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IWBA

INTERNATIONAL WOUND BALLISTICS ASSOCIATION

WOUND BALLISTICS REVIEW

JOURNAL OF THE INTERNATIONAL WOUND BALLISTICS ASSOCIATION

VOLUME I NUMBER I WINTER 1991

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STATEMENT OF PURPOSE

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

The effects of penetrating projectiles on the body is of vital concern to trauma surgeons, weapon designers and users, and those involved with the forensic aspects of ballistic trauma. Yet, we know of no organization that deals with the subject exclusively and in depth. Papers containing ballistic injury data appear in widely scattered sources, since many groups include projectile effects peripherally in their interests. However, in each source, these comprise a very small percentage of the total papers and most 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.

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

What needs to be done? First, the valid literature needs to be identified. This will give the interested reader the scientific background material on which to build a solid understanding of the subject. Next, an ongoing periodic critical review of the wound ballistics literature needs to be initiated. Finally, an easily accessible source of wound ballistics expertise needs to be established. When a need and no ready and recognized source of expertise exists, mythology fills the gap.

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

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

Martin L. Fackler, MD
President, IWBA

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JOURNAL OF THE INTERNATIONAL WOUND BALLISTICS ASSOCIATION

IWBA is a non-profit scientific, educational, and public benefit California corporation awaiting IRS 501 (c) (3) determination. It is comprised of scientists, physicians, criminalists, law enforcement members, engineers, researchers, and others engaged or interested in the study of wound ballistics.

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INSTRUCTIONS TO AUTHORS

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

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

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

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

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

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

SUBMISSION INSTRUCTIONS

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

2. In submitting original work, the manuscript and one copy is requested ; one set of glossy illustrations are required. Corresponding author must be clearly identified on the title page with address and telephone number. Manuscript must be double-spaced with ample margins (at least one inch on all sides) on standard (8 1/2" x 11") paper. NOTE: THE PREFERRED MANUSCRIPT FORM IS THE 5 1/4" (1.2 Meg or 360K), or 3 1/2" (1.44 Meg or 760K) PC FLOPPY DISK WITH A PAPER COPY. All major PC word processors are acceptable but Wordperfect 5.0 or 5.1 is preferred.

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

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

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

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

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

6. The editors reserve the right to require a CV from any author who is not a member or technical consultant of the IWBA and whose previous works are not known to them.

Association News

From the President

Several of our members have already begun correcting errors by writing to editors. BRAVO! Keep it up. Include your IWBA Affiliation in your letter and please send us an info copy (include a copy of the original article). We will keep them on file and report progress in this column.

We have a membership of outstanding quality; many are the world's top authority in their area of specialization. We encourage our members to share their ideas of how we might better accomplish our goals.

Martin L. Fackler, MD
President, IWBA

MEMBERSHIP: How It Works

The IWBA is unlike many other associations in that our Full Member and Technical Consultant memberships are only available by nomination and invitation. There is no automatic qualification for Full Member or Technical Consultant status. For example, while many Full Members are physicians, just having a medical degree is not qualification for Full Membership and while many Technical Consultants are law enforcement members, all police officers are not automatic TC's. The overall primary consideration in our nominating FM's and TC's is that they possess a solid understanding of elementary wound ballistics.

Several people have asked how they can be nominated as an FM or TC. We suggest that they become Associate Members and then contribute articles to our Journal and/or demonstrate their knowledge and value to the Association in other ways. It is our hope that FM or TC status in the IWBA will have some intrinsic value by virtue of the caliber of the expertise, abilities, knowledge, and accomplishments of our members. We are seeking quality; not quantity in our memberships.

The membership types are:

Full Membership ($40/yr) is only available to those actively engaged in wound ballistics research and/or to those who have made substantial contributions to the subject. Full Membership status is by invitation after nomination by two Full Members.

Technical Consultant ($30/yr) is only available by invitation after nomination by two Full Members to those with specific expertise in related fields who are available to provide assistance or information of value to our membership.

Associate Membership ($60/yr) is available to individuals with an interest in the field. Associate Members receive the *Wound Ballistics Review* and all Association mailings.

Subscriber Membership ($60/yr) is open to libraries, corporations, organizations, and other entities which wish only to receive the *Wound Ballistics Review: The Journal of the IWBA*.

(All memberships are subject to review and acceptance by the Membership Board.)

Alexander Jason
Executive Director

Bad Body Armor?

We have recently received several inquiries from law enforcement officials concerned about national news media (CBS, Associated Press, etc.) reports and a FBI "bulletin" stating that two manufacturers of soft body armor (Second Chance and American Body Armor) had made protective vests which were in some way "substandard" or deficient. While we are not able to discuss the allegations in this issue, we are fully aware of the details of the controversy and those concerned should be aware that it is our opinion that the allegations are without merit and should be disregarded. To those in law enforcement wearing vests made by either manufacturer we can state that if you had confidence in your vest before the news reports, you should continue to maintain that confidence.

The source of the spurious allegations is the National Institute of Justice (NIJ) and are political, not scientific in nature. The real problem is not with the maligned vests but with the incompetence of the NIJ. We may have more on this matter in the next issue. Those interested in the subject should read the "Body Armor Standards: A Review and Analysis" article starting on page 14.

AJ
MLF

Reader's Forum

To The Editors:

I am writing in the hope that your association will be able to help our Unit. I am currently serving in a newly established Unit within our Police Department. The Victoria Police Department has a strength of over 9000 Police personnel.

The Unit is called Firearms Operational Survival Training Unit (F.O.S.T.U.) and has been set up as a response to a number of factors.

- The lack of Training in Officer Survival
- The need to keep abreast of current training trends Nationally and Internationally
- The need to research Operational Incidents ie, shooting incidents etc.

This is a small insight into the unit and why it is has been established. The last area mentioned is where we are having a great deal of problems obtaining information. Our unit attends scenes of major violence, particularly those involving Police shooting Offenders and being shot at.

At the present time our state Government is conducting an inquest into Police Shootings dating back to 1985. Questions are being asked concerning the number of shots fired at offenders and whether they are excessive.

As a result of a recent shooting incident involving our Special Operations Group (S.O.G) equivalent to your S.W.A.T. teams our unit has been required to provide details concerning shooting incidents. The operation involved S.O.G. entry to search for a violent offender who had been involved in a shooting. The entry team encountered the offender with a firearm. He was shot a number of times by 9mm rounds and by 12 gauge SG shotgun rounds. During this whole incident the offender remained a threat and struggled with the Police after being shot.

Questions have been asked "How can a person continue to be a threat after being shot so many times?" We are in the position of requiring information and documented cases of similar incidents where offenders have been shot and continue to be a threat to Police.

I feel your Association could provide valuable information to out unit and assist us in our enquires. If we can become members of your association please provide details.

Bob Carter, Sergeant
Firearms Operational Survival Training Unit
C/- Victoria Police Academy
ViewMount Rood Glen Waverley
Victoria Australia 3150

Response:

Dear Sergeant Carter,

The reasons for setting up the Victoria Police Department's Firearms Operational Survival Training Unit coincide closely with the goals of the International Wound Ballistics Association. The questions you pose are extremely pertinent and need good documented answers.

I have testified in numerous court cases and inquests defending law enforcement officers against allegations of excessive use of force. In some cases this translates into someone actually believing that too many shots were fired — an easy judgment to make by those who were not engaged in the gunfight — but, more commonly, it is simply an attempt to make money from a civil lawsuit by drumming up public emotion over a case. In a Canadian case in 1989, thirteen 9 mm body hits were clearly justified; in a more recent California case, three 9 mm shots in the head were justified.

LaGarde recounts, in the enclosed pages from Gunshot Injuries (Wm. Wood & Co., 1916), the charge of a Moro warrior who was alive and presumably still a threat after ten body hits from the 30-40 Krag service rifle. Also shown in these pages is a survivor of three chest shots and one in the arm from the .38 Colt revolver. Additionally, I have enclosed a copy of a letter to the Los Angeles Police Firearms Unit which contains eight historical references to many head shots that did not result in death (or even unconsciousness in some cases).

In my files, I have an autopsy report (with X-rays, police and crime lab report) of a case in which 27 hits by 9 mm 115 grain Silvertip were needed to incapacitate a determined person. These bullets, which expand too much and lack adequate penetration even from a handgun (see enclosed copy of the FBI 1987 Wound Ballistics Workshop), were fired from a submachine gun. The additional velocity caused them to fragment in the superficial tissues and they just were not reaching vital organs.

In order to make any meaningful comment on the recent shooting involving your Special Operations Group I will need a copy of the autopsy report (including copies of pertinent X-rays), the police report and the crime lab report on the recovered bullets. If you send these I will be happy to provide you with an analysis of the incident including answers to your questions. We will then add the information to the International Wound Ballistics Association files so that it can be made available to other law enforcement agencies as needed.

Disbelief that a person can continue to be a threat after absorbing many shots results from widespread public ignorance on bullet effects. This ignorance is fostered by the entertainment and the news media's constant exaggerations and preference for the spectacular (whether it bears any relation to the truth appears to be of no concern). Collecting and correlating both recent and historical documented cases to combat misinformation is a major goal of our newly formed organization.

The good news is that over the past few years more law enforcement groups are electing to fight unjust allegations and go to court when needed rather than caving in to pressure from the press and other sources — and they are winning. As word gets around that logic and realistic analysis are defeating the typical nonsensical emotional appeals in court I suspect that we will see a decrease in these lawsuits. Then law enforcement can get back to their job rather than having their resources bled by ill-conceived and opportunistic accusations. Also, then officers may become less hesitant about putting the number of shots into their adversary needed to end the threat — however many shots that may be! (OFFICER SURVIVAL LESSON ONE)

The question of how many times a criminal may be shot has drawn much interest from the law enforcement community and may be the subject of a full article in our next issue – Ed.

Editorials

Data Versus Doctrine

Douglas Lindsey

Thirty years ago Janice Mendelson and I did a study of the course and outcome of wounds produced by a number of commonly used bullets ranging in velocity from 605 to 2844 feet per second (1961). Doing the study was straightforward wound ballistic research: lasso the goats in the pen; bring them into the laboratory for anesthesia, positioning, shooting, and measurement of velocity; return the goats to the pen.

Getting the study published was a drawn-out, bitter, recriminative struggle with the higher echelons. The data were in conflict with doctrine: all of the wounds--even at the highest velocity--healed without evidence of muscle necrosis or infection. The last sentence of our paper was, "It seems reasonable to conclude that . . . the amount of debridement required for a bullet wound should depend more on the damage inflicted than on the nature of the missile." This statement is a forerunner of "Treat the wound, not the weapon" but it is couched in restrained, modest, and less inflammatory terms. Nevertheless it was anathema in the Pentagon.

Other studies have confirmed our findings. Tissue which is stretched and contused by the temporary cavity produced by passage of a missile is "non-viable" only if it is excised and discarded; if left alone it heals. Finally, after the passage of nearly thirty years, the Department of Defense has recognized this fact, but many authors and practitioners of the surgery of trauma have not.

Why is the doctrine so impervious to the revision demanded by clear evidence? There are many factors involved. The momentum of long standing practice. Reluctance to swallow the pill of retraction. Public and professional fascination with "assault rifles" and "high velocity." But if revision or reversal is not possible, perhaps we can make do with erosion: patient and repetitive impact of data against doctrine. I welcome the advent of this Journal, a critical review of wound ballistics.

Douglas Lindsey is Professor of Surgery, Emeritus at the University of Arizona and an IWBA founding member.

The "Twilight Zone" of Wound Ballistics

Alexander Jason

There is one common misconception which has done much to confuse and mislead people about wound ballistics: the belief that there is some mysterious mechanism by which a bullet can cause sudden incapacitation without disruption of the central nervous system or rapid blood loss. Rod Serling might have introduced it this way: "There is another method of incapacitation beyond that which is known to man. It is in the middle ground between light and shadow, between science and superstition and it lies between the pit of man's ignorance and the summit of his imagination. It is a mechanism we call:"

(Take your choice:)

- Stopping power
- Hydrostatic shock
- Relative Incapacitation Index
- Remote effects
- Kinetic energy transfer
- Temporary cavitation
- "Chi" vibrations
- Reticular activating system shutdown
- Shocking power

While the above exotic, mysterious, and always ambiguous definitions have a powerful attraction to many people, the reality of incapacitation is much more banal. The *only* reliable mechanisms by which bullets can cause rapid incapacitation are:

1. The bullet either struck and damaged the central nervous system, the heart, a major vessel, organ or bone rendering the suspect physically incapable of continuing or;

2. The person being shot consciously and voluntarily decided to cease his assault or escape.

These are not theories but clear and easily comprehensible facts yet many people who should know better appear to find them excessively simple. They prefer to search for more complex and enchanting mechanisms to explain how bullets work.

One of the roots of this search for "magic bullets" nonsense is found within the Oriental martial arts world. There are many myths within Karate, Aikido, Kung-Fu and other such disciplines suggesting that there is a certain "force" or method of "focusing energy" upon an opponent which can cause his internal organs to "melt" or simply to cause immediate unconsciousness. The talk is that there are (or were) various old martial arts "masters" able to incapacitate or even kill opponents with only the touch of finger or by a single punch to the midsection. While never scientifically defined, these "powers" are usually vaguely described as techniques causing certain destructive "vibrations" within the body.

Contributing to belief in such phenomena are martial arts "demonstrations" during which a self-proclaimed "master" will announce to his audience of True Believers that he will demonstrate his superior powers by simply touching someone on the chest and causing him to immediately fall unconscious. An eager volunteer (usually an adoring student) will be chosen and after an impressive fanfare of deep breathing, contemplation, and perhaps a shout by the "master," the volunteer will, of course, fall over on cue when touched. The real cause is self-suggestion or simply a desire to save the guru from public embarrassment. The event is much like a faith healing; although the "healed" person may not have felt his cancerous tumor "melt away" as proclaimed, he's not going to admit it among thousands of cheering believers. The unquestioning, sympathetic spectators at such events come away with their beliefs strongly reinforced.

The martial arts deadly "vibrations" myths have worked their way into wound ballistics because many in law enforcement and among those interested in firearms often also have an interest in the martial arts and most have heard of these mysterious "powers." Their logic suggests that if incapacitation can be achieved by means of a simple touch or punch then it must follow that a bullet's "punch" into a human body must be capable of producing those same "vibrations" (or whatever) and therefore sudden incapacitation.

Those who attempt to rate bullets by "one-stop-shots" or by how quickly shot animals collapse contribute to this wound ballistics mysticism yet some of these people do so unintentionally. It is often the result of their failure to have "checked their premises;" to examine their own fundamental assumptions. While there is certainly a need for scientific thought and analysis in the martial arts world, we have enough mythology and nonsense within our own world of wound ballistics and it is not my intention for us to branch out into other fields. But I hope that this *Journal* will encourage us all to analyze and question our assumptions; to continually check *our* premises.

Performance of the Winchester 9mm 147 Grain Subsonic Jacketed Hollow Point Bullet in Human Tissue and Tissue Simulant

Eugene J. Wolberg

Twenty-seven shootings were reviewed. The penetration depth of the 147 grain Winchester Subsonic JHP bullet in living human tissue was measured at autopsy, and the bullet's expansion was measured from the recovered bullets. These were compared to the bullet's performance in 10% ordnance gelatin shot at 4 degrees Centigrade. A close correlation was found.

In 1987 the San Diego Police Department adopted the 9mm Parabellum 147 grain Subsonic jacketed hollow point (JHP) Winchester bullet for its duty pistols. The adoption was based on the recognition that adequate penetration potential is of paramount importance to bullet performance. Shots with this bullet into 10% ordnance gelatin shot at 4 degrees C confirmed that it reliably and consistently penetrated over 12 inches.

Recognizing that the human torso contains different organs of varying densities, while gelatin tissue simulant is a homogeneous material, it was decided to collect results from shootings with the newly adopted 147 grain 9mm bullet and compare them with results from the shots into the 10% gelatin. Bullet penetration depths were measured at autopsies resulting from officer involved shootings. Ordinarily, measured penetration depth figures are **not** found on autopsy reports. However, for this study our medical examiner agreed to measure bullet penetration depths and include them in the autopsy reports. Only shots into the torso that remained in the body for their entire penetration depth were included in this study. Measurements of bullet expanded diameter and its remaining length were taken directly from the bullets recovered at autopsy. These results were then compared with results from the 10% ordnance gelatin in order to assess the accuracy of this tissue simulant's predictive accuracy.

SHOTS INTO ORDNANCE GELATIN

The gelatin was prepared using the method of the Letterman Army Institute of Research (1). After each shot, the bullet's penetration depth in the gelatin, its expanded diameter (average of the largest and smallest diameter - most expanded bullets are not exactly round), and its length were measured. An expansion ratio was derived for each bullet by dividing its expanded diameter (ED) by its remaining length (RL).

The 147 grain Winchester Subsonic JHP bullet had an average penetration depth in the 10% gelatin of approximately 13 inches with a range of 12 to 14 inches. The bullet's expansion ratio approximated 1.20. It's average velocity (measured with an Ohler Model 33 chronograph) was 950 feet per second. These results were obtained from 20 shots, from two different lots of ammunition.

SHOTS FROM HUMAN AUTOPSIES

The following chart lists information retrieved from the autopsy reports and crime laboratory investigations and observations. It should be noted that all head wounds, and bone hits were eliminated; this study deals only with shots that penetrated soft tissue of the torso and did not hit bone.

Eugene J. Wolberg is Senior Firearms Criminologist at the San Diego Police Crime Laboratory.

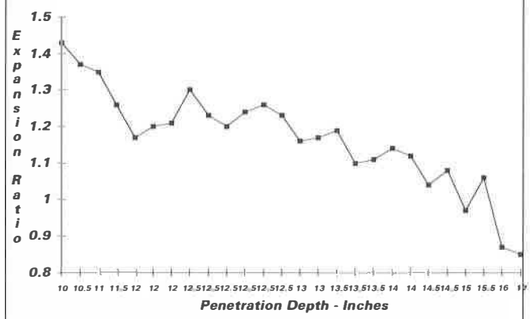
Measurements From Human Shootings with Winchester Subsonic 147 Grain JHP Bullet

	BULLET DATA	RATIO	Final Weight	Penet. Depth		BULLET DATA	RATIO	Final Weight	Penet. Depth
1.	ED .535 RL .470	1.14	142 gr.	14"	17.	ED .539 RL .445	1.21	139 gr.	12"
2.	ED .565 RL .435	1.30	137 gr.	12.5"	18.	ED .582 RL .425	1.37	135 gr.	10.5"
3.	ED .584 RL .410	1.43	140 gr.	10"	19.	ED .542 RL .437	1.24	140 gr.	12.5"
4.	ED .538 RL .460	1.17	143 gr.	12"	20.	ED .531 RL .483	1.10	141 gr.	13.5"
5.	ED .538 RL .437	1.23	141 gr.	12.5"	21.	ED .537 RL .516	1.04	138 gr.	14.5"
6.	ED .480 RL .552	0.87	145 gr.	16"	22.	ED .533 RL .494	1.08	135 gr.	14.5"
7.	ED .550 RL .515	1.06	139 gr.	15.5"	23.	ED .462 RL .544	0.85	146 gr.	17"
8.	ED .572 RL .454	1.26	132 gr.	11.5"	24.	ED .535 RL .425	1.26	143 gr.	12.5"
9.	ED .545 RL .562	0.97	145 gr.	15"	25.	ED .530 RL .431	1.23	138 gr.	12.5"
10.	ED .562 RL .468	1.20	138 gr.	12"	26.	ED .537 RL .484	1.11	134 gr.	13.5"
11.	ED .542 RL .467	1.16	135 gr.	13"	27.*	ED .531 RL .506	1.05	137 gr.	14.5"
12.	ED .532 RL .475	1.12	132 gr.	14"	28.*	ED .540 RL .495	1.09	144 gr.	13.5"
13.	ED .540 RL .450	1.20	137 gr.	12.5"					
14.	ED .536 RL .458	1.17	134 gr.	13"					
15.	ED .539 RL .453	1.19	144 gr.	13.5"					
16.	ED .581 RL .430	1.35	141 gr.	11"					

NOTES

- *Shots marked with an asterisk (*) had stopped just under the skin.*
- *ED = Expanded Diameter*
- *RL = Recovered Length*
- *Shot number 22 passed through an arm before penetrating the torso; the length of the path in the arm was added to the path in the torso to arrive at the final 14.5 inch penetration depth.*

These penetration depths were plotted against the expansion ratios; the results are shown below.



Measurements from shootings demonstrate that as bullet expansion increases, penetration decreases

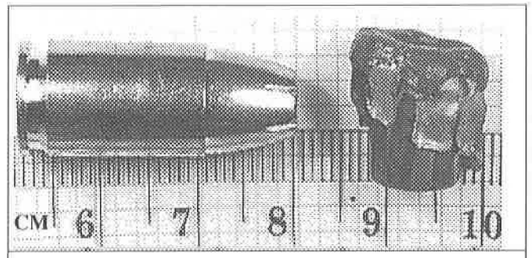
DISCUSSION

Shots into gelatin show a narrower range of penetration depths than that observed in the living human torso; while the penetration range in gel was 12 to 14 inches, the same bullet, in the torso, had a range from 10 to 17 inches.

The expansion ratios of the 147 grain 9mm bullet in 10% ordnance gelatin was about 1.20, with an average penetration depth of 13 inches. In living human torsos, the average penetration depth was also found to be 13 inches, with an expansion ratio of 1.15. The greater spread in the torso shots is not surprising considering the variety of tissues encountered, compared to the homogeneous gelatin. The two bullets found just beneath the skin (# 27 and 28) would most likely have penetrated more deeply if they had not been stopped by the "holding in" effect of the skin (2).

The data presented shows a clear relationship of expansion ratio to bullet penetration depth; the higher the ratio, the less the penetration depth. The penetration of a handgun bullet in tissue or tissue simulant is analogous to the penetration of a long range center-fire rifle bullet in air; tissue is about 800 times as dense as air, but the same physical laws apply. The 1000 yard target shooter, the military or law enforcement sniper, and the long range "varmint" shooter know the critical importance of bullet sectional density (heavier bullets in the same caliber retain velocity better -- or, one might say, penetrate air more efficiently), along with bullet shape, in determining its long range performance.

Handgun penetration potential was rarely considered prior to 1986, except perhaps by those who used the larger handguns for big game hunting. When the FBI lost two agents, in the "Miami



Winchester 9 mm 147 grain JHP subsonic bullet. The expanded bullet was recovered from gelatin and is typical of the deformation seen in muscle tissue.

shootout," due to inadequate bullet penetration, they convened a workshop (Sept. 1987) and determined that they (along with many others) had been misled by the National Institute of Justice's now infamous Relative Incapacitation Index (which rated bullet performance by temporary cavitation -- ignoring penetration depth).

Post-expansion sectional density of a handgun bullet predicts how deeply it will penetrate in tissue or tissue simulant. All other things being equal, heavier bullets in a given caliber can be expected to penetrate more deeply. The penetration capacity of a bullet is modified by the frontal resistance of the expanded bullet. The greater the expansion, the less the penetration. Overexpansion can decrease penetration potential to the point that deeply placed vital structures are unlikely to be disrupted, even with a perfectly placed shot (especially if it must pass through an arm on the way to the torso -- not uncommon: it occurred in shot

22 of this series). Underexpansion can result in too small a bullet path and an increased probability of overpenetration.

Everyone worries about overpenetration because of the danger posed to others beyond the bullet's intended target. In purely practical terms, overpenetration should also be viewed as a waste of the limited potential available to the handgun user. That wasted potential should ideally be put into making a larger hole.

Between 12 and 20 inches of penetration should assure that the bullet reaches vital organs and vessels from any angle, even in heavily built persons, *with enough potential remaining to disrupt them.*

Shots fired into correctly prepared gelatin tissue simulant can be a valuable guideline in the selection of police ammunition. It is most useful in separating out the grossly inadequate bullets; those that penetrate only 6 or 7 inches, or SP/HP bullets that do not expand adequately.

CONCLUSION

Based on comparisons of data from living tissue penetrations by the 147 grain Subsonic Winchester, 9mm Parabellum bullet with test shots of the same bullet into 10% Knox Ordnance Gelatin, type 250A, shot at 4 degrees centigrade, it is concluded that this gelatin can be a useful predictor of this bullet's penetration and expansion characteristics in shots in the human torso.

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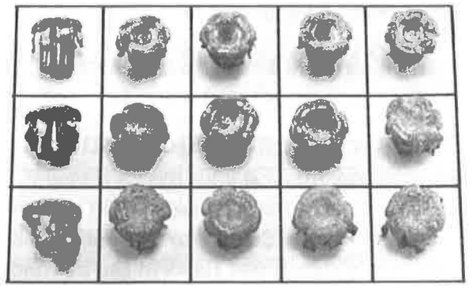


Display of Winchester 147 Gr.. JHP rounds fired into : Pig abdomen (top row); pig muscle (middle row); and water (bottom row). Note that the abdomen shots caused the least expansion; the shots into muscle caused slightly greater expansion and the water shots caused the most expansion.

EDITOR'S COMMENT

What Gene Wolberg has done here is what every clear thinking law enforcement agency should be doing. Skepticism and meaningful comparison are the essence of common sense and all scientific thought. Let's all exercise some healthy *skepticism* -- don't believe that your tissue simulant is a good predictor just because some Army Lab or the FBI uses it and says so – check it out for yourself.

It was encouraging to see the penetration depth measurements taken by the medical examiner for this series. Now that bullet performance is being measured, by many, in a reproducible manner in gelatin, the forensic and crime solving potential of this technique can be greatly enhanced if medical examiners can be persuaded to include measured bullet penetration depths in their autopsy reports (a scale drawing showing the tissue disruption pattern along the bullet's path would be nice, too – but that will be the subject of future article).

Martin L. Fackler
Editor-in-Chief

Body Armor Standards: A Review and Analysis

Alexander Jason and Martin L. Fackler

An examination of the standards used by the National Institute of Justice to test police body armor reveals significant flaws in the methodology and the underlying assumptions which invalidates the standard and contributes to police deaths.

SYNOPSIS

THE PROBLEM:

An agency of the Federal government has created a very serious situation which has caused the deaths of American police officers. If the situation is not corrected, additional deaths will occur.

BACKGROUND:

Over the past 20 years, more than 425 American police officers have been saved from death or serious injury because they were wearing soft body armor when shot. Although soft armor vests have a flawless performance record "on the streets," only about 25% of officers wear them regularly.

Soft armor could have saved 40% (approx. 110) of the officers killed by gunfire in recent years. Lack of comfort is the reason most cited for not wearing body armor regularly.

The National Institute of Justice (NIJ) in cooperation with the National Institute of Standards and Technology (NIST) have created soft armor performance standards which do not recognize the comfort of body armor as a factor to be considered.

THE CAUSES:

1. The NIJ/NIST body armor testing procedure is seriously flawed causing erratic, misleading, and ultimately invalid test results. *More than 50% of current vests fail the NIJ/NIST test procedure despite their perfect performance record in saving officer lives.*

2. The NIJ/NIST has made erroneous assumptions concerning the amount of potential damage the impact of a bullet into a vest, and the resulting "punch," will cause to the human body. These two primary flaws in the NIJ/NIST testing procedures are highly significant, as they require soft armor manufacturers to make vests which are much heavier, thicker and more rigid than necessary. Such body armor is much less comfortable to wear, and is less likely to be worn. Decreased vest use results in unnecessary deaths of police officers.

3. The NIJ/NIST refuses to acknowledge their errors or to make corrections. They have responded by attempting to quash all criticism and to seek Congressional legislation to make their

This project was funded by a grant from the E.I. du Pont de Nemours Company as a service to law enforcement. The research was independently performed by the Center for Ballistic Analysis. The conclusions, recommendations and comments are solely those of the Center for Ballistic Analysis. At no time did the Du Pont Company, or any other individual or entity, attempt to influence the conclusions, recommendations or analysis of this report.

Dr. Fackler's participation in this report was voluntary and performed without compensation as a service to the Law Enforcement Community.

INTRODUCTION

THE CONTROVERSY: SCIENCE VERSES POLITICS

Over the past 20 years, more than 425 American police officers have been saved from death or serious injury by bullets because they were wearing soft body armor (commonly called "bulletproof vests").[1] Although soft armor vests are known to have a flawless record of performance during "on the street" use by police officers, studies show that only 21 to 49% actually wear them regularly.[2] FBI data indicate that about 40% of the officers killed by gunfire during recent years could have been saved had they worn soft armor.[3] Surveys of police officers revealed that most of the 75% who do not regularly wear body armor cite various lack of comfort characteristics (thickness, weight and stiffness) as primary complaints.[4 5 6]

The challenge facing law enforcement administrators, vest manufacturers, and others concerned about protecting police officers is to create vests which provide both realistic protection levels *and* the highest degree of comfort possible so they might actually be worn on a regular, day-to-day basis as intended. *Uncomfortable vests will be worn less than comfortable vests.*

One branch of the Federal Government does not see it that way: The National Institute of Justice (NIJ) in cooperation with the National Institute of Standards and Technology (NIST) have established a performance standard for soft body armor used by police officers. The NIJ/NIST standard does not recognize the comfort (or wearability) of body armor as a factor to be considered.

There are two primary elements within the NIJ/NIST Standard. One describes "acceptable" performance characteristics of soft armor to prevent penetration of specified bullets at specified velocities. The second establishes a limit for the level of "backface deformation" —which is simply the temporary "dent" in the human body caused by a bullet pushing into the armor and the armor in turn pushing into the body. This effect is roughly similar to what might occur when one is struck in the stomach by a fist.

There is a need for a performance standard in police body armor which defines acceptable ballistic penetration and allowable backface deformation. However, a good standard must also incorporate a balance of user protection *and* user comfort. It is easy to specify that a vest must be able to stop all known bullets and to produce a zero backface deformation level. It is very difficult to make such a "perfect" vest wearable as the weight, stiffness, thickness, and heat retention would have to rise to intolerable levels to achieve such "perfection" —and a "perfect" vest would never be worn. A vest performance standard cannot ignore user comfort and wearability.

The fact that more comfortable body armor is likely to be worn more often is not only common sense, it has been proven to be true in the NIJ/NIST's own studies.[7]

When we began our research into the NIJ/NIST vest specifications, we learned that a key element—the backface deformation depth limit of 1.73" (44 mm) —is not supported by any medical or other scientific data. Not only is this our conclusion, but it is also supported by the principal physicians who were once part of the original NIJ/NIST body armor project. (The origin of this number and how it became "sacred" is described later in this report.)

The flawed NIJ/NIST backface limit has substantial significance because it requires police body armor to be much heavier, stiffer and thicker than necessary. The direct result is a severe increase in discomfort and overall vests wearability, which means many police officers will be much less likely to wear them.

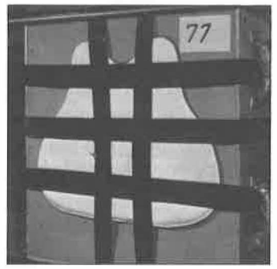
When we discovered that the NIJ/NIST deformation depth limit had not been correlated to any human injury level, we investigated further to determine if the limit could safely be raised (thereby increasing vest usage through enhanced comfort) and still provide adequate protection. We did a preliminary study which involved taking data from actual police officer "saves" and reproducing the ballistic elements (weapon model, bullet type, weight and velocity) against a vest identical to the one worn by the officer. When the vests were shot with the same bullets used in the incidents, we found there were many cases in which those bullets caused backface deformations ("dents") far in excess of the NIJ/NIST limit—*yet none of the officers in these incidents suffered any significant injury from backface deformation.*

Another important point to consider is that almost all of the vests worn in the actual shooting incidents were *not* NIJ/NIST "approved." Most of these vests could not pass the NIJ/NIST standards, yet they performed flawlessly by protecting the wearer from both penetration and from backface deformation injury. This fact alone should be sufficient to cast doubt on the applicability of the NIJ/NIST standards to real life.

Based on the results of our preliminary study—and with knowledge of the fact that there has not been a single life-threatening or otherwise significant injury in over 425 actual handgun or shotgun shooting "saves" —we believe that the NIJ/NIST limit can be revised. The exact level of acceptable backface deformation should be determined after further study by competent medical and other experts. (A description of how the "save" data could be used in such a study is on page 21 of this report.)

The NIJ/NIST's reaction to our research has been surprising. Instead of providing supporting data to refute our assertions in a scientific manner, or utilizing our research to modify and improve their standard, NIJ/NIST management has, regrettably, reacted defensively by engaging in personal and professional accusations and denunciations.[8] They are apparently unwilling to admit that they may have made a mistake, and will go to extremes in their attempts to counter any criticism.

Our research also uncovered several substantial errors in the NIJ/NIST's vest testing procedures (all of which are discussed in detail within this report). One of these errors concerns the NIJ/NIST's refusal to allow test vests to be "patted down" or flattened after they have been shot against a solidly backed block of clay. The clay backing specified by NIJ/NIST for testing does not simulate the human body in any meaningful way, and causes the ballistic fabric layers inside the vest



The NIJ test protocol mandates the use of a clay-filled wooden box with five poorly functioning straps holding the vest against the clay.

After a shot the vest layers become uncontrollably and inconsistently jumbled due to the very dense clay backing which does not realistically simulate human tissue and does not occur on the human body. Note complete penetration at shot no.5.

Subsequent shots cause more fabric disorientation and invalid results.

to become loose and jumbled after being hit by a bullet.

Armor panels are shot against a flat wall of clay. Bullet impact causes a dent in the clay behind the armor. Multiple shots are done without smoothing or repositioning the soft armor panel between shots. A bullet's impact upon the soft armor protected body causes a momentary indentation that rebounds several times due to body tissue elasticity. The elastic body wall rebounding against the armor tends to smooth it and return any layers separated by the bullet's impact toward their original positions. This self-smoothing and repositioning of layers cannot occur when the armor is pushed into non-elastic clay.

This effect makes it easier for subsequent bullets hitting the vest to penetrate completely. A useful analogy might be to visualize a small rock thrown at a standard magazine being held by its corner; the rock would not likely penetrate at all if the magazine was closed and all the pages were flat. However, a rock would likely penetrate many pages if the pages were all separated from each other instead of lying flat.

An overall view further demonstrating the uselessness of the NIJ/NIST standard is revealed in the fact that the NIJ/NIST has stated that approximately 60% of all vests they tested fail their standards—in spite of the fact that no vest has ever failed to perform as expected in the over 425 actual shootings!

In reaction to the unrealistic and unreliable NIJ/NIST test procedures, the Personal Protective Armor Association (PPAA), which includes most of the body armor manufacturers, established their own test procedure and standard. This further confused the law enforcement community as they now were faced with choosing between two competing standards. We have spoken to several police officials who have stated that while they agree that the NIJ/NIST's standard is flawed, they are afraid to ignore it because a standard issued by an agency of the Federal Government will *appear* to most as more authoritative than one issued by a group of manufacturers.

The NIJ/NIST's test procedure also contributes greatly to user discomfort by forcing vest manufacturers to make their vests much stiffer and bulkier than they need to be. Once again, we are not the only ones who believe that this particular NIJ/NIST testing requirement is wrong: both the former U.S. Army chief physician and one of the principal ballistic engineers, who worked on the initial NIJ/NIST project, publicly stated to NIJ/NIST management that they were in agreement with us. The statements of these experts is particularly significant as the two men were brought by NIJ/NIST to a public meeting to refute our findings![9]

The PPAA test protocol employes a clay-filled upper body mannequin which makes use of each vest's own particular fastening system thereby reducing the uncontrolled disorientation (jumbling) of the fabric layers. As long as clay is used as a backing, smoothing of the vest after each shot is still mandatory for valid testing.

An understanding of the human body's reaction to trauma is a complex subject that taxes the intelligence and capabilities of even the most qualified to deal with the subject. The present body armor standards dispute (and past NIJ/NIST standards disasters) were and are predictable by a simple examination of the qualifications (or the lack of qualifications) of the NIJ/NIST personnel involved. The committee they created to advise them includes 69 members but only one of those has the credentials necessary to deal with the subject of injury in the human body (and he was not present at the last NIJ/NIST Body Armor Users Seminar, 6-7 June 1990 in Reston, VA).

The NIJ/NIST management has, again, refused to correct their flawed test procedure or admit any error. We believe their resistance on this is further intensified by the fact that this test fault has been strongly and continually criticized by the Du Pont Company, makers of the ballistic fiber (KEVLAR®) used in most body armor vests. NIJ/NIST literature, and recent public and private remarks made by NIJ/NIST managers, makes it clear that NIJ/NIST management has a great deal of personal hostility towards that firm, and it also appears that they regard an admission of error as tantamount to "giving in" to Du Pont. They would apparently prefer to force a flawed standard upon the law enforcement community.

NIJ/NIST's unwillingness to admit their errors is further strengthened by a reaction common to weak bureaucracies: A strong tendency to evade responsibility by "passing the buck. " In this controversy, the NIJ/NIST prefers to pretend that comfort is not a factor in vest usage. They are then free to specify impractical and unrealistic vests while hiding behind the argument that "if a cop doesn't want to wear his vest, that's his problem—by specifying a 'perfect' vest, we've done our job."

An additional development in this controversy is that the NIJ/NIST has asked for Federal legislation which would force all vest manufacturers to comply with their standards under rule of law.[10] We believe that mandatory compliance with a flawed, invalid standard will have a direct, detrimental effect upon the law enforcement community.

The issues involved are technical and scientific and should be decided in a technical, scientific manner. It is regrettable that NIJ/NIST management apparently regards our (and any other) critiques as personal attacks on their positions and their authority. They have turned this technical debate into a "turf war" —a struggle for power. We sincerely believe that one of the central causes of the NIJ/NIST's unwillingness to admit errors or simply to make appropriate corrections, is that the management people involved lack sufficient expertise on the technical issues, and most importantly, they appear not to understand how this matter could be scientifically resolved without loss of "face."

A true scientist, when presented with valid criticism, welcomes it as an opportunity to either confirm the validity of his work or to correct his errors. Only those insecure of their knowledge, or those operating beyond their abilities, will react defensively by attempting to muzzle the critic.

The NIJ/NIST does not have a good track record in setting standards in other law enforcement matters relating to firearms and ballistics. They had previously established a standard called "Relative Incapacitation Index" (RII) which was purported to evaluate individual bullet effectiveness. The RII has since been proven to not only be invalid, but to have misled many law enforcement agencies in their selection of handgun ammunition—with grave consequences. In April 1986, the FBI had two agents killed and five wounded in a Miami shootout because bullets rated high on the RII failed to perform as predicted. After studying the problem, the FBI repudiated and discarded the NIJ/NIST's RII and developed their own bullet performance standard. Many other law enforcement agencies have adopted the FBI standard or their own standard.

More recently, the NIJ/NIST attempted to "set standards" for police handguns and shotguns. *Not a single handgun or shotgun used by law enforcement passed their standards!* This abortive attempt was ignored by the firearms industry and the law enforcement community. It is interesting that the NIJ/NIST, remaining true to their "we don't make mistakes" tradition, has never admitted any error on their part or made any changes in these meaningless standards.

The body armor controversy has a very negative effect upon the law enforcement community and serves to undermine confidence in soft armor—which has proven to be one of the most effective and valuable equipment items available to police officers. We believe that police officers will continue to be killed unnecessarily if this matter is not resolved rationally.

RECOMMENDATIONS

1. We propose that an independent board of technical experts be formed to re-evaluate these issues on a scientific basis. The board members must be individuals with comprehensive knowledge of firearms technology *and* expertise in the reaction of the human body to trauma. A competent board must include surgeons and forensic pathologists who possess a thorough understanding of weapons and the effects of projectiles on the human body.

The Board would make specific recommendations on:

A. A valid vest testing procedure (to include such items as: the backing material to be used, number and placement of test shots, impact angles and a detailed ammunition specification.)

B. The relative risk associated with backface deformation based on medical review of the more than 425 actual shooting incidents.

(Because of their demonstrated inability to deal with these issues in a scientific manner and their prejudicial behavior, we do not believe NIJ/NIST personnel should be included on the committee.)

2. Any mandate of the NIJ/NIST to assist police in weapons technology, or the effect of bullets on the human body, should be immediately revoked. Their repeated failures (RII, attempts to set "standards" for police handguns, shotguns and body armor), coupled with their unprofessional defensive reaction to well-founded criticism, have deceived the public, cost police lives, and reflected adversely upon the United States government.

THE COMFORT FACTOR:

IS IT IMPORTANT FOR VESTS TO BE COMFORTABLE?

There are three known studies which reveal police officer views on comfort. All agree comfortable vests are worn more often than less comfortable vests. While the term "comfort" represents a subjective perception which the NIJ/NIST insists cannot be measured, it has, in fact, been directly related to several identifiable factors:

Heat Retention
Weight
Rigidity (thickness, stiffness, bulk)

The MC LEAN Survey:[11]

This one-year study of 156 field officers in three Mid-west departments found that the top reasons given for not wearing body armor were:

1. Too hot
2. Restricts movement
3. Lack of concealability
4. Too heavy

In choosing a vest, the officers rated their priorities:

1. Rated stopping power
2. **Comfort**
3. Amount of body coverage
4. Concealability

5. Blunt trauma protection
6. Manufacturer's reputation
7. Price
8. Meeting NIJ/NIST standards

The author reported that the most frequent requests were for "lighter, cooler, thinner and more flexible vests . . ."

Comments included:

"If it is uncomfortable, I won't wear it . . . I don't think a vest needs to be able to stop everything. Comfort is the most important consideration."

and,

"If the unit is not comfortable, it won't be worn. I am so hot and uncomfortable wearing a vest that if forced to wear the vest, I would have to think about either quitting or a transfer of jobs."

The BRAND CONSULTING GROUP Study:[12]

In focus group discussions with police officers across the nation, this study discovered:

"Even minor improvements in comfort turn out to be a powerful motivating force for utilization."

The study concluded that vest use could increase substantially if available vests:

1. Weighed less ". . . *even a little lighter.*"
2. Were less thick ". . . *even a little thinner.*"
3. Were less rigid ". . . *even a little less 'boardy!*"

The AEROSPACE CORPORATION Study:[13]

This largest study involved over 5,000 police officers throughout the country who were issued vests of different weight, thickness and design. The officers in the two year study were required to report monthly on their opinions of the vests and the amount of time it was worn.

The conclusions were:

"In general, as more plies (layers) *are added, the percent of complaints regarding heat increased."* and

"The main point is that as more plies (layers) *are added to increase the level of protection, the garment becomes heavier, more uncomfortable and is worn less."* and

"Heat containment, stiffness and bulk are the primary reasons given for non-wear."

(The Aerospace study was part of the NIJ/NIST original soft body armor program. NIJ/NIST is apparently incapable of understanding the data and conclusions of its own study.)

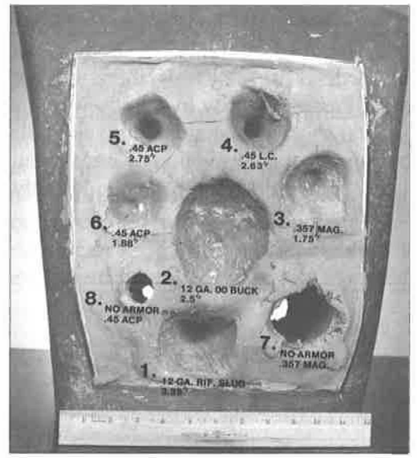
The data collected and presented in these studies is clear and unambiguous: comfort is a very important factor in vest selection and wear. Although NIJ/NIST literature often states their agreement that comfort is an important factor to be considered, their refusal to make the slightest revision in their standards to enhance comfort shows their complete lack of concern for the officers who need to wear body armor.

WHAT THE REAL LIFE SHOOTING INCIDENTS TELL US

A PRELIMINARY STUDY Preliminary studies were conducted by Du Pont at the request of CBA. Lightweight armor panels were mounted on Roma "Plastilina" #1 (NIJ/NIST spec.) clay and shot with medium-high energy threats. Backface signatures were then measured and photographed. (Chart and photograph below.)

The ballistic events chosen for these initial

scouting trials were typical of those in which the armor was known to have performed well against various threats in actual use. Four of the six tests (12 Ga. rifled slug, 12 Ga. 00 Buckshot, 45 cal. ACP and .357 Mag.) were re-creations of actual shootings in which the details of the event (vest, gun, ammo, distance, etc.) were known. As in the rest of the known bullet vs vest incidents, no officer suffered any life-threatening or significant injury from the backface deformation. At this time, we know of no broken bones or serious internal injury caused by blunt trauma.



Examples 1-6 are unsatisfactory results to NIJ but very satisfactory results to law officers. Note: Examples number 1, 2, 3, and 6 represent re-creating of actual armor saves. Examples 7 and 8 (no armor "worn") are unsatisfactory results to all of us.

The data from this important preliminary study show that all six incidents resulted in backface deformation depths greater than the NIJ/NIST's 1.73" (44 mm) absolute limit. The fact that none of these officers were significantly injured indicates that the NIJ/NIST limit may be unrealistically low. A scientific review of all 425+ incidents will likely provide sufficient data to determine a realistically safe backface limit.

DU PONT — JUNE 1990 — PRELIMINARY STUDY

Evaluate the Amount of B.F.S. in Shootings Similar to Known Armor Saves June 2, 1990

	CONSTRUCTION	AREAL DENS. lbs./sq. ft.	#S-713 PLIES EQUIV.	THREAT	MUZZLE VEL. ft./s	DIST.	B.F.S. in./mm
†1.	1 x 713 16 x 328 1 x 713	.82	14	FED. 12 GA. RIF. SLUG*	1500	30 FT	3.25" 83
†2.	1 x 713 16 x 328 1 x 713	.82	14	REM. 12 GA. 00 BUCK*	1308	10 FT	2.5" 64
†3.	1 x 713 16 x 328 1 x 713	.82	14	.357 MAG. 158GR. JSP	1327	25 FT	1.75" 44.5
4.	1 x 713 8 x 328	.41	7	.45 L.C. 250GR. LD	840	10 FT	2.625" 67
5.	1 x 713 8 x 328	.41	7	.45 ACP 230GR. FMJ	763	10 FT	2.75" 70
†6.	1 x 713 16 x 328 1 x 713	.82	14	.45 ACP 230GR. FMJ	845	10 FT	1.875" 48
7.	NO ARMOR			.357 MAG. 158GR. JSP	1332	10 FT	PENET.
8.	NO ARMOR			.45 ACP 185GR. JHP	910	10 FT	PENET.

*REMINGTON M-870 W 26" BARREL/IMP. CYL.

Other Known Data Points:

PPAA-STD-1989-05
Sixteen typical level B (NIJ Level II) models tested against 12 GA. 2.75" 00 buckshot
Avg. vel. 1339 ft./s (range 1262-1374 ft./s)
Avg. B.F.S. 2.2"/56mm (range 1.9-2.6"/48-66mm)

27 plies KEVLAR® 129 S-703 quilted in 1" squares tested at BTL against 12 GA. 2.75" Rem. rifled slug B.F.S. was 3.25"/83mm

†20 plies KEVLAR® 29 S-713 commercial vest tested at BTL against 12 GA. 2.75" 00 buckshot B.F.S. was 1.875"/48mm (cavity was 3.6 x 3.1")

†Re-creations of actual shootings

The NIJ/NIST has expressed no interest in studying the actual shootings, preferring instead to rely on experimental and provisional theories and assumptions from testing of dubious value performed over 15 years ago on goats, pigs and monkeys.

HOW A VALID BACKFACE DEFORMATION LIMIT COULD BE DETERMINED

Although there have been NO reported incidents of significant injury from ballistic blunt trauma, it is possible to determine a reasonably safe limit from the hundreds of "saves."

Every shooting of a police officer will have at least an official report of the event in which the shooting incident is described in detail. Many of these reports will identify the type, caliber, manufacturer, and model of the weapon used and the brand, weight, caliber, and type of bullet which struck the officer's vest. The brand and model of the vest are also available. There will also be many incidents in which medical records were created after hospital examination of the "saved" officer (officers "saved" are routinely taken to a hospital for evaluation.)

From this data, it is possible to re-create many of the ballistic details of a "save" incident. A clay (or other substance)backed vest of identical construction would be shot with an identical bullet fired from a weapon of the same model and/or barrel length. The resulting dents (deformations) in the clay could be measured and recorded.

After several dozen or perhaps several hundred re-creations, it would be possible to state that a particular deformation depth, 2.2" (56 mm) for example, observed in the clay never caused an injury in any of the incidents and could therefore be assumed to be allowable.

Common questions regarding ballistic replication:

QUESTION: How can the actual range from which the officer was shot be replicated?

ANSWER: With handguns, the range is insignificant in most incidents as the great majority of cases involve ranges of less than 50 feet. For those concerned about bullet range and velocity: A 158 grain, 38 caliber bullet will only lose about *1%* of its velocity in 50 feet and much less than that in ranges of less than 10 feet—inconsequential amounts. Incidents in which the weapon was fired at contact or near contact range could easily be replicated. Other test shots will be made at a distance of less than 6 feet.

QUESTION: What about the fact that the angle at which the bullet struck a vest may not be recorded in the police report?

ANSWER: True in some cases. But where the angle is not clear, a "worst" case scenario of O degrees will be used.

There are, of course, unknowns and uncertainties with any study; but with the wealth of data available, recorded by trained observers, investigators and medical professionals, there will certainly be a much greater validity in a study which reviews actual shootings against humans in place of bean bags on goats, "provisional" mathematical models or "incomplete, unproven and highly subjective" suppositions.

CONCLUSIONS:

1. There are significant problems within the testing methodologies of both the NIJ/ NIST body armor performance standards and the Personal Protective Armor Association (PPAA) performance standards which invalidates them as meaningful testing protocols The marked physical dissimilarity between the body armor test protocols and the situations actually encountered by soft body armor users "on the street" significantly detracts from overall relevance and credibility of both test protocols:

• The use of the specified Roma "Plastilina" #l clay is a poor simulant when compared to the dynamic, elastic human body. Clay is much harder and more resistant to compression than is soft body tissue. The specific gravity of the clay is between 1.6 and 1.8, which makes it much heavier than soft body tissue (with a specific gravity of approximately 1.02.) Clay is also inelastic; when a dent or deformation is made in clay, the dent persists; most soft body tissue is elastic. The abdomen, for example, will easily deform when a finger is pushed into it, yet the deformation will disappear once the finger is removed.

• Unlike the specified clay, the rib cage of the body is resilient. It can be compressed several inches as it is whenever external cardiac massage is performed. This characteristic is not simulated in the current testing protocols, and may affect not only backface deformation, but overall ballistic resistance of soft armor.

• It is well known to those familiar with soft body armor testing that a hard backing will cause penetrations which would not occur with a soft and resilient backing. Thus, the results of a penetration test protocol using a wall of hard clay held in a nonyielding carrier is highly questionable when compared to a protocol utilizing a soft, resilient backing.

• Another effect of the elastic soft body tissue that is not reproduced by the clay backing is the "self-patting" or tendency to return the body armor layers (which are separated to some degree by bullet impact) to their original positions. This effect is caused by the multiple rebounds of the elastic body wall after impact, in contrast to the non-elastic clay which does not rebound, and which will preserve a dent. Because of this difference, any legitimate test in which multiple shots are made into body armor using clay as a backing must require smoothing of the body armor fabric layers between shots to accurately simulate shots against soft armored humans. If this is not done, erratic and spurious test results will occur.

• In the great majority of real-life situations in which soft armor is impacted by bullets, the upper body is free to move. Both the NIJ/NIST and PPAA standards mandate the use of clay backing in an unyielding, non-moveable structure. While the resultant movement of the body in response to the impact of a handgun bullet is small, this effect cannot be ignored if the scientific veracity of soft armor ballistic testing is to be conserved.

2. While we do not believe that clay is a suitable backing material all soft armor testing which continues to use clay must require that vests be "patted down" or smoothed after each shot.

• The current NIJ/NIST standard protocol does not allow smoothing of a test vest after the first penetration test shot is made. When struck by a bullet backed by clay, a vest will usually bounce off the clay which will result in a "ballooning" or "bunching and balling" of the fabric layers. This effect causes a partial delamination of those layers in an unpredictable re-arrangement. This results in two significant flaws: (l) Penetration resistance of the vest cannot be measured accurately because the strength of any vest is severely deteriorated when fabric layers are not in contact with each other; and (2) The random bunching up of fabric layers does not allow accurate determination of the angle at which the bullet strikes the fabric. This error prevents accurate measurement of resistance to penetration and does not allow a determination of a bullet's actual angle of incidence into a vest.

3. The description of ammunition to be used in testing is not adequate and will cause inconsistent and unreliable test results. This is particularly true in the NIJ/NIST description of bullets which are designed to deform: the "JHP" (jacketed hollow point) and the "JSP" (jacketed soft point.) Bullets of identical weight and caliber are made by many different manufacturers, each with its own particular bullet design and metal/alloy formulation.

These different bullets, although matching the NIJ/NIST description, may perform quite differently when impacting against a vest. A much more detailed description is required, identifying the test bullets, at the very least, by particular manufacturer and lot numbers.

4. The current NIJ/NIST backface deformation limitation requirement of 44 mm (1.73") is not supported by medical or other valid data. A scientific review of the medical and other reports used by NIJ/NIST reveals the fact that their own data do not, in fact, support their standard. The detailed analysis of the NIJ/NIST data is contained within the body of this report.

