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International Wound Ballistics Association

WOUND BALLISTICS REVIEW

JOURNAL OF THE INTERNATIONAL WOUND BALLISTICS ASSOCIATION

The Lee Clegg Case: A Study in Self Deception
—*Martin L. Fackler, MD*

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IWBA ORGANIZATION

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 technical study of wound ballistics, including evaluation of literature in the field as well as encouraging and promoting new work. The *WOUND BALLISTICS REVIEW* is the Journal of the IWBA.

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EDITORIAL *Martin L. Fackler, MD*

About this Issue:

The evidence presented in our lead article, on the Clegg case, teaches the critical importance of analyzing forces in accounting for deformation of recovered bullets. The action of forces at the interface of the penetrating projectile and what it is striking is the crux of wound ballistics: it must be the focal point of any valid analysis. Some who were involved in the Clegg case disagree with my opinion that the errors and false impressions presented by the prosecution were due to self deception. They feel that they were due to attempted conscious fraud. I am, however, aware of no objective evidence supporting either their opinion or my own. Ordinarily, the differentiating of truth from error is all we can do in forensic science. Determining if error is a result of ignorance, self-deception, or fraud is most often impossible. It is hoped that our presentation and analysis of strong confirmatory evidence beyond that presented in court in the Clegg case will help the prosecution's experts to see though their cloud of self deception. It should clear up their nagging doubts and ease the pain of defeat. It is meant to educate rather than further embarrass them.

For comments on the FN P-90 see the editorial note following the article.

The study on fragmentation and deformation of the M 855 bullet was used recently in the case US v Manion, tried in a US Marine Court Martial. The prosecution claimed a Marine was shot and killed (during a live fire exercise) by an M 855 bullet fired from 300 to 350 yards. X-rays taken at autopsy showed a fragmentation pattern consistent with shots from less than 150 yards as shown by our study. The prosecution's expert shot through gelatin blocks at various distances and took X-rays of his blocks rather than collecting the bullets and fragments. His X-rays actually showed results similar to ours – but he misinterpreted them. He had done shots at 100 yards, showing the M 855 bullet breaking at the cannelure, with the jacket behind the break remaining intact -- as in 3 of 4 of our shots at 150 yards. This complemented our results; and gave me evidence to opine that the shot that killed the Marine came from less than 100 yards. Major Manion was found not guilty.

We have had several communications from readers requesting publication of wound profiles because of their usefulness in illustrating the basics of wound ballistics. We have decided to do this by publishing several Institute Reports from the Letterman Army Institute of Research. These reports use wound profiles to illustrate the fundamentals of wound ballistics. We hope these will provide the information desired, help our readers review the basics of wound ballistics, and provide reference material for them to help educate their confreres. The first of these Institute Reports is included in this issue, beginning on page 39.

Reader Reviews:

Todd Moldower, an Orthopedic surgeon IWBA member sent us a copy of a recent wound ballistics paper from an orthopedic journal. Dr. Moldower's not only recognized the article as riddled with fallacy, but identified the reason. The authors had been seriously misled by the papers of Ordog et al.; which they cited 26 times. As our readers will recall, we not only exposed Ordog's errors and misconceptions, but tried, in vain, to get those papers retracted (Wound Ballistics Rev 1997;3[1]:36-42). But the system didn't work: Martin Luther King, Jr./Drew Medical Center failed to request the retraction of Ordog's papers. Thus this flawed work remained in the literature to mislead the unwary. Dr. Moldower and I collaborated on a letter to the editor who published the recent faulty paper. We will give a follow up on this in the Autumn 2000 issue.

We encourage our readers to follow Dr. Moldawer's example and identify wound ballistics errors in the scientific literature they read. The IWBA needs the help of its members to uphold its Statement of Purpose by following Dr. Moldower's example. If readers wish help in correcting errors they have identified we will be happy to collaborate on a letter to the editor as we have with Dr. Moldower.

Diallo Case:

Two members of the IWBA Board of Directors, Richard Mason and myself, served as the scientific experts for the defense. We pointed out to the jury that the angles of the bullet paths, as shown at autopsy, did not permit Mr. Diallo to be flat on his back while most of the bullets were fired – as claimed by the prosecution. The news media grudgingly reported the verdict -- not guilty on all charges for all of the officers. The media, however, "forgot" to mention that it was clearly shown that Mr. Diallo was standing, and still an apparent threat, rather than flat on his back and defenseless, for most of the shots. This oversight was pointed out to the *New York Times*, yet they failed to correct their distorted reporting of the case.

QUESTIONS AND COMMENTS

Questions and Comments

Note: Questions to the IWBA office are given a timely personal response. Some of these questions that are considered to be of general interest are included in this format for all members.

Credit Cards

We have occasionally received requests from members relative to making payments by credit card, and would like ourselves to have this capability for foreign members because non-USA checks cause us a lot of trouble and expense. We have investigated our options on accepting credit cards from time to time, but always found set up too expensive to be practical. However, we have now found a legal but circuitous approach that allows us to incur only costs per transaction. Although these costs are higher than typical, we can now offer a credit card payment option to those who want this option enough to make up the added costs we incur.

For members inside the USA, payment by credit card will incur a fee of $4.00 per payment, and we must add this cost as a surcharge on this form of payment.

For members outside the USA, we can no longer accept payment by foreign check, and will accept credit card payments without any associated surcharge.

This will provide a convenience to domestic members, lessen the inconvenience to our foreign members having to obtain a check in USA dollars drawn from a USA bank, and solve the problem we have with our bank.

Question

Dear Dr. Fackler,

I hope all is well with you, I am writing with a rather unique request that only someone in your position can help us out with.

As you know, we have been training police snipers for the last seven years. One of the things we have been stressing in all of our classes is the fallacy of the so-called "medulla shot" so many sniper schools have taught in the past. We have been educating snipers about the cranial vault, and crediting you as the medical authority on which we base our teaching.

I am writing to see if you could help us by providing us with a short, written explanation of the dynamics behind the cranial vault shot which we can use as a class handout. I would also like to know if you can provide us with a side view photograph of a brain and skull, showing in life-size scale, the cranial vault and the brain stem, to be used as an overhead slide in class. Any other materials you can provide us to help in teaching about proper shot placement for immediate incapacitation shots would be a big plus.

For your interest, I know you have long tried in vain to get Federal to redesign their .308 BTHP bullets for snipers. There is a company in California, Weapons Unlimited, which has taken your advice and made modifications to the basic .308 bullet, and selling it as their Hostage Rescue Cartridge. They pretty much guarantee the bullet will not over penetrate a human target. If you are unaware of them, you might want to contact Jeff Semko at (310) 543-5112, to obtain test samples.

Thanks for your assistance in this matter. If I can ever return the favor, don't hesitate to contact me.

Respectfully, Derrick D. Bartlett

Response

Dear Derrick,

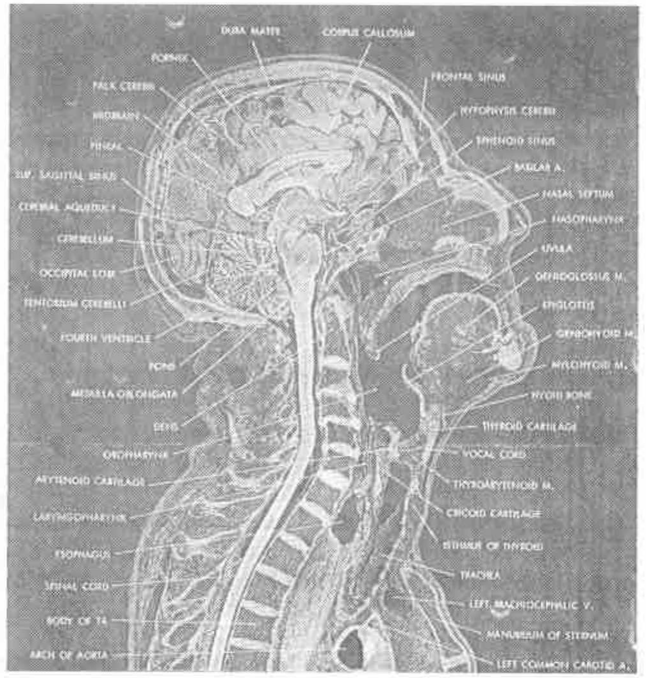
Thanks for your letter. I am glad that you have seen fit to include, in your training, the debunking of the "medulla shot fallacy" that I presented at your SWAT/Sniper Seminar at Ft. Lauderdale in 1995. I have enclosed a copy of the cross section of the brain that I used, during my presentation, to expose that fallacy. Below I have explained the dynamics of the cranial vault shot, as you requested.

THE MEDULLA SHOT FALLACY

The medulla oblongata is essentially the upper end of the spinal cord; the part that enters the brain. As the spinal cord goes into the cranial vault (the rounded encasement of bone which surrounds and protects the brain) through the foramen magnum it becomes the medulla. The foramen magnum, an oblong hole about an inch in its longest diameter, is the only large hole in the cranial vault. The nerve impulses that activate muscles of the torso and the extremities pass through the medulla and the spinal cord. Disrupting either the medulla, which is inside the cranial vault, or the spinal cord high in the neck, would certainly cause instant incapacitation.

The medulla shot fallacy is the false concept that to cause immediate incapacitation it is necessary for a bullet to strike the medulla itself. Fortunately, this is wrong: to cause immediate incapacitation with certainty the sniper's rifle bullet must penetrate the cranial vault. I say "fortunately" because the medulla is a one-inch target, whereas the cranial vault is a five-inch target.

As a sniper's rifle bullet breaks into the cranial vault and penetrates the brain, it causes the brain tissue to be displaced, away from the projectile path, in forming a temporary cavity. Whereas loops of bowel in the easily expandable abdominal cavity might be displaced up to several inches by the temporary cavity without appreciable damage, the hard and inflexible cranial vault cannot expand in response to the pressures produced by the temporary cavity. Therefore, the pressure inside the cranial vault rises sharply. The force of this confined pressure often fractures the skull, and sometimes splits the scalp, causing considerable amounts of brain and bone to be expelled from the wound (recall the Zapruder film of the JFK assassination – considerable brain was lost).



A pressure rise in a confined fluid-or-body-tissue-filled space is transmitted to all parts of that space, as in a hydraulic system. As the temporary cavity pressure increases inside the cranial vault it pushes the brain against the inside of the skull. The medulla, however, is just inside of a hole -- the foramen magnum. Thus it gets wedged into the foramen magnum by the suddenly increased intracranial pressure and gets compressed by the unyielding walls of the foramen. This compression and displacement of the medulla causes an immediate interruption of all nerve impulses from the brain to the spinal cord. No trigger will get squeezed; no muscle will function in the torso or extremities after the sniper's bullet penetrates the cranial vault.

I have also seen a variant of the medulla shot fallacy, which suggests, as a method of causing instant incapacitation, disrupting the motor cortex of the brain; where the impulses for voluntary movement begin. The motor cortex is a strip on the surface of the brain about a half-inch wide and about three inches long. It starts near the ear canal and ends at the top of the head, running roughly upward and curving front-to-back. With this variant, however, there is a confounding factor. There are two motor cortex strips, one on each side – *and the nerve impulses which control the muscles on the right side of the body come from the strip on the left side of the brain, while those controlling the left side of the body start in the strip on the right side of the brain.*

The medulla shot fallacy, and its motor cortex variant, are examples of the harmful misinformation promulgated by certain gun writers who seek to impress their readers by dabbling in fields they don't understand: anatomy, physiology, surgery, even law. The nonsense disseminated by these self-promoting unscrupulous exploiters of the eternally gullible gets people killed. Beware, be wise – be skeptical.

THE 30 CALIBER SIERRA MATCHKING BULLET

During the discussions at your training seminar in 1995, numerous verifications of the Matchking's erratic performance in human and animal tissue were recounted by those present. Since that time, in my forensic practice, I have had several additional cases in which the Matchking acted as an FMJ bullet in the human torso. One was a shot through the heart in which the minimal damage it caused was sufficient – and in the others no disaster occurred. A disaster with that bullet did occur, however, with the first shot by the FBI sniper at Ruby Ridge, Idaho, in August 1992. The 30 caliber Matchking perforated four inches of soft tissue in Randy Weaver's torso, producing only a small punctuate entrance and exit, and causing no incapacitation whatsoever. Had that bullet deformed and fragmented (as 30 cal Matchkings do when the hole in their tip is 0.055 or larger), it would certainly have caused much more disruption, possibly incapacitating Weaver and making the second shot, *which killed Mrs. Weaver*, unnecessary. Few seemed to have noticed that particular failure of the Matchking bullet. Most were more interested in blaming the FBI and the sniper, rather than putting blame where it belonged -- on the inadequate performance of the Matchking bullet.

The potential for disaster with that bullet – *the totally unnecessary and preventable potential for disaster – continues*. Apparently neither you, myself, nor anybody else, will get any of the large manufacturers to order large-hole 30 caliber Matchkings from Sierra and load them for law enforcement snipers *so long as the tactical shooter users want the hole small.* The smaller hole gives a slight improvement in ballistic coefficient – of insignificant consequence – while it *destroys the reliability of the Matchking's performance in the human target.*

As one might expect, small bullet manufacturers are moving in with new bullet designs to cash in on a problem that was inadvertently created by tactical shooters – and persists because of their apparent lack of interest in anything but group size. Tactical shooters cannot be expected to possess sufficient knowledge of human anatomy, physiology, and pathology to be experts in wound ballistics. One would hope, however, that they might have the good sense to pay attention when those of us who do possess this expertise when we try to help them. *Sierra will make Matchking bullets with any size hole. It is just a matter of educating enough tactical shooters to demand that their administrators order Matchking bullets with 0.055" or larger holes.*

Personally, I find it disturbing that the marketing of the major bullet manufacturers is apparently driven completely by customer demand: if law enforcement snipers want inadequate bullets, the manufacturers will sell them inadequate bullets. These manufacturers use ordnance gelatin for testing. How could any of them *not* know that the 30 caliber Matchking's performance in the human target is erratic? At least one of them, apparently attempting to avoid responsibility for any future Matchking disasters, hides behind the subterfuge that they market the bullet for accuracy alone. When that disaster comes, it will be interesting to see if these manufacturers will stand up in court and try to protect the contents of their "deep pockets" by claiming they did not suspect that any of their customers might use Matchking bullets against the human target.

Sincerely, Martin L. Fackler

Handgun ammunition Effectiveness

Question

After considering your response to my question on .380 and .32 ammunition, I decided to carry a .40S&W Glock Model 27 pistol with Speer Gold Dot ammunition to have acceptable wounding effectiveness if its use becomes necessary. This pistol has a 3.46-inch barrel length, which appears to be more than an inch less than "standard pistol barrel length". My current questions are about ammunition for this pistol.

The IWBA Handgun Ammunition Specification Supplement states (in 3.2a) that the suggested mean bullet weight range minimum and maximum desired is 177 and 182 grains for .40 S&W, and that these suggested values are compatible with the belief (based on the dynamics of penetration) that handgun bullets should be near the conventional maximum value for the caliber in standard barrel lengths for best wounding effectiveness.

I currently carry the 180-grain Speer Gold Dot ammunition. Would the 165-grain or the 155 grain .40 S&W Speer Gold Dot ammunition produce significantly better wounding effectiveness when fired from my shorter barreled pistol? I recognize that my need to carry a shorter barreled pistol will cause some unavoidable loss of wounding effectiveness, but I want to use the ammunition that will minimize this loss.

I would appreciate any advice you can give me on this matter.

Carson L. Owen

Response

Reference 1 gives an extended discussion of the effect of bullet parameters on the volume of the permanent wound cavity. In summary, heavier JHP bullets (in any selected caliber) create a larger permanent wound cavity volume if the constraint of maintaining an adequate penetration is imposed. This is a good thing to know (and the fans of light, high velocity bullets are universally not aware of it), but it is not the only consideration in ammunition selection. Note that this does not say that the wound trauma created as measured by the volume of the permanent wound cavity is inadequate for lighter bullets. In particular, the effectiveness of a 147-grain JHP bullet in .40 S&W should be the same, as a 147-grain JHP 9mm bullet if both are designed to give the same expansion and penetration, and this performance level is usually considered adequate.

The most important attribute of JHP handgun ammunition is reliable expansion that achieves a desirable penetration depth (e.g., 12 to 15 inches) in the presence and absence of soft barriers (i.e., heavy clothing). The denim test in the IWBA Handgun Ammunition Specification is designed to test for this much more rigorously than most "heavy clothing" tests. Some shooting scenarios involving hard barriers are important for law enforcement; the FBI Ammunition Test Protocol emphasizes hard barriers. When initiated in 1990, this FBI Protocol was an important driver in the great improvement in handgun ammunition in the early 1990s, but in my view is now impeding progress through over emphasis on hard barriers.[2] All ammunition manufacturers interested in the law enforcement market design JHP ammunition to "meet" the FBI Protocol, which inevitably compromises soft barrier expansion.

Tests of .40S&W ammunition that pass the IWBA Handgun Ammunition Specification in standard barrel lengths are reported in Reference 2. Informal tests were run for the 155 grain and 165 grain Gold Dot ammunition during that time period; the design of these lighter bullets was clearly not nearly as robust as the 180 grain Gold Dot because they did not expand reliably through the denim despite their somewhat higher velocity. The bottom line is that higher velocity is not an adequate substitute for good bullet design.

The problem with short-barreled handguns is that the bullet velocity is reduced below "standard", and requiring appropriate expansion over a range of velocities is a serious engineering challenge in JHP bullet design. The best engineering solution for short barreled handgun ammunition would be special short barreled handgun ammunition designed for robust expansion in the absence of hard barriers; this could be done, but the manufacturers do not think the limited market would justify the development costs. The market is limited primarily because considerable sophistication in wound ballistics knowledge is required to understand the advantages, and this market segment is a very small part of the total.

The second best engineering solution for short-barreled handgun ammunition is a JHP bullet whose design is so robust that it expands satisfactorily over a very wide range of bullet velocities. The only JHP handgun bullet I know of with this potential is the Winchester Partition Gold; I have some of this in .40S&W, but have not had a chance to test it to verify the Winchester engineer's claims. In any case, this wouldn't help you because this is a "law enforcement only" round not available on the commercial market.

I think the best choice for you in commercially available ammunition is what you are now carrying. The 180-grain Gold Dot does pass the IWBA Handgun Ammunition Specification in standard barrels, and will very likely give acceptable expansion in bare gelatin in your pistol. Heavy clothing is less of a concern in your area than in many parts of the country, and this helps you. I haven't run any tests, but I think that the 180-grain Gold Dot is unlikely to pass the denim test in the IWBA Handgun Ammunition Specification in your pistol. However, this is a much more rigorous test (it was designed to be) than most ordinary clothing.

You can determine the maximum expansion in your pistol by shooting into a couple of feet of water and catching the bullet (which will be traveling 100 ft/sec or so) when it exits in layers of cardboard or cloth. Hold the water in a trash bag or the equivalent, not in a container made of hard material.

Note that the expansion in bare gelatin or bare tissue will not be greater than obtained in this water test, but for well designed bullets (including the 180 grain Gold Dot) expansion usually isn't substantially smaller.

JHP bullet performance in shorter than standard barrels is of considerable interest to law enforcement for backup guns, and I have participated in some law enforcement ammunition tests to this end. If anything worthwhile comes out of this, it will be reported in future issues of the *Wound Ballistics Review.*

References

1. MacPherson, Duncan, *Bullet Penetration - Modeling the Dynamics and the Incapacitation Resulting from Wound Trauma*, Ballistic Publications, El Segundo, CA, 1999, pages 278-285
2. MacPherson, Duncan, *Improved Handgun Ammunition*, *Wound Ballistics Review*, 1998;3(3):12-21

Shotgun Lethality

Question

I need some help with a case that is going to trial.

On October 3, 1998, at approximately 0300 hours, two individuals sneaked up on an outdoor marijuana grow to steal the plants. Barking dogs alerted the property owner. He exited his residence and fired several rounds at the two individuals using a Winchester Model 1300 Defender 12 gauge shotgun with an 18" barrel and cylinder choke. The ammunition used was Remington Nitro-Steel High Velocity Magnum Loads, 2 $^3/_4$", with Number 1 Galvanized Steel Shot. I have included a specification sheet that I obtained from Remington's Web Site for the ammunition used.

Victim #1 was struck with ten pellets from a distance of approximately 25 yards. The pellets struck the victim's right hand, back of the right arm, lower right back, and right buttock. One pellet penetrated the right lung. Victim #2 was struck in the right hip from a distance of approximately 40 yards. The pellet did not penetrate the skin.

The prosecutor in the case has no knowledge of firearms or wound ballistics and came to me for help. I am very knowledgeable on firearms, but not wound ballistics, so I thought you might be able to help. The main question the prosecutor has is this: Could this weapon/ammunition combination have caused great bodily injury or death at a distance of 25 yards? 40 yards? The prosecutor would also like to know the velocity of the shot at 25 and 40 yards and any other information that might be pertinent to the case.

Robert W. Anderson
Chief Civil Deputy Sheriff, Washington Co.

Response

You probably looked for shot velocity at range in manufacturer's literature without success; one reason for this reticence is the fact that almost all available tables of shot velocity at range are wrong. There are a variety of reasons for this situation that are related to technical complexities and testing limitations in the past. I used modern engineering and test results to generate a computer program to model shot velocities accurately for my personal use some time ago, and I have used this to calculate velocities for the load you are interested in. The #1 steel shot with a muzzle velocity of 1275 ft/sec has residual velocities of about 840 and 700 ft/sec at 25 and 40 yards, respectively. These theoretical velocities are rounded to the nearest 5 ft/sec. As you undoubtedly know, the ammunition manufacturer's claimed muzzle velocity is not always achieved; and the 18 inch barrel will also produce slightly less velocity than the test barrel used by the ammunition manufacturer. The combined effects of these uncertainties will lower the velocities by less than 20 ft/sec at the ranges of interest. These effects are offset by drag reduction from "drafting" of the shot when it is clustered near the muzzle. There is also a shot-to-shot variation in muzzle velocity, but this effect is much reduced at the ranges of interest. The bottom line is that the velocity values on the shots actually fired in your case are almost certainly within 25 ft/sec of the values given above; i.e., indistinguishably close for wound ballistics purposes.

The penetration model for projectile penetration that is described in my book was used to calculate penetration in typical soft tissue for the #1 shot at the calculated velocities. The depths are 4.5 inches at 25 yards (840 ft/sec) and 3.7 inches at 40 yards (700 ft/sec). These penetration depths are comparable to depths of BB penetration with modern air rifles (3.4 inches at 600 ft/sec); note that this is not the spring "BB gun". Note also that lungs are not typical soft tissue; lung tissue is not as dense as typical tissue (which is about as dense as water), and penetration depth in lungs in much greater as a result. The presence of heavy clothing or other barriers can prevent penetration; the depths referred to are for shot contact with bare skin. However, if the clothing is penetrated, the penetration depth in the underlying tissue is usually not reduced very much by the presence of the clothing. This may seem strange, but is a result of the dynamics of barrier penetration.

The term "great bodily injury" may have a specific legal meaning, but "death" seems unambiguous. The #1 shot in this case (or equivalently, the BBs fired in air rifles) are not usually considered lethal projectiles; in fact, the BB air rifles are too often considered toys (possibly due to not recognizing the difference from the spring powered "BB guns"). The damage inflicted obviously depends on what tissues are hit; a hit in the eye can easily cause blindness. The question of whether these air guns can cause death is easily answered; they do cause a couple of deaths per year in the USA when the BBs strike in a location where their modest penetration depth is adequate to reach a vital body structure.

Duncan MacPherson

IWBA

THE LEE CLEGG CASE: A STUDY IN SELF DECEPTION

Martin Fackler, MD

...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. 342-3)

Abstract

PURPOSE – To describe and document what happens when expert witness minds apparently become closed to contradictory evidence -- and fail to observe the basic tenets of the scientific method - in trying to support preconceived opinions.

METHOD – The case will be described, and physical findings analyzed. This will show the nature of the evidence confirming that the bullet recovered from of Karen Reilly's body came through the left-rear-side door of the car, rather than from the back of the car as claimed by the prosecution. Physical evidence will be analyzed and synopses of expert witness testimony provided.

RESULTS – The lack of a flattened area on the FMJ bullet removed from the deceased proved it could not be the bullet that perforated the sheet steel of the automobile's rear seat-back, which struck the steel in a predominantly side-on position. The prosecution apparently attempted to direct attention away from that fact by presenting a mass of confusing, convoluted, and seriously flawed, experiments. When properly analyzed, much of the data presented by the prosecution actually quite strongly supported the defense case. In addition to the lack of flattening on the bullet recovered from Karen Reilly's body, neither the asymmetric pushing back of the bullet's jacket around its penetrator, nor the front-to-back scraping on one side of the bullet's jacket could have been caused by the forces generated if the bullet had come through the back of the car.

CONCLUSION – The court appeared to praise the prosecution's case, apparently in an attempt to appease public opinion; but, in the final analysis, acquitted Lee Clegg of the murder of Karen Reilly for the stated reason that the prosecution had not proved its case. It is hoped, however, that perceptive readers will conclude for themselves that the analysis of physical evidence presented below demonstrates that the evidence **against the prosecution** was, in fact, "beyond a reasonable doubt."

Introduction

The above citation by Richard Feynman also headed the article on the Monica Dunn case that we published in 1996.[1] These two cases have many similarities: they were both high-profile cases; in both cases, prosecution expert witnesses made glaring errors, and persistently stuck to those errors despite substantial relevant and significant contradictory evidence. I believe that, in both cases, had the experts been aware of Feynman's caution about self delusion; had they consciously forced themselves to look in the mirror and ask "could it be that my ego has overcome my rational thought? And that my desire to avoid being shown wrong has clouded my regard for scientific method?" – perhaps then they could have avoided falling into the trap of fooling themselves into isolating their preconceived opinions from contradictory facts.

I also believe that the errors and false impressions presented by those experts were most likely contrived at a subconscious level: they probably actually believed what they were presenting was valid and correct. The standard for evaluation of new medicaments is the double blind study in which neither the subject nor the person administering the treatment knows if the treatment is the medicament or a placebo. This is precisely to avoid the well-recognized self-deception of believing what we wish to believe, regardless of contradictory facts.

My increasing experience in forensic science has taken me from a gnawing concern to an increasing conviction that being misled by one's beliefs, and then insulating these false beliefs from any evidence that challenges them, is widespread among forensic experts. My prior experience as a clinical surgeon and as a research scientist also revealed, to a lesser extent, the same problem in those fields. Yet Richard Feynman is almost alone in bringing this problem of "fooling yourself" to the attention of the scientific community. Everyone who has anything to do with scientific endeavors, such as evaluating evidence, needs to read the entire chapter, "Cargo Cult Science," from which Feynman's caution against self-delusion is taken. Then, they need to put "AM I FOOLING MYSELF ?" on a checklist as a reminder. It is easy to forget something. It is much easier when the something forgotten challenges beliefs. Pilots routinely use a checklist with such things as "put landing gear down prior to landing." If they forget to use the checklist disasters occur. Similar disasters appear to occur in forensic science, especially in high-profile cases; or those in which experts have allowed their emotions to blind them to contradictory evidence – to overwhelm their regard for the basic tenets of the scientific method.

The analysis of evidence and expert testimony from this case was done out of a sense of duty to science. If those of us, who have the capacity to do so, fail to provide such analyses and thereby allow serious errors to go uncorrected, forensic science will degenerate. We must learn from our mistakes, we must educate ourselves to help those who err by suggesting to them possible reasons for their misinterpretations. We should all perform a cool, dispassionate, retrospective analysis of our forensic opinions. Only in that way can we teach ourselves to recognize the possible fallacy in what we have opined and to avoid self-deception in the future.

The Shooting Incident

On 30 September, 1990, Private Lee William Clegg, of the third battalion of the British Parachute Regiment was one of a group of soldiers patrolling a Vehicle Check Point on the Glen Road, Belfast, Northern Ireland. A stolen Vauxhall Astra automobile, containing a driver and two passengers, sped through the checkpoint and was fired upon by members of the patrol. Karen Reilly, the sole passenger in the rear seat of the car, was struck by one bullet, which was recovered from her body at autopsy. Another bullet that perforated her body was never found. Also, a third bullet (or part of one) that probably was retained in her body was never recovered. Bullets, or pieces of bullets, were able to remain in her body undetected because, astonishingly and regrettably, no X-rays were taken of her body as a part of the autopsy.

The bullet recovered from Reilly's body was matched to the rifle of Private Clegg. The bullets used by the soldiers were the British L2A2, which are similar to the American M-855 bullets in all respects except that the L2A2 has a jacket about 0.002 inch thicker than the jacket of the M-855. This makes the L2A2 bullet less likely to fragment in penetrating the human body.

There was an oblong hole, about 0.75 inches in length, and about 0.24 inches in width, in the 0.030-inch thick sheet metal back of the rear seat (Fig 1). The bullet that made that hole (designated as hole 4) traveled from back-to-front, and horizontally, up the middle of the car (Fig 2). Karen Reilly had a transversely oriented oblong hole (27 X 22 mm or 1.06 X 0.87") in the right side of the upper portion of her posterior chest wall (Figs 3, 4). That was the entrance hole of the bullet that was matched to Private Clegg's rifle. The police investigation concluded that the bullet that perforated the seat back (hole 4) was the bullet that produced the large hole in Reilly's back. They reasoned that such a shot through the back of the car was a crime since the car could no longer have been a threat when such a shot was fired. The shots fired at the side and at the front of the car were considered legally justified.

Another hole (designated as hole 8) entered the back seat area of the car through the front part of the left rear door, below the window frame, where it passed through a plastic ashtray. The bullet that made hole 8 traveled from front-to-back, left-to-right (55° angle of incidence), and downward about 14° (Fig 2). Experts on both sides of the case accepted as fact that the bullet that made hole 8 must have struck Karen Reilly.

Original Trial

Private Clegg was convicted of murder, on 4 June 1993, at the Belfast Crown Court, primarily on the testimony of a firearms examiner from the Belfast Criminalistics Laboratory. He testified, unequivocally, that a bullet passing through hole 8 could not have yawed sufficiently in the space available to strike Reilly with the large degree of yaw obvious from the oblong hole of entry in her back (see Figs. 3, 4). Therefore, he concluded that the bullet that made the oblong hole in her back must have come through the back of the car (hole 4). He also testified that the bullet that made the three mm hole, to the right of the large oblong hole, had come through hole 8. He reached these conclusions, astonishingly, without the benefit of any firing tests. Even more astonishingly, the defense team did not challenge his unsupported speculation on yaw angles: it was, thus, allowed to pass as valid evidence.

A Professor of Military Surgery, called by the defense, failed to analyze the bullet impacts, missing the crux of the case. He fell into the same pattern of testimony as the other experts in the case – giving opinions without any supporting evidence. His repeated use of "kinetic energy transfer," rather than describing the mechanical bullet interactions with car parts and body tissue, obscured the critical issues of the case. He opined that Karen Reilly was killed by some mysterious "energy transfer" from the bullet through the lung tissue to the heart, despite the fact that the bullet did not pass within 10 cm (4") of the heart. This was described as "a fanciful suggestion" by the prosecution. That description is difficult to dispute.

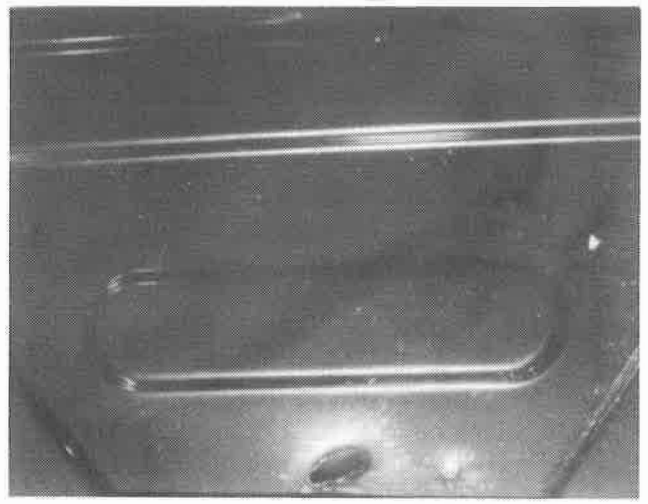


FIG 1 - Oblong hole in the steel sheet metal of the back of the rear seat

FIG 2 - Rods through hole 4 and hole 8. Hole 4 is indicated by the horizontal rod through the rear seat back Hole 8 is indicated by the rod angling downward, backward, and left-to-right, passing through the ashtray in the left rear door.

Two Appeals Dismissed

Private Clegg appealed his conviction to Her Majesty's Court of Appeal in Northern Ireland and this appeal was dismissed on 30 May 1994.

He then appealed to the House of Lords on 19 January 1995, and that appeal was also dismissed.

Simon Mckay Enters Case

Mr. Simon McKay, a Solicitor, and a friend of Private Clegg's parents then took over the case. He hired Dr. Graham D. Renshaw, an independent firearms examiner and scientist with a PhD degree in Physical Chemistry, to review the case. Dr. Renshaw recognized the weaknesses of the trial testimony unsupported by the necessary shooting tests. He did shooting tests using a Vauxall Astra automobile, and replicated holes 4 and 8 in the car body. He used paper "witness" cards to determine the yaw behavior of these bullets and caught the bullets in cotton (which does not deform the bullet in the process of stopping it).

Dr. Renshaw's tests showed that five of the six bullets fired through the hole 4 position that struck the steel seat back in a sideways (near maximum yaw) position fragmented. But all showed a flattened area (with flattened rifling marks) on their circumference where they had struck the steel seat back. The Clegg bullet, recovered from Karen Reilly, however, showed no area around its circumference where the rifling was flattened (Figs 6, 7). Dr. Renshaw also showed that bullets perforating the car through the hole 8 position "struck the witness card in a side-on orientation." This definitively proved the fallacy in the pivotal testimony given by the firearms examiner in the first trial.

From these tests, Dr. Renshaw concluded that the bullet recovered from Karen Reilly's body could not have come through hole 4. He concluded that it had entered the car through hole 8.

Mr. McKay presented Dr. Renshaw's report to the Secretary of State, who sent it to an independent laboratory, the Strathclyde Police Forensic Scientific Laboratory, in Scotland. The Strathclyde laboratory duplicated Dr. Renshaw's findings and came to the same conclusions. Due to this new evidence, the Secretary of State ordered a new appeal.

Faced with Dr. Renshaw's results, and Strathclyde's verification of them, the prosecution hired a firearms examiner from outside the Northern Ireland Forensic Laboratory in an apparent attempt to prop up a rapidly disintegrating case.

Defense Wins Appeal

The defense presented its appeal to Her Majesty's Court of Appeal in Northern Ireland, before three judges, from November 1997 to early 1998.

Defense Scenario

In light of Dr. Renshaw's evidence showing that the bullet recovered from Karen Reilly could not have come through hole 4, the defense suggested the following scenario of the shooting incident:

- Karen Reilly was sitting near the middle of the back seat when she heard the shooting begin. She threw her upper torso, face down, across the left side of the rear seat, angled forward, toward the back door, with her upper torso somewhat raised – probably she had her arms on the seat under her upper torso. In this *quite natural position* she was struck by a bullet from Clegg's rifle, which came through hole 8 in the back passenger side door (Fig 2). This bullet (Figs 3, 4) traveled in a sharp downward angle in her body as shown in figure 5.
- Startled by the bullet strike, she sprang to an upright position, turned her torso to face the right rear window, and moved somewhat toward that window. In that position she was struck by another bullet which came through the left rear window (which had been broken out previously), entering her back, making a minuscule three mm hole just to the right of the large hole (Figs 3, 4). That bullet perforated her torso making a near horizontal path and exiting her right breast. It then perforated the upper part of her right arm, where it fractured her humerus.
- She then collapsed from her upright sitting position, with her upper torso falling backward; face up, across the mid portion of the back seat. As she was falling, a bullet came through hole 4, most likely fragmented, and a part of the broken out

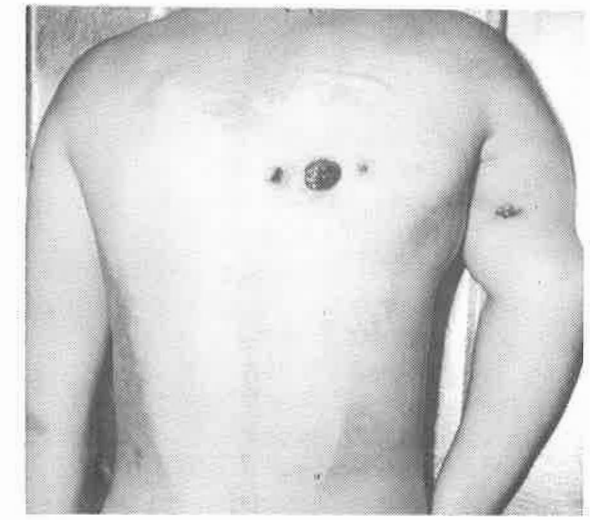


FIG 3 - Photograph of Karen Reilly's back

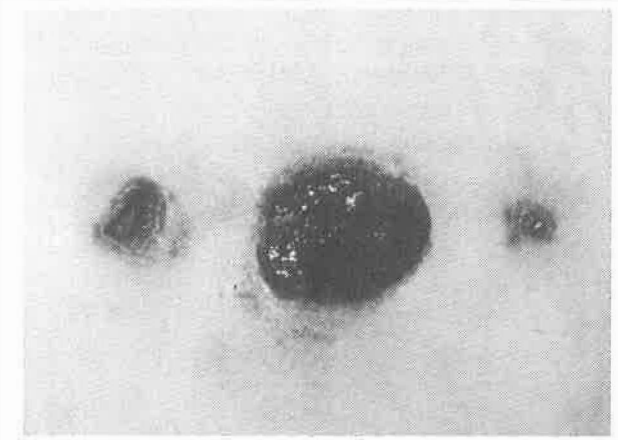


FIG 4
Close up photograph of holes in Karen Reilly's back

steel plug from hole 4 was found in another hole in her back, to the left of the large hole (Figs 3, 4). I think it is likely that the piece of the steel plug was carried into the wound by at least a part of the bullet that came through hole 4. That bullet, or part of it, probably remains in the body of Karen Reilly in the paraspinal musculature (to the left of the hole) or in the posterior part of the spinal column itself. *A bullet in this area would be unlikely to be found at an autopsy in which no X-rays were taken. Such a position would not allow it to be seen from the inside of the thoracic cavity when the lungs and heart were removed.*

Prosecution Scenario

At long last, the prosecution did some shooting tests, which confirmed Dr. Renshaw's tests. Faced with the problem of hole 4 bullets fragmenting, the prosecution changed their scenario: then claiming that Clegg had fired the hole 4 bullet from a distance of "approximately 490 feet" (150 meters). From that distance, hole 4 bullets lost enough velocity so that they were likely to remain intact after a sideways perforation of the seat back. *The prosecution then also pursued the unusual theory that such a velocity loss would allow a bullet to survive a sideways impact without flattening the rifling marks at the point of impact.* They produced a bullet from their tests that they claimed had intact rifling around its circumference. Defense experts had to visit the Belfast Criminalistics Laboratory to expose that claim as fallacious. The bullet the prosecution produced had perforated the seat back steel at an angle of only about half that needed to duplicate the length of the hole shown in figure 1. Also, contrary to prosecution claims, *that bullet did have an area on its circumference where the rifling was flattened.* It is difficult to imagine that any qualified firearms examiner could believe, considering the laws of physics, that a bullet which still retained enough velocity to break out an oblong piece of 0.030 inch thick steel, as shown in figure 1, could do so without flattening its rifling marks. Yet, that is what the prosecution falsely claimed had happened.

In addition to claiming the hole 4 shot came from a distance of 490 feet or more, the prosecution's scenario had the bullet that made the three mm hole in Karen Reilly's back (Figs 3, 4) coming through hole 8 in the rear passenger-side door. As supporting evidence, they claimed that the tiny piece of steel resting in the three mm hole (Fig 4) was a "cap" pushed out from the car body. That "cap" purportedly remained on the bullet's tip as it passed through the ashtray and had been carried into the hole by the bullet. In testifying for the defense. I pointed out that *no bullet which passed through the car door steel and ashtray and had its tip deformed, as all such bullets had in the shooting tests, could possibly have made an entrance hole anywhere near so small as three mm.* Additionally, I pointed out that *if the tiny "cap" had been carried into the three mm hole by the bullet that made the hole, it could not possibly have remained easily visible (Fig 4), essentially in the surface of the hole.* Details of those two points are discussed below. Additionally, the outside firearms examiner declared some very superficial narrow linear impressions on the Clegg bullet to be absolute proof that the Clegg bullet came through the back of the car. His misinterpretation of these impressions is discussed below.

The appeal was upheld, the conviction overturned, and a new trial was ordered.

The New Trial

The prosecution presented its case, before a single judge, in November and December of 1998. They essentially stuck to their scenario presented in the appeal. The pathologist who did Karen Reilly's autopsy testified, as he had in the appeal, in support of the prosecution's case. He added to his embarrassment over having done an inadequate autopsy on Karen Reilly, in failing to have X-ray films of her body taken, and failing to describe adequately the location where the Clegg bullet came to rest. He

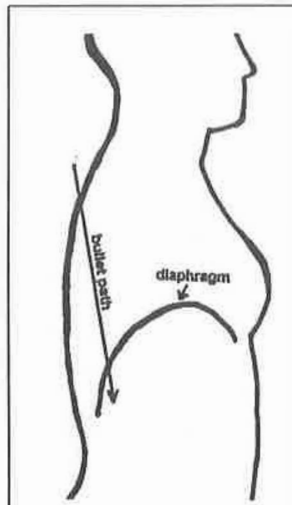


FIG 5
Drawing from my report, of 12 Oct 97, indicating downward angle of Cleg bullet in Karen Reilly's torso

FIG 6 - Clegg bullet side A (gouged and scraped side)

FIG 7 - Clegg bullet side B

claimed that he had to "dissect out" the steel "cap" lying in the surface of the three mm hole and that he had dissected to the bottom of the hole to the left of the large oblong hole (Fig 3, 4). He claimed he could establish with certainty that there were no foreign bodies that entered that hole other than the small piece of seat back steel he had removed from it. These fallacies are analyzed below.

The outside firearms examiner hired by the prosecution did numerous new tests, apparently attempting to divert attention from the effective points made by the defense in the appeal. Some of these are discussed below. I believe that our readers, after analyzing the various distortions of the Clegg bullet from the perspective of the directions of the forces necessary to cause those distortions, will agree that only the defense conclusion is rational. There are three undeniable proofs that the Clegg bullet came through the side of the car rather than the back, in addition to much physical evidence which contradicts the rest of the prosecution's case (analysis below).

cont.

The Critical Physical Evidence – The Clegg Bullet

PERSISTENCE OF RAISED RIFLING, CIRCUMFERENTIALLY, ON THE CLEGG BULLET

The rifling marks on the Clegg bullet (Figs 6, 7) extend around the entire circumference of the bullet at their rearward ends. To fully appreciate that these marks are, in fact, raised and not flattened one needs to feel them (the thumb nail is useful) or use magnification from an angle. The prosecution did not dispute that these raised rifling marks survived. Comparison of the length of an L2A2 bullet whose copper tip had been removed back to the steel penetrator (as seen in Figs 6, 7) with the 0.75-inch length of the hole in the steel seat back (measured from the scale in Fig 1), demonstrates that the bullet struck in a predominantly side-on position. Since the steel of the seat back is much harder than the copper of the bullet jacket, it is certain that any such impact would cause a flattened area along the entire impacting side of the bullet. *Such a flattening was confirmed by all of the shooting tests done in preparation for the last appeal and the second trial in this case. Since no such flattened area appeared on the Clegg bullet, it is certain that the Clegg bullet could not have come through the seat back.*

ASYMMETRIC PUSHING BACK OF THE CLEGG BULLET'S JACKET AROUND ITS PENETRATOR

The bullet that came through the back of the car perforated the car body about 30 inches behind the seat back. It struck the car body traveling point forward, with the path of the bullet essentially perpendicular to the surface of the car body where it struck, as shown by the round hole it made. The forces generated by this impact could only collapse the bullet's tip and push its copper jacket straight back -- symmetrically. That same bullet then yawed and perforated the seat back traveling nearly side-on. This second impact with steel, being predominantly against the side of the bullet, could not account for the asymmetrical front-to-back force needed to cause the asymmetrical pushback of the jacket on the Clegg bullet (Figs 6, 7). The Clegg bullet, therefore, could not have come through the back of the car. The asymmetrical front-to-back force necessary to produce the tip deformation seen on the Clegg bullet, however, is produced when a bullet traveling point forward passes through the car's body at a 55° angle of incidence – such as the bullet which passed through the car's rear passenger-side door. Bullets Dr. Renshaw tested that passed through the left rear door at the 55° angle of incidence, produced bullets with asymmetric push-back of the their jackets around their penetrators identical to that seen on the Clegg bullet.

TIP-TO-TAIL SCRAPING AND GOUGING ON THE CLEGG BULLET'S JACKET

The tip-to-tail direction of the scraping and gouging on the Clegg bullet (Fig 6) can have been caused only by a force acting from the tip of the bullet towards its tail. The direction of the force can be determined easily by examining the scraped and gouged surface: many small "heaped-up" areas of copper jacket material are seen at the tail ends of individual gouged grooves. An unmistakable, more than one mm wide, heaped-up mound of copper jacket material is seen at the lowermost extent of a large scraped area (shown in figure 6). Such tip-to-tail forces could not have been developed on a bullet striking the back seat in the predominantly sideways position necessary to cause the hole shown in figure 1. Such scraping and gouging were not produced in any of the shooting tests with perpendicular penetrations of car body type steel. Such deformation did occur regularly, however, in Dr. Renshaw's hole 8 tests, which passed, at a 55° angle of incidence, through the left rear door and the ashtray contained in that door.

Other Physical Evidence Supporting The Defense Case

LINEAR IMPRESSIONS ON THE CLEGG BULLET

Seen best in figure 7 (but also visible in figure 6, to the left of the gouged and scraped area) are multiple straight, largely parallel, very narrow impressions of uniform width, which extend about one-third of the way around the circumference of the Clegg bullet. These impressions make angles of from 60 to 70° with the long axis of the Clegg bullet.

Misinterpretation -- The outside firearms examiner apparently viewed these impressions as absolute proof that the Clegg bullet came through the back of the car. He theorized that the impressions resulted from "sandwiching" of the coarse fibers of the mat covering the seat back between the bullet and the steel seat back as the hole shown in figure 1 was made. Evidence against his theory includes:

- The uniform narrow width of the straight and largely parallel impressions are inconsistent with the widely varying thickness, the mostly curved configuration, and the scattered orientation of the fibers of the mat covering the seat back.
- If caused by "sandwiching," the impressions would have to be confined to one flattened strip on the bullet rather than curve, as they do, around one-third of the circumference of the bullet.
- *The impressions extend across intact non-flattened rifling marks on the Clegg bullet.* Any "sandwiching" mechanism would have flattened the rifling marks.

Rational Interpretation – When the forces necessary to account for the impressions are analyzed, it is clear that they could not have been formed by the fibers from the mat. The fact that *the impressions extended across rifling marks; and the rifling marks between the impressions were not altered at all is a critical consideration*:

- The straightness of the impressions and their extension one-third of the way around the curved circumference of the Clegg bullet, coupled with the lack of any change of the rifling marks between these parallel impressions, could be accounted for by the impressions being caused by strong fibers stretched around the bullet's surface and leaving their impressions before being broken by the bullet.
- At the time she was shot, Karen Reilly was wearing a nylon jacket, a nylon shirt, and a nylon undershirt. Nylon fibers are very strong: they were used to make soft body armor before kevlar was developed.
- The prosecution discounted this source of the impressions on the grounds that a cross weave print should have been made by the nylon material rather than just parallel impressions. Also, their outside firearms examiner had done a few shots through some pieces of nylon fabric and claimed to have produced no impressions.
- Overlooked by the prosecution, however, was the sharply downward path of the Clegg bullet as it struck Karen Reilly (within 20° of parallel to the surface of the nylon material perforated – Fig 5), and the significance of this angle to the production of impressions made by the material perforated. The bullet, traveling at 60° or more of yaw, made a transversely oriented oblong, 27 X 22 mm hole (Fig 4).
- Examination of partially flattened full-metal-jacketed handgun bullets recovered from a soft body armor test often shows a very revealing pattern of impressions on the bullet's jacket. In the center of the flattened tip of the bullet is an imprint of the weave: one set of threads runs at right angles to the other set. *On all four sides, however, just the parallel threads running from tip-to-tail mark the bullet.* The reason is clear: When a bullet, or part of a bullet, impacts a woven material nearly parallel to the surface of the fabric, only the fibers running in the direction of the bullet's path are put on stretch – as are the fibers on the four sides of the aforementioned bullet. And only those fibers put under tension apply the necessary localized force to make impressions on the bullet's jacket.
- After passing through hole 8, the Clegg bullet, then struck Karen Reilly after yawing to at least 60°. It struck her nylon clothing in a sharply downward angle, about 20° from parallel to the cloth's surface. As shown in the above example from soft body armor testing, the fibers put under stretch in such a bullet impact would be the ones parallel to the bullet's line of flight. The fibers put on stretch, and thus able to apply the sharply localized forces necessary to make impressions on the bullet, would make angles of 60° or more from the long axis of the Clegg bullet – which corresponds closely with the angles of the impressions found extending one-third of the way around the circumference of the Clegg bullet.

When all the facts are considered, and the

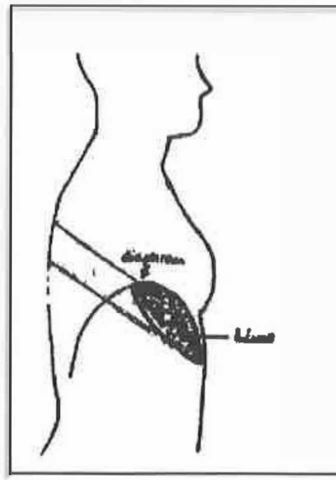


FIG 8
Prosecution pathologist's drawing showing right lobe of liver in just the anterior half of the upper abdomen

forces analyzed rationally, the nylon clothing of Karen Reilly appears to be an entirely reasonable source for the superficial impressions on the Clegg bullet.

THREE MM HOLE IN KAREN REILLEY'S BACK

The prosecution's scenario depended on the three mm hole in Karen Reilly's back (Fig 4) being made by the bullet that had first come through hole 8. As described above, test bullets that passed through the rear passenger-side door, at the 55° angle of incidence, produced bullets with asymmetric push-back of the their jackets around their penetrators. It is clear to those who understand the dynamics of bullet penetration in skin that the long, very streamlined bullet ogive and fine point on the L2A2 bullet can produce a hole of only half the bullet's diameter by stretching the skin slightly as it pushes it aside relatively gradually compared to a more blunt or deformed bullet tip. The skin, being somewhat elastic, then returns to its initial position after the bullet's passage. Only an undeformed L2A2 bullet, however, striking with essentially no yaw, could have produced the three mm hole. The shooting tests demonstrated that bullets fired through hole 8 almost invariably yawed to large angles – in 49 out of 50 shots. So there might be a one in 50 chance that a bullet through hole 8 could strike with essentially no yaw. There is *no chance,* however, that a bullet whose streamlining was deformed by having its penetrator uncovered by passing through hole 8 could have produced such a tiny hole.

The amount of disruption caused at skin level by a bullet traveling in the 2,000 ft/sec and above range is very dependent upon the shape of the bullet's tip. Small amounts of flattening or deformation decrease the bullet's streamlining and result in greatly increased tissue disruption by increasing the amount of temporary cavitation caused by the bullet. The temporary cavitation is nothing more than the same mechanism that causes the water to be pushed aside to form what we call a splash when we throw a pebble into a pond. This is a subject that has been studied extensively using sophisticated high speed imaging equipment[2].

In my testimony on appeal, I expressed the opinion that any L2A2 bullet that had passed through hole 8 would have its streamlined shape significantly disrupted as its tip was deformed, and, as a result of this decreased streamlining, would produce a permanent hole in the skin of 10 mm or larger diameter due to the increased temporary cavitation.

On 2 May 1998, I confirmed this opinion by shooting into a freshly killed 130-pound pig using M-855 bullets that I had modified to demonstrate the effect of disrupting the bullets' streamlining. Two M-855 bullets were modified by using a metal lathe to cut off the tip of the copper jacket so that 2 mm of the steel penetrator was exposed. The cut was made perpendicular to the long axis of the bullet. The weight of the removed tip of the bullets' jacket was 2.5 grains. The original M-855 cartridges contained 25.3 grains of powder. This was reduced to 23 grains before the modified bullets were reloaded, to lower bullet velocity below what would be expected for the retained velocity of a full power L2A2 bullet after perforating the car body and ashtray.

Each of the two bullets was fired into the outstretched left rear leg of the pig, perpendicular to the skin surface, striking the inside surface of the leg about two inches from where the leg joined the torso. The bullets struck about 1 ¾ inches apart. The velocities, recorded on an Oehler Model 35P chronograph, were 2,412, and 2,485 ft/sec. Each bullet produced a gaping hole in the pig's skin with a diameter of 9 mm. Additionally; one hole had a single 1 mm long radial split. This experiment was described, in sufficient detail to allow its reproduction, in my report of 30 August 1998.

The modification of the M-855 bullets in this experiment produced less disruption of the bullets' streamlining than was seen on the Clegg bullet or any other bullet that passed through the hole 8 position and the velocities were lower than what would be expected from hole 8 perforations. Despite this, 9 mm gaping holes were produced. *These results provide strong support for the assertion that the 3 mm hole in Karen Reilly could not have been made by any bullet that passed through hole 8.*

THE OVOID STEEL "CAP" IN THE SURFACE OF THE THREE MM HOLE IN KAREN REILLY'S BACK

The prosecution claimed this cap to have come from the tip of the bullet that caused the 3 mm hole (which they assert came through hole 8) and to have been carried into the three mm hole by that bullet which made the hole. The evidence against this point is formidable:

- A photograph taken at autopsy shows the edge of the ovoid cap visible in the center of the three mm hole. It could not, therefore, have been carried there on the tip of the bullet that made the hole. The prosecution addressed this point by claiming that the ovoid cap had somehow become detached from the bullet's tip, slid down the side of the bullet, and assumed a position on the bullet's base – apparently held there by the vacuum that occurs on the base of bullets in flight. This highly speculative claim, even if it could be supported, simply does not help the plight of the prosecution. It addresses only the most obvious problem presented by the ovoid cap's position in the center of the three mm hole, at skin level.
- If the ovoid cap arrived, as the prosecution claims, carried by the bullet that made the three mm hole, it would share the approximately 2,600-ft/sec velocity of the bullet that carried it. Newton's First Law of Motion (things in motion remain in motion unless acted upon by a force to stop the motion) simply does not allow a projectile possessing such a velocity to come to a sudden halt when striking flesh without penetrating a certain distance. It is undeniable that if the ovoid cap had been carried into the wound by the bullet that made the hole, it would have penetrated at least 1 cm, and certainly would not have been visible from the skin surface.
- The superficial position of the ovoid cap, verified by photograph, rather than providing evidence that the bullet that made the 3 mm hole came through hole 8, actually strongly supports the opposite proposition that *the cap could not have been carried to the position it came to rest by the bullet that made the 3 mm hole.*

The Prosecution's Expert Testimony

PATHOLOGIST WHO DID KAREN REILLY'S AUTOPSY

The autopsy of Karen Reilly was, in my opinion, incompletely recorded by any reasonable standard. The prosecution's pathologist described the Clegg bullet's path in the autopsy report only as "downwards and forwards" (which could mean anything from straight downward [vertical] to 1 degree below horizontal). He apparently took no photographs of the bullet holes in the inside of the rib cage, the diaphragm, or other internal organs, nor where the bullet came to rest. He included no scale on the photographs of the external wounds that he did take. He described the final bullet path and location where the Clegg bullet came to rest only as "The bullet had then passed through the right half of the liver lodging beneath it where it was recovered." Since the right lobe of the liver occupies the entire extent of the abdominal cavity from front to back and from the right abdominal wall to the midline, the prosecution's pathologist told us that the Clegg bullet was found somewhere in an area that measures about six by six inches. Such lack of precision in describing findings in a forensic autopsy is as astounding as the pathologist's failure to take X-rays of Karen Reilly's body before doing the autopsy.

Because of the lack of information that should have been provided by X-rays and an adequate description of the bullet's resting place, its downward angle had to be estimated by looking for clues elsewhere. The Clegg bullet fractured three adjacent ribs on entering the chest cavity. The prosecution's pathologist testified, at the final trial, that the bullet actually struck all three of these ribs (as opposed to one or more being broken by displacement from the temporary cavity generated by the bullet). He also testified, in the original trial, that "…the right half of this [the diaphragm] bore a hole *at the back*."(my emphasis). I used these two clues, as well as the downward angle from the entrance hole in the skin to the 5[th] through 7[th] ribs broken by the bullet, to establish the estimate of the bullet's path shown in figure 5. Interestingly, to support his testimony in the final trial, the prosecution's pathologist submitted to the court the diagram shown in figure 8. In his diagram, the right lobe of the liver is located entirely in the front half of the abdominal cavity. *Actually, the right lobe of the liver fills the entire right side of the abdominal cavity beneath the diaphragm.*

One might ask why the prosecution's pathologist would contradict his own previous testimony (in his diagram, the bullet does *not* go through the *back* of the diaphragm), and present to the court a diagram with such an embarrassingly distorted placement of the liver. Possibly because the sharply downward path of the Clegg bullet presents almost insurmountable difficulties for the prosecution. It makes nearly impossible lining up the torso of Karen Reilly so that the path of the bullet coming out of the rear seat back horizontally (Fig 2 – hole 4) would follow the sharply downward path in her torso. She would have to have her head bent sharply forward (chin on chest) with the back of her neck pressing against the back seat cushion and her buttocks wedged against the front seat back, or extending between the seat backs. Additionally, she would have had to attain this highly improbable position without the help of her right arm or hand: because (according to the prosecution's scenario) the bullet that came through the back of the car would have to have been shot *after* the bullet that fractured the bone of her right arm (this compound fracture of the humerus would have essentially inactivated her right arm). Thus the sharply downward angle of the bullet path in Karen

Reilly's torso argues strongly against the bullet removed at autopsy being the one that came through the back seat. Conversely, if Karen Reilly had thrown her torso across the back seat, prone, in a very natural position, with her upper torso resting upon her arms, head facing the left rear door, her torso would have been in a position that lines up well with the hole 8 bullet path that came through the left rear door -- the scenario proposed by the defense.

The prosecution pathologist's testimony on the steel "cap" resting in the three mm bullet hole (Fig 4) emphasized that it was "embedded" and that he "had to" remove it by dissection. I suggest that the photographs of this wound show the tiny piece of steel to be lying in the wound, clearly visible, no deeper than the dermis of the skin. I further suggest that the only instrument *needed* to remove it would have been a toothpick.

As a surgeon very experienced at following paths of projectiles in the body, I found the most misleading impression given by the prosecution pathologist was that by dissecting and removing the steel tab from the small wound on the left (Fig 4), he could tell, with certainty, that the wound path ended there -- and he could not have missed a continuation of the path into the paraspinal muscles, or into the spine itself, at the end of which might be a large bullet fragment or a whole bullet.

Most of the time a projectile path through tissue is difficult to follow; sometimes it is impossible to follow. One reason, especially applicable in the location of the path in question, is that when a projectile passes through two or more thin layers of muscle *the path remains continuous afterwards only so long as the position of the body part penetrated does not move.* When the part moves, layers of muscles slide over one another. This displaces the part of the projectile path in one muscle from the part in the contiguous muscle. Under the hole from which the steel tab was removed we find the thin sheet-like trapezius muscle, just deep to that we find another thin sheet of muscle, the rhomboideous major, under that there is the thoracolumbar fascia, a thin tough sheet of fibrous tissue covering the paraspinal muscles. When a path is at a sharp angle to the surface penetrated, the problem explained above is made worse. So the prosecution pathologist's apparent claims of perfection in following projectile paths, in my opinion, give an extremely misleading impression.

FIREARMS EXAMINER OF BELFAST FORENSIC LABORATORY

Probably the most pivotal evidence in the original trial was the testimony of the firearms examiner from the Northern Ireland Forensic Laboratory, located in Belfast, that the bullet which passed through hole 8 could not have yawed rapidly enough to strike Karen Reilly's back traveling nearly sideways, since it had produced an essentially round hole in the ashtray holder. This opinion was rendered without the support of any shooting tests. When confronted with Dr. Renshaw's tests, this firearms examiner reproduced the tests – and verified Dr. Renshaw's results. His own shooting tests conclusively proved his testimony in the original trial to be false.

OUTSIDE FIREARMS EXAMINER

Finding his theory demolished by undeniable facts, the outside firearms examiner apparently attempted to divert attention from the facts by presenting mountains of complex, confusing, and difficult-to-follow material. If confused by the evidence, perhaps the judge would decide for the most likable lawyers – or experts. The outside firearms examiner wrote numerous reports, made a videotape, and his testimony in court ran to more than 600 pages. Long-windedness appears to be a necessary bedfellow of obfuscation.

The voluminous reports and testimony of the outside firearms examiner alluded to, or partially described, many dozens of experimental shots. But he failed to include in his reports those experimental results, which did not support his theories. This was exposed on cross-examination and detracted seriously from his credibility – as it should have, since selective reporting of data is the antithesis of valid scientific method. Additionally, he failed to report sufficient details of his methodology to allow his experimental shots to be replicated – another serious violation of the scientific method.

The outside firearms examiner also failed to address directly Dr. Renshaw's experimental findings which formed the basis for the new appeal – the lack of flattening of rifling marks on the Clegg bullet compared with the constant, uniform flattening of rifling marks on all of the test bullets and pieces of test bullets that came sideways through the steel seat back in the hole 4 position. In his first report he did not even mention Dr. Renshaw's work. In his second, he wrote "This writer is ***un***able to account for Dr. Renshaw's observation that the bullets he fired…to simulate **Hole 4** resulted in the obliteration of land and groove impressions and/or bullet fragmentation." In that same report the outside firearms examiner showed sideways bullet perforations of a seat back, which approximated the yaw angle of the hole 4 bullet (photo's 28, 29, and 32). *He did not, however, include photos of any of those recovered bullets:* but wrote "These tests resulted in the recovery of bullets like that recovered from the decedent to include surviving land and groove impressions…." By contrast, his colleague, the firearms examiner from the Belfast lab, honestly reported (22 May 1997, p. 6) "My findings from this series of [hole 4] tests are in agreement with those of Doctor Renshaw." Unless the outside firearms examiner was able to repeal Newton's Laws of Motion, each of the three bullets which made the oblong holes shown in his photos 28, 29, and 32 had flattened rifling marks on the side which impacted the steel of the seat back. But he apparently concealed that information which would lend support to the defense case. Apparently, in law, the failure to produce evidence in one's control as an expert witness without adequate explanation is, itself, evidence *against* the opinion of the expert.

Neither the outside firearms examiner nor any other experimenter was able to reproduce, in any of the dozens of bullets fired through the hole 4 position, the narrow, uniform impressions as found on the Clegg bullet. *Reproducibility is the indispensable requisite for scientific evidence. Continuing to "believe in" evidence that cannot be reproduced violates fundamental scientific method.* The outside firearms examiner's persisting belief in unsubstantiated evidence contrasted sharply with his willingness to dismiss the possibility of Karen Reilly's clothing being the source of the uniform, linear impressions on the Clegg bullet. This dismissal was based on very scant evidence: "several" shots in an experiment which duplicated neither the sharp downward angle with which the bullet entered Karen Reilly's back nor the kind of nylon material she was wearing when shot.

The outside firearms examiner's voluminous reports and testimony contained many unwarranted conclusions, contradictions, errors, and indications of his apparent failure to comprehend at a very basic level the interactions of bullets with what they hit. A few examples are:

- He testified that the flattening of Clegg bullet was "almost all" caused by its perforating the sheet of metal of the seat back (assuming it came through hole 4) with little or none of it coming from the penetration of Karen Reilly's body. In contrast, however, he also testified that If the Clegg bullet had come through hole 8, it would have flattened and fragmented from striking her body.
- He testified that the lengthwise scrapes and gouges in the Clegg bullet (Fig 2) were caused by the tab of steel punched out from the steel seat back in hole 4 scraping the bullet as they passed through the foam of the back seat together. This theory fails to recognize that when the bullet breaks the metal tab loose from the seat back, and the bullet nests in the tab's concavity, *the tab and the bullet have the same velocity. The force necessary to cause these scrapes and gouges could not be generated between two pieces of metal traveling in the same direction at the same speed.*
- See **LINEAR IMPRESSIONS ON THE CLEGG BULLET** above.

The outside firearms examiner also unwisely encroached upon the field of wound ballistics: the lack of any medical training whatsoever did not stop him from expressing opinions on the paths of bullets in the human body and the fragmenting behavior of bullets in the human body. He exposed his lack of understanding most vividly when he presented an experiment (submitted as a report on 8 October 1998) which, he claimed, studied the size of holes in the skin caused by the increased temporary cavity produced by rifle bullets that were blunted, compared to holes produced by streamlined rifle bullets. He shot through a piece of pig skin placed over a block of gelatin. The immensity of the error in that experimental design is typical of what happens when firearms examiners testify beyond their expertise. As mentioned above (see THREE MM HOLE IN KAREN REILLEY'S BACK), this subject has been described in the scientific literature.[2] High speed cinematography has shown that when a blunt projectile makes a hole several times its diameter in the skin, the hole made by the projectile is initially no larger than the projectile's diameter. The stretching that dilates the hole comes a few milliseconds later.[2] The temporary cavity that causes the stretching occurs considerably deeper than skin level. *The skin is dilated only because it is **attached** to the underlying tissues that are impelled radially outward from the bullet's path. Since the skin in the outside firearms examiner's "model" was **not attached** to the underlying gelatin, the mechanism was not duplicated: the skin would not be stretched. Such a "model" is worthless for studying temporary cavity effects on skin.*

Speculating in wound ballistics was unwise – as shown by the "model" which so clearly illustrates the outside firearms examiner's failure to understand basic tissue disruption mechanisms. However, he also claimed to the court (referring to studying temporary-cavity-produced enlargement of holes in the skin) that "This is an area where I have worked in the past, have published and been cited a number of places...." *His CV, however, lists no such publications.*

In the cross-examination of the outside firearms examiner, his selective reporting of results was exposed. A graph made from his own numerical results was used to expose fallacy in his testimony. The defense barrister had done his homework. The cross-examination of the outside firearms examiner was a serious blow to the prosecution's case.

Conclusion

Simple Became Complex

The defense permitted the prosecution to fight the battle on the turf of their choice. The prosecution essentially attempted to ignore the simple lack of flattened rifling marks on the Clegg bullet that clearly showed it could not have made hole 4. *That fact alone should have been all that was necessary to decide the case.*

The prosecution apparently chose a strategy of obfuscation to direct attention away from the clear, conclusive, undeniable physical evidence that disproved their theory of the case. The outside firearms examiner produced experiment upon experiment. The defense scurried around countering each new prosecution theory as it appeared. The outside firearms examiner constantly turned out more complex experiments in apparently attempting to add to the obfuscation. Although the tactic of obfuscation when faced with clear unanswerable evidence is common, the extent to which it was carried, by the prosecution, in this case produced a caricature of the method.

The Political Factors: a defense strategy of sparing the reputation of the prosecution's pathologist

The defense team was extremely hesitant in exposing the errors of the prosecution's pathologist. He was protected from full disclosure of the serious deficits in his autopsy, and in his resulting testimony, because the defense legal team apparently believed that exposing these errors might prove counterproductive. The trial was, after all, being held in Belfast; and the judge had obviously depended on the testimony of this pathologist in the past and would be called upon to do so in the future. The defense believed that exposing all the errors and misconceptions in the testimony of the prosecution's pathologist would be resisted by the judge, since it might seriously undermine the Northern Ireland judicial system. The judge, being a part of this system, might be inclined against the defense if they became too explicit. This was also one apparent reason for the defense failing to demand an exhumation: finding a bullet or a piece of one that had been missed at autopsy would have proved disastrous to the reputation of the prosecution's pathologist. Another reason was that an exhumation, even if only for non-invasive x-ray examination, in such a highly charged political atmosphere would most likely have caused great public unrest – possibly even riots.

After the cross examination of the outside firearms examiner called much of his work and testimony into serious question, the defense team decided to cut short their case. They relied upon the testimony of Dr. Renshaw and did not even call the two American experts who had testified for them in the appeal. Because of this, the following points described above were not made by the defense:

- Analysis of tip-to-tail markings on the Clegg bullet using the forces necessary to produce them
- The impossibility of the 3 mm hole having been made by a bullet that came through hole 8
- The impossibility of the tab found in the 3 mm hole having been carried there by the bullet that made the hole
- The possibility of a third bullet (or part of one) remaining in Karen Reilly's body
- The rational interpretation of the linear impressions on the Clegg bullet.

Defense Wins

It is difficult to fault a strategy that wins. For a scientist, however, it is dissatisfying to see easily obtainable facts left unexamined– as in the failure to have an exhumation done in this case. It is also disappointing to see experts mislead the court without having this fully exposed. But trials are not conducted in a vacuum. Political factors and potential bias can and do affect verdicts. A good defense team must consider these things and react appropriately, which they did. The defense team of lawyers deserves congratulations for a job well done.

Acknowledgements: The author wishes to thank Paul M. Dougherty, Esquire, David M. Gross, Esquire, and Simon McKay, Esquire for reviewing the manuscript and providing insightful suggestions and corrections.

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2. Fackler ML, Bellamy RF, Malinowski JA. A Reconsideration of the Wounding Mechanism of Very High Velocity Projectiles – Importance of Projectile Shape. J Trauma 1988;28(1Suppl):S63-S67.

WOUND PROFILE OF THE 5.7 X 28 MM FN CARTRIDGE (SS 190) FIRED FROM THE FN P90 SUBMACHINE GUN

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Kramer D. Powley, *R.C.M. Police Forensic Laboratory, Regina, Saskatchewan, Canada*
Cst. Gordon, *Pope,Regina Police Service, Regina, Saskatchewan, Canada*

Abstract:

PURPOSE: To establish the wound profile of the 5.7 x 28 mm FN cartridge (SS 190) fired from the FN P90 submachine gun.

METHOD: 10% ordnance gelatin, gelatin covered with heavy clothing, and gelatin covered with Barrday Inc. Level II soft body amour was shot at 3 m and 25 m with the FN 5.7 x 28 mm SS 190 cartridge fired from the FN P90 submachine gun.

RESULTS: The average depth of bullet penetration in all test events was 10.4 inches with no bullet deformation and fissures created by temporary cavitation not greater than 3¾ inches.

CONCLUSION: The 5.7 x 28 mm SS 190 FN cartridge fired from the FN P90 submachine gun lacks sufficient penetration and has a limited wounding potential as a handgun ammunition unless penetration of soft body amour is necessary.

Introduction:

Fabrique Nationale in their technical brochure entitled "The 5.7 x 28 mm Weapon System" states, "The P90 submachine gun and the SS190 5.7 x 28 mm round have been designed jointly. Today, they are an efficient, unique and unbeatable weapon system.

They provide what today's conditions demand: performance greatly superior to 9 mm; including extreme effectiveness against body amour out to 200 meters."[1]

Wound profiles of 9 mm ammunition firearm combinations have been presented by the authors in previous publications.[2]

The purpose of this research is to establish the wound profile of the SS190 5.7 x 28 mm ammunition fired from the FN P90 submachine gun. The average size of the fissures as produced by the temporary cavitation, the depth of bullet penetration, the lateral deviation of the bullet, and the orientation of bullet at rest were measured and recorded.

The ammunition firearm combination was tested following established R.C.M.P. methodology with some variation.[3] Swine rib embedded in ballistic gelatin tests were replaced by ordnance gelatin blocks covered by Barrday Inc. Level II soft body amour. The purpose of this test event was to determine whether or not the ammunition was capable of penetrating soft body amour and could be considered as prohibited by "Prohibited Weapons Order No. 10 of the Orders in Council of the Government of Canada.

Methods And Materials:

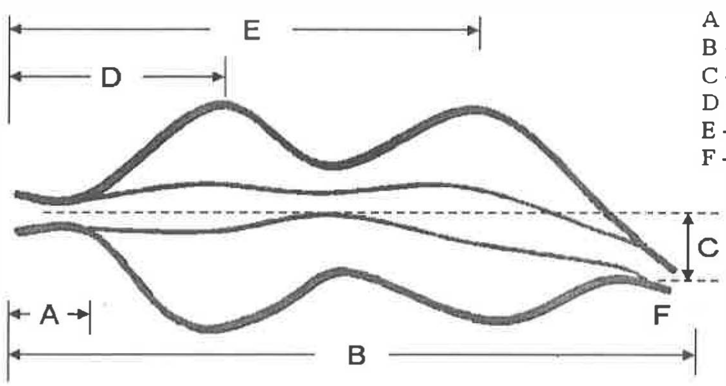
All tests were conducted using an FN P90 submachine gun, Calibre 5.7 x 28 mm, with a 10" barrel, Serial Number FN015131. Lot number of the ammunition was FNB97E013009.

The SS190 5.7 x 28 mm ammunition has been altered from its original design. The new bullet has an aluminum core and a steel penetrator. The bullet weight is 31 grains; the length is 2.1 cm, shortened from its original 2.4 cm.[4]

Ten rounds were chronographed using an Electronics Counters Division of MV Ordnance Industries Model 4040 chronograph at an instrumental distance of 20 feet.

Dr. M. Fackler's recipe for manufacturing 10% ordnance gelatin was followed. The only variation from previous R.C.M.P. handgun ammunition testing protocol was the elimination of the swine rib ordnance gelatin tests, and the inclusion of Barrday Inc. Level II soft body amour covering a block of 10% ordnance gelatin. The Barrday Inc. soft body amour was labeled 588242 Nov 95.Jan 96-Jun 96 G.S. 1045-177 R.C.M.P. Spec. and contains 22 layers of "Twaron". The test events, including the soft body amour, were shot at 90° to the target surface at distances of 3 meters and 25 meters.

Results:



A - distance of penetration prior to formation of fissures
B - overall depth of penetration
C - lateral deviation of bullet path
D - distance to centre of 1st lobe
E - distance to centre of 2nd lobe
F - bullet orientation at rest

Test Type: Bare Gelatin					Distance: 3 metres	
Shot	**A**	**B**	**C**	**D**	**E**	**F***
	Penetration depth in inches					
1	3	10.75	0	5	8.25	S
2	3	11	1.75	5		F
3	3	10	1.25	5	9	F
4	3	11.5	1	5.5	8.5	F
5	3	10	1	5.5	8.5	F
avg	3	10.65	1	5.2	8.56	
Average fissure size (as produced by temporary cavity): 2.5 inches						
Calibration Temperature (°C)	5°	5°				
Calibration Velocity (ft/sec)	595	595				
Calibration Penetration (cm)	8.0	7.8				

* S=Sideways F=Nose Forward B=Base Forward

Test Type: Vest					Distance: 3 metres	
Shot	**A**	**B**	**C**	**D**	**E**	**F***
	Penetration depth in inches					
1	1.75	9.5	0.5	4	7.5	F
2	2.5	9.75	0.5	4.5	8.75	F
3	2.25	10.5	1	5.25	8.75	F
4	1.5	9.5	0.5	3.75	7	F
5	2	10.5	0.5	4	6.25	F
avg	2	9.95	0.6	4.3	7.65	
Average fissure size (as produced by temporary cavity): 3.5 inches						
Calibration Temperature (°C)	5°	5°				
Calibration Velocity (ft/sec)	595	595				
Calibration Penetration (cm)	8.0	7.8				

* S=Sideways F=Nose Forward B=Base Forward

Test Type: Heavy Clothing					Distance: 3 metres	
Shot	**A**	**B**	**C**	**D**	**E**	**F***
	Penetration depth in inches					
1	2.75	12.25	1.5	5	10	B
2	2.75	11.75	1.25	5.5	9.5	F
3	2.5	11.63	0.5	5	11.25	S
4	3.25	11.5	0.5	5.5	9.5	F
5	3	11.5	0.5	4.75	9	B
avg	2.84	11.73	0.85	5.15	9.85	
Average fissure size (as produced by temporary cavity): 3.75 inches						
Calibration Temperature (°C)	5°	5°				
Calibration Velocity (ft/sec)	599	607				
Calibration Penetration (cm)	8.3	8.6				

* S=Sideways F=Nose Forward B=Base Forward

Test Type: Bare Gelatin					Distance: 25 metres	
Shot	**A**	**B**	**C**	**D**	**E**	**F***
	Penetration depth in inches					
1	3	10.5	0.75	4.5	6.75	F
2	3	10.75	1	5.25	8	F
3	3.5	10.5	1.25	5.75	9	F
4	2.75	10.75	1.5	5.5	9.25	F
5	2.75	10.25	0	5	8.75	F
avg	3	10.55	0.9	5.2	8.35	
Average fissure size (as produced by temporary cavity): 3.0 inches						
Calibration Temperature (°C)	6°	6°				
Calibration Velocity (ft/sec)	585	581				
Calibration Penetration (cm)	8.0	8.0				

* S=Sideways F=Nose Forward B=Base Forward

Test Type: Vest					Distance: 25 metres	
Shot	**A**	**B**	**C**	**D**	**E**	**F***
	Penetration depth in inches					
1	2.75	9.75	0.25	4.5	9	F
2	2.25	10	0	4.25	8	F
3	2	9.5	0.75	4	7.75	F
4	1.75	9	1.5	3.5	7.5	F
5	3.75	11	1	5.5		F
avg	2.5	9.85	0.7	4.35	8.06	
Average fissure size (as produced by temporary cavity): 3.75 inches						
Calibration Temperature (°C)	6°	6°				
Calibration Velocity (ft/sec)	588	604				
Calibration Penetration (cm)	8.2	8.2				

* S=Sideways F=Nose Forward B=Base Forward

Test Type: Heavy Clothing					Distance: 25 metres	
Shot	**A**	**B**	**C**	**D**	**E**	**F***
	Penetration depth in inches					
1	2	9.5	0.5	4.25	8.25	F
2	2.5	9.5	1	4.5	7.5	F
3	2.5	10.25	0.75	4.5	6.75	F
4	2.5	10	0.75	5	9	F
5	3	10.5	0.25	5	8	F
avg	2.5	9.95	0.65	4.65	7.9	
Average fissure size (as produced by temporary cavity): 3.75 inches						
Calibration Temperature (°C)	6°	6°				
Calibration Velocity (ft/sec)	588	604				
Calibration Penetration (cm)	8.2	8.2				

* S=Sideways F=Nose Forward B=Base Forward

Chronographed velocities (at instrumental distance of 20 ft)											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**avg**
velocity (ft/sec)	2315	2384	2295	2337	2309	2351	2325	2315	2325	2336	2329

The recovered bullets in all test events retained 100% of their weight with no bullet deformation. Twenty-two layers of Twaron did not reduce the overall penetration of the bullet a significant amount at either of the distances tested.

Conclusion:

The measured fissures of the gelatin as produced by the temporary cavity are not significantly different than those produced by handgun bullets, and are substantially smaller than previously measured rifle bullets.[5] As a result, the wounding profile of the bullet must be based on the depth of penetration and the size of the permanent cavity produced.

The SS190 31 grain bullet as fired through the FN P90 submachine gun has a very limited penetration profile with no bullet deformation as tested and is probably not as effective as many hollow point handgun ammunitions, except in its ability to defeat soft body amour. Fackler, contradicting FN'S claims, best describes the performance of the ammunition relative to the 9 mm, stating ". . . the expended 9 mm bullet strikes about three times as much tissue as the P-90 bullet at 90° of Yaw - and does it throughout most of its path. Thus, the permanent cavity volume produced by the expanded 9 mm bullet is many times longer than that produced by the nondeforming P-90 bullet."[4]

References:

1. The 5.7 x 28 mm Weapon System, FN Herstal, S.A. - Voie de Liege, 33-B4040 Herstal, Belgium
2. Dahlstrom and Powley, Comparative Performance of 9 mm Parabellum, .38 Special and .40 Smith and Wesson Ammunition in Ballistic Gelatin, Canadian Police Research Center Technical Report TR-01-95, Sept. 1994
3. Ibid.
4. Martin L. Fackler, Corrections on the Wound Ballistics of the Current Fabrique Nationale (FN) P-90 Bullet IWBA Wound Ballistics Rev, 1998;3(3):36-37
5. Powley and Dahlstrom, Wound Profile of the Briese Controlled Disintegrater Tactical Ammunition in Calibre .308 Winchester, Wound Ballistics Rev 1999;4(1):25-28.

Editorial Note:

In recent months, there has been a spate of advertisements, masquerading as objective articles, regarding the FN P-90. FN apparently continues to feed gullible gun writers outlandish claims that they print as fact. FN started their exaggerations of the P-90's effects with a poster presentation at the 11th International Symposium on Ballistics in 1989 (Brussels, 9-11 May), Body Armour and Wound Ballistics Vol III pp. 107-117). In Fig 4, FN showed a table comparing their measurements from shots into gelatin. It showed the P-90 to have a "cavite residuelle" larger than any of the cavities produced by the other bullets tested. The P-90's cavity was, in fact, more than twice the volume of the one produced by the well-expanded 44 Magnum hollow point bullet. This is despite the fact that the 44 Magnum lost almost three times the energy in the gelatin block as did the P-90. Giving FN the benefit of the doubt, I thought these enormous exaggerations might have been the result of oversight, or ignorance of gelatin testing techniques. So when I visited the FN factory to discuss the P-90 shortly after the symposium, I pointed out to them the inconsistencies in their reported results. But the recent claims by American gun writers that the P-90 produces a permanent cavity of 2 ¾ inches is as ludicrous an exaggeration as the one mentioned above. Surely the FN engineers, and the gun writers who write FN's propaganda, must be aware that the permanent cavity produced by a non-fragmenting bullet cannot exceed the amount of tissue actually struck by the penetrating bullet. It is difficult to escape the conclusion that what has recently appeared in print about the P-90 is deliberate falsification and deception.

The following is a letter that I wrote to the American Rifleman. Most of it was printed in their Jan 2000 issue (p 4, 59).

To the editor:

The article "FN's FiveseveN System" (Rifleman Nov-Dec, pp. 40-41, 51) reads like an advertisement. It seriously misrepresents the wounding capacity of the 31-grain P 90 bullet. Claiming it "produces a wound cavity that is similar to that of the 5.56mm NATO ammunition used in M 16 rifles." is an absurd exaggeration. The 31-grain P 90 bullet has only half the weight of the M 16 A2 bullet and its velocity is about 1000 ft/s less.

The amount of tissue disruption produced by the P 90 bullet is less than one-third of that produced by a well-designed expanding 9x19 mm handgun bullet. And the P 90 bullet produces a temporary cavity of only about 8 cm diameter smaller than that of an expanding 9x19 mm handgun bullet. Most of the P 90 bullet's wounding potential is wasted in producing a temporary cavity that is too small to be a reliable wounding mechanism in the human target. The P 90 bullet doesn't even come close to matching the wounding capacity of a well-designed expanding 9x19 mm handgun bullet.

The light recoil of the P 90 should hardly come as a surprise: the momentum and kinetic energy of its bullet are only about half that of the 22 Hornet bullet. The P 90 bullet's wounding potential is about equal to that of the 22 Winchester rimfire magnum bullet. The laws of Physics cannot be denied minimal recoil is inconsistent with maximal tissue disruption.

For the military, where any wound is often all that is required to cause an enemy soldier to leave the battlefield, perhaps this tiny P 90 bullet is OK (but a 22 rimfire magnum would be a lot less expensive and equally effective). But I find it extremely disturbing that FN is trying to sell the P 90 to law enforcement agencies. Law enforcement officers are often faced with armed violent criminals at close range. In that scenario a bullet capable of disrupting a significant amount of tissue is needed: one must incapacitate the criminal, a minor wound will not suffice. By no stretch of the imagination is the P 90 bullet adequate for that task -- its use would be sure to get law enforcement officers killed unnecessarily.

Martin L. Fackler, MD, FACS, President, International Wound Ballistics Association

References for further reading: Law enforcement please take note.

1. Wound Ballistics Rev 1998;3(3);36-37. Corrections on the Wound Ballistics of the current FN P 90 bullet.
2. Wound Ballistics Rev 1997;3(1):44-45. More on the bizarre FN P 90.
3. Wound Ballistics Rev 1991;(1):46. Description of first generation P 90.

The article by Dahlstrom, Powley, and Gordon confirms the true limitations of the wounding pattern possible from the P-90. They found an average temporary cavity in bare gelatin of only 2 ½ inches. This is about the same size as that produced by a 22 Long Rifle hollow point bullet. It is considerably smaller than any 9 mm hollow point bullet that I have ever tested; and even smaller than the cavity produced by a nonexpanding full metal jacketed 9 mm Parabellum bullet.

Recently, while giving a presentation at Ft. Benning, it struck me that many law enforcement and military firearms users have difficulty grasping the cavities and penetration depths produced by various bullets and applying them in a comparative sense. I thought of an idea to help communicate the approximate wounding capacity of various weapons. Perhaps it would help to look at law enforcement and military bullets in terms of the animal such bullets would be used to hunt in a civilian setting. We can think of the AK-47 as deer rifle (its ballistics closely resemble the 30-30), and the M 16 as a woodchuck rifle. The P-90 might be thought of as a squirrel rifle. I think this helps to convey its extremely limited wounding potential.

Martin L. Fackler

EFFECT OF DISTANCE OF FIRE ON DEFORMATION OF THE M 16 A2 M 855 BULLET IN SHOTS PENETRATING ORDNANCE GELATIN TISSUE SIMULANT

Martin L. Fackler, MD, *Wound Ballistics Consultant* ***Alan J. Brown,*** *Naval Surface Warfare Center, Crane, IN*
David Johnston, CWO4, *Naval Special Warfare Development Group*

Abstract:

PURPOSE: To determine the difference in deformation and fragmentation of the M 855 bullet as it penetrates human soft tissue when striking at various distances

METHOD: Four shots were fired from a standard military issue M 16 A2 rifle into 10 % ordnance gelatin shot at 4° C at distances of 50, 150, 250, and 350 yards

RESULTS: At 50 yards, the bullet fragments, with the jacket behind the cannelure breaking - At 150 yards, most of the bullets break at the cannelure and the jacket behind the cannelure is flattened but remains an unbroken tube - At 250 yards, the bullet flattens behind the cannelure but does not break - At 350 yards the bullet flattens only slightly and remains intact.

CONCLUSION: The degree of deformation and fragmentation of the M 855 bullet striking at various distances is quite constant and provides a useful and reliable standard for comparison in forensic cases when the distance of fire is an important element of evidence. The deformation and fragmentation of the M 855 bullet similar to that seen with its predecessor, the M 16 A1 (M 193) bullet.

Introduction

The distance of fire is often critical to an accurate reconstruction of shooting incidents. Distance of fire from contact with the skin to about five feet can often be determined from the presence of soot or the presence or effects of powder particles on the skin or clothing around the bullet's entry wound. At greater distances, the amount of bullet deformation or fragmentation can often be used to determine an approximate distance of fire for some types of bullets.[1]

A systematic study to document the decreasing degree of deformation and fragmentation with increasing range (and concomitant decreasing velocity) of the 55 grain M 193 bullet fired by the military M 16 A1 rifle was done, and published, when the M 193 was the bullet currently used by the armed forces of the United States.[2] The M 16 A1 rifle has now been superseded by the M 16 A2 rifle which shoots a 62 grain bullet, designated the M 855. The purpose of this study is to determine the degree of deformation and fragmentation with the M 855 bullet when shot into soft tissue at various distances of fire and to compare the results with those of the previously done study with the M 193 bullet.

Methods

Four M 855 bullets were fired at ranges of 50, 150, 250, and 350 yards from a standard US military M 16 A2 rifle fitted with a four power telescopic sight using a bench rest and rifle support. The bullets were fired into blocks (9 X 12 X 17 inch) of 10 % ordnance gelatin at a block temperature of 4° C. Each block was calibrated, immediately before it was shot by the M 855 bullets, with a shot from a steel BB fired at 590±15 ft/sec, which met the 8.5±1 cm penetration standard.

Two gelatin blocks were placed so that the block nearest the shooter was facing him end-on. The second block was placed behind the first block, with its side in contact with the back surface of the first block. A standard military soft body armor vest was placed around the rear block to catch any bullets that might pass through both blocks. Bullets and bullet fragments were collected from the gelatin blocks.

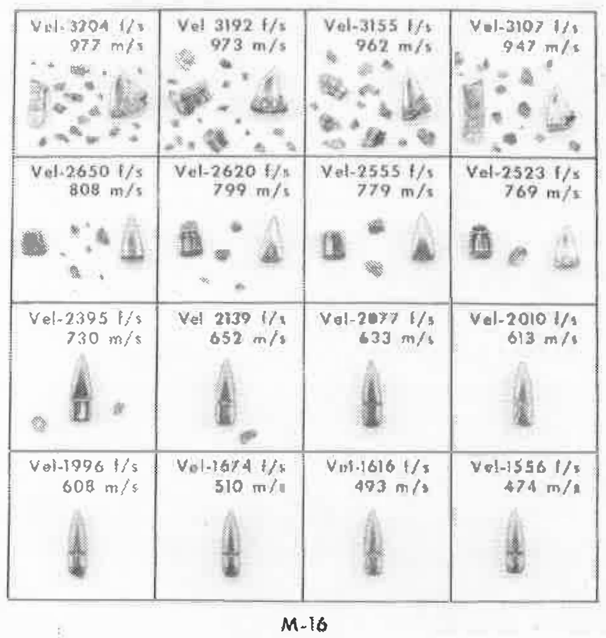


Figure 1

Deformation and fragmentation patterns of M 193 bullets fired into 10% ordnance gelatin at a distance of 10 feet are shown. The decreasing striking velocities for this study were produced by reducing the powder charges. The bullets shown in the bottom two rows were fired from an M 16 A2 barrel with a rifling twist of one turn in seven inches. This was done to add the rotational velocity needed to stabilize the bullets and avoid yaw at the lowered velocities required by the study.

- At velocities corresponding to distances of fire less than 100 yards, the bullet breaks at the cannelure, the jacket of the rear part of the bullet tears apart, and the lead core of the rear part of the bullet becomes fragments of lead.
- At velocities corresponding to distances of fire between 100 and 200 yards, the bullet breaks at the cannelure, but the jacket around the rear part of the bullet remains intact; although the rear of the bullet is flattened considerably and much of the lead it contained is squeezed out by the flattening.
- At velocities corresponding to distances of fire greater than 200 yards, the bullet flattens but does not break (although some lead is squeezed out the base of the bullet by the flattening). As the velocities corresponding to distances beyond 200 yards decrease with increasing distance of fire, the amount of flattening of the bullet decreases concomitantly.

Striking velocities were recorded for the bullets fired from 50 and 150 yards using an Oehler Model 34 chronograph and Model 55 velocity screens. Striking velocities for the bullets fired at 250 and 350 yards were estimated from data recorded previously from shots made with M 855 bullets fired from an identical M 16 A2 rifle and recorded using a Weibel Scientific Doppler Radar Chronograph.

Results

The deformation and fragmentation of the recovered bullets is shown, along with their striking velocities, in Figure two.

The smallest diameters of the four flattened bullets fired at 250 yards measured 0.135, 0.130, 0.137, and 0.129 inches. The smallest diameters of those fired at 350 yards measured 0.200, 0.201, 0.208, and 0.196 inches. In all of these bullets, which measure 0.224 inches in diameter before striking the gelatin, the most flattened areas (smallest diameters) were within one-fourth inch from the bullets' bases.

The maximum penetration distances into the gelatin by the sixteen shots fired in this study, and shown in figure two, were:

Shot #	Penetration depth in inches	Shot #	Penetration depth in inches
1	12.25	9	18.00
2	13.00	10	19.00
3	13.00	11	19.00
4	12.50	12	17.50
5	17.50	13	21.00
6	13.00	14	20.50
7	18.00	15	17.00
8	17.50	16	20.50

Discussion

Since 10% ordnance gelatin shot at a block temperature of 4° C has been shown to be a quantitative tissue simulant for living animal soft tissue,[3] it follows that nearly equal force is applied to a bullet penetrating it as is applied during that same bullet's penetration of living tissue. All other factors being equal, the higher a bullet's striking velocity the higher will be the force applied to it; and the higher the force the more likely the bullet is to be deformed or fragmented.

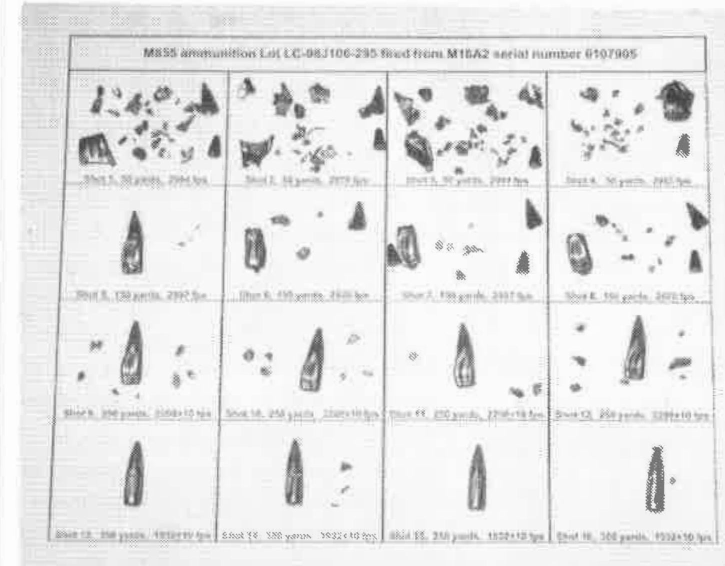


Figure 2

Deformation and fragmentation patterns of M 855 bullets fired into 10% ordnance gelatin at distances of 50, 150, 250, and 350 yards are shown. In this study it was necessary to obtain the velocity reductions by firing at actual distances rather than reducing powder charges as was done in the study with the M 193 bullet. A rifle barrel chambered for the M 16 military cartridge and having a rifling twist significantly faster than the one-in-seven used in the M 16 A2 rifle would be needed to boost the rotational velocity and increase bullet stability at the lower velocities. Since no such barrels were available, the more difficult and time-consuming shots at actual distance had to be done to accomplish the study.

Thus by comparing the deformation or fragmentation of bullets removed from shots fired into the human body from unknown distances with bullets recovered from shots into gelatin at various known distances, the unknown distance of fire can often be determined.

Once the deformation and fragmentation of a given bullet has been established by firings into gelatin at regularly decreasing velocities (or increasing distances) this information (Figs. 1, 2) can be used to determine the unknown distances of fire for future forensic cases. In some cases, the information on bullet deformation and fragmentation needed for the comparison can be determined from radiographs or from bullets that have passed through a body and then been recovered.

The apparent paradox of bullets penetrating more deeply at lower striking velocities, shown clearly by the penetration depths observed in this study and often confusing to the layman, can be understood by studying figures one and two. The degree of a bullet's deformation and fragmentation is generally inversely proportional to the depth to which it penetrates. Since bullet velocity decreases regularly and predictably as bullets travel through the air, therefore, longer distances of fire are often associated with lessened bullet deformation and fragmentation – and concomitantly increased bullet penetration due to the decreased drag of un-deformed bullets in passing through body tissue.

The previous study to determine the deformation and fragmentation pattern of the M 193 bullet at various distances of fire[2] has proven its forensic usefulness.[4] One of the reasons this study using the M 855 bullet was undertaken was a death during a military live fire training exercise in which the distance of fire of the M 855 bullet that caused the death was a critical element of evidence. Since the M 16 A2 rifle firing the M 855 bullet has been adopted as the standard weapon used by US military forces, the first author has been involved in two cases in which the distance of fire in shootings with the M 855 bullet has been pivotal evidence.

Conclusion

The findings of this study have established, for future reference, the deformation and fragmentation patterns produced by M 855 bullets in shots into ordnance gelatin, from 50 to 350 yards. These patterns are noted to be very similar to the patterns produced by M 193 bullets at similar distances of fire.

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WOUND BALLISTIC REVIEW
JOURNAL OF THE INTERNATIONAL WOUND BALLISTICS ASSOCIATION

.223 AMMUNITION DEVELOPMENTS

***Duncan MacPherson**, Wound Ballistics Consultant*

Introduction

Development work is ongoing on a new type of .223 bullet. These bullets have a tungsten-tin core under a conventional appearing moly coated copper jacket, and fragment much more completely than conventional bullet designs. These bullets have great promise for improving wound trauma generation in the .223, and status of the development is described.

Background

Powell River Laboratories has investigated rifle bullet designs for improved long range accuracy and hunting for several years. An outgrowth of this activity has been development of special purpose rifle ammunition for government agencies. Dr. Fackler and I learned of this work and believed that it held promise in offering law enforcement a substantial improvement over conventional .223 ammunition. All parties have been attempting to realize that promise ever since. In the latter part of 1999, Powell River decided to furnish only the bullets (their specialty) and to make arrangement with Black Hills to manufacture any resulting law enforcement ammunition.

Bullet Design

Powell River considers their tungsten-tin bullet design concept proprietary, since the details of bullet fragmentation differ significantly from those of typical fragmenting bullet designs. I believe that I finally understand the basic dynamics of this bullet type's fragmentation, which are unconventional, but technically sound. This general topic will not be discussed further in recognition of Powell River's desires.

The bullet shape is a boat-tailed spitzer. The tip does not have a hollow point, but is not completely closed; it is quite similar to the MatchKing in having this feature as a result of manufacturing issues not related to terminal performance. It differs from the MatchKing in that this feature does not degrade the tungsten-tin bullet terminal performance.

The tungsten-tin cores are significantly more dense than conventional lead cores, so these bullets are heavier than lead core bullets of the same length.

Terminal performance

The tungsten-tin bullet fragments on impact, but differs substantially from most fragmenting bullets. The fragmentation of the tungsten-tin bullet is essentially a complete reduction of the core to powdered metal, although a very small core fragment sometimes remains intact. The jackets do not retain core metal fragments, and so are light and a relatively inconsequential factor in creating wound trauma.

The powdered core penetrates after breakup to create a relatively large diameter (about 2-3cm) cylinder of destroyed tissue. This is effectively a permanent wound cavity, although the tissue damage mechanism is not identical to that in a typical permanent wound cavity. This is a very effective incapacitation mechanism, and much more effective than the permanent wound cavities produced by conventional .223 bullets (fragmenting or otherwise). This difference in the permanent wound cavity does not extend to the temporary wound cavity produced by the bullet impact, which is very similar to other bullets of similar energy as a result of the same dynamics.[1]

The wound cavities also have another very important variable not yet discussed; specifically, the effective amount of penetration before the bullet fragments. (While this fragmentation actually takes place over a small distance, it is convenient to describe it as taking place instantly, and it almost appears that way during gelatin inspection.) This pre-breakup penetration depth is almost "free" because there is very little velocity reduction (or wound trauma) during this penetration. The length of the permanent wound cavity after bullet fragmentation (and the temporary cavity volume) are thus almost independent of the depth of this initial "free" penetration. Selection of the magnitude of the "free" penetration is, in effect, selection of the penetration depth of the significant wound cavities. This control of effective wound depth location is precisely what is wanted to achieve effective incapacitation. Most .223 wound cavities occur at too shallow a penetration depth to ensure reliable incapacitation.

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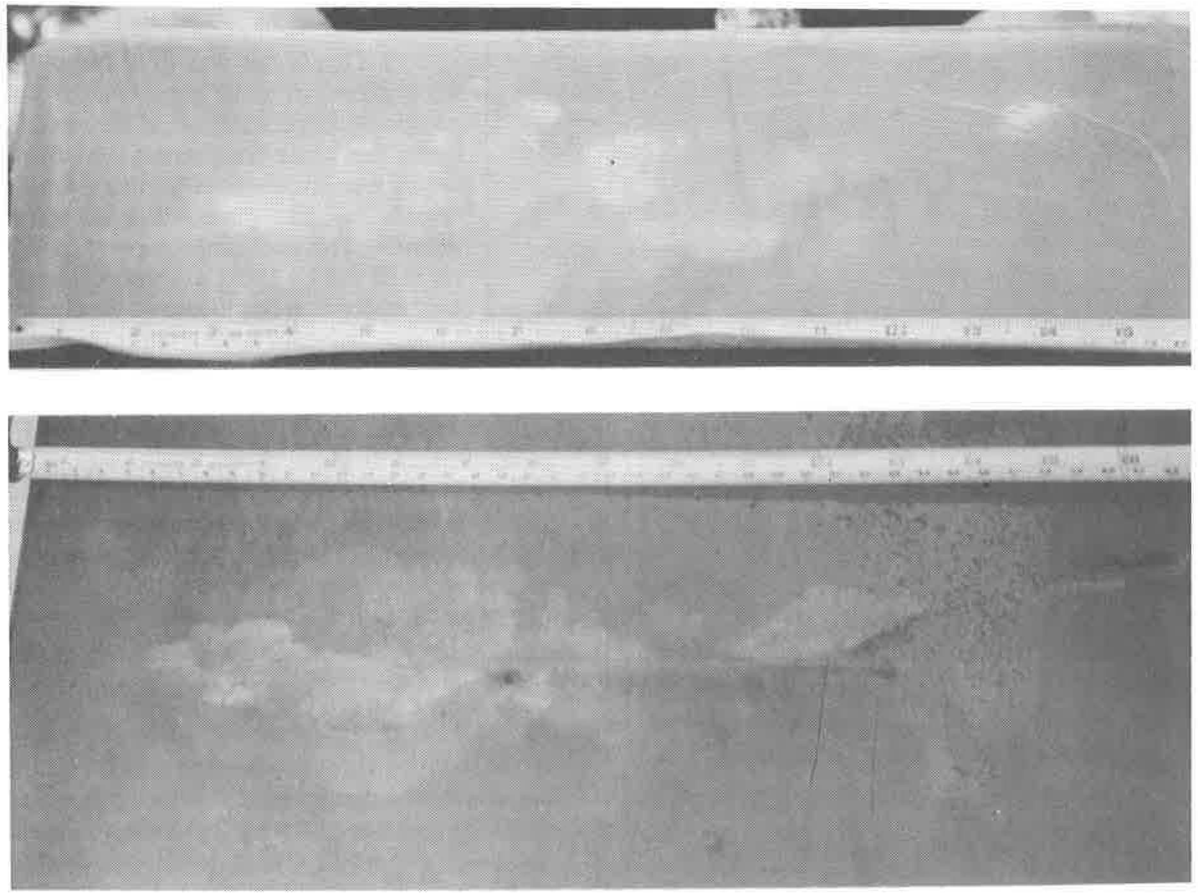

Figure 1
87 grain Government Load into Bare Gelatin

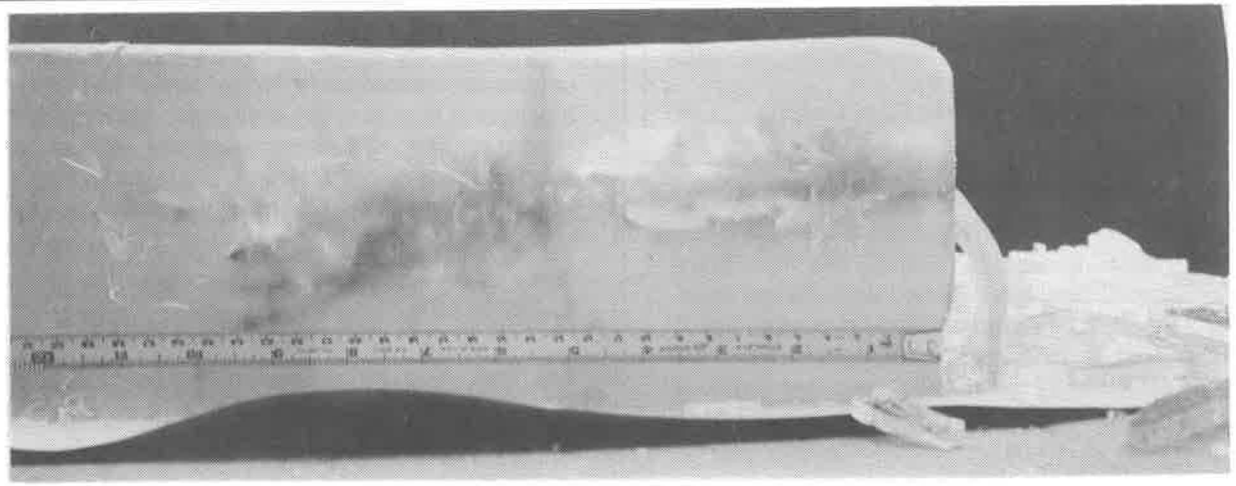

Figure 2
87 grain Government Load Through Plate Glass

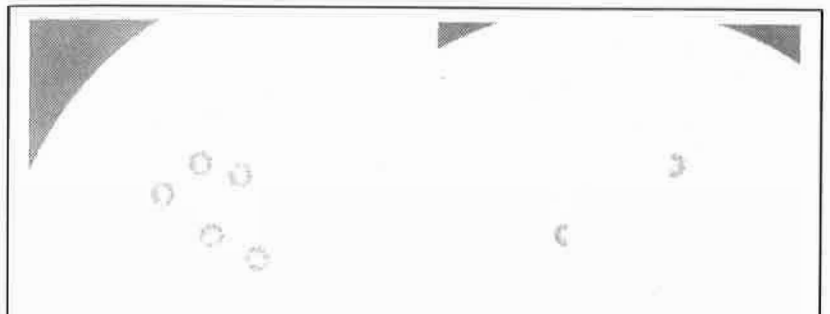

Figure 3
60 grain M16 Load at 100 Yards (Iron Sights)

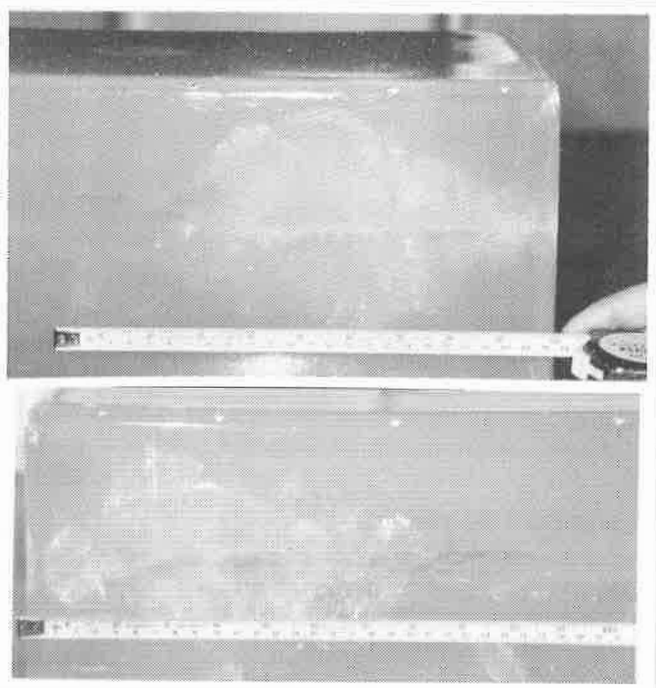

Figure 4
60 grain M16 Load into Bare Gelatin

Ammunition Development and Testing

Load development and testing has been complicated by several issues not related to technical feasibility. As a result, load optimization is not complete.

The first load tested in mid-1999 was the original Powell River 87 grain bullet load that had been developed for a special purpose government contract. The results from this testing were very satisfactory; two penetrations in gelatin are shown in Figure 1.

Note that the penetration before bullet break-up is about 2½ inches and the overall penetration is about 12 inches. The small "streamers" at the end of the trajectory are not typical bullet fragments, and do not represent significant wound trauma mechanisms.

One bullet was fired through a $^3/_8$ inch thick pane of plate glass placed against the gelatin; this penetration is shown in Figure 2 (note the glass fragments). In this case the bullet was fragmented by the glass, losing the "free" 2½ inch penetration at entry in bare gelatin. The permanent wound cavity was little affected by the glass penetration, although the penetration depth shows the 2½ inch loss.

Bullet fragmentation on impact with a substantial barrier means that the "dust cloud" starts to disperse at this point, with substantially reduced capacity for producing wound incapacitation as the distance from the barrier is increased. This bullet is not a generally effective round if incapacitation capability after barrier penetration is desired. On the other hand, this feature is ideal if non-lethality is desired after barrier penetration, as is the case in many (perhaps most) law enforcement scenarios.

The bullets shown in Figures 1 and 2 were fired in a 7 inch twist rifle. Not surprisingly, these loads tumble severely in a 12 inch twist barrel. Since a lot of local law enforcement agencies have obtained Ml M16 rifles from the government for general patrol use, it seemed that a lighter bullet version of this load should be developed for use by these agencies.

A 60 grain bullet load was developed and tested in 12 inch twist barrels. The targets shown in figure 3 were fired with this load in an iron sighted M16 at 100 yards by a marksman in the LAPD firearms unit. While this is far from a definitive accuracy test, it clearly shows the bullet contribution to inaccuracy will be negligible under practical field conditions.

Penetrations of two of the 60 grain loads into bare gelatin are shown in Figure 4. Note that the bullet opens up immediately upon entry into the gelatin block, and also that the temporary cavity is wider and shorter. The effective permanent wound cavity is shorter, being about 8 inches. This deficiency in penetration is a result of a mismatch between the jacket design and the velocity of the bullet in this loading.

Conclusion

While the optimum loadings have not yet been finalized, this bullet design technology holds great promise. Future developments will be reported in the *Wound Ballistics Review.*

Reference

1 MacPherson D., The Temporary Wound Cavity, Wound Ballistics Rev 1999;4(2):22-25

TUNGSTEN FRANGIBLE BULLET WOUNDS IN PIG: EXAM BY AUTOPSY & X-RAYS

Martin L. Fackler, MD*, Wound Ballistics Consultant*

The frangible bullets of the 1980s were singularly unimpressive. There was a rifle bullet of iron-filing impregnated plastic: there was the Glaser Safety Slug. They produced a wide, but very superficial, area of tissue disruption: *their penetration was limited to a few inches.*

Tungsten core bullets first gained attention because of their greatly improved long-range performance. Tungsten is about 70% denser than lead. Taking advantage of this, Powell River Laboratories (PRL) has developed ultra-high ballistic coefficient bullets that lose less velocity over distance and are affected less by wind. They have used this technology to make the .223 Remington a 1000 yd. target rifle.

During the past few years, I have found an increasing demand for evaluation of the tissue disruption potential of tungsten frangible bullets. In examining the spread of the tungsten in gelatin blocks, the question is how to correlate it with that seen from lead core bullets with which we have a base of experience. Mr. Harold Beal, President of PRL, sponsored the study, reported here, to try to correlate the fragmentation pattern produced by tungsten frangible bullets with actual tissue disruption.

All shots were fired from an M 16 M 4 Carbine with a 14.5 inch barrel from a distance of 10 feet, through an Oehler Model 35 P chronograph. The bullets used were .224 inch PRL 76 grain tungsten frangible bullet striking at about 2000 ft/sec. These are special purpose bullets, downloaded to less than maximum velocity. Their copper jacket is of typical .224 bullet hollow point design. I understand that their core is a tungsten and tin mixture; but more detail would get into proprietary information and is beyond the scope of this report. In addition to obtaining data on disruption of various soft tissues of a 130 lb. pig (killed 15 minutes before the experimental shots), one shot was fired into 10% ordnance gelatin (BB calibration shot at 584 ft/sec penetrated 9.1 cm). An X-ray was taken of the gelatin block and is shown as Figure 1. X-rays were also taken of the bullet paths through 1) the freshly killed pig's chest, 2) the upper abdomen, 3) the lower abdomen, and 4) the proximal part of a lower leg. The X-ray film of the leg is shown as Figure 2.

Impressions regarding the tissue damage are:

- At autopsy, the permanent wound cavity observed as the bullets entered the chest and abdominal walls, perforated the diaphragm, lung, bowel wall, and muscle of the leg were from 0.9 to 1.5 inches in diameter. This is considerably larger than what one would expect from a copper jacketed lead core hollow point bullet fired at 2000 ft/sec.

- The permanent wound cavity produced by these PRL frangible tungsten core bullets was essentially sausage shaped and penetrated 7 to 9 inches. This contrasts sharply with earlier frangible bullets, made of less dense cores, which produced more of a lemon shaped permanent cavity which penetrated only 3 to 4 inches.

- The tissue disruption produced by the PRL frangible bullets appears to extend over a considerably larger velocity range (or more extended distance of fire range) than that produced by lead core hollow point bullets. Expansion of lead core bullets is dependent on the force applied to their points as they penetrate tissue. As their striking velocity decreases with increasing distance of fire, their expansion decreases concomitantly. Tungsten core frangible bullets, however, are essentially prefragmented and apparently do not need high striking velocity to peel back their copper jacket. Once the jacket is peeled back, the spreading of the core (the equivalent for expansion of a lead bullet) is apparently not nearly so limited by velocity, as is the expansion of lead bullet cores.

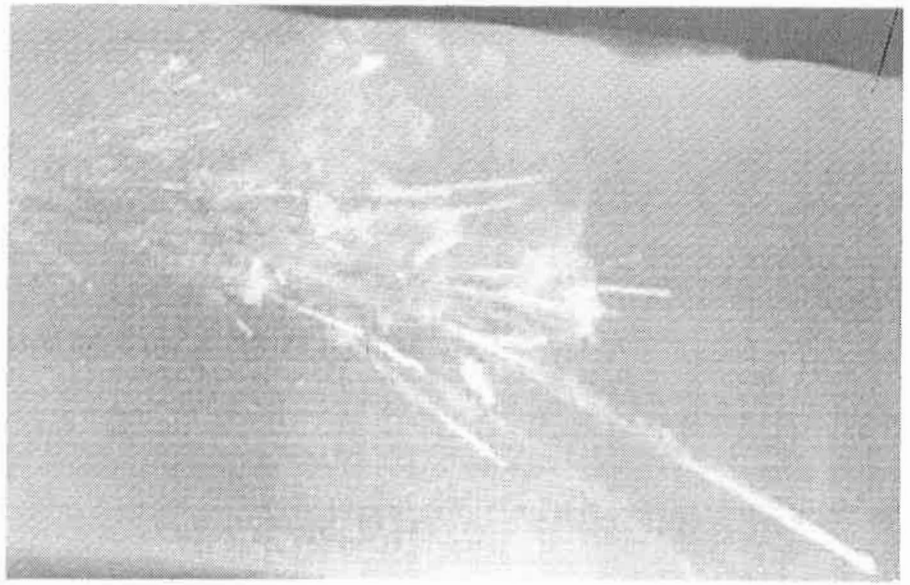

Figure 1
X-ray of shot into gelatin

It must be emphasized that these are preliminary observations on an emerging technology.

I am not conversant with the proprietary techniques used by various manufacturers, but obviously these differ: one would expect varying results from various frangible tungsten core bullets, just as we see from various lead core bullets. Recently. I was sent photographs of shots into gelatin blocks and asked to compare the relative tissue disruption caused by .224 inch hollow point lead core bullets with similar bullets of frangible tungsten-mix core construction (not PRL bullets). The fragmentation patterns were so similar that I could not postulate a difference in wounding potential between the two.

Appearance of the PRL frangible tungsten core bullet paths on X-ray films:

- On the X-ray films taken in this study, I cannot differentiate the particles from the core of the PRL bullets from lead particles the basis of their density.
- The streaks caused by chunks of bullet core losing part of their mass as they penetrate, as well as the spread out finely divided particles, appear to be the characteristics that differentiate bullet paths from these PRL bullets from bullet paths caused by fragmenting lead core bullets. Both these characteristics are best shown in Figure 1.
- Of the X-rays taken, Figure 2 shows a fragment pattern that most closely resembles that of a lead core bullet. I believe that most trauma surgeons viewing Figure 2 would mistake it for the path made by a lead core bullet.

In addition to the aforementioned advantages, the frangible tungsten core technology provides a unique opportunity for manufacturers to tailor the yaw behavior in tissue of FMJ type bullets by varying the placement of the high density tungsten (separating it from the light metal) to shift the bullet's center of gravity.

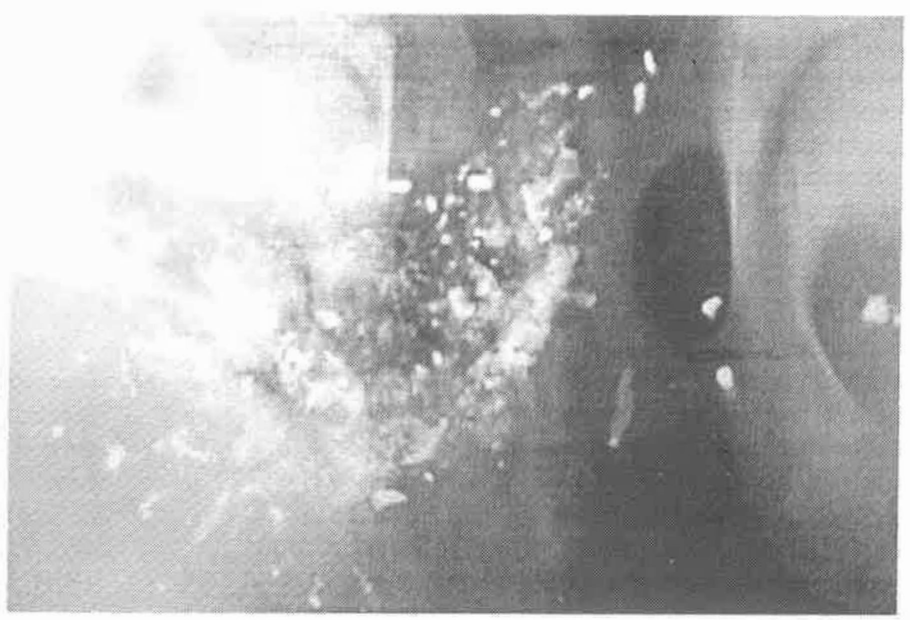

Figure 2
X-ray of shot into pig's leg

TERMINAL PERFORMANCE OF .38 SPECIAL AND .380 ACP HOLLOW POINT BULLETS

INTENDED FOR LAW ENFORCEMENT BACK-UP AND OFF DUTY SELF-DEFENSE - USING 10% ORDNANCE GELATIN AS A TISSUE SIMULANT

Gary K. Roberts, D.D.S.

Abstract:

10% ordnance gelatin is used as a tissue simulant to analyze the wounding effects and physiological incapacitation potential of .380 ACP and .38 Special hollow point bullets intended for law enforcement back-up and off duty self-defense use.

Introduction

Semi-automatic pistols, most commonly in 9mm Parabellum, .40 S&W, and .45 ACP calibers, have rapidly replaced the revolver as the primary defensive handgun for American law enforcement agencies due to their increased rate of fire potential. Small semi-automatic pistols are often used as both backup weapons and for off duty self-defense. While no longer pre-eminent as a primary defensive handgun for law enforcement use, small revolvers are still commonly used by law enforcement personnel in both the back up and off duty self-defense roles. Back-up weapons offer law enforcement personnel an alternate method of self-defense should their primary weapon malfunction or be lost during a lethal confrontation. Both back-up and off duty hand guns should be simple to use in high stress situations, be easily concealable with compact dimensions and light weight, and must fire bullets which provide sufficient terminal wound ballistic performance to rapidly incapacitate and stop dangerous individuals who pose an immediate threat to public safety in order to prevent them from continuing their violent actions.

Bullets which may be required to incapacitate an aggressor in law enforcement use must reliably penetrate a minimum of approximately 12 inches of tissue in order to ensure disruption of the major organs and blood vessels in the torso from any angle and through excessive adipose tissue, hypertrophied muscle, or intervening anatomic structures, such as a raised arm. Law enforcement officers are generally trained to shoot at the center of mass, usually the torso, of an aggressive opponent who must be stopped through the use of lethal force. Physiological incapacitation with wounds to the torso is usually the result of circulatory system collapse. More rapid incapacitation may be expected with-greater tissue damage. Tissue is disrupted through two wounding mechanisms: the tissue in the projectile's path is permanently crushed and the tissue surrounding the projectile's path is temporarily stretched. Projectiles, which penetrate the body can only disrupt tissue by these two wounding mechanisms, although, unlike rifle bullets, handgun bullets generally only disrupt tissue by the crush mechanism; the stretching effect from most handgun bullets does not reliably damage tissue and is not usually a significant mechanism of wounding.

This study compares the terminal performance of several .380 ACP and .38 Special hollow point bullets fired from small handguns used for law enforcement back-up or off duty self-defense using 10% ordnance gelatin as a tissue simulant.

Background

Many small, easily concealed semi-automatic pistols which are recommended for law enforcement backup or concealed carry use fire .380 ACP or smaller bullets. Bullets smaller than .380 ACP have generally been described as having inadequate performance for self-defense and for law enforcement use whether on duty for use in a back-up weapon or off duty for self-defense. Previous articles have indicated that the terminal performance of .380 ACP jacketed hollow point (JHP) bullets is often erratic, with inadequate penetration and inconsistent expansion being common problems, while .380 ACP full metal jacket (FMJ) bullets offer adequate penetration, but no expansion.

Small versions of 9 mm, .40 S&W, and .45 ACP pistols available for use in plain clothes and off-duty roles may also be used as back-up weapons, however, these pistols are usually heavier, larger, and more awkward to conceal and carry in a back-up weapon role than a small .38 Special revolver. In addition, back up handguns are frequently concealed in unusual locations and are often subjected to dust, lint, moisture, poor lubrication, and other environmental factors which can cause malfunctions and which may be better tolerated by small revolvers than small semi-automatic pistols. In addition, a small revolver can be fired from a jacket pocket if necessary, while a pistol will usually malfunction in that location.

Small .357 Magnum revolvers have been touted as defensive handguns for civilians and backup handguns for law enforcement personnel, yet the terminal wound ballistic performance of .357 Magnum bullets fired from small revolvers is not significantly different than that of the .38 Special. The .357 Magnum has a higher velocity, but does not usually form a larger permanent wound cavity than the .38 Special; in lighter bullet weights, inadequate penetration is common with the .357 Magnum. For use in civilian self defense or as a law enforcement back-up, the small .357 Magnum revolver, with it's larger muzzle blast and flash and harsher recoil, offers no advantages and has several deficits compared to the more controllable .38 Special.

Materials And Methods

Five bullets of each type were fired (except for the Federal +P+ 147 "Hydra-Shok" jacketed hollow point where ten shots were fired to verify it's unusual performance). The .380 ACP bullets were fired using a Colt Mustang Pocket Lite pistol with a 2.75 inch barrel, while the .38 Special bullets were fired using both a Smith & Wesson Model 60-3 revolver with a 3 inch barrel and a Smith & Wesson Model 38 revolver with a 2 inch barrel. All testing was performed at the California Highway Patrol Academy Weapons Training Department Indoor Firing Range using the protocol described previously. Acceptable performance was arbitrarily defined as meeting both minimum penetration (12.0 inches/30.5 cm) and expansion (0.55 inch/14 mm) requirements.

Results

Tables 1 & 2 show the bullet type and lot #, along with the five (or ten) round averages of velocity, penetration depth, recovered diameter, recovered length, and recovered weight for each ammunition type. All of the bullets formed a temporary cavity with a maximum diameter of approximately 3 to 5 cm. Previous tests indicated that penetration and expansion differences are minimal between .38 Special bullets fired from three or four inch revolvers.

Discussion

All of the .380 ACP JHP bullets tested offered generally inconsistent, unacceptable terminal performance for law enforcement back up and off duty self-defense use due to inadequate penetration, as well as inadequate expansion.

Throughout the 20th Century, the .38 Special has remained one of the most widely used law enforcement and civilian self-defense cartridges in the United States. The best .38 Special terminal performance has traditionally been accepted as that of the +P 158-grain lead semi-wad cutter hollow point bullet (LSWCHP), the FBI standard issue load for many years. Ammunition tests by the FBI's Firearms Training Unit resulted in the 147 go JHP being adopted as the new FBI standard .38 Special load. The Federal +P+ 147-gr "Hydra-Shok" JHP was the new load initially adopted by the FBI. FBI test results showed that the new bullet offered improved accuracy and better penetration of intermediate obstacles without sacrificing terminal performance when compared to the previous FBI standard .38 Special +P 158-gr LSWCHP when fired from the old FBI standard issue Smith and Wesson Model 13 revolver with a three inch barrel. This paper verifies, that when fired from a revolver with 3 inch barrel, the .38 Special Federal +P+ 147-gr "Hydra-Shok" JHP bullet expands as other .38 Special bullets. When fired from a 2 inch barrel revolver, this study found that the .38 Special Federal +P+ 147-grain "Hydra-Shok" JHP bullets will not expand sufficiently and will have very poor wounding characteristics similar to those exhibited by full metal jacket (FMJ) and lead round nose (LRN) .38 Special bullets.

TABLE 1: .380 ACP

Load	Lot #	Vel	Pen	R. D.	R. L.	R.W.	BB CALIB
Cor Bon +P 90-gr JHP (38090/20)	RC1138	945 f/s	23.5 cm (9.3")	0.57"	0.25"	90.3-gr	9.5 cm @ 576 f/s
Horn 90-gr JHP (9010)	027 95 8838	803 f/s	31.7 cm (12.5")	0.45"	0.38"	89.4 -go	9.5 cm @ 576 f/s
Fed 90-gr JHP (C380BP)	094798Z021	901 f/s	39.7 cm (15.6")	0.40"	0.38"	89.6-gr	9.5 cm @ 576 f/s
Fed 90-gr JHP (PD380HS1)	094489Z154	938 f/s	27.2 cm (10.7")	0.49"	0.34"	90.0-gr	9.5 cm @ 576 f/s
Rem 88-gr JHP (R380A1)	C03PB03	867 f/s	35.5 cm (14.4")	0.40"	0.43"	88.7-gr	9.5 cm @ 576 f/s
Rem 102 gr JHP (GS380B)	K 27G B6601	750 f/s	35.0 cm (13.8")	0.44"	0.44"	101.5-gr	9.5 cm @ 576 f/s
Speer 90-gr JHP (23606)	M26D1	823 f/s	28.8 cm (11.3")	0.45"	0.39"	89.3-gr	9.5 cm @ 576 f/s
Win 88-gr JHP (X380ASHP)	94PG90	879 f/s	10.8 cm (7.1")	0.58"	0.34"	84.7-gr	9.5 cm @ 576 f/s
Win 95-gr JHP (S380)	8ND70 46 98	781 f/s	24.5 cm (9.6")	0.51"	0.37"	95.0-gr	9.5 cm @ 576 f/s

TABLE 2: .38 Special

Load	Lot #	BL	Vel	Pen	R. D.	R. L.	R.W.	BB CALIB
Win 110-gr STHP (X38S9HP)	34DG1397	3"	881 f/s	26.3 cm (10.3")	0.57"	0.37"	109.3-gr	10.5 cm @ 577 f/s
Win 110-gr STHP (X38S9HP)	34DG1397	2"	802 f/s	23.5 cm (9.3")	0.54"	0.39"	109.8-gr	8.0 cm @ 587 f/s
Win +P+ 110-gr JHP (Treasury)	12FF2	3"	1019 f/s	24.3 cm (9.5")	0.64"	0.32"	110.0-gr	10.0 cm @ 586 f/s
Win +P+ 110-gr JHP (Treasury)	12FF2	2"	1016 f/s	25.0 cm (9.8")	0.59"	0.38"	109.5-gr	8.0 cm @ 587 f/s
Fed +P 125-gr JHP (38E)	16A-0685	3"	889 f/s	27.5 cm (10.8")	0.57"	0.40"	118.4-gr	8.0 cm @ 587 f/s
Fed +P 125-gr JHP (38E)	16A-0685	2"	820 f/s	24.8 cm (9.7")	0.59"	0.43"	124.9-gr	8.0 cm @ 587 f/s
Fed +P 129-gr JHP (P38HS1)	120149V149	3"	883 f/s	29.8 cm (11.7")	0.61"	0.41"	127.7-gr	8.0 cm @ 587 f/s
Fed +P 129-gr JHP (P38HS1)	120149V149	2"	793 f/s	37.3 cm (14.7")	0.43"	0.56"	128.0-gr	8.0 cm @ 587 f/s
Win +P 138-gr JHP (SXT S35P)	15LH91141	3"	898 f/s	28.3 cm (11.2")	0.61"	0.39"	130.1-gr	8.0 cm @ 587 f/s
Win +P 138-gr JHP (SXT S35P)	15LH91141	2"	817 f/s	30.7 cm (12.1")	0.55"	0.47"	129.4-gr	8.0 cm @ 587 f/s
Fed +P+ 147-gr JHP (P38HS2)	12A-0573	3"	868 f/s	36.8 cm (14.5")	0.62"	0.42"	145.4-gr	9.6 cm @ 578 f/s
Fed +P+ 147-gr JHP (P38HS2)	12A-0573	2"	806 f/s	46.2 cm (18.2")	0.32"	0.63"	147.3-gr	8.0 cm @ 587 f/s
Win +P 147-gr JHP (RA38147HP)	11EA110249	3"	795 f/s	36.8 cm (14.5")	0.58"	0.48"	146.3-gr	10.0 cm @ 586 f/s
Win +P 147-gr JHP (RA38147HP)	11EA110249	2"	741 f/s	33.9 cm (12.6")	0.55"	0.53"	148.1gr	8.0 cm @ 587 f/s
Fed +P 158-gr LSWCHP (38G)	702771W007	3"	796 f/s	29.9 cm (11.8")	0.59"	0.53"	156.0-gr	9.0 cm @ 585 f/s
Fed +P 158-gr LSWCHP (38G)	702771W007	2"	744 f/s	33.8 cm (13.3")	0.50"	0.60"	157.1-gr	9.0 cm @ 585 f/s
Rem +P 158-gr LSWCHP (R38S12)	M17MB8602	3"	872 f/s	34.0 cm (13.4")	0.62"	0.44"	156.3-gr	8.0 cm @ 587 f/s
Rem +P 158-gr LSWCHP (R38S12)	M17MB8602	2"	824 f/s	30.8 cm (12.1")	0.61"	0.46"	156.7-gr	8.0 cm @ 587 f/s
Win +P 158-gr LSWCHP (X38SPD)	93UH917141	3"	828 f/s	35.4 cm (14.0")	0.54"	0.56"	156.7-gr	10.0 cm @ 586 f/s
Win +P 158-gr LSWCHP (X38SPD)	93UH917141	2"	785 f/s	38.5 cm (15.2")	0.50"	0.57"	156.8-gr	8.0 cm @ 587 f/s

The lightweight .38 Special hollow point bullets in 110-gr and 125-gr weights offer insufficient penetration to be considered acceptable for law enforcement or self-defense usage. The .38 Special Federal +P 129-gr "Hydra-Shok" JHP (P38HS1) also exhibits unacceptable performance, although in an unusual fashion: in 3 inch barrel revolvers expansion is adequate, but penetration is unacceptable, while in 2 inch barrel weapons, penetration is adequate, but expansion is poor. The Winchester +P 138-gr JHP (SXT S35P) has acceptable expansion, but lacks adequate penetration when fired from a 3 inch barrel revolver, however, both penetration and expansion are acceptable in 2 inch revolvers. The Federal +P 158-gr LSWCHP (38G) has acceptable expansion, but marginally inadequate penetration when fired from a 3 inch barrel revolver, while in 2 inch revolvers penetration is acceptable, but expansion is deficient. The Winchester +P 158-gr LSWCHP bullet (X38SPD) has the necessary penetration, but has inadequate expansion in both two and three inch barrel lengths.

The Winchester +P 147-gr JHP (RA38147HP) and Remington +P 158-gr LSWCHP (R38S12) both offer acceptable penetration and expansion when fired from .38 Special revolvers with a two or three inch barrel length.

Conclusion

A small .38 Special revolver firing appropriate ammunition is probably the best back-up handgun available for law enforcement personnel and is a far superior choice to a .380 ACP pistol. Examples of ideal back-up handguns for law enforcement use are the Smith & Wesson J-Frame series, such as the Model 38 "Body Guard", Model 642 "Centennial", or model 342 "Air Lite Ti".

A small lightweight .38 Special revolver firing appropriate ammunition should be the minimum caliber off duty self-defense handgun carried by law enforcement personnel. Optimal off duty handguns for law enforcement personnel may be 3.5 to 5 inch barrel 9 mm Parabellum, .40 S&W, or .45 ACP caliber pistols using standard department issue ammunition which has been tested & meets acceptable performance standards.

The .38 Special bullets which offered the most reliable wounding effects for law enforcement back-up and off duty self-defense use in revolvers of two or three inch barrel lengths and were most likely to provide rapid incapacitation were the Remington +P 158-gr LSWCHP (R38S12) and Winchester +P 147-gr JHP (RA38147HP).

The Federal +P+ 147-gr "Hydra-Shok" JHP (P38HS2) bullet expands in revolvers with at least a 3 inch barrel, but should not be used in two inch barrel weapons due to insufficient bullet expansion. The Winchester +P 138-gr JHP (SXT S35P) bullet offers acceptable performance in two inch barrel revolvers, but should not be used in longer barrel lengths due to insufficient bullet penetration.

All of the other .380 ACP and .38 Special bullets tested offered unacceptable terminal performance for law enforcement and self-defense use.

Acknowledgments: The author would like to thank the Weapons Training Staff at the California Highway Patrol Academy for their generous support.

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INSTITUTE REPORT NO. 231, LETTERMAN ARMY INST. OF RESEARCH, APRIL 1987

MISSILE-CAUSED WOUNDS

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Preface

This paper was submitted to the Office of the Surgeon General of the Army in September 1986 in response to a request by COL Thomas Bowen MC USA of the Surgeon General's staff that Dr. Fackler revise/rewrite "Missile-Caused Wounds" (Chapter II from the 1975 edition of the NATO HANDBOOK - EMERGENCY WAR SURGERY), for the upcoming revised edition. The chapter has been completely rewritten, and none of the wording or figures from the previous Chapter II has been included. Since COL Bowen felt that the wording in the submitted chapter was too blunt or "confrontational," he and Dr. Fackler worked together to edit the chapter for publication.

The purpose of this Institute Report is to preserve the chapter in the form it was submitted (and thus distinguish it from the edited chapter) and to clearly establish authorship, since authors' names will not be included with their contributions in the NATO HANDBOOK.

Abstract

Wound profiles made under controlled conditions in the wound ballistics laboratory using gelatin tissue simulant that has been calibrated against living animal soft tissue show the location along the tissue path and amount of both crush (permanent cavity) and stretch (temporary cavity) caused by the penetrating projectile. Characteristic wound profiles are presented for a variety of penetrating projectiles, including rifle, pistol, shotgun. The data on these profiles is used to correct common fallacies and lay the groundwork for better understanding and more effective treatment doctrine.

Chapter II: Missile-Caused Wounds

Missiles that penetrate the human body disrupt, destroy, or contuse tissue, and the resultant wound is invariably contaminated. Triage and treatment decisions are based on the estimation of the location, type, and amount of tissue disruption. Objective data from the physical examination and appropriate roentgen graphic studies of the wounded individual provide the information needed to make these decisions.

Mechanisms of Wounding

The penetrating object crushes and destroys tissue as it bores a hole through it (Fig. 1). This hole is the permanent cavity. Its size is limited by the presenting area of the missile causing it, and its dimensions are roughly the same for all soft tissues.

After passage of the projectile the walls of the permanent cavity are stretched radially outward. The maximum lateral tissue displacement delineates the temporary cavity. Any damage inflicted by temporary cavitation results from stretching of the tissue. Resistance to stretch damage depends mostly on tissue elasticity. The same stretch that causes a moderate contusion and little interference with function in muscle can cause massive disruption if it occurs in the liver. The temporary displacement of tissue is actually a localized area "blunt trauma" surrounding part of the projectile path, and it is useful to keep this in mind in assessing relative vulnerability to disruption.

The sonic shock wave shown at the far right of Fig. 1 precedes the passage of the projectile through tissue. Although the sonic wave generated by penetrating projectiles may range up to 100 atmospheres, its duration is so brief (circa 2 microseconds) that it does not displace tissue. It has no detectable harmful effect on tissue.

The typical wounding potential of a given missile can be assessed by measuring the two types of tissue disruption it produces. A method developed at the Letterman Army institute of Research captures the entire path of the fired missile in gelatin tissue simulant. Measurements taken from the gelatin are used to depict the location and extent of both crush and stretch types of tissue disruption on a drawing or "Wound Profile". Figures 2 through 12 illustrate selected "Wound Profiles". The scale included on each profile can be used to measure the extent of tissue disruption at any point along the projectile path. It also facilitates comparisons between wound profiles.

Gunshot Wounds

Figures 2 through 7 show profiles of bullets that do not deform on striking soft tissue.

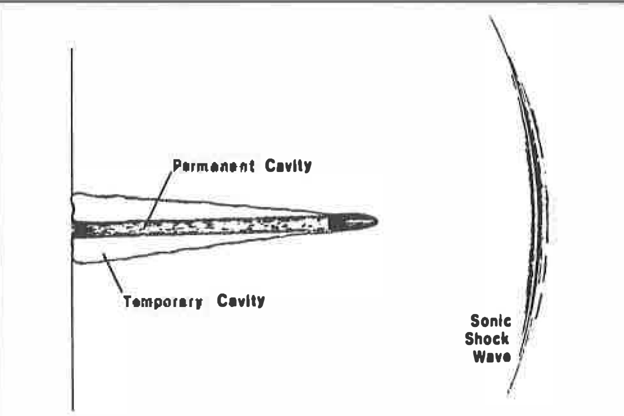

FIG. 1. - Diagram of bullet passing through tissue showing sonic shock wave and how the temporary cavity is formed by outward stretch of the permanent cavity.

45 AUTOMATIC –

This full-metal-jacketed military bullet (Fig. 2) is one of few that do not yaw (turn the long axis in relation to direction of travel) significantly in soft tissue. Lack of yaw, coupled with the large mass of this bullet, results in deep penetration. The crush tissue disruption remains nearly constant throughout the bullet path. Temporary cavity stretch is maximal near the surface, gradually diminishing with penetration, but with this bullet type and velocity the temporary cavity is too small to show a wounding effect.

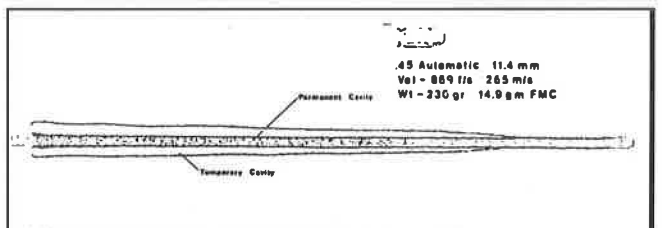

FIG. 2. - 45 Automatic - This was the standard U.S. Army pistol until recently. The short, round nosed, full-metal-cased bullet does not deform or yaw significantly in tissue but penetrates deeply.

22 LONG RIFLE –

This commonly used rimfire bullet (Fig. 3) yaws through 90 degrees and ends up traveling base forward for the last half of its tissue path. The crush tissue disruption increases with yaw angle, reaching its maximum when the bullet is traveling sideways. Temporary cavity stretch increases with increasing bullet yaw, as a diver hitting the water makes a larger splash as his body angle to the water surface increases. Even at the point of maximum bullet yaw the temporary cavity produced remains too small to add a detectable wounding effect.

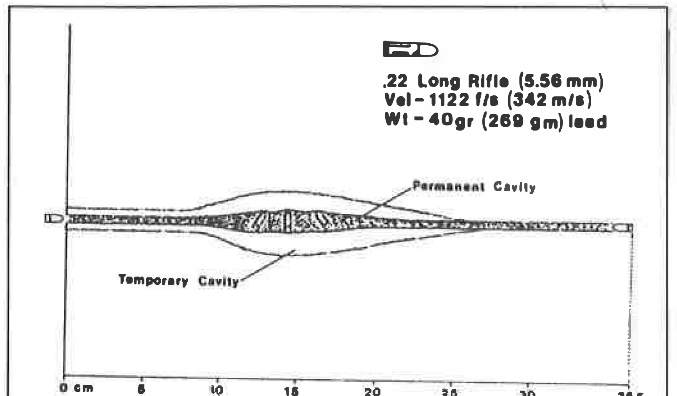

FIG. 3. - 22 Long Rifle - This solid lead round nosed bullet yaws through 90 degrees and travels base-forward for the last half of its tissue path.

38 SPECIAL –

This lead round nose bullet (Fig. 4), like the 45 Automatic (Fig. 2) and the 22 Long Rifle (Fig. 3), produces it's wounding almost solely by the crush tissue disruption mechanism. Although still too small to show an observable wounding effect, the maximum temporary cavity is of 20% greater diameter than that made by the 22 Long Rifle despite the fact that its velocity is 40% less.

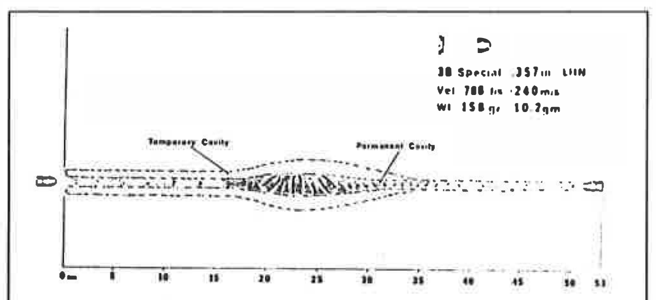

FIG. 4. - 38 Special lead round nosed bullet - Seven out of ten of these bullets yawed through 90 degrees and traveled base-forward for the latter part of their tissue path as show. Three shots yawed to about 80 degrees, then straightened out and traveled point-forward for the remainder of their path.

9 MM PARBELLUM –

This bullet is widely used in both pistols and submachine-guns. It produces a profile (with the full-metal-jacketed bullet type) that resembles that of the 38 Special (Fig. 4) but the maximum temporary cavity is about 2 cm larger in diameter and will show some stretch effects (radial splits) in the more susceptible tissues such as liver.

7.62 NATO FMC –

(FMC is the abbreviation for full- metal-cased which is a synonym of full-metal-jacketed. This refers to the harder metal covering of the bullet core.) This full-metal-jacketed military bullet (Fig. 5) shows the characteristic behavior in tissue observed in non-deforming pointed bullets. It yaws through 90 degrees and after reaching the base-forward position continues the rest of its path with little or no yaw. The bullet is stable traveling base first in tissue since this position puts its center of mass forward. The rotation imparted to the bullet by the rifled gun barrel is sufficient to cause point-forward travel in air, but not in tissue where such factors as bullet shape and location of center of mass outweigh rotation effects. The tissue disruption produced in the first 15 to 18 cm of bullet penetration, where the streamlined bullet is still traveling point-forward, is minimal. At 20 to 35 cm, however, where bullet yaw is marked, a large temporary cavity is produced. If the bullet path is such that this temporary cavity occurs in the liver, this amount of tissue disruption is likely to make survival improbable.

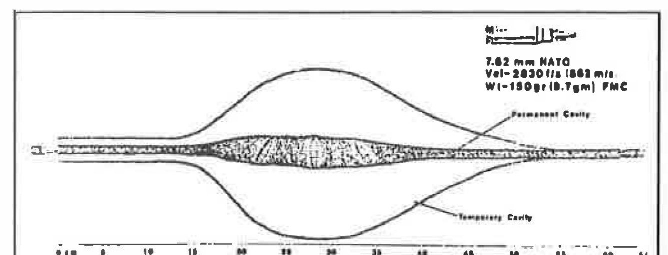

FIG. 5. - 7.62 NATO cartridge with full metal cased military bullet- This was the standard U.S. Army rifle until the adoption of the M-16 in the 1960s. It is still used in sniper's rifles and machine guns. After about 16 cm of penetration this bullet yaws through 90 degrees and travels base forward. A large temporary cavity is formed and occurs at the point of maximum yaw.

AK-47 –

The Russian Assault Rifle's full-metal-cased military bullet (Fig. 6) travels point-forward for 25 to 27 cm in tissue prior to beginning significant yaw. Wounds from this rifle are familiar to those surgeons who served in Vietnam and are well documented in the WIDMET study of wounds from that conflict. Even with the long tissue path of a transverse shot across the abdomen, the disruption is likely to be no more that that produced by the 38 Special pistol bullet.

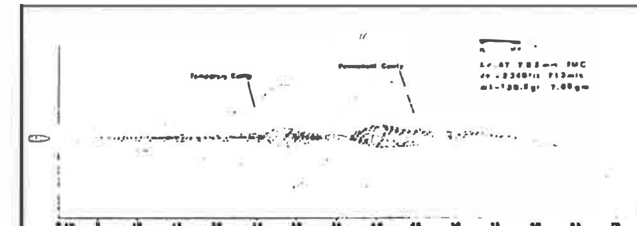

FIG. 6. - AK 47 - This was the standard rifle used by the communist forces in Viet Nam and is used today very widely throughout the world. The long path through tissue before marked yaw begins (about 25 cm) explains the clinical experience that many wounds from this weapon resemble those caused by much lower velocity handguns.

AK-74 –

This new generation smaller caliber Russian Assault Rifle (Fig. 7) follows the example set by the USA with the M-16. The lighter cartridge weight makes it possible for the soldier to carry more ammunition and the considerably lighter recoil makes the weapon easier to shoot. The full-metal-cased bullet designed for this weapon has a copper plated steel jacket, as does the bullet of its predecessor the AK-47. A unique design feature of the AK-74, however, is an air-space (about 5 mm long) inside the jacket at the bullet's tip. The speculation that this air-space would cause bullet deformation and fragmentation on impact proved to be unfounded, but the air-space does serve to shift the bullet's center of mass toward the rear. This bullet yaws after only about 7 cm of tissue penetration, assuring an increased temporary cavity stretch disruption compared to the AK-47, even in many extremity hits. The typical exit wound from a soft-tissue thigh wound (12 cm thick) is stellate, with skin split measuring from 9 to 13 cm across. The underlying muscle split is about half that size. The bi-lobed yaw patterns shown in the profiles of the AK-47 and the AK-74 represent what is seen in four- fifths of shots. In the rest the bullet reaches 90 degrees of yaw and continues to 180 degrees or the base forward position in one cycle. Whether there are one or two yaw cycles, it does not influence the point of prime clinical relevance -the distance the bullet travels point- forward before yaw.

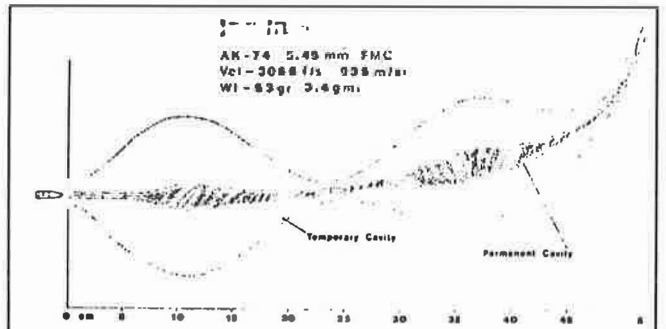

FIG. 7. - AK 74 - This is the Russian contribution to the new generation of smaller caliber assault rifles. The bullet does not deform or fragment in soft tissue but yaws early (after about 7 cm of penetration). As this bullet strikes soft tissue, lead flows forward filling the air space inside the bullet's tip. X-rays of recovered fired bullets show that this "internal deformation" produces an asymmetrical bullet which may explain the unusual curve of close to 90 degrees made by the bullet path in the latter part of its penetration.

357 MAGNUM JSP –

The jacketed soft-point bullet (Fig. 8) and the jacketed-hollow-point bullet flatten their tips on impact. This "expansion" or "mushrooming" (final bullet shape resembles a mushroom) results in a doubling of effective bullet diameter in tissue, and allows the bullet to crush four times as much tissue (pi times radius squared equals cross section area of the bullet which impacts tissue). Also, the change in the bullet to a non- aerodynamic shape causes the same sort of increased temporary cavity tissue stretch, as does the yawing bullet. The maximum temporary cavity produced by the expanding bullet occurs at a shallower penetration depth than that caused by the full-metal-jacketed military type bullet. This soft-point pistol bullet is typical of the type most commonly used by law enforcement agencies in the USA. Its lessened penetration depth (compare with Fig. 2) decreases the likelihood of the bullet perforating a criminal and going on to injure an innocent bystander.

7.62 NATO SP –

(SP is the abbreviation for soft-point)- The same cartridge case shown in Figure 5, when loaded with a soft-point bullet, produces the wound profile shown in Figure 9. Changing only the variable of bullet construction causes massively increased tissue disruption compared to that of the full-metal-cased bullet (Fig.5). Bullet expansion occurs on impact as seen with the 357 Magnum pistol bullet (Fig. 8) but, in this case the crushed tissue from the expanded bullet accounts for only a small part of the large permanent cavity. As this bullet flattens, pieces break off and make their own separate paths of crushed tissue. These bullet fragments penetrate up to 9 cm radially from the bullet path. The temporary cavity then stretches muscle that has been weakened by multiple perforations. The fragment paths act to concentrate the force of the stretch, increasing its effect and causing pieces of muscle to be detached. This synergistic effect, resulting in the large tissue defect shown in Fig. 9, is seen only with bullets that fragment. The 7.62 NATO soft-point is a popular big game hunting bullet and although shooting accidents are not infrequent with such rounds, they are rarely seen in the hospital since few victims of torso shots survive.

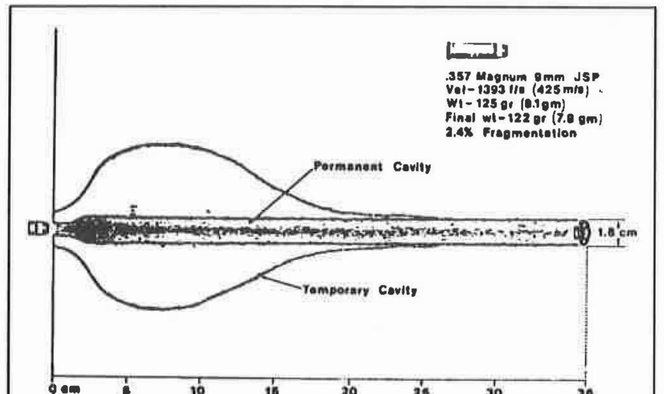

FIG. 8. - 357 Magnum jacketed soft-point pistol bullet - This expanding bullet is typical of those used by the majority of law enforcement agencies in the USA.

22 CAL FMC –

This is the military M-193 bullet shot from the M-16AI Assault Rifle (Fig. 10). The large permanent cavity shown in the profile was observed by surgeons who served in Vietnam, but the tissue disruption mechanism responsible was not clear until the importance of bullet fragmentation as a cause of tissue disruption was worked out and described (Fackler, 1984). This bullet is a full-metal-jacketed military bullet, and as with

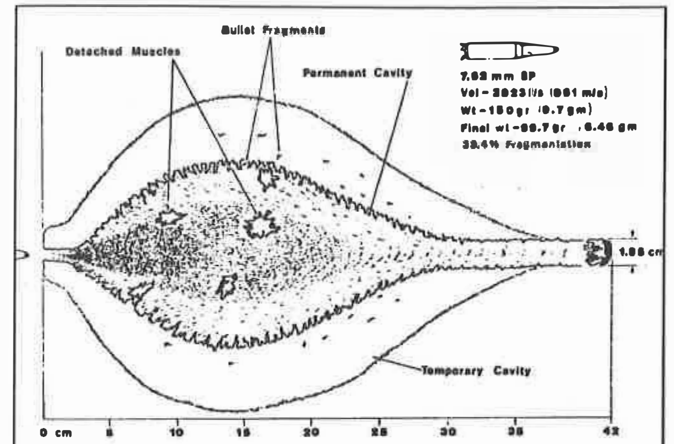

FIG. 9. - 7.62 Soft point bullet - The fragmentation of this bullet is largely responsible for the massive tissue disruption seen as compared to that produced by the nondeforming military bullet fired from the same cartridge (Fig. 5).

other bullets of this type, it causes little tissue disruption so long as it remains traveling point forward through tissue. Its average distance of point-forward travel is about 12 cm, after which it yaws to 90 degrees, flattens, and breaks at the cannelure (groove around bullet midsection). The bullet point remains as a flattened triangular piece, retaining about 60% of the original bullet weight. The rear portion breaks into many fragments that penetrate up to 7 cm radially from the bullet path. The temporary cavity stretch, its effect increased by perforation and weakening of the muscle by fragments, then causes a much-enlarged permanent cavity by detaching muscle pieces. The degree of bullet fragmentation decreases with increasing distance (as striking velocity decreases). At a shooting distance of 80 meters the bullet breaks in half forming two large fragments, and at over 180 meters it does not break, although it flattens somewhat squeezing out a few small fragments from its base. Thus at ranges over 180 meters the wounding capacity and mechanisms are essentially the same as the AK-74.

M-855 22 CAL FMC –

The slightly heavier M-855 bullet shot from the M-16A2 Assault Rifle will eventually replace the M-193 bullet shot from the M-16AI as the standard bullet for the US Armed Forces. The wound profile is similar to that produced by the M-193 bullet. The percentage of fragmentation is higher than the M-193, since the tip generally does not remain in one piece, and the temporary cavity size and location is about the same. Although the permanent cavity is slightly larger, a difference in wounds caused by the two would be difficult to determine.

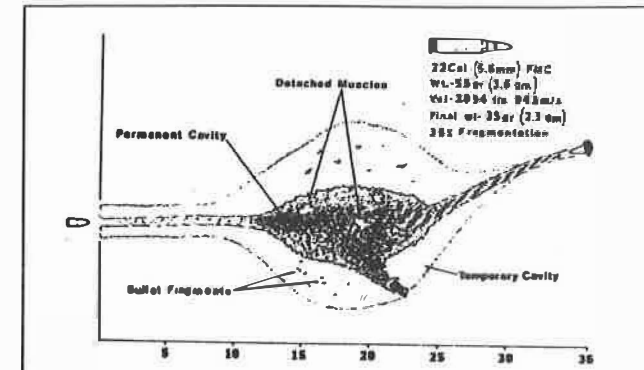

FIG. 10. - 22 Caliber full metal cased (M-16 rifle firing M-193 bullet) - This is the standard weapon of the U.S. Armed Forces, although it is soon to be replaced by a new rifle using the same caliber and cartridge but with a longer and slightly heavier (62 grain) bullet.

The smaller bullets of the new generation Assault Rifles (M-193, AK-74, M-855) are susceptible to deflection and disturbance of their point-forward flight by intermediate targets such as foliage that had insignificant effects on previous larger and slower projectiles. This can result in large yaw angles at impact and a shallower location in the body of maximum tissue disruption. For these bullets that rely on yaw in tissue for their maximum effect, the wound profiles show the average penetration depth at which this yaw occurs. It is not unusual for this distance to vary fifty percent from that pictured.

.224 SOFT-POINT –

This 50 grain soft-point bullet is designed for maximum deformation and fragmentation. To produce the wound profile shown in Fig. 2, it was shot from the M-16 cartridge case (known as the 223 Remington in civilian shooting parlance). The amount and type of damage caused is about the same as that caused by the military M-193 (M-16) bullet but the location of the maximum disruption is at a shallower penetration depth. Modification of the M-193 bullet tip by filing or with a wire-cutter, a practice that is more common than realized in military conflicts, will result in a similar tissue disruption pattern to that produced by this soft-point bullet.

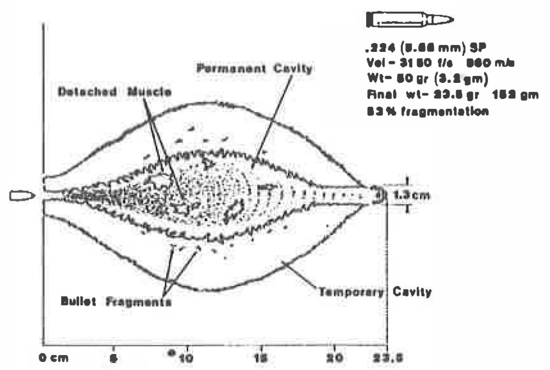

FIG. 11. - .224 soft-point bullet - This is a typical 22 caliber center-fire hunting bullet (.224 inches is actual bullet diameter) fired from the same cartridge as the military M-16.

12 GAUGE SHOTGUN #4 BUCKSHOT –
Loaded with 27 pellets of #4 Buckshot (Fig. 12), the 12-gauge shotgun at close range (3 meters in this case) causes massive crush type tissue disruption. At this short range, soft-tissue impact deforms the individual pellets, increasing their original 6 mm cross section to about 10 mm with concomitant increase in tissue crush or hole size. The 27 perforations of this size in a 7 to 8 cm diameter area result in severe disruption of anatomy by direct crush and in disruption of blood supply to tissue between the multiple wound channels.

The Wound Profiles portray an estimate of the maximum soft-tissue disruption expected at short range (under 25 meters). A gradual decrease in the amount of bullet deformation, fragmentation and maximum temporary cavity size occurs with distance as striking velocity decreases. If bone is struck by the penetrating projectile the result is predictable (and easily seen on X-ray). Total penetration depth will be less and an increase in tissue disruption due to increased bullet deformation as well as fragments of bone acting as secondary missiles may greatly increase the damage.

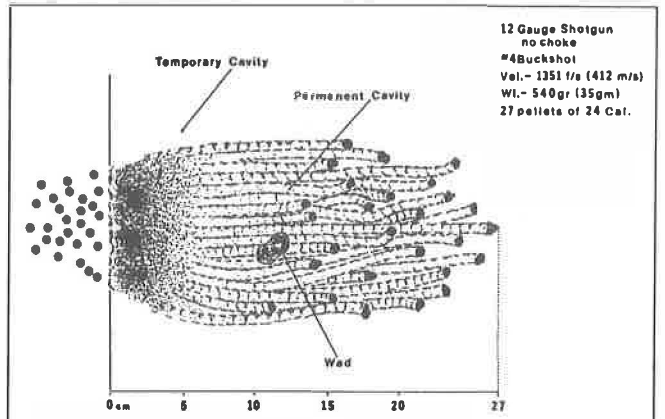

FIG. 12. - 12 Gauge Shotgun with # 4 size buckshot - This load is used by the military and by law enforcement groups for special situations.

Fragments From Explosive Devices

The great majority of fragments from explosive devices are of blunt or irregular shape - distinctly not aerodynamic- and of steel or less dense material. This causes them to lose velocity rapidly in air and decreases tissue penetration depth compared to the denser streamlined rifle bullets. The crush type of disruption predominates in the injury pattern caused by the individual fragment from these devices, with little evidence of temporary cavity stretch. The hole made by the fragment is consistent with its size and generally remains constant throughout its path. It is analogous to the wound from a shotgun pellet. Although initial fragment velocities in the 1800 m/sec range are reported for some of these devices (Beyer, 1962), the wounds observed in survivors indicate that striking velocities were less than 600 m/sec. For this reason, body armor affords much better protection against these fragments than against the rifle bullet.

In cases where a survivor was close enough to the device to be struck by many fragments in a localized area, such as stepping on a landmine, the injury pattern is similar to that produced by #4 Buckshot at close range (Fig. 11). Again, the crush mechanism predominates but this is an example of the massive tissue disruption which results when many permanent wound paths in close proximity destroy anatomic integrity.

Misconceptions

It becomes obvious from observation of data on the Wound Profiles that projectile striking velocity and mass determine only the potential for tissue disruption. When this potential results in significant tissue disruption, the variables of projectile construction, projectile shape, and type of tissue struck determine where the disruption occurs and what kind of disruption predominates (crush or stretch). For example, a shot through soft tissue of the average human thigh by a 7.62 NATO round loaded with the soft-point bullet (Fig. 9) could result in an exit wound up to 13 cm diameter with much tissue loss. The same potential is available in the 7.62 NATO FMC military bullet (Fig. 5), but the exit wound it causes in a comparable shot would most likely not exceed 2 cm in its largest dimension.

If one walked into a large city hospital with a gunshot wound in the thigh (entrance and exit holes of less than1cm in diameter), and gave the history of being shot with a 22 Long Rifle bullet, surgical treatment rendered would be minimal. The same would apply if the history were of a wound from a 38 Special or a 45 Automatic. If, however, the history was given that the wound had been made by an M-16, most likely the victim would be subjected to a massive excision of the entire bullet path and several cm of tissue on all sides of the path. Comparing the first 12 cm of penetration on the M-16 wound profile (Fig. 10) with that of the other examples mentioned (Figs. 2-4), shows that in such a wound the M-16 is unlikely to cause any more tissue disruption than the 22 Long Rifle. The widespread belief that all wounds caused by "high-velocity" projectiles must be treated by "radical debridement", is an example of a harmful fallacy resulting from failure to recognize the role of bullet mass and construction in the projectile-tissue interaction.

Serious misunderstanding has been generated by looking upon "kinetic energy transfer" from projectile to tissue as a mechanism of injury. In spite of data to the contrary (Wang,et al. 1982), many assume that the amount of "kinetic energy deposit" in the body by a projectile is a measure of the damage it does. Such thinking stops short of delving into the actual interaction of projectile and tissue that is the crux of wound ballistics. Wounds that result in a given amount of "kinetic energy deposit" may differ widely. The nondeforming rifle bullet of the AK-74 (Fig.7) causes a large temporary cavity, which can cause marked disruption in some tissue (liver), but has far less effect in others (muscle, lung, bowel wall) (Fackler,1984).

The temporary cavity of about the same size produced by the M-16 (Fig. 10), acting on tissue that has been perforated by bullet fragments, causes a much larger permanent cavity in tissues such as muscle and bowel wall and a similar disruption to that caused by the AK-74 in liver. A large slow projectile will crush (permanent cavity) a large amount of tissue, whereas a small fast missile with the same kinetic energy will stretch more tissue (temporary cavity) but crush little. The "temporary cavity/energy deposit mystique" has also misled those in weapon development and evaluation. A large study (Bruchey, 1979) which attempts to rate handgun bullets makes the unfounded assumption that the temporary cavity size produced by a bullet is directly proportional to the incapacitation that bullet causes in the human target. Many body tissues (muscle, skin, bowel wall, lung) are soft and flexible - the physical characteristics of a good energy absorber. The assumption that tissue must be damaged by temporary displacement makes no sense physically or biologically. Not surprisingly, law enforcement agencies are finding increasing numbers of cases in which handgun bullets chosen on the basis of such studies fail to perform as predicted.

Anyone yet unconvinced of the fallibility of using kinetic energy alone to measure wounding capacity might wish to consider the example of a modern broadhead-hunting arrow. It is used to kill all species of big game, yet its striking energy is about 68 Joules - less than that of the 22 Short bullet.

Clinical Applications

Penetrating projectile wounds, like any other mechanical trauma, cause their harm by tissue disruption. The restoration of the integrity of disrupted body systems (circulatory, GI, respiratory, GU, etc.) are a top priority. The missile path, contaminated with bacteria, may later become a source of invasive infection, which can threaten life or at least prolong healing. This threat is covered in detail in Chapter XVI - "Wounds and injuries of the Soft Tissues", but it should be mentioned here that the top priorities in the treatment of penetrating projectile wounds are the establishment of an adequate blood level of a penicillin-like antibiotic as soon as possible, and the establishment of open wound drainage. The high priority of antibiotic coverage may surprise those who have forgotten that a streptococcal bacteria was by far the most common cause of death in war wounds in the pre-antibiotic era (Ireland, 1929).

In the combat casualty with a missile caused wound, determining the course of the missile in the body is a major concern. Since the majority of penetrating projectiles follow a relatively straight course in tissue, an estimate of the missile path can be made from the location of the entrance hole and the position of the projectile in the body, or the location of the exit hole. In most cases, physical examination and biplanar x-rays establish these two points and estimation of structures that might have been damaged is clear. In some cases oblique x-ray views will be needed and it may be impossible to determine with certainty if penetration of a body cavity has occurred. "Is that fragment intraperitoneal or in the abdominal wall?" - combat surgeons are very familiar with that question, is a laparotomy needed or not? In cases of uncertainty, do the laparotomy - missed gut perforations do not do well in the combat scenario.

Bullet fragmentation and its correlation with severe permanent tissue disruption (Figs. 9-12) is an especially useful roentgen graphic sign. Rifle wounds of the chest wall in which a large disruption has occurred in the muscles of the shoulder girdle (M-16, Ak-74, or AK-47 if it hit bone) may be expected to have pulmonary contusion even without penetration of the pleural cavity. This may not be evident on x-rays taken shortly after the wound occurred. Be aware of this potentially life threatening situation, and assure adequate follow-up observation and treatment. This is probably the only common situation in which truly occult damage from temporary cavity "blunt trauma" results in a clinical problem.

Comparing tissue disruption patterns observed in the wounded with the Wound Profiles shown should allow some conclusions to be drawn about the wounding projectile. This information may well prove useful for military intelligence as it has for forensic science.

Conclusion

An intelligent surgeon, knowing nothing more about penetrating missile injuries than that the path they make is contaminated, would most likely treat them appropriately. Much of the data presented in this chapter is to counteract dogma that preaches unfounded, illogical, and harmful methods such as the excision of an entire missile path with several cm of healthy surrounding tissue because of a history that the wound was caused by a "high velocity" projectile. Treatment decisions are made on hard evidence- physical and roentgen graphic findings. To paraphrase Lindsey, "treat the wound, not the weapon".

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The widespread misinformation and lack of understanding concerning ballistic injury are well known to anyone who understands the subject and keeps up with its literature. The undesirable consequences of these deficiencies range from substandard gunshot wound treatment to lessened law enforcement effectiveness.

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

What needs to be done? First, the valid literature needs to be identified. This will give the interested reader the scientific background material on which to build a solid understanding of the subject. Next, an ongoing periodic critical review of the wound ballistics literature needs to be initiated. Finally, an easily accessible source of wound ballistics expertise needs to be established.

The International Wound Ballistics Association has been founded to fill these needs. The IWBA publishes a journal, the *Wound Ballistics Review*, which contains original articles and reviews of other publications. By focusing its expertise upon the literature relating to wound ballistics, the IWBA hopes to stimulate an increased awareness among editors, writers, and readers and to help minimize future inaccuracies. Additionally, the International Wound Ballistics Association is prepared to offer expertise to assist any publication concerned with avoiding error and maintaining technical accuracy.

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

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