DEFENSIVE HANDGUN AMMUNITION

CHARACTERISTICS AND BULLET TYPES

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FORWARD

There are four main types of bullets each with a distinct design and purpose. There are four main characteristics or qualities a bullet has in regards to wounding. This report will define and discuss the four individual characteristics of all four bullet types.

This report brings together the most credible information regarding wound ballistics. It combines the knowledge and results of many federal wound ballistics tests. Research into wound ballistics includes both industry accepted ballistic gelatin and medically recommended animal tissue media to create relevant realistic data. The comparison of effective handgun ammunition for federal, state and local agencies is critical and complex. Representative data of a real target is needed for instruction and selection.

No specific ammunition will be discussed rather this is an overview of bullet characteristics and types. No conclusions or choices will be included in this report. Any agency wishing to use this report to make conclusions must first understand their needs and be able to quantify their requirements using the four characteristics described herein. Any agency wishing to discuss either in person or remotely the contents of this report or more detailed information need only contact us.

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TACTICAL REALITIES OF A LIVE TARGET

There are four main subjects involved in stopping a live target.

1. Shot Placement. Proper wound placement is the most important determinant to stopping/incapacitating a human target. However, shot placement is NOT wound placement and where a projectile hits the target does not always determine the path of the bullet through the target due to barriers (clothes, bones and outside items) and bullet performance/failures. Many common defensive rounds are easy to defeat or vector away from the original path. Barrier performance is extremely important in judging whether a round will continue on its original path or be deflected/defeated.

2. Number of hits. Amount of hits on target is critical and any agency considering choosing a new weapon, ammunition type, caliber or specific round should certainly take into account how many rounds the weapon contains, recoil and ease of follow up shots, the weight of the weapon and ammunition to be carried.

3. Bullet Capability. This is the wound ballistic profile of a specific round of ammunition and what is measured and documented in wound ballistics tests. It quantifies the performance of a single round in regards to four wound ballistics characteristics. Penetration Depth, Reliability/Consistency, Barrier Performance and Permanent Wound Cavity (PWC). This is what is discussed in this report.

4. The Target. The health and physical condition of the target is extremely important in determining the results of a shooting. Age, sex, size, health and outside influences such as drugs and alcohol greatly affect the target's capability to stay active or be incapacitated.

THE HUMAN TARGET

There are four main kinds of human tissue.

1. Epithelial. Covers the body surface (skin) and forms the lining of most internal cavities and organs. Skin is extremely strong. The resistance of skin to projectile penetration is equal to about 3-4 inches of IWBA calibrated ballistics gelatin as evidenced in the gel calibration test.

2. Nervous. Thin nerve tissue which constitutes the smallest percentage of human tissue by weight and area.

3. Connective. Tissue providing a variety of functions to include support and protection. Bone, cartilage and blood vessels are the most common types of connective tissue. Bone is an excellent protective barrier and is similar but stronger than the plywood that is used as a barrier in most ballistics testing.

4. Muscular. Made up mostly of muscle tissue and of most internal organs. It is the most common type of human tissue in the thoracic cavity which is the target area or center of mass. In some professional wound ballistics tests animal tissue is used to as closely as possible consistently replicate human muscular tissue.

The average human male is 10" thick. Most human tissue is very elastic. Organs, skin, muscle and blood vessels are capable of substantial stretching with minimal damage. Tissue can stretch in most cases up to 6 times its normal length before tearing occurs. Medical and military studies have shown that the outward velocity of tissue causing the temporary stretch cavity from energy transfer is between 8-15% of the velocity of the projectile at the depth the stretch is created. Furthermore, in these studies it was proven that human muscular tissue (other than brain or liver tissue) can stretch much faster than that velocity before becoming destroyed. Also, the distance created by the temporary stretch cavity does not exceed the elastic capability of the muscular tissue to stretch without tearing. At greater than around 2,000 fps it was tested, seen and measured that animal tissue did show signs of over-stretching and damage. This was noted only on the rounds that were extremely high speed at impact (>2,000 fps). All pistol rounds, except for a few 5.7 x 28mm rounds, impact at velocities that are nowhere close to what is required to cause stretch damage. With high-speed rifle rounds stretching damage is difficult to measure but is a contributing factor to overall wounding. Since the projectile slows quickly in the media or target the stretch damage only occurs near the entry. For rifle bullets impacting at extremely high speed (>3,000 fps) there is a substantial stretch damage to actual tissue much deeper and temporary stretch cavity is a wounding effect. For pistol rounds temporary stretch cavity is meaningless and does not contribute to wounding.