5. The current NIJ/NIST backface deformation limitation requirement should be re-evaluated and revised based on the data available from the over 425 actual bullet vs soft armored human incidents:

• Many of the shooting incidents involved high energy weapons such as .357 Magnums, 44 Magnums, and even shotgun slugs which produce backface deformations far in excess of the NIJ/NIST limitation, yet there has never been a single recorded incident in which a life threatening or significant injury was caused by ballistically induced blunt trauma.

6. The current invalid NIJ/NIST backface deformation limitation has caused, and is likely to continue to cause decreased vest wear by police officers with resultant injuries and deaths. These casualties have been, and will continue to be, caused by the NIJ/NIST's disproportionate backface deformation requirement which directly and substantially affects the weight, thickness, rigidity and hence, the overall wearability of soft armor.

• In the four year period from 1985 to 1988, 261 law enforcement officers were killed by gunfire. Of that number, more than 40% (approximately 110) were shot in the upper torso and would have been saved had they been wearing body armor.

NIJ/NIST REACTION AND RESPONSE

After our in-depth review and analysis of the literature cited by NIJ/NIST to support its current backface limitation of 1.73" (44 mm), we were unable to find any conclusion, recommendation or other determination which substantiates that limitation depth. On 10 April, 1990 we wrote a letter to NIJ/NIST asking specifically how their limitation depth was determined. To date we have not received a meaningful reply. On 16 April, during a telephone conversation with the NIJ/NIST's Dr. Stanley Whidden, he admitted that he was unable to answer the question and that he did not know how the determination was made, nor did he know of anyone who could provide that information.

We were able to contact one of the former medical officers in the program, Dr. Carl Soderstrom, who was the first author of the program's last soft body armor medical assessment report. In a telephone conversation on 6 Mar 90, Dr. Soderstrom was asked about the source of the NIJ/NIST backface deformation limitation. He stated that he had never made such a determination and that he "did not know of any science that could come up with that (number.)" In a letter, he formally stated that he had never made a determination of any maximum allowable backface signature and that after a review of the medical reports cited by NIJ/NIST, he could not find support for any definitive backface depth.

In a later letter, he further explained that he and his surgical team "did not make recommendations as to allowable deformation characteristics" and that he assumed there were others who were making those recommendations. Our review of the data and the NIJ/NIST's inability to explain its own standard indicates that the assumption is without justification.

Our conclusion was confirmed during a "Body Armor User's Workshop" sponsored by the NIJ/NIST on 6 Jun 90. NIJ/NIST management brought in Dr. Micheal A. Goldfarb to refute our assertions regarding their 1.73" (44 mm) backface deformation limit. Dr. Goldfarb, a surgeon, was a principal member of the Army medical team which worked on the body armor research program in the 1970's public meeting. He also denied being the source of the 1.73" (44 mm) limit.

Another of our conclusions was confirmed during the 6 Jun 90 meeting. Dr. Goldfarb, Dr. Martin L. Fackler (co-author of this report) and Mr. Larry Sturdivan, one of the senior ballistics engineers on the NIJ/NIST project, jointly announced their agreement that for the NIJ/NIST test procedure to be valid, it must allow flattening out of a test vest after each shot. NIJ/NIST later issued a release which stated that they were not going to make any corrections on this matter—completely ignoring the highly significant agreement by Dr. Fackler *and their own two experts*.

SUMMARY OF THE NIJ/NIST BODY ARMOR RESEARCH DATA:

The overall failing of the NIJ/NIST Body Armor Standard for backface deformation is that it depends upon a collection of documents which are at best (and by the authors' repeated warnings) "preliminary," "provisional" and "incomplete." They are also technically flawed for several reasons, most significant of which result from extrapolating data from blunt trauma experiments with various animal species impacted by such high-mass/low-velocity objects as bean bags, rubber balls, "noncompliant rings," which have little or no relevance to blunt trauma caused by much smaller, lighter and faster bullets. The irrelevance of these experiments is further amplified when the gross physiological differences between humans and animals are considered.

Other serious flaws include the NIJ/NIST's reliance upon deformation measurements taken from blocks of 20% gelatin, a formulation which has been shown to be an *invalid* tissue simulant, and the fundamental and repeatedly cited reliance upon a type of fabric which is not the same as the fabric actually used in police body armor.

The NIJ/NIST's early interest in animal tests—however marginally relevant they may be—is understandable in view of the fact that when the body armor evaluation program was begun, the authors had no human ballistic blunt trauma data to study. The project members were also faced with the fact that experimenting upon humans would be impossible. But there is no excuse for the NIJ/NIST's complete (and continuing disregard) for the subsequent large and extremely relevant database of actual human ballistic blunt trauma experience: the police officers saved by soft body armor —a number which has grown steadily over the years to more than 425 to date.

Animal tests can certainly be of valuable assistance to medical investigators involved in research on human medical questions, but no serious investigator would ever ignore actual human experiences which could provide direct evidence as to the validity and relevance of a particular standard—especially when that standard is of such importance to have an actual life and death effect upon the community involved (law enforcement.) The animal test data reviewed and generated in the study were never meant to outweigh or supersede any human data.

The NIJ/NIST administrators have continued to be oblivious to the value of the human data available to them. In a recent speech, Mr. Paul Estaver of the NIJ/NIST [14] discussed the fact that blunt trauma experiments on animals were no

longer possible due to "pressure groups." This indicates that the NIJ/NIST still does not understand the value of the human shooting incidents and would prefer to do more animal testing if they were allowed to do so. Mr. Estaver also stated "if any aspect of any of our standards can be improved on the basis of verifiable, relevant data, we will make that correction," apparently meaning that they are unaware of, or uninterested in, the over 425 actual human blunt trauma incidents.

Both the data from the first NIJ/NIST police shooting study (five cases) and the very substantial human data now available from the over 425 actual shooting incidents demonstrate several facts, most important of which is that there is considerable evidence demonstrating that a revised backface deformation limitation could be instituted with safety.

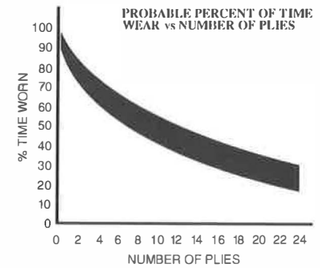
The importance of the NIJ/NIST backface deformation standard goes far beyond a simple technical requirement. The backface deformation limitation directly affects the overall comfort and wearability of the vest. This was clearly demonstrated by another of the program's own studies which tested how often vests were actually worn by police officers.[15] The study, in which police officers were issued vests of various designs, clearly showed that as the number of layers in a vest increased, wearing of the vest decreased. The report stated:

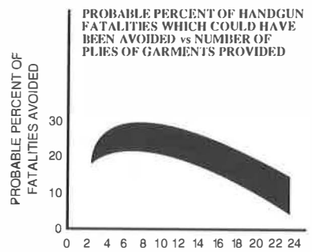
"The main point is, that as more plies (layers) *are added to increase the level of protection, the garment becomes heavier, more uncomfortable and is worn less."* (Page 17)

The report also made a very significant conclusion which was also completely ignored by NIJ/NIST:

"The advantage of the additional protection afforded by garments (with increased number of layers) *is more than offset by the tendency of the officers to stop wearing them."* (Page 17)

From "Body Armor Program, Executive Summary."
"Plies" = Layers of Fabric





From "Body Armor Program, Executive Summary."
"Plies" = Layers of Fabric

It is important to note that there is a "cost" involved in constructing a vest which will pass the NIJ/NIST backface deformation limitation standard. That "cost" turns out to be *comfort* as a vest which must limit backface deformation to NIJ/NIST's standard must either be thicker (with additional layers) or stiffer (through cross stitching or the inclusion of some form of "trauma pad") than it need be simply to resist projectile penetration. This is a cost which translates into less comfort which results in a reduced frequency of vest wear by law enforcement officers.

While the NIJ/NIST preoccupied themselves, the body armor manufacturers and the law enforcement community with compliance to their backface deformation requirement—an invalid, unsupported technical requirement with no medical basis; they turned their back on those in the front lines of law enforcement: the street cops who each day had to overcome a natural reluctance to make their work day more physically uncomfortable by having to strap on a vest which is much thicker, stiffer, hotter, and overall much less comfortable than it need be.

It is the responsibility of the agency which created the standards to verify and insure that their standards are based on valid data. It is not enough for them to state that they will change if they are proven wrong; it is incumbent upon them to check their premises on a continuing and ongoing basis.

The NIJ/NIST's failure to recognize the preliminary, incomplete and often invalid nature of the data they used to support their standards, and their complete and reckless disregard for the considerable body of highly valuable and relevant data within their midst and available to them has, we believe, had a serious and harmful effect upon the law enforcement community. How many police officers have been killed because—that one hot night—they just couldn't stand wearing a vest meeting NIJ/NIST 02/03 standards because it was just too stiff and uncomfortable?

While it is understandably easy for governmental bureaucrats to concern themselves with producing reams of rules and regulations, when a regulating or advisory governmental body loses sight of the end to which it is supposed to be dedicated, that lack of understanding, sensitivity and good sense should be identified for what it is: incompetence.

NIJ/NIST BODY ARMOR PROJECT HISTORY

In the early 1970's the Law Enforcement Assistance Administration (LEAA) (a predecessor to what is now the National Institute of Justice) funded the "Lightweight Body Armor Program." The overall program goal was to determine if soft body armor was a practical and effective method of protecting public officials and police officers from handgun bullets.

Several research studies were performed from 1973 to 1976 on various aspects of soft body armor function and use. The current NIJ/NIST literature cites these and other related works, all of which were published during the 1970's (the most recent NIJ/NIST literature does not reference or list any blunt trauma research study later than 1978).[16]

Although the reports cited by NIJ/NIST reflect a considerable amount of effort in terms of man-hours and federal funds expended, these reports are only of very limited value in current soft body armor design and standards development and should never have been used by NIJ/NIST to establish a backface deformation standard. This is not only our conclusion, but *it is also the conclusion repeatedly stated by the medical assessment and armor evaluation teams who performed the original research and wrote the reports.*

The researchers who performed the early work were well-intentioned and showed a great deal of ingenuity, competence and skill. It is important to note that the reports themselves are not the cause of the current defective body armor standards; it is the interpretation and misapplication of those reports by NIJ/NIST management, which has apparently been incapable of understanding its own research.

REVIEW AND ANALYSIS OF NIJ/NIST DATA

In 1972, the program managers began the program by funding several studies tasked with answering basic questions on body armor. The first pertinent issue addressed by the program was an evaluation of the effect upon the body from the impact of a bullet against soft armor which causes the vest material to deform and be "pushed" into the body. While it was clear that ballistic nylon and later KEVLAR® Aramid would indeed stop

many handgun bullets from penetrating into the body, there was a question concerning the amount of injury which might be caused by this impact—usually described as "blunt trauma."

Input on practical considerations of soft armor by potential users were made by several law enforcement agencies including the FBI, New York Police Department, U.S. Secret Service, as well as by many other federal agencies. Several medical assumptions on body armor were deemed acceptable. Among them:

- " Any blunt trauma effects requiring surgical repair should have a mortality risk of 10% or less.

- A man wearing the garment should be able to walk from the site of a shooting after being hit in the chest or abdomen by a bullet of specified caliber or weight and velocity.

- *It is assumed that the patient will receive medical attention at a hospital within one hour."* [17]

The goal of the first program study, "Protective Garments for Public Officials," [18] was to develop not a concealable vest but a sport coat or overcoat which would protect the wearer from handgun bullets. Tests were made of various fabrics for penetration resistance with the recommendation that an early form of KEVLAR® be used (not the fabric style of "KEVLAR® 29" used today in police body armor.) The study also included the program's first testing of ballistic blunt trauma effect on animals. Thirty-three goats were shot (with .38 cal 158 grain lead bullets) and the damage to their lungs was measured via blood gas analysis in the form of a Respiratory Index (R.I.) value.

The goats were all shot while wearing differing numbers of layers (from 5 to 52) of many different types of test materials. As there was no correlation between injury and the areal density of the armor used, the report did not attempt to provide any conclusions relating to backface deformation or other limitations. The authors recommended that a method should be found to relate animal trauma to human trauma.

Prior to the completion of the above report, two other related studies began. One titled, "Blunt Trauma Data Correlation," [19] involved a literature search of previous blunt trauma research. The authors of this report began their task by reviewing the available data, selecting the data to be used and then by analyzing these data in an attempt to correlate their applicability to the central question of the effect of ballistic blunt trauma.

All the previous studies selected involved various forms of blunt trauma effects on animals. The first study analyzed was that of a 1973 Army research project [20] which involved impacting 30 goats with projectiles described as "noncompliant cylinders" (rings) which were from 40 to 80 mm (1.6 to 3.2") in diameter and weighing from 50 to 200 gm (771 to 3,086 grains.) These objects impacted at velocities ranging from 25 to 83 m/s (82 to 270 f/s.) The data generated from this study (in the form of graphs and charts) was reproduced and/or referenced in several later documents all of which failed to note the serious inadequacies and non-relevant nature of the actual experiments performed.

The goats were *not* protected by any form of armor, and twelve of thirty animals died within 24 hours after impact. Certain data was generated correlating the deaths to overall impact energy levels. A mathematical model was created and then statistically tested against several other animal studies involving pigs, dogs, baboons, monkeys and more goats in an attempt to identify variables which could be used to predict lethality from blunt trauma. None of the studies involved animals shot with bullets or similar projectiles; the studies were actually on the effects of a variety of experimental riot control items such as:

1. Bean bags ("stun bag") weighing 132 gm (2,036 grains)

2. "Sting RAG's" weighing 43 gm (663 grains)

3. A tear gas projectile ("XM674"), weighing 210 gm (3,240 grains)

4. "Noncompliant cylinders" 1.6 to 3.2" in diameter, weighing from 63 to 383 gm (972 to 5,909 grains)

5. "Hi-Q Spheres" (one inch diameter rubber balls), weighing 12 gm (185 grains)

(Note that handgun bullet weights range from 2.6 to 15 gm or 40 to 230 grains.)

The tests were designed to evaluate only one of two types of injury caused by these experimental riot control projectiles: lung lesions or liver fractures. The test animals were targeted appropriately: either over the rib cage (thorax) or over the liver. The results of the original studies were simply in the form of a "live or die" criterion: that some animals received sufficient thoracic injuries to cause death within a 24 hour period in one study and that other animals sustained some degree of liver fracture after certain impacts.

The authors of this report did not perform any actual animal or other ballistic testing, but used mathematic and statistical methods in an attempt to correlate the data generated in the (above described) previous nonpenetrating animal liver or lung injury studies. Their goal was a mathematical model, a "formula" which they hoped could be used to determine whether safe and unsafe levels of blunt trauma could be predicted. The report did suggest two such models, but the authors realized that they simply did not have enough data of sufficient validity to make any useful conclusions. The authors were careful to include a strong warning describing the deficiencies in their report:

"Although the above models represent the best correlations thought possible with the available data base, the insufficiency and inconsistency within that data base permit only restricted model formulation and validation. For this reason, pending availability of additional data for further validation, the models presented in this report should be considered provisional." [21] (Emphasis in original)

The authors were also careful to give notice that the best data available to them—the animal studies reviewed and analyzed in the report—were not applicable to ballistic blunt trauma evaluation and vest design:

1. "There is a general scarcity of empirical data of the type relevant to nonpenetrating projectile and body armor effectiveness evaluations.

2. Of those data sets which are available, none offers a complete consideration of all of the parameters thought to be important in blunt trauma assessment." [22]

And that:

"A sufficient data base from which to form generalizations (criteria) for blunt trauma produced by high-velocity, low-mass objects does not appear to exist. Mathematical models and relationships proposed for blunt trauma and riot control system evaluations to date are incomplete, unproven and/or, because of state-of-the-art limitations, highly subjective." [23]

Some of the salient deficiencies in the report were:

1. All the mathematical formulae presented in the report (and all subsequent reports) rely upon kinetic energy (KE) levels of the projectiles. The KE then directly relates to the "vulnerability" of the test animal to injury or death. The application of KE to levels of injury is an invalid concept—a fact which has been demonstrated in several published studies.[24 25 26 27 28]

2. All the armored animal tests and all the backface deformation tests in gelatin were made

using a type of KEVLAR® which has never been used for commercial body armor. The differences in modulus (resistance to stretch) and denier (thickness of the fiber) between the type of fabric used in the NIJ/NIST tests and the fabric used in police body armor will cause differences in backface deformation performance between the two fabrics.

3. The test animals were much smaller in mass and size than a typical human. Most animals weighed less than half the typical human male weight of 70 to 80 kg (154 to 176 lbs.)

4. The anatomical differences between the animals and humans is such that no direct correlation to the amount of injury can be made between animal and humans.

In the earliest program report, the medical team pointed out two significant anatomical differences:

"It should be emphasized that the human chest wall is thicker than that of the goat, and this will offer the human more protection than the goat. In addition, the same amount of damage in the goat and the human would represent a smaller percent in the human since human lungs are larger than the goat's." [29]

5. The animal tests only measured either lung or liver damage, thereby completely ignoring other potentially vulnerable organs and structures such as the heart, spleen and/or spine. In addition, the liver fracture tests did not attempt to make any evaluation concerning the severity, or even the dimension, of the fracture.

6. The goats in the initial study were regarded as "killed" by blunt trauma if they died within a 24-hour period after impact. This is in conflict with one of the program's basic assumptions: that a police officer impacted by a bullet could receive surgical treatment (if it were necessary) within one hour after the event.

7. The mass, geometry and velocity of the projectiles used in the tests are of such inordinate dimensions to preclude their being useful in simulating the effects of handgun bullets against soft body armor. This is particularly true as bullets are relatively high-velocity/lowmass projectiles and the program animal tests utilized either low-velocity/high-mass or low velocity/low-mass projectiles.

Another of the early reports often cited in subsequent reports is titled, "A Method for Determining Backface Signatures of Soft Body Armors." [30] Its goal was to find a method to measure backface deformation, and to then produce a predictive model (i.e., mathematical formula) which could be used to correlate the effect of backface signature with animal physiological effects.

There are two fundamental defects within the data generated in this report:

1. All the backface deformation signatures were taken from measurements of ballistic impacts on soft armor into blocks of 20% gelatin—a formulation which is not valid as a human or animal tissue simulant. In the fifteen or so years since the original backface deformation measurements were taken from 20% gelatin blocks, that formulation has been discredited as a tissue simulant as it will produce errors of more than 200% in penetration measurements. This fact has been documented in a recently published study of ballistic gelatin use and preparation.[31]

2. The program's use of gelatin to simulate backface deformation is highly questionable in view of the fact that although properly formulated and calibrated gelatin can simulate human tissue in terms of ballistic *penetration,* there are no studies calibrating any formulation of gelatin in terms of its ability to simulate human tissue in *deformation* dynamics.

In spite of the substantial defects, the measurements taken from the flawed tissue simulant

were then mathematically correlated against a test series in which anesthetized goats (average weight of 40 kg/88 lb) protected by soft armor were impacted with projectiles of varying weights. From a minimum of 223 grains to a maximum of 920 grains (a typical .38 Special RNL bullet weighs 158 grains). The velocities varied from a low of 43 m/s (140 ft/s) to 120 m/s (395 ft/s). A .38 Special travels at approximately 259 m/s (850 ft/s). In spite of the extreme variation in projectile mass and velocities, the product of the two variables (mass and velocities) were always nearly equivalent to a 158 grain .38 Special bullet at 800 ft/s (259 m/s).

Although a complex and ambitious methodology was used in the goat tests, only one type of injury to one organ was monitored and reported. The authors explained:

"The animal target is, of course, a combination of many systems and subsystems and the monitoring of all of these would be an impossible task. Targeting, therefore, was restricted initially to one target organ and monitoring to one physiological system. The system chosen was the respiratory system and the target organ was, of course, the lung." [32]

The blunt trauma effect upon the animal was determined by drawing arterial and venous blood samples 15, 30 and 60 minutes after impact and once again after 24 hours. These samples were analyzed for oxygen content variations which would reflect proportional levels of lung injury.

None of the goats were substantially injured or killed by the blunt trauma received and the results of this animal study were so indeterminate that the authors did not even bother to comment directly or make any analyses of the tests. Their final recommendations fairly sum up the usefulness of the report:

"The backface signature parameters cannot be used to evaluate the effectiveness of protective armor until these physical measures are related to the probability that a particular combination would result in a serious or lethal injury. A predictive model relating the physical measures of the backface signature to the physiological effects, particularly in the non-lethal area, would greatly reduce the cost of armor evaluations. At this time, only a limited data base is available, insufficient for developing an overall vulnerability model." [33] (Emphasis added)

Unlike later interpreters of their work, the authors were quite aware that the various vulnerability models tested in their report were only experimental and provisional. In their final recommendation, they wrote:

"By increasing the data base from which to draw conclusions, the goal on an overall vulnerability model for predicting the effectiveness of soft armor materials could be reached." [34] (Emphasis added)

"Body Armor Medical Assessment" [35] was another concurrent study begun in mid 1973. The authors of this report included three physicians. It was the first significant medical study on the potential for human blunt trauma injury. The team began with an experiment to compare goat organs (lung, liver, spleen and kidney) to human organs. The tests were to determine if the goat organs were equally susceptible to damage from blunt trauma. Human organs from cadavers (at least 24 hours postmortem) and goat organs were subjected to water jet tests, and the report's conclusions were that the human kidney and liver are more resistant to blunt trauma than the goat's and that:

"Because the human chest and abdominal wall are about twice as thick as the goat's, the human would probably incur even less damage than the goat." [36]

This report sought to determine the actual extent of injuries produced by ballistic blunt trauma. The authors performed a series of test shots of 158 grain, 38 cal. bullets against goats protected by soft armor. Selected target areas on

the animals were the heart, lungs, liver, spine, abdomen and spleen. All the animals were monitored for 24 hours, killed by injection and then autopsied.

The authors also evaluated the total area of exposure of each of these and other organs in the human body and made calculations based on (1) the probability of a hit in a particular organ and (2) the comparative probability of mortality should that organ be penetrated by a bullet or be impacted by the blunt trauma effect of a 158 grain, 38 cal. bullet at approximately 800 ft/s.

This report made no recommendations or offered any conclusions regarding backface deformation depths or limitations. It did make overall "probability of surgery" and "probability of mortality" conclusions between a person shot (with a ".38" or ".22") and wearing and not wearing armor.

"In summary, without the garment, the mortality rate after a random hit with a .38 caliber bullet is between 6.9% and 25.4%. If the garment is worn, the mortality rate decreases to between 1% and 5%. The chance of surgery without armor is 81.5% to 100%, and with armor it is 7% to 10%." [37]

We believe that by the program's own criteria, the conclusions in this report indicate that the current NIJ/NIST backface deformation should be reevaluated and/or revised for the following reasons:

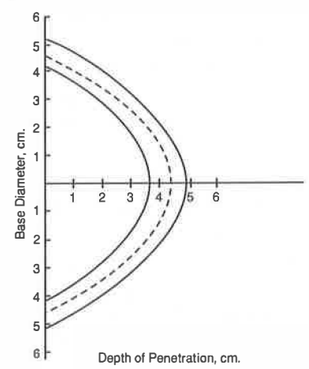
The predicted mortality rate from this preliminary study for a human wearing soft armor after a random hit with a 38 cal, 158 grain bullet at 800 ft/s is determined to be from 1% to 5%—well beneath the acceptable project goal of 10% or less.[38] The program's own data from the deformation measurements in the flawed 20% gelatin showed that a 158 grain 38 cal. bullet at approximately 800 ft/s would cause deformation depths

Table 3. Backface Signature Parameters
.38-Caliber, 158-Grain Projectile Versus 7-Ply Kevlar 29, 400/2-Denier

FILM NO.	STRIKING VELOCITY	MAXIMUM VOLUME	MAXIMUM DEPTH	MAXIMUM BASE RADIUS	DEFORMATION TIME
	M/SEC	CC	CM	CM	SEC
30008	243.7	155.69	4.82	4.76	0.0017
30177	253.9	165.15	4.99	4.12	0.0018
30178	255.4	202.07	5.17	5.18	0.0018
30179	249.6	148.51	5.00	4.61	0.0021
30180	247.8	132.50	4.72	4.01	0.0018
30181	249.3	159.95	4.88	4.99	0.0018
30182	251.5	121.50	4.60	3.79	0.0016
30183	249.0	138.26	4.64	4.60	0.0018
30184	259.1	165.86	5.08	4.79	0.0015
30185	254.8	153.35	5.20 MAX.	4.62	0.0021
30186	255.4	143.60	4.80	4.97	0.0016
30187	254.5	101.12	3.98 MIN.	4.50	0.0016
30318	249.8	172.66	4.65	4.91	0.0015
30319	246.8	134.97	4.71	3.99	0.0014
30320	247.3	132.94	4.84	3.77	0.0016
30321	245.9	115.77	4.14	3.84	0.0013
30322	248.1	136.24	4.42	4.45	0.0015
MEAN	250.7	145.89	4.74	4.46	0.0017
STANDARD DEVIATION	4.17	23.89	0.33	0.46	0.0002

The graph (Figure 5) on page 18 was purportedly generated from this data, but they don't agree. Note the circled maximum depths and the mean (average).

Figure 13. .38 Caliber Deformation Envelope.



from 3.98 cm to 5.20 cm with an average of 4.74 cm (1.85")—NOT as erroneously shown in Figure 5 of page 18 of "A Method of Determining Backface Signatures of Soft Body Armor."

The overall summary stated:

". . .without the garment, the mortality rate after a random hit with a 38 caliber bullet is between 6.9% and 25.4%. If the garment is worn, the mortality rate is decreased to between 1% and 5%." (Page 28)

But the authors' final conclusion warned against using their data to predict the effects of higher energy bullets:

"No inference can or should be drawn from these tested threats to other partially or totally untested threats such as the 45 caliber bullet, 9mm bullet, shotgun or higher velocity weapons. Thus from the blunt trauma aspect of our investigation, only the damage produced by the 38 caliber and the 22 caliber bullets beneath the 7 ply unaged KEVLAR® vest has been evaluated." (Page 28)

Not only did the NIJ/NIST body armor program managers ignore these conclusions, they also ignored one of the central points made in the report which directly relates to the core of the program's database: the initial Edgewood Arsenal thoracic impact tests on various animals with bean bags, "noncompliant cylinders," etc. This report offered the first comprehensive medical review and analysis of these tests. Their conclusions were:

". . . it is unlikely that the amount of damage sustained by the KEVLAR® protected goats would be of any serious consequence whether it occurred in the goat or in the man." (Page 15)

Further comments on thoracic injuries in man:

"According to the experimental data, the lungs and non-dilated GI tract are not vulnerable and, therefore, have an associated mortality of zero if impacted while the garment is worn." (Page 24)

In the group's own goat studies, they found that lung injuries:

". . . would present minor medical problems. . . The impact might cause a rib fracture . . . A human with a rib fracture and minor lung contusion should not be incapacitated at the time of injury and, under stress and well motivated, might only feel minimal discomfort. When the stressful period subsided, the patient would still be able to walk into a hospital." (Page 13)

And after a review of a human study of 177 patients who had received actual thoracic blunt trauma injuries [39] was correlated to the ballistic blunt trauma injuries of the Edgewood Arsenal animal series, the authors stated:

"In this project, one assumes that if a human were wearing a bullet-proof garment and were impacted over the chest wall, he would be treated at a hospital within one hour. . . therefore, the lung damage levels in the injured, KEVLAR®protected human would not be a serious risk and would require non-operative treatment." (Page 16)

The significance of these medical conclusions are such that they completely undermine the validity of the "Probability of Lethality" graph [40] published in the program's 1976 report titled, "Backface Signatures of Soft Body Armors and The Associated Trauma Effects." This graph is based on data from animals subjected to thoracic impact, and has been erroneously used by NIJ/NIST to determine its backface deformation limitations. That graph was generated using data from goat lung injury and liver fracture experiments which has been shown—in this NIJ/NIST report—to not be applicable to humans.

The goat blunt-trauma experiments were also of highly questionable use because they involved relatively large, slow projectiles instead of small, fast projectiles like bullets. Not only is the area

deformed smaller in diameter, but the time span in which the deformation occurs were not similar to those produced by bullets. Other studies have shown the significance of this time span as it relates to injuries, i.e., that faster times will produce greater injury to tissue.[41] This factor was completely ignored in the program's probability of lethality graphs, in spite of the fact that, once again, the program's own data contained warnings against applying the results of the goat experiments to humans. The program's Medical Assessment team stated:

"The deformed cone of armor, smashing into the body wall over a discrete area in short interval, describes a unique mechanism capable of producing trauma. This rapid jolting force focused on a small area, much like an "impulse," contrasts greatly with the usually encountered mechanisms producing blunt trauma injury; i.e., those delivered by large objects over large areas, with relatively prolonged periods of force application.

". . . previous methods used to produce blunt trauma generally employed larger objects impacting larger surfaces. In addition, the application of force was generally over a long period of time relative to the two millisecond "impulse" in the ballistic studies.

Therefore:

"Much of the blunt trauma experience in the clinical literature is not comparable to that seen behind a pliable body armor." [42]

One of the program's later reports, "Backface Signatures of Soft Body Armors and the Associated Trauma Effects" [43] attempted to pull together all the previous human medical and animal data to produce practical and meaningful results.

This report had two goals:

1. To find a substance which would *". . . simulate the tissue response appropriately beneath the point of impact so that the ballistic data generated in laboratory tests can be correlated to the effects seen on the human body"* [44] and could therefore be used as a valid backing material for soft body armor deformation testing, and

2. To correlate the chosen substance's deformation with the effect of blunt trauma upon the human body, i.e., to show that a backface deformation of a particular depth in a test medium will correspond with a particular level of blunt trauma effect upon the human body.

The report fails to support either correlation.

In their first task, the authors chose a clay ("Roma Plastilina No. l") as a soft armor backface deformation medium. Ballistic testing was performed against soft armor backed by this clay, but correlations were never directly attempted with human or animal tissue. The "positive" correlations described were made with 20% gelatin bloc a formulation which does not simulate human or animal tissue, as several publisher studies have shown. [45 46 47 48]

In an attempt to fulfill their second task of demonstrating that a particular depth of deformation in clay (or gelatin) can be correlated to a particular level of injury, the report's authors first established a mathematical model which they attempted to correlate against what they assumed was a valid blunt trauma lethality model published in an earlier work, "Blunt Trauma Data Correlation."

But the authors were apparently not aware that this model should never have been used for such a purpose. It was created only as a mathematical experiment—not as a usable blunt trauma lethality model. The creators of the model were aware of its lack of validity and directly warned against using it as such:

". . . the reader is reminded of the high risk involved in this (or any other) extrapolation and cautioned against placing any quantitative significance in (the model.)" [49]

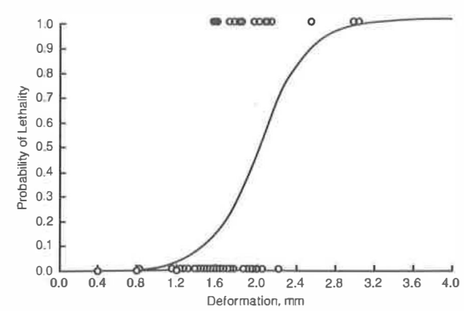
Not only was this warning ignored, so were the report's conclusions:

"A sufficient data base from which to form generalizations (criteria) for blunt trauma produced by high-velocity, low-mass objects does not appear to exist. Mathematical models and relationships proposed for blunt trauma . . . to date are incomplete, unproven and because of state-of-the-art limitations, highly subjective." [50]

Apparently unaware of the deficiency in the data they were relying upon, the authors then compounded their error by correlating the "incomplete, unproven and highly subjective" data with deformation depth data taken from yet another faulty source: the clay measurements which had been erroneously "calibrated" against a defective tissue simulant.

The end result of these errors is displayed in a graph (Page 38, Appendix B, Figure B-10) which indicates that a deformation depth of 4.4 cm (1.73") is associated with a "Probability of Lethality" (PL) of approximately 8%. This is the source of the current NIJ/NIST Police Body Armor Standard requiring soft armor to limit the backface deformation depth to 1.73" (44 mm), as the project's basic definition of soft armor "protection" stated that, "Any blunt trauma effects should have a mortality risk of 10% or less." [51]

Figure B-10. Correlation of Probability of Lethality with Deformation Depth



The "safe" maximum deformation depth of 1.73" (44 mm) is purported to be the average deformation depth observed in the flawed 20% gelatin blocks via high speed motion picture analysis with a 38 cal, 158 grain round nose lead (RNL) bullet fired into a seven-layer protective vest.[52] But that data is erroneous not only by our analysis, but by the NIJ/NIST's failure to perform simple arithmetic.

We learned from individuals who were part of the limitation selection process in 1978 that the actual source of the 1.73" (44 mm) limitation is found in a graph (Figure A) which appears in several project reports. This graph purports to show the minimum, maximum and average (mean) deformation depths measured in the clay backing of a seven-layer vest shot with a 158 grain bullet. The dotted line showing the average deformation appears to indicate a value of approximately 4.4 cm (1.73"), but a careful reading of the first report displaying and explaining this graph states that the graph was generated from data in "Table 3" (shown in Figure B).

While the graph shows a maximum depth of approximately 4.9 mm, Table 3 clearly shows there were four shots with depths of 5.0 cm or greater. The mean shown in Table 3 is stated to be 4.74 cm while the mean shown in the graph is less than 4.5 cm. This shows that even if it were somehow valid for the NIJ/NIST to have picked the 1.73" (44 mm) because it was the average of that particular test series, it would still be an incorrect figure. The correct limit would be 1.87" (47mm): an increase of 6%.

In spite of the substantial collection of graphs, equations and tables, the report's conclusions reveal the authors' own awareness of deficiencies in attempting to apply their work to body armor specification and design:

"Attempts have been made using the original blunt impactor data to correlate deformation depth with the probability of lethality . . . However, the available data is limited, and hence, no solid conclusions can be drawn as yet regarding the effect of deformation depth." [53]

Literature Review & Comment

THE "SHOCK WAVE" MYTH

The following letter was published in the *Journal of Trauma* (29[10]:1455, 1989). No reply was made by the authors and no editorial comment was made.

To the Editor of the *Journal of Trauma*:

In ascribing "local, regional and distant injuries" to the sonic pressure wave, Suneson et al. ("Pressure wave injuries to rat dorsal root ganglion cells in culture caused by high-energy missiles," **J Trauma** 29:10-18, 1989) have overlooked the effect of transmitted tissue movement from temporary cavitation. Since two distinct mechanisms are acting in the Suneson et al. experiment, one cannot arbitrarily assign any effects observed to only one of them.

Movement of tissue by temporary cavity formation is a well-known tissue disruption mechanism, but the sonic wave does not move tissue perceptibly. Harvey (1, and Suneson et al. ref 4) clearly identified temporary cavity formation, not the sonic pressure wave, as the tissue disruption mechanism in all of his experiments. As with any blunt trauma, tissue movement initiated by temporary cavitation can be transmitted to other parts of the body than those impacted.

Suneson et al., also neglected to define "high-energy." The energy "transferred" by the 6mm sphere in their experiment was no greater than that available in many common handgun bullets. Uncomplicated extremity wounds from handgun bullets are handled on an outpatient basis in many of our urban hospitals with excellent results (and no signs of the "distant" injuries).

Recently, eleven adult-human-sized swine (90 kg) were shot in the proximal part of the hind leg with a projectile producing the damage profile of the Russian AK-74 Assault rifle bullet (2). This same projectile was used in another study in which five 90 kg swine were shot through the abdomen (3). These animals were observed from three weeks (leg shots) to two months (abdomen shots). No indication of any sort of "distant" damage was seen in the pigs' behavior and no "distant" injuries were found at autopsy.

A review of 1400 rifle wounds from Vietnam (Wound Data and Munitions Effectiveness Team) should lay to rest the myth of "distant" injuries. In that study there were no cases of bones being broken, or major vessels torn, that were not hit by the penetrating bullet. In only two cases, an organ that was not hit (but was within a few cm of the projectile path), suffered some disruption (personal communication, Bellamy, R.F., 1989).

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COMMENT

Five months after the above letter was published, **J Trauma** printed two more papers by Suneson et al., which repeat the same basic errors and misconceptions as the one about which the letter was written (1,2).

To separate the two mechanisms of sonic pressure wave and temporary cavitation, Harvey et al.(3) shot into a steel plate which stopped the projectile (and its cavitation) but exposed the target to just the sonic wave. This classic work by Harvey et al. clearly identified temporary cavity formation, not the sonic pressure wave, as the tissue disruption mechanism in all of their experiments. Some who have read Harvey et al. come away with the impression that they ascribed pathology to the sonic pressure wave in air-containing organs. Careful reading of these studies makes it clear that *Harvey et al. were unable to demonstrate effects caused by sonic pressure waves in any tissues -- solid or air-containing.*

Tissue movement is tissue movement; whether initiated by temporary cavitation or by any other form of blunt trauma. It is transmitted to other parts of the body than those impacted, and when the tissues moved are sufficiently susceptible and the movement of sufficient magnitude, damage can be done. Why ignore this obvious cause, and attribute the observed changes to sonic waves, which do not move tissue, and have been shown to cause no tissue damage (3)? Could it be that the competition for research funds is the motive for trying to make these mechanisms of injury appear as complex as possible?

Anyone who has viewed a high-speed cine film of a 20 kg pig shot in the hind leg by projectiles producing temporary cavities the size of the sphere used by Suneson et al. recognizes that the entire animal was set in motion. Although Suneson et al. include no description of the local tissue disruption (thus depriving the reader of any chance to compare these wounds with those in his own experience), others report broken femurs with similar shots (4,5). Rather than the "control" used by Suneson et al. (shooting their "smoothbore rifle" but missing the leg), perhaps striking the leg with a baseball bat hard enough to break the femur would be more appropriate. I suspect it would also cause the changes that Suneson et al. found with their electron microscope and attributed to sonic pressure waves caused by their sphere.

Wound ballistics research needs to be guided by problems from the field of battle. Common sense must guide the use of technology rather than being overshadowed by it.

Is it not the duty of a journal editor to assure continuity of thought in the material published? To avoid the perpetuation of error? It is truly surprising (and sad) that the trauma surgeons and other **J Trauma** readers tolerate this continuing comedy of errors related to wound ballistics papers.

NOTE

It has come to our attention that the University of Gothenburg, Sweden, has recently turned down the PhD thesis (by the first author) based largely on these "high energy missile" papers. By printing

these faulty papers the **J Trauma** has done a disservice not only to their readers, but to the papers' authors as well..

Martin L. Fackler, MD
Editor-in-Chief

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CAT BRAIN SHOTS

The paper by Carey et al., (*Experimental missile wound to the brain*, **J Neurosurg** 71:754-764, 1989) on wounding of the anesthetized cat brain by 2 mm steel spheres needs critical comment. Major problems with this work include:

Humans survive penetrating brain wounds caused by projectiles of widely varying weights, shapes and velocities. The extent of differing ballistic characteristics seen in daily reality bears little similarity to the very narrow limits in the experiments reported by Carey et al.

The irregular fragments, seen in battlefield wounds, cut or slice their way through tissue -- spheres (used by Carey et al. and most of those they cited) do not. Bullets yaw and deform in tissue, especially when passing through the skull -- steel spheres cannot yaw and do not deform (at the velocity used). Experiments done with irregular fragments would more closely approximate reality.

The heterogenity of the skull (from very thin bone in the temporal zone to the thick and hard bone in the occipital region) can produce very different damage patterns from the same projectile depending upon which area it passes through. The extreme variation in effect is evident in the forensic science literature as well as in the history of war wounds.

To use results from an experiment using unrealistic projectiles, in a very limited velocity range, with very localized paths through the brain, and suggest that they produce the respiratory arrest mechanisms for all penetrating projectiles is both illogical and unjustified.

The authors mention direct crush of the tissue hit by the projectile and the displacement of tissue adjacent to the projectile path but apparently do not recognize this as the crux of the wound ballistics. They proceed with obtuse, confusing explanations using three kinds of "pressure waves" caused by "kinetic energy transfer" in trying to explain something (it is painfully obvious) they do not understand. They misread and misquote several of their sources (Harvey, Fackler). They perpetuate the myth of tissue damage from the sonic pressure wave (which they call "longitudinal 'strong' shock wave pressure"), and by so doing they present the subject in such a confused fashion, (apparently self-contradictory in part) that this reader cannot tell what they mean.

The authors appear unable to choose between contradictory concepts of wounding. They try to compromise, but synthesis between correct and incorrect is not possible. They should start by abandoning all reference to sonic pressure wave as a wounding mechanism, and then eliminate "kinetic energy" from their vocabulary.

Some of their data appears contradictory (14.3% of the low velocity group and 16.7% of the high velocity group did not have any apnea but only 2.8% of the intermediate group did not have apnea) yet they do not comment on this.

The greatest merit of Carey et al.'s work is that they made an effort at serious research on the subject of cranio-cerebral injury. It is truly unfortunate these long and costly experiments yielded no practical information of consequence. One might say it lends support to providing respiratory support for those found apneic on the field of battle due to a penetrating injury of the head. However, this is already well founded: current battlefield doctrine gives respiratory support, regardless of the cause of the apnea. These studies have yielded essentially nothing positive. The errors and misinterpretations contained therein will only add to the confusion that already contaminates the field of wound ballistics.

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COMMENT

Here we have yet another example of unwary authors being victimized by the wound ballistics literature. Some of the references cited by Carey et al. have apparently so confused them that they have taken the rather simple mechanisms of projectile wounding and complicated them beyond recognition.

Carey et al. neglect to mention if the skin, subcutaneous tissues, muscle, etc. were closed after the outer layer of the frotal sinus was removed (group of 20), or if these structures were left open and the first structure encountered by the projectile was the posterior bony wall of the frontal sinus. Also on the other 83 shots they mention an intact skull was shot: did they remove all the soft tissue and shoot directly into the skull or did they really mean they shot into an intact head? Was the trajectory through the head essentially the same in both groups? By omitting this critical information, Carey et al. fail to provide the reader with sufficient detail to reproduce the experiment; this is the prime requisite of any scientific paper.

The spheres fired by Carey et al. simply destroyed what brain it hit and impelled the surrounding tissue radially outward. In other parts of the body, tissue impelled away from the projectile path pushes aside neighboring tissues. The nonyielding walls of the cranium cannot expand. There is no place for the tissue to go: the brain gets pushed against the bony walls of the vault and the brain stem gets forced down into the foramen magnum to start; more pressure fractures the skull. The hard covering that protects the brain from much trauma, also makes it by far the most susceptible part of the body to injury from projectile induced temporary cavity tissue displacement. This most pertinent point was not emphasized by Carey et al. In fact, they make a point of mentioning that tissue displacement adjacent to the missile track is less destructive than direct tissue crush from projectile contact because of the elastic properties of the displaced tissue. This is true in most tissues -- *the brain (not so elastic) in its closed vault is the major exception.*

The authors also do not appear to understand the implications of their statement that "The magnitude of these derangements appeared to be missile energy dependent..." Projectile mass and projectile velocity combine to determine kinetic energy. Light

fast projectiles use more of their disruptive potential in displacing tissue by temporary cavitation than heavy slow ones *of the same kinetic energy* which crush more tissue. It is erroneous to infer that disruption caused by a particular projectile would be duplicated by all projectiles that possess that same kinetic energy. The limited experimental results reported (all shots with identical projectiles) certainly do not support such a sweeping generalization.

Martin L. Fackler, MD
Editor-in-Chief

THE PEER REVIEW SYSTEM: Where Are The Checks and Balances ?

The following letter was published in *Professional Ethics Report*, 3(1). 1990, without the italicized portion. We have published the entire letter below.

To the Editor of *Professional Ethics Report*:

A reviewer who plagiarizes material which has been sent to him for review is quite properly denounced for "wanton abuse of the peer review system..."(1). However, a reviewer recommending acceptance of a paper he is clearly not qualified to review, or has reviewed carelessly escapes scrutiny. Because this practice is so widespread, it probably has a far more pernicious overall effect on the scientific literature than outright plagiarism.

In the field of wound ballistics, the peer review system has failed so badly that the majority of the material in print is in error (2,3). So many blatant and repeated errors have appeared in the literature that during the past six years the Wound Ballistics Laboratory of the Letterman Army Institute of Research alone has submitted 30 letters to the editor pointing out these incongruities (list available on request).

Doesn't the peer review system itself need some kind of objective measure? Mandatory periodic auditing of papers in the open literature should be implemented to discern and publicly reveal how much error is slipping through the system. Without checks and balances, any system can go awry. Realizing that periodic auditing is unlikely to be initiated soon, an immediate improvement could easily be realized by simply removing the reviewers' cloak of secrecy. Public scrutiny would most certainly improve the quality of the peer review system, as well as bring it more into line with the modern "freedom of information era." *Recently a paper containing fifty-seven factual errors (4), and another paper in which the authors repeatedly described the position in space of bone fragments seen on high speed radiographs -- despite the fact that their radiographs were taken in one plane only (5), were both published after peer review. If the identity of the reviewers who approved publication of these seriously flawed papers were made public, it is unlikely that errors of such magnitude would be repeated.*

Clearly, the scarcity of expertise in wound ballistics is a predisposing factor in its deficient peer review. Possibly the rest of the scientific literature does not suffer the same affliction; most would assume so -- but science is not built on assumption; it is built on fact.

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COMMENT

The peer review system is unlikely to improve unless concrete examples of blatant failures are pointed out. Thus we are publishing the above letter *including* the two examples omitted by the editors of the **Professional Ethics Report.**

Your editor submitted letters to the **Journal of Trauma** editor regarding each of the omitted examples. The editor refused to publish the letter about the Ordog et al. article; he gave no reason. Surely it is embarrassing when an article containing *fifty-seven factual errors* slips through your review system, but is choosing to ignore it by refusing to publish corrections an appropriate reaction? This letter was published, however, in the **Association of Firearm and Toolmark Examiner's Journal** Vol 21, number 1, January 1989, pages 50-52 (co-authors of this letter were P.M. Dougherty and P.J. Dougherty).

The **Journal of Trauma** editorial staff did not refuse the following letter outright, but offered a variety of excuses for about nine months. Finally, on 10 July 1990, we wrote asking if they did, in fact, intend to publish the letter. We received no reply. Therefore, we are publishing this letter below.

Martin L. Fackler, MD
Editor-in-Chief

*(sent to **Journal of Trauma** for publication on 22 September 1989)*

Sir:

Radiographically defining the position of a retained foreign body or bone fragment requires *evaluation of x-rays taken in at least two planes.* In "Bone as a Secondary Missile: An Experimental Study in the Fragmenting of Bone by High-velocity Missiles," Amato, Syracuse, Seaver and Rich (29[5]:609-612) have ignored this most fundamental principle and, considering the method and data they presented, have drawn unwarranted conclusions.

They interpreted the photograph in Fig. 3 as showing that "some bone fragments go to the edge of the cavity," and Fig. 4 as "showing a number of fragments returning to the center of the cavity." Dramatic as the high-speed x-rays and cine films may be, they cannot define the position of the bony fragments unless they are taken simultaneously in two planes. Amato et al. reported using a single cine camera for their studies and made no mention of taking simultaneous biplanar x-rays. Therefore, they cannot be certain that the bone fragments they claim are "in" the temporary cavity are not actually in the gelatin outside the margins of the temporary cavity (beside the cavity), and only appear to be "in" the cavity because they overlie it on the single plane x-ray view.

They also wrote that "The critical velocity for fracturing bone is approximately 200 feet per second," but the only data they presented concerned a projectile striking at 3000 ft/s. Aside from being unsupported by their data, this statement simply does not make sense. Since anatomy of bones varies greatly (from the very thin midpor-

tion of the scapula to the much thicker and stronger cortex of the femoral shaft) the claim that a single threshold velocity applies to every bone cannot be correct. Amato et al. apparently consider the kinetic energy of a projectile to be of paramount importance; they might do well to calculate the kinetic energy available in their 16 grain sphere at their proposed 200 ft/s velocity. It would be 1.42 foot-pounds: do they really think this would fracture even the thinnest and weakest of bones?

Another cause for concern is the timeliness of the references -- their most current is 1974. Have Amato et al. overlooked similar experiments (done with human rather than animal femurs) reported ten years after the most recent reference they presented (1)?

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COMMENT

The Amato et al. paper presents a striking irony -- if a medical student or intern had presumed to identify the position of a foreign body using x-rays taken in a single plane only, he would be – at least – roundly chastised and embarrassed before his peers: when learned pedagogues, researchers and professors of surgery made the same error, it "slipped through" the peer review system and was published.

Martin L. Fackler, MD
Editor-in-Chief

Tributes &Tragedies

We are aware that there are individuals and organizations in need of recognition and we hope to bring both those worthy and worthless to the attention of our readers. We encourage reader nominations.

DUMB-DUMB AWARD

To Remington Arms Company, Inc., for their new +P 185 grain 45 ACP hollow point bullet. Several years ago, when the world was starting to wake up to the realities of what makes a handgun bullet reliable, the Remington 185 grain hollow point was the best available hollow point bullet in 45 ACP caliber. Even so, it was about an inch short of adequate penetration depth. If this bullet had had 40 grains more weight on its rear end at the time of the first FBI bullet tests, most certainly the 45 ACP, rather than the 10 mm would now be the official FBI handgun.

So what did Remington do? -- bring out a heavier bullet with the same tip to insure adequate but not overexpansion and thus deeper penetration? No, they increased the velocity of the 185 grain bullet. The result, as anyone with even a minimal understanding of bullet dynamics should have predicted, was even less penetration depth, due to bullet overexpansion and fragmentation.

They took a marginally acceptable bullet (but the best of the lot at the time) and made it into a totally unacceptable one. Congratulations, Remington.

SILVER BULLET AWARD

To the Firearms Training Unit of the FBI. They had a disaster in the Miami shootout of 1986. They sponsored a Wound Ballistics Workshop in 1987 to examine why the bullets they were using didn't have the effects predicted by those who recommended them. They listened, they learned, they made some changes. They started an extensive bullet testing and education program which has benefited not only law enforcement but all those seriously interested in weapon effects.

Along with the FBI, the California Highway Patrol, the San Diego Police Department, the Phoenix Police Department, and the Arizona Department of Public Safety share this award since all of these departments *test their bullets and specify bullet performance standards (penetration depth and expansion ranges) in a reproducible tissue simulant as a part of their bullet procurement contracts.*

NOTE

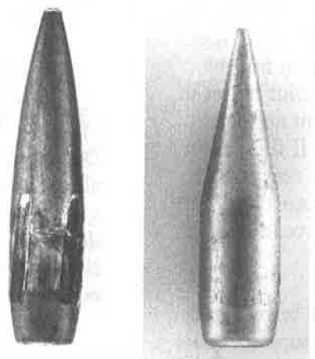
We are sure that there are other law enforcement groups who test their bullets and specify performance standards in bullet procurement contracts. If these departments will notify us we will be happy to recognize them for a silver bullet award in a future issue.

Errors & Omissions

The *Wound Ballistics Review* encourages corrections of previous inaccuracies made in these pages or anywhere else. This section is available to allow anyone an opportunity and a forum to set the record straight. Our belief: "To err is human; to make public correction, divine."

Upon finding the peculiar "internal deformation" of the Russian AK-74 bullet (the shifting of lead into the hollow tip that caused an unbalanced bullet — Fackler ML, Malinowski JA. Internal deformation of the AK-74: A possible cause for its erratic path in tissue. J Trauma 28 Suppl:72-75, 1988), your editor and co-workers suggested that the unbalancing of this bullet was responsible for its unique right-angle turn in the latter part of its path through tissue simulant.

Recently, however, Fabrique Nationale has produced another bullet, the P-90, that constantly makes a right-angle turn in the latter part of its path in tissue. This very lightweight 5.7 mm bullet (23 grains [1.5 gm]), has a copper-plated steel jacket and a plastic core. It has no air-space inside the tip (as does the AK-74), and thus no possibility for a shift of its core to cause an asymmetrical and unbalanced bullet on striking tissue.



AK-74 bullet is on the left, the P-90 is on the right. Note the similarity of the shapes. The long, tapered, point is, in both cases, nearly twice the length of the bearing surface; both have a similar boat-tail.

So, it appears that we were wrong in our suggestion and that the sharply curving bullet path was caused by bullet asymmetrical balance. This new evidence makes it appear more likely to be related to bullet shape (see Fig. 1).

In the case of the AK-74, this sharply curved path makes little practical difference in the human body, since it curves only after it has penetrated 35 to 40 cm.

The P-90 bullet, however, curves after only about 10 cm or less. The practical consequences are, therefore, enormous. Aimed at any body structure more deeply situated than 15 cm, it will always miss that structure. The direction of the curve is unpredictable (although a sharp curve away from the initial projectile path is constant). FN sees this erratic behavior as a positive point for this bullet (I suppose one needs a financial interest in the bullet to follow that twist in logic). When this long bullet (0.94 in.) yaws, it loses most if its velocity in making an orange sized temporary cavity. FN is making the same error as those from Picatinny Arsenal and the Ballistics Research Lab at Aberdeen Proving Grounds who are pushing the flechette for the next generation Advanced Combat Rifle. They continue to be deluded by the misconception that the "energy deposit" of a projectile is proportional to its capacity to "incapacitate" the human target. It is unfortunate that these ordnance engineers can't seem to get it through their heads that when only a few hundred foot-pounds of energy is available in a projectile, wasting it making a temporary cavity is counter-productive (historically, projectile reliability has related to permanent cavities of adequate depth). Such limited potential is incapable of inducing a cavity large enough to cause reliable incapacitation of a 150 pound animal — especially the two-legged kind whose mind is set on continuing his mischief.

Martin L. Fackler, MD
Editor-in-Chief

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