all the
characteristics of a hard contact wound but also had a
single radially oriented marginal abrasion, about 3/8
inch in length, that resembled the slap mark
made by a partially outstretched shot cup petal (fully
outstretched, a petal would have made an abrasion
about one inch long). The shotcup recovered from the
body showed conspicuous bending, buckling, and
tearing distortion of all the shotcup petals. Additionally,
one of the distorted petals had been broken
off at its base (Fig. 2).

We did test shots using pig skin draped over
10% ordnance gelatin to show that the shotcup petal
distortion pattern differs in the contact wound from the
two foot distant shot. We were also interested in seeing
if we could produce shotcup petal marks on the skin
experimentally in contact wounds. The conspicuous
difference in shotcup petal distortion was obvious in our
tests. Additionally, marks on the skin made by shotcup
petals occurred in half of the contact shots in our study.

vote without even leaving the jury box. Additionally, in
these questionnaires appeared such unusual comments as:
- Prosecution failed completely in relating the
physical evidence to the charge made.
- The entire case suggested to me possibly
some kind of political or emotional motivation
which cost the taxpayers extravagantly and
persecuted an individual unduly.
- It would be fair, in my opinion, in this case,
if the prosecution were forced to defray the
costs of the defendant and to reimburse him for
lost salary.

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191, 195.
2. Dowling GP, Dickinson JAH, Cooke CT. Shotcup Petal Abra­
METHODS

At the Forensic Laboratory of the Royal Canadian Mounted Police (RCMP), at Regina, Saskatchewan, six hard contact test shots were fired into freshly removed pig skin draped over 10% ordnance gelatin. One test shot was done with the muzzle two feet from the skin. In Hawthorne, Florida, a single test shot was fired into ordnance soap with the muzzle two feet from the soap. All shots were fired from a 12 gauge shotgun using two and three-fourths inch Federal shotgun shells loaded with 00 Buckshot similar to the one used by Monica Dunn. The shots done at the RCMP Forensics Laboratory were fired from a shotgun with an 18 and three-fourths inch Federal shotgun shells loaded with 00 Buckshot similar to the one used by Monica Dunn. The other test shot was fired from a 12 gauge shotgun with a 27 inch barrel with no choke.

All of the petals recovered from the contact shots were deformed, especially their leading edges (Fig. 3). None of the leading edges were damaged in those shot cup petals recovered from the test shots from two feet (Fig. 4).

The shot cup removed at autopsy from the body of Monica Dunn (Fig. 2) showed the same type of marked deformation of the shotcup petals as seen with our contact test shots. In three of the contact test shots there was no indication of marks on the skin made by the shot cup petals. In three there were marks on the skin from shot cup petals. These petals marks varied between 1/8 and 1/4 inch (3 and 6 mm) in length (see Fig. 5). The petal marks on the excised pig skin, however, were more difficult to discern than those on the living person where they turn red. In one of the contact shots there was a mark that obliterated the soot from a rectangular area about 9/16 inch (14 mm) long and 1/2 inch (13 mm) wide (Fig. 6). We are not sure if this mark was made by a shotcup petal or not.

DISCUSSION

The presence of radial abrasions around a shotgun entrance wound, made by outstretched shot cup petals, has been thought to invariably indicate a one to three foot distance of fire. When there are four, evenly spaced abrasions, as long as the petals, this is undoubtedly true. In less clear-cut cases, however, such as having only one abrasion, which is less than half the length of the petal (see preceding article) reliance upon the shotcup petal abrasions must be considered less than certain and needs to be correlated with other evidence. This study investigated the distortion pattern of shotcup petals to determine its predictive value in separating contact from several foot distant shots.

In contact shots, the shot cup petals are held by the shotgun barrel in a position forcing their leading edges to strike the skin straight on. It is not surprising that their leading edges were deformed, as well as having considerable folding and buckling deformity in the remainder of the petal. Likewise, it is not surprising that those fired from two feet never had a deformed leading edge, since they struck with their large flat side. The obvious red abrasions left by the four petal slaps (three in the .410 gauge) is the distinguishing characteristic of the one to three foot distant shotgun wound. The opening of the petals has been shown with high speed photography and the presence of these abrasions is often used to differentiate suicide from homicide. Although we could find no reports of petal slap type abrasions in contact shotgun wounds, we did find a report of a suicide with a .410 gauge shotgun in which petal marks were identified (3). Test firing of the deceased’s shotgun in this case showed spread of the shotcup petals started at a range of 3 only inches.
suggested more variation in this mechanism than is commonly recognized.

Monica Dunn clearly committed suicide (see preceding paper), yet there was one short abrasion, extending from the entrance wound, which appeared to be a petal slap abrasion from a partially opened shotcup petal. How could this happen with a contact wound? Analyzing the mechanisms it became apparent that a single petal had caught on the skin edge and slid up on the outside of the skin to produce the mark. In a contact wound, the skin would increase the chances that a petal would catch and slide up outside the skin. It would then break off at its base and probably be forced into the wound by the following wads and powder gasses. One of the petals of the deformed shot cup removed from the body of Monica Dunn was broken off at its base.

In a hard contact wound there is a mechanism that could produce an angle between the skin and the advancing shotcup petal: the gas that slips past the shot column in the gun's barrel and precedes the shot out of the barrel has to go somewhere. Since there is no hole in the skin when this high-pressure gas strikes it, the gas pushes the skin away from the muzzle and could set up an angle that would increase the likelihood of a shotcup petal catching and sliding up on the outside of the skin.

Half of our contact test shots produced shotcup petal marks on the skin that were somewhat shorter than the one on Monica Dunn. If the 14-mm long and 13-mm wide area of sooť-free skin (Fig. 6) represents a shotcup petal mark, however, it is considerably longer than the 9-mm long abrasion on Monica Dunn. We suggest that this mark might have been caused by a petal that slid up outside the skin.

ends of the forward pointing shotcup petals, in a contact wound, turn outward and mark the skin surrounding the wound. If one stops to ponder the mechanism, this also should come as no surprise. What is surprising is that the obvious and striking difference in shotcup petal deformation has not heretofore been noticed as an indicator to separate contact from one to three foot distant shotgun wounds.

We undertook this study to investigate shotcup petal marks in contact shotgun wounds. Our test shots verified what common sense and the laws of motion dictate must be true when shotcup petals strike with their leading edges: they bend, buckle, and deform, when they strike on their large flat surface (with the leading edge pointing 90° from the direction of travel) they do not deform, except slightly at their base when they are torn from the base of the cup (which happens often).

Our test shots also demonstrated that some of the CONCLUSION


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Ballistics Misconceptions

WOUND BALLISTICS MISCONCEPTIONS

Duncan MacPherson—Technical Consultant

Introduction

The RCMP recently implemented a very thorough ammunition testing program in an attempt to improve their issue handguns and ammunition. This program is a good example of how a sound project of this type can be implemented by an organization without initial expertise; the secret is selecting capable people who are willing to search out information, think carefully about the information received, and then make informed decisions in planning and implementation. The story of this program is summarized in the article "Comparative Performance of 9mm Parabellum, .38 Special and .40 Smith & Wesson Ammunition in Ballistic Gelatin" in this Journal issue.

The RCMP study included considerations of factors important in effectiveness in handgun ammunition. Opinions on this topic were collected from a number of references cited in "Comparative Performance of 9mm Parabellum, .38 Special and .40 Smith & Wesson Ammunition in Ballistic Gelatin." Most IWBA members are aware of the divergent views on this topic, and so will not be surprised to learn that these references are not all in agreement. After study, the RCMP accepted views that are consistent with the views expressed by most IWBA members in the articles they publish.

The references cited and briefly described in "Comparative Performance of 9mm Parabellum, .38 Special and .40 Smith & Wesson Ammunition in Ballistic Gelatin" include several that are in strong disagreement with the "IWBA consensus." These views were wisely rejected by the RCMP as a guide for their ammunition selection program. This article comments briefly on two major claims in these references that are frequently mentioned by IWBA critics even though each is unquestionably incorrect. These two claims are 1) kinetic energy deposit is a valid measure of wound trauma; 2) the inhomogeneities in tissue make gelatin (which is homogenous) invalid as a tissue simulant.

Kinetic Energy

The belief that kinetic energy deposit in tissue is a fundamental wounding mechanism is very common and this assertion has been made by innumerable writers, most of whom have little or no understanding of either the physics or physiology involved. The popularity of this claim led me to devote an entire chapter in Bullet Penetration - Modeling the Dynamics and the Incapacitation Resulting from Wound Trauma to explaining energy relationships and why there is no general direct relationship between energy and the trauma that leads to incapacitation. No attempt is made to cover all this material here, but the following paragraph briefly summarizes the "bottom line".

Attempts to determine bullet effectiveness or assign wound trauma incapacitation by assessing bullet kinetic energy are doomed to failure for two interrelated reasons: 1) damage is done by stress (force), not energy; 2) an indeterminate, but usually large, amount of the bullet kinetic energy leads to tissue stresses that are not large enough to cause significant trauma (especially in handgun loads).

Tissue Simulation

The bullet penetration model derived and explained in Bullet Penetration implicitly defines the penetration dynamics, and these dynamics are described in non-technical (as well as technical) terms in that book. However, the fallacy in the assertion that the inhomogeneities in tissue make gelatin invalid as a tissue simulant is not explicitly described in Bullet Penetration, and so is discussed here.

When a bullet is penetrating any material (tissue, water, air, wood, etc.), the total force the bullet exerts on the material is the same as the total force the material exerts on the bullet (this is Newton's Third Law of Motion). These forces may be represented as a combination of shear forces and inertial forces (don't be concerned here, but are described in "Bullet Penetration," and so is discussed here).

You can fan your hand back and forth in air quite rapidly because there seems to be no resistance, but a similar flailing motion cannot be done nearly as rapidly underwater because moving the water can take all the strength you can muster. The force that resists the movement of your hand in water are inertial forces, and are due to accelerating the mass of the water (giving it a velocity). There are also inertial forces that resist the movement of your hand in air, but these forces are so much smaller that they are not obvious because air density is so low. (Moving your hand also produces inertial forces because your hand has mass, but we are used to the feel of this because it happens all the time.)

Most common activities have some combination of shear and inertial forces. Those actions that involve deformation often primarily involve shear forces (e.g., snapping a twig, tearing a sheet of paper). Actions that result in giving an object a velocity usually primarily involve inertial forces; putting the shot is a classical example, almost all games that put balls in motion (e.g., baseball, golf, tennis) are equally applicable.

A bullet penetrating a solid soft tissue (or a tissue simulant like gelatin) meets resistance that is a combination of shear forces and inertial forces. The penetration model described in Bullet Penetration shows (and proves) what the bullet deformation model just mentioned this insight is invaluable. Concepts and beliefs concerning bullet penetration dynamics and the resulting wound trauma incapacitation generated before this model existed were based on intuitive guesses; some of these guesses made by individuals with good insight (like Hatchet) were reasonably close to reality, but guesses made by many others were grossly wrong. This is not unusual in technological progress, and the important thing now is to try and keep authors (in gun literature, JAMA, and everything in between) from endlessly repeating these concepts that have now been proven fallacious.

The penetration model shows that the force resisting a bullet penetrating soft tissue at velocities above the cavitation threshold (about 500 fps/sec for typical handgun bullets) is almost totally an inertial force; in effect, this force is due to accelerating a mass of tissue in and near the bullet path. This force is nearly identical to the force resisting a bullet penetrating water (which as a liquid does not support a shear force) at velocities above the cavitation threshold) because the densities of water and tissue are nearly the same. This is the reason we look at the penetration at this velocity. This force is due to accelerating a mass of tissue in and near the bullet path. This force is nearly identical to the force resisting a bullet penetrating water (which as a liquid does not support a shear force) at velocities above the cavitation threshold) because the densities of water and tissue are nearly the same. This is the reason we look at the penetration at this velocity. This force is due to accelerating a mass of tissue in and near the bullet path. This force is nearly identical to the force resisting a bullet penetrating water (which as a liquid does not support a shear force) at velocities above the cavitation threshold) because the densities of water and tissue are nearly the same. This is the reason we look at the penetration at this velocity. This force is due to accelerating a mass of tissue in and near the bullet path. This force is nearly identical to the force resisting a bullet penetrating water (which as a liquid does not support a shear force) at velocities above the cavitation threshold) because the densities of water and tissue are nearly the same. This is the reason we look at the penetration at this velocity. This force is due to accelerating a mass of tissue in and near the bullet path. This force is nearly identical to the force resisting a bullet penetrating water (which as a liquid does not support a shear force) at velocities above the cavitation threshold) because the densities of water and tissue are nearly the same.

Anywho has worked with gelatin knows that a finger can be pushed into gelatin with a force of only a few pounds; this force is similar to the resistant to a finger poked into the stomach, but the tissue does not fracture as easily as gelatin does. A finger poked into water does not meet this kind of resistance, which is due to shear forces. Penetration of a 9mm bullet at 1000 fps/sec is resisted by an inertial force of about 300 pounds; it is obvious that the presence or absence of a 3 to 5 pound shear force makes no practical difference in the penetration at this velocity. This also explains why the fact that gelatin fractures more easily than tissue does not important.

The extension of these dynamics to soft tissue variation is obvious. Different types of tissue present different resistance to finger probing by a surgeon, but the surgeon is not probing at 1000 fps/sec. Different tissue types do have differences in the amount of shear force they will support, but all of these forces are so small relative to inertial forces that there is no practical difference. The tissue types are closer to each other than they are to water, and bullet penetration results prove that the dynamics of penetration in water and tissue are nearly identical at velocities over 600 fps/sec where all bullet penetration takes place (see Bullet Penetration for a detailed explanation of bullet expansion dynamics).

Since inertial forces depend on accelerating mass, it makes sense that these forces should be lower at lower bullet velocities (because the penetrated material cannot be accelerated to a velocity higher than the bullet). Shear forces have little velocity dependence, and as a result, shear forces are a much larger fraction of the total when bullet velocity is below the cavitation threshold. This low velocity effect is the reason that total bullet penetration depth is much different in water and in tissue or a valid tissue simulant.

As a result of the penetration dynamics, most soft solids with a density very near soft tissue (i.e., near the density of water) are satisfactory tissue simulators when shot shear forces are not important. However, total penetration depth depends significantly on dynamics at velocities below 400 fps/sec, so most materials do not properly simulate penetration depth. The total bullet penetration depth in tissue and a valid tissue simulant should be the same, standard practice is to use calibrated gelatin to insure this. In effect, gelatin calibration is done to ensure that the shear forces in the gelatin are the same as in typical soft tissue (as described in Bullet Penetration, the technical parameter used in the dynamic analysis is viscosity).

WOUND BALLISTICS REVIEW

JOURNAL OF THE INTERNATIONAL WOUND BALLISTICS ASSOCIATION

Ballistics Misconceptions

Vol. 2, No. 3
Letter to the editor: (FOR PUBLICATION)

An article referring to the superb wound ballistics research of Professor Theodor Kocher is a welcome addition to the literature. Kocher's research on projectile effects produced two books and four research papers, as well as the presentation dealt with in the "JAMA 100 Years Ago" column, "Professor Kocher on Modern Projectiles in Warfare". (JAMA 1994; 272(5):330b). Kocher's wound ballistics studies were extremely influential in his day, but we are unaware of any published English translations, and, unfortunately, this work has faded into relative obscurity.

The "JAMA 100 Years Ago" column attempted to summarize Charles G. Camanaday's 1894 report on Kocher's lecture concerning the improvement of military rifle bullets from the humanist point of view. Unfortunately, this attempt presented Kocher's work inaccurately. The title of Kocher's research should be accurately corrected, that his wound ballistics research was driven by a desire to make military rifle bullets less disruptive in the human body. The JAMA column, however, ends with:

- But the modern guns surpass greatly this scope, because they tear or destroy the body, exposing the victim to the risk of losing his life even through non-vital injuries, and either opposes or prevent the re-establishment of the normal functions...

This makes it appear as if Kocher had failed in his efforts to reduce bullet disruption. This description of the excessive effects of "modern" bullets is actually Kocher's description of the damage caused by the large caliber soft head bullets that preceded his then new jacketed bullets. In the final paragraphs of Camanauday's report, following the italicized"The results already obtained..." we find Kocher's description of the effects of the smaller caliber full metal jacketed (FMJ) bullets:

- One of the greatest improvements from a medical point of view is the reduction of the hole, as the healing of the wound is then materially facilitated and dangerous complications are rendered less frequent.

Kocher's research, in fact, laid the scientific foundation for the development of the FMJ military bullet—the invention which was attributed to Kocher's co-worker Major Rubin, then Director of the Swiss Government Ammunition factory in Thun. Kocher's work succeeded to such a degree that by 1892 virtually all military forces in the civilized world had switched from their 10 to 12 mm soft lead bullets to the new 6.5 to 8 mm "humane" bullets (jacketed with copper or steel). This basic FMJ bullet design, which resulted from Professor Theodor Kocher's wound ballistics research, continues to be used by all military forces up to the present day.

Kocher's research elucidated the critical importance of bullet deformation as a determinant of tissue disruption. No matter how high a bullet's velocity, its effects in soft tissue can be kept minimal by keeping the caliber of the bullet small and making the bullet hard enough (by jacketing with a hard metal) so it will not deform in human soft tissue. Yet today, most surgical textbooks continue to claim that a bullet's disruptive effect is directly proportional to its velocity. If a bullet's destructive effects were invariably directly proportional to its velocity (or the square of its velocity as some claim), Kocher's FMJ bullets, with merely double the velocity of their predecessors, should have produced a massive increase in tissue disruption—rather than the universally observed conspicuous decrease. Battlefield reports, from every war since the adoption of the FMJ bullet, verify Kocher's success in his goal of designing a bullet that would produce limited tissue disruption—despite its "high" velocity.

Martin L. Faciller, MD and Paul J. Dougherty, MD

REFERENCES


Management of the bone and vascular tissue differs from that of low velocity projectile wounds. Wounds caused by high-velocity bullets are likely to be fatal... Massive evidence shows all these points to be in error. Interestingly, the authors' own evidence for their claims does not support or even address their claims. The Technical Report, wrongly cited, did not mention even the types of weapons causing the wounds let alone wound care of different weapon or velocity types.

From the current edition of Emergency War Surgery - NATO Handbook we learn that "The widespread belief that every wound caused by 'high-velocity' projectiles must be treated with 'radical debridement' is incorrect and results from failure to recognize the role of variables, such as bullet mass and construction, in the projectile-tissue interaction." Specifically, regarding performance of the AK-47 rifle bullet, the NATO Handbook notes that "The long path through tissue before marked yaw begins (about 25cm) explains the clinical significance that many wounds from this weapon resemble much lower velocity handguns. Additionally, depending upon the bullet type, fired from the AK-47 attain velocity of 2,200 to 2,350 ft/sec, not the 2,800 ft/sec of stories such as which makes or models of firearms are used for lethal purposes.

Second, standardized procedures do not exist to ensure that officers use consistent definitions or terms in the reports of circumstances that lead to each trace request. Some trace requests do not even identify the circumstances that resulted in the request. No crime need be involved to initiate a gun trace. For example, efforts to return stolen guns to rightful owners and guns found incidental to other investigations are included amongst gun traces. The statistically unreliable nature of gun traces should be clear. Additionally, in the period 1986-1992 cited by the authors, increased media attention and changing definitions of "assault weapon" further complicate interpretation of gun trace data. In the worst areas of gang and drug crime, the studies show that military-style, semiautomatic guns account for generally 0% to 3% of crime guns and, nationally, represent less than 1% of crime guns, far less than their proportion amongst American guns.

More pointedly, ten times more Americans die annually from attacks using hands and feet than die from military-style rifles.

We hope that this information helps put the authors' usual case report in perspective.

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The Congressional Research Service and the Bureau of Alcohol, Tobacco and Firearms (ATF) have acknowledged that the gun trace system is inappropriate for statistical purposes:

The BATF tracing system is an operational system designed to help law enforcement agencies identify the ownership path of individual firearms. It was not designed to collect statistics ... From this we learn that "The widespread belief that every wound caused by 'high-velocity' projectiles must be treated with 'radical debridement' is incorrect and results from failure to recognize the role of variables, such as bullet mass and construction, in the projectile-tissue interaction."

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The BATF tracing system is an operational system designed to help law enforcement agencies identify the ownership path of individual firearms. It was not designed to collect statistics...

Two significant limitations should be considered when tracing data are used for statistical purposes:

- First, the firearms selected for tracing do not constitute a random sample and cannot be considered representative of the larger universe of all firearms used by criminals, or of any subset of that universe. As a result, data from the tracing system may not be appropriate for drawing inferences such as which makes or models of firearms are used for lethal purposes.
- Second, standardized procedures do not exist to ensure that officers use consistent definitions or terms in the reports of circumstances that lead to each trace request.

Some trace requests do not even identify the circumstances that resulted in the request.

No crime need be involved to initiate a gun trace. For example, efforts to return stolen guns to rightful owners and guns found incidental to other investigations are included amongst gun traces. The statistically unreliable nature of gun traces should be clear. Additionally, in the period 1986-1992 cited by the authors, increased media attention and changing definitions of "assault weapon" further complicate interpretation of gun trace data. In the worst areas of gang and drug crime, the studies show that military-style, semiautomatic guns account for generally 0% to 3% of crime guns and, nationally, represent less than 1% of crime guns, far less than their proportion amongst American guns.

More pointedly, ten times more Americans die annually from attacks using hands and feet than die from military-style rifles.

We hope that this information helps put the authors' usual case report in perspective.

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