Except for penetration into the brain cavity or spinal cord, reliable and consistent immediate incapacitation of the human target by projectile wounding to the torso is extremely unreliable. Even shots to the heart are not immediately incapacitating as stored oxygen may allow for voluntary action for 5-15 seconds after functional heart destruction. Failure of the Central Nervous System (CNS) and/or massive blood loss sufficient to drop blood pressure, cause organ failure or deprive the brain of oxygen is the only way to cause reliable incapacitation. Common “One Shot Stop” and “Knock Down Power” are both myths perpetuated by the uninformed.

Energy transfer is often quoted and is completely immaterial. First, the transfer of energy is represented by the temporary stretch cavity and as stated is insufficient in rounds <2,000 fps to cause any damage except for brain and liver tissue. Secondly, the human body can absorb a great amount of energy without being damaged. Thirdly, a baseball or a hockey puck hit in a game has approximately half the energy of a 9mm bullet being shot. Lastly, the human body is not one solid mass where energy is easily transferred throughout the body. Changes in tissue density and space between organs nullifies a vast amount of transfer of energy.

We must also discuss Energy vs Momentum for hollow points. During major federal handgun hollow point ballistics tests it was conclusively found that the heaviest bullets in each caliber average larger Permanent Wound Cavities (PWC) than lighter bullets in the same caliber. Using hollow points as the example because they were the only type of bullets tested during many federal tests, there were 6, 7, 3, 6, 6, 5 and 5 calibers tested in each of 7 large scale tests. The 9mm and 45 ACP were the most common calibers tested and were tested in each of the 7 tests. The 40S&W was tested in 6 of the tests. In 6 of 7 tests the heaviest 9mm (147 grain) bullets averaged the largest PWC over any other weight 9mm. In 5 of 6 tests the heaviest 40 S&W bullets averaged the largest PWC over any other weight .40. In 7 of 7 tests the heaviest 45 ACP (230 grain) hollow point bullets averaged the largest PWC over any other weight .45. In all cases the heavier hollow point bullets in any caliber have less energy than the light weight bullets in that caliber that have the highest energy. So, does that mean that momentum is more important? Well, the heaviest rounds do have more momentum, but in actuality what it proves is that energy calculations have no bearing or indicators to bullet performance. Otherwise, the fastest bullets in any particular weight/caliber would be the best and that simply isn't the case.

True bullet performance must be measured in a consistent media. Realistic animal tissue media yields better analysis to real world shootings. Mathematical calculations without shooting are not tests and have no bearing on reality. Different bullet types yield different results as the actual mechanism to destroy tissue is different for different bullet types. The above discussion of weight vs wound cavity size is for hollow points only as their destructive mechanism is crushing or tearing of tissue through physical contact with the bullet. Other bullet types will yield different weight vs velocity results.

VOLUME OF WOUND INDEX

IWBA calibrated ballistics gelatin has several good and some bad properties. The good: Its consistent for comparison purposes. It is easy to purchase, create and handle. It shows what happens as the projectile goes through the media by being clear enough to see through and witness the effects. After the shot the effects are retained and can be measured. It is one of the only media that has all of these great factors. The bad: It does not replicate or represent human tissue and was not designed to. Unfortunately, the uninformed non-professional believes that it does. It is a non-compressible liquid which is not like human tissue. Its density and drag do not mimic tissue so the penetration depth results are nowhere close to reality. For some projectile designs (like the hollow point that uses direct contact as its destructive mechanism) the wound diameter is similar in gel as it is in tissue. For other bullets the wound channels are drastically different (like any rounds creating a compression: high speed rifle rounds and solid copper rounds) when comparing results from the same bullet in gel and tissue.

If one round does better in gel then it is assumed it will do better in tissue. This is normally the case even though the volume of the wounds from the different media/target will be vastly different. This is untrue for compression rounds like the solid copper. Also, using the recovered bullet is meaningless in trying to determine the actual cavity size with any bullet design. Only by measuring the actual cavity on the target will you know the true size and amount of destroyed material.

Using multiple medias to more truly understand the actual effects of projectile destruction on target material is required. Volume of Wound Index (VWI) uses two different medias to ascertain a better understanding and provided a quantitative result for comparing bullets. It is not a direct measurement from any single test, but rather a calculation from a combination of 4 tests, so it’s an index. It is measured in cubic inches of volume, and can be used in a direct comparison from round to round.

The reasons for using Volume of Wound Index along with IWBA gel is as follows:

1. Since IWBA gel is a nonrealistic, non-compressible (human tissue is compressible) media using it does not simulate a real target.

2. Rounds that cause compression like tumbling or fluid transfer rounds, create a huge permanent cavity in gel that is larger than in actual tissue. When only testing rounds like hollow points, that cause minimal compression, gel works ok. But when mixing HPs and compression causing rounds the results are impossible to compare using gel alone.

3. Gel is consistent. Using it to determine comparable (nonrealistic) penetration depths is acceptable.

4. Therefore a realistic media (animal tissue) must be used. Unfortunately, an enormous amount would be required to measure penetration depths. Also, cutting into tissue to measure penetration depths, changes the size of the wound. So, the rounds must completely go thru the tissue to measure the size of the exit hole. Tests using back-to-back tissue pieces will allow measurement of 2 holes on every shot, a midway hole and an exit hole.

5. Barriers are encountered in a majority of actual shootings. Bone, heavy clothing and common domestic barriers like plywood and dry wall are present more times than not. Testing must incorporate barriers and any end calculation, like VWI must have barriers included to be a realistic presentation.

To calculate VWI 4 tests are accomplished. At least 4 (normally 6-8) shots per round are taken in each test.

The first two tests are accomplished with IWBA calibrated gelatin.

1. IWBA gel with 4 layers of denim in front (IAW FBI and DoD protocols).
2. Same as the first test except add a layer of 3/4 inch AA fir plywood between the denim and the gel (IAW FBI and DoD barrier protocols). Average the two tests together. This effectively increases the sample size and is a combination of non-barrier and barrier. That average is where the penetration depth for VWI comes from. The results from the two gel tests can be used independently for comparison to other tests using the same standardized protocols.

The third and fourth tests are accomplished using animal tissue.

3. 2 hanging cow briskets 7-9 inches total thickness, 35-38 pounds (2 pieces back-to-back, fat side toward shooter on both, point up on one and down of the other for a more consistent thickness) with 4 layers of denim in front.

4. Same as the third test except add a layer of 3/4 inch AA fir plywood between the denim and the tissue.

Each shot into tissue yields 4 measurements: major and minor diameter from the exit of both pieces of tissue. Those 4 diameters are averaged, and converted to area. Then average the results from test 3 and 4 together to get the average hole area which includes both the non-barrier and barrier tests. That area is multiplied by the average penetration depth discussed above from tests 1 and 2. That's VWI. It combines consistent penetration measurements from IWBA gel along with consistent realistic measurements of hole size in real tissue and uses barriers and non-barriers. Currently it's the most comprehensive single value of comparative bullet effectiveness.

FOUR TYPES OF HANDGUN BULLETS

Four types of handgun bullets exist.

1. Hollow Point. The most common defensive ammunition used. These rounds are intended to expand upon impact to increase the frontal area of the projectile. This will create a larger diameter wound (if the bullet doesn't turn) and also increase drag which limits penetration depth as compared to an FMJ. The destructive mechanism of the hollow point is crushing or tearing of tissue through physical contact with the bullet. Most hollow point rounds are copper jacketed lead, but some monolithic hollow points have no lead. Some of the lead-free hollow points are only copper but will be considered hollow points because their design is identical to other hollow points and the only difference is the material. Hollow points are generally not designed to fragment, but rather have weight retention. This will keep the mass high to allow for deeper penetration. Some common hollow point failures include but are not limited to: fragmentation, jacket separation, failure to expand and turning. All will limit the round's ability to wound and are not supposed to occur.

2. Full Metal Jacket (FMJ). The second most common ammunition used. This is typically a copper jacketed round that is solid and is not designed to expand, tumble or fragment. This is also the most widely used training or practice ammunition. They create deeper wounds of less diameter. The destructive mechanism of the FMJ is the crushing of tissue through physical contact with the bullet. About the only failure is deformation due to barriers. Since the copper jacket is thin this is possible with strong barriers and this can cause revectoring inside the target.

3. Solid Copper. These rounds have varied designs, most are fluted. Some perform extremely well, while others are simply gimmicks. For the purpose of this discussion the solid copper category is comprised of non-expanding bullets. Their designed destructive mechanism is tearing and fluid transfer. Recent testing has proven that fluted solid copper bullets transfer fluid (castoff speed) as high as 30% projectile velocity. Fluted bullets lower the TBC, Terminal Ballistic Coefficient (term described by G9), increasing drag, which increases cast off fluid quantity. This high-volume high-speed liquid tissue cast off destroys adjacent non-directly impacted tissue. This is not energy transfer temporary stretch cavity which doesn't destroy tissue. This fluid transfer is direct contact high-speed fluid on live tissue.

   Since they are solid and don't expand about the only failure is tumbling which stops the designed fluid transfer. A tumbling round of this type will create a substantially smaller wound diameter and also less deep penetration than normal. The solid copper rounds designed as hollow points are included in the hollow point category.

4. Frangible. These rounds are designed to break apart and fragment upon striking a target either immediately at the surface or after minimal penetration. They are designed to create large diameter wounds that do not penetrate deep. In all cases these rounds did not penetrate the required 12 inches of ballistics gel, except for some cores. The only common failure of frangible rounds is failure to fragment. If minimal penetration or absolute barrier failure is desired, then these rounds are designed for that task.

FOUR CHARACTERISTICS OF BULLET WOUNDING

There are four main characteristics or qualities of handgun projectile wounding. Each of these can be quantitatively graded. Before picking a bullet type or specific ammunition these four characteristics must be understood. Decide what is needed for each characteristic. From there use these four characteristics and your desired results to determine the best bullet type and specific round for your application.

1. Penetration. The overall distance traveled by the bullet through the selected media or target. This is generally accepted as the single most important characteristic in projectile wounding. A projectile must create a wound that is deep enough to disrupt/destroy the Central Nervous System (CNS), cause sufficient blood loss or destroy enough vital organs to incapacitate a human target. This must be accomplished from different target body angles and through common barriers such as clothes and bone. Side shots through an arm must penetrate greater than 10 inches to contact the heart or other critical organs and frontal shots must penetrate at least 7 inches to reach the back of the abdominal cavity. The above figures ARE NOT ballistics gel depths, but rather human tissue penetration depths. IWBA ballistics gelatin is NOT a tissue simulant but rather a consistent media that shows the effects of bullet entry and travel and holds the effects after the shot. Do not equate what a bullet does in calibrated gel to what would happen to an actual live target. Most if not all federal agencies require a minimum of 12 inches of penetration in calibrated ballistics gel just to be considered viable. It is generally accepted that between 15-18 inches (for several agencies) or 18 inches ±10% (16-20 inches) of overall calibrated ballistics gel penetration is what is required for a defensive round to be effective in a real-world live target situation. Under-penetration will result in lack of critical body function destruction. Superficial shallow wounding does not stop a live target. Deep penetration is a critical requirement.

   Over-Penetration: Fear that a properly functioning hollow point, solid copper or frangible round will pass through a target body and damage a bystander are unfounded. First, approximately 40% of all shots fired during daylight hours do not hit any target at all and even less bullets hit the target at night. That’s cause for real concern. Secondly, shots passing through the target torso do not have sufficient remaining penetration capabilities. Lastly, there haven't been any cases where this has actually happened. No recorded medical reports or lawsuits come from a bystander wounding resulting from over-penetrating functioning handgun bullets through the torso of a target. Missed shots, grazing shots, or bullet failure are the problem. Only Full Metal Jacket (FMJ) and Hollow Point rounds that Failed To Expand (FTE), penetrated to such a depth that could cause an overpenetration issue.

2. Reliability and Consistency. Reliability is a percentage based on failure to perform as designed. Each bullet type is designed to do something specific and each design has separate and different design features. If the round doesn't do what it is designed to do then that is a failure. Some examples are Failure To Expand (FTE), fragmentation or failure to fragment, tumbling and jacket separation.

   Consistency is the ability of the round to perform the same way every time and how much deviation occurs. Once a specific round is graded it is important to know how often it can perform to that standard. Reliability and consistency are typically thought to be the second most important criteria in ammunition selection but are unfortunately under appreciated. Since failures do cause dangerous under-performance and in hollow points can cause overpenetration the reliability and consistency of duty rounds is critical.

3. Barrier Performance. Barriers are items that may cause degradation to the bullet before bullet stoppage or exit. They can exist between the weapon and target or be part of the target. Barriers can include bones, thick clothing, dry wall, plywood and other common everyday items. Other stronger barriers can include doors and auto glass. Barriers can destroy, degrade and deflect a bullet. The percentage of degradation can be measured with consistent barriers during testing. Penetration and Permanent Wound Cavity (PWC) size lost from non-barrier shots to barrier shots are analyzed and calculated. Real-world shots including barriers are extremely common and are generally out of the control of the shooter. Multiple shots on a barriered target does not increase the chance of penetration or incapacitation. Barriers that stop one bullet generally will stop multiple shots. Bones are an exception to this rule

due to their size and chance of hitting, but doors, plywood and glass will stop multiple bullets if they can stop one.

4. Permanent Wound Cavity (PWC). The actual size of the hole left behind after the bullet passes through the target/media. This is the destroyed part of the target. It is measured in cubic inches of volume. Unlike penetration depth, reliability of a round and barrier performance this can be increased with multiple shots. With a given penetration depth, a projectile creating a larger diameter wound will destroy an equally larger amount of tissue. Small increases in diameter cause large amounts of frontal area change (Area = л x Radius squared). PWC is calculated by multiplying the depth (penetration) of the wound and the area (not diameter) of the hole left by the passage of the bullet. Unfortunately, many reports simply measure the area of the recovered bullet after it stops or passes through the media. **The hole created by the bullet in actual tissue in most cases is not equal to the size of the projectile**. This is greatly misunderstood and is caused by several factors. In hollow points, the round does not expand fully immediately at impact. Also, if a hollow point tumbles or turns sideways then the large frontal area of the bullet is not what's producing the wound resulting in a much smaller wound then the recovered bullet size would suggest. In frangible rounds there is a large amount of intentional fragmenting and the individual channels often times cross or pieces follow other paths already destroyed in the target. With solid copper rounds the fluid transfer destroys adjacent tissue and can't be measured except on the actual target. Measuring the recovered bullet will render no information on the wound channel size. The wound area is extremely difficult to measure in the case of fragmenting rounds, solid copper rounds which create holes larger than their caliber and tumbling bullets that have holes that vary greatly at different depths.

The temporary stretch cavity is caused by the expansion and temporary displacement of media or tissue due to the transfer of kinetic energy to the target. This stretch cavity only causes wounding in high velocity rounds greater than 2,000 feet per second (fps) and for all rounds that do not exceed that velocity while inside of the target it does not contribute at all to any wounding effects or incapacitation. The displaced tissue is not destroyed and in most cases is not even damaged. Most human tissue (other than brain and liver tissue) can be stretched as much as 6 times its normal size before overexpansion and tearing occurs. Also, human tissue can expand extremely rapidly and the outward force caused by the kinetic energy transfer is typically <15% of the velocity of the projectile causing the displacement. Exceeding roughly 2,000 fps causes an outward force velocity greater than the maximum rate of expansion for most human tissue which in turn causes a tearing wound. Since almost no pistol rounds (except for some 5.7 x 28mm) exceed 2,000 fps inside of the target by even 10%, temporary stretch cavity from pistol rounds caused no damage to actual tissue and therefore is not considered of any importance. High speed (>3,000 fps) rifle rounds were tested and the animal tissue media was dissected and showed tearing which was never present in any of the handgun rounds <2,000 fps further confirming that temporary stretch cavity has no effect on wounding a target with <2,000 fps projectiles. Unfortunately, it is still used by non-experts during assessment. Do not confuse temporary stretch cavity with the fluid transfer from fluted solid copper rounds. The former is energy transfer and the latter is fluid transfer. Temporary stretch is caused by intact non-destroyed tissue pushing on adjacent tissue causing a stretch which then pushes on the next layer of tissue. There is no wounding effect with this stretching from low-speed pistol rounds. Fluid transfer from the solid copper rounds is sending a jet of liquified tissue into adjacent tissue. It is not energy transfer! This will destroy some of the tissue not actually contacted by the bullet. It increases the actual hole in the tissue target. Outside of that wound channel there is still more material that is the temporary stretch cavity which just like the other bullet types is non-destroyed material and is insignificant in wounding in handgun rounds.

HOLLOW POINT SUMMARY

All hollow points are designed to expand after contact with the target/media. Some are designed to open slowly or a lesser amount to aid in barrier performance and to provide deeper penetration, while others are designed to open more rapidly to cause the largest area wound.

Results from multiple tests have showed there are four main characteristics to hollow point performance in order.

1. Caliber. The larger the caliber hollow point the deeper the average penetration depth, the more reliable the rounds were with a lower failure to function percentage, better barrier performance and the largest average PWC. In all four grading criteria the largest caliber hollow point rounds did the best when compared to other hollow points.
2. Weight. In each of the 5 major calibers that hollow points were tested the heaviest weight in each caliber did the best in all four graded characteristics.
3. Bullet Design. Certain bullet designs outperformed other designs. This was the third most important characteristic after caliber and weight.
4. Velocity. In all calibers of hollow points velocities less than 800 fps resulted in larger failure to expand percentages in all 7 major tests. Between 800-900 fps the percentage decreased and ceased to be a problem above 900 fps. Velocities over 1,200 fps resulted in extremely high failures due to jacket separation and fragmentation. This happened with bonded hollow points as well. The reliability rate was slightly better between 1,100-1,200 fps and accidental fragmentation happened far more rarely below 1,100 fps. The sweet spot for hollow point reliability is between 900-1,100 fps. Remember hollow points are designed to expand and function properly with specific impact velocities. Changing barrel lengths or using +P rounds may alter the desired effects in a negative manner. A faster hollow point is not always a better hollow point. For the other three types of ammunition tested increased velocity always produced better results, not true for hollow points.

1. Penetration. Most hollow points penetrated at least 12 inches in IWBA gel, but fail to reach 16 inches. Some exceeded 24 inches during failure to expand occurrences. In all cases increasing bullet weight increased penetration, while increasing velocity did many things and none of them reliably.

2. Reliability and Consistency. Unfortunately, of all 4 types of bullets tested hollow points recorded the worst reliability and the worst consistency. Hollow point bullets failed to function properly about 30% of the time. Reliability and consistency continue to degrade as barriers are added. Factors in this include the caliber, velocity, target media, barriers and bullet design. This means that at least 1 out of every 4 shots resulted in a failure! In realistic tissue with barriers such as clothes and bone 1 out of every 3 hollow point shots resulted in failure to function. This is extremely poor reliability and consistency. Failure to expand can cause the hollow point to behave as an FMJ with extreme over-penetration depths normally considered unsafe. Fragmentation occurs unintentionally by the accidental breaking apart of the projectile. Hollow points have the highest occurrence of accidental fragmentation. Two distinct characteristics increase accidental fragmentation with hollow points.
    a. Velocity. Rounds traveling at over 1,200 fps have an alarmingly higher rate of accidental fragmentation. Rounds below 1,100 fps had a relatively low fragmentation rate. Between 1,100-1,200 fps the rate was abnormally high but not as catastrophic as over 1,200 fps.
    b. Thickness of the metal of the sidewall of the hollow point projectile. Smaller caliber rounds have less thick walls. This makes them less strong and increased the rate of fragmentation. At the same velocity the smaller the caliber the higher the accidental fragmentation rate across the board with no exceptions.

    These two characteristics which cause accidental fragmentation greatly reduced the penetration, consistency, reliability, barrier performance and overall Permanent Wound Cavity size. In the cases where accidental fragmentation occurred the pieces were generally very close to or inside of the PWC which limited additional wounding effects.

3. Barrier Performance. Barriers greatly affected hollow points. Hollow points are neither barrier blind nor barrier fail. Results varied greatly from shot to shot. With simple barriers such as drywall and plywood:

a. 9mm hollow point rounds recorded an average of a 30% degradation in penetration and PWC due to barriers.
b. 357 SIG hollow points recorded an average of a 35% degradation due to barriers. The higher velocity caused more cases of accidental fragmentation.
c. The 40 S&W recorded an average of 15% degradation due to barriers.
d. The 10mm hollow points recorded an average of 20-25% degradation in penetration and PWC due to barriers because of accidental fragmentation caused by excessive velocity similar to the 357 SIG.
e. The 45 ACP recorded an average of 10% degradation due to barriers.

4. Permanent Wound Cavities were almost always larger than the FMJs and frangible rounds due to a good combination of expansion resulting in larger diameter wounds and deep penetration. Within a certain caliber and bullet weight the differences in PWC were minimal signifying that penetration, reliability and barrier performance are of greater concern.

Overall, hollow points generally don't penetrate as deeply as desired and are less reliable than the other bullet types. They don't go through barriers or get stopped by barriers consistently. Their overall wound cavity is smaller than the solid copper rounds.

FULL METAL JACKET (FMJ) SUMMARY

FMJs are the second most used defensive rounds and are also the most used training ammunition. They are typically not the first choice for defensive ammunition.

1. Penetration. FMJs penetrate very deeply. FMJs routinely penetrate completely through the IWBA calibrated gelatin blocks and all barriers that are used during testing. Overpenetration with this bullet type is probable and dangerous for defensive application.

2. Reliability and Consistency. Every round does almost exactly what it is supposed to do and does it every time. There are rarely problems with function on any FMJs. About the only failures that can occur would be tumbling which was witnessed almost never.

3. Barrier Performance. FMJs are almost completely barrier blind. They did extremely well and are a great choice if your agency considers barrier performance to be one of the top criteria in ammunition selection. They easily exceeded the barrier capability of all the hollow points and frangible rounds. Given that hollow points fail 25%-35% of the time and are unreliable versus barriers consider Full Metal Jacket rounds.

4. Permanent Wound Cavity. In each caliber tested the FMJ rounds produced the smallest Permanent Wound Cavity size compared to the other three bullet types. The wound channel in actual tissue during testing was smaller than the diameter of the round. This has also been seen in medical forensic documentation in real-life shootings.

Overall, if extremely deep penetration, reliability/consistency and barrier performance are important while small diameter wounding is acceptable then FMJs are a logical choice. Overpenetration is a serious concern as a defensive round.

SOLID COPPER PROJECTILE SUMMARY

Solid copper bullets are non-expanding. Their designed destructive mechanism is tearing and fluid transfer. Since they are solid and don't expand about the only failure is tumbling which stops the designed fluid transfer. A tumbling round of this type will create a substantially smaller wound diameter and also less deep penetration than a functional projectile. As stated earlier some hollow points are made exclusively of copper but their design (expansion) remains the same and those rounds are discussed in the hollow point section.

These designs are non-deforming rounds designed to use a specific technology to create a larger wound cavity than FMJ or hollow point bullets. Tearing and hydraulic compression tissue redirection (fluid transfer) are the two mechanisms used to create larger wounds. Because gel is non-compressible and human tissue is compressible wound channels from these rounds are larger in gel tests than in tissue tests. Hollow point wound diameters are very similar when comparing gel to tissue with and without barriers (the penetration depths are completely different and therefore the volume of the wound). This makes the use of animal tissue in testing required because gel is used not as a tissue simulant but rather a consistent media. With solid copper rounds due to their design use of compression, testing in a non-compressible liquid (gel) creates unrealistically large wound channels. If only gel was used then solid copper rounds would appear to be an order of magnitude better than all hollow points.

Tissue is liquified by the bullet shock wave and by impact. The radial flutes increase liquified tissue velocity because liquid is non-compressible. The flutes then also direct the tissue outward to impact and destroy adjacent tissue not being contacted by the projectile itself, increasing wound diameter. This is fluid transfer, not energy transfer. *Many testers wondered if vectoring high speed liquified tissue sideways into tissue would actually destroy that adjacent tissue that is not directly being impacted by the projectile. Remember that a hollow point opens the same way. Hollow points do not open because of friction, they open because tissue fills the hollow point cavity, gets compressed from the continued crushing of more material until it's a liquid (instantaneous) and then pushes outward, tearing and bending the metal petals. Once the petals are pushed outward the pressure is released and then friction takes over causing the continued opening to complete the expansion. If liquified tissue can be compressed to the point of tearing and bending metal (hollow* *point) then higher speed liquified tissue can certainly destroy tissue. For those who think this will only work in a non-compressible fluid like gel, it was confirmed that this technology works extremely well in actual animal tissue with or without barriers. In every tissue test and forensic report with these rounds the wound diameters far exceed the actual diameter of the projectile. Animal tissue tests confirmed that in over 200 shots the measured wound channel was not only larger than that of an FMJ but in most cases was the largest wound channel produced in that caliber compared to all other rounds to include fully functioning hollow points.*

There are two main characteristics to solid copper performance…. Velocity and specific design. The faster any solid copper round goes the larger the wound diameter. We tested the same 9mm projectile in standard pressure 9, 9+P, 9+P+ and the 357 SIG in multiple tests in gel and tissue. That's 4 of the exact same projectiles with the only difference being velocity. The wound channel size increased exactly in proportion to increase in velocity. Unlike hollow points which are designed for a certain impact velocity to best perform as designed, solid copper rounds always work better when faster.

1. Penetration. All solid copper rounds in all calibers tested penetrated 15 – 20 inches with and without barriers.

2. Reliability and Consistency. Every single shot did roughly the same thing. There were no recorded instances of tumbling, a 0% chance of failure to expand, and no chance to fragment. These were the most reliable and consistent rounds tested.

3. Barrier Performance. The solid copper rounds and FMJs were the most barrier blind rounds tested. Not only did barriers not deflect the round it didn't change the wound diameter much and only slightly reduced penetration depth. Solid copper barrier degradation was approximately 5%.

4. Permanent Wound Cavity. In the realistic animal tissue tests these rounds produced the largest wound areas and with the incredible penetration depth exhibited in the gel tests they recorded the largest overall PWC in all calibers. Data from the IWBA gelatin tests show results with enormous wound diameters. The radial flutes work perfectly in fluid/gel. As noted, the PWC numbers are inflated in the gel tests due to non-compressible gel, but the

penetration depths are more realistic to compare. Calculated PWCs in all medias and forensic reports are the largest ever recorded in all calibers!

Overall, the solid copper rounds are very impressive if deep consistent penetration is desired. They exhibit great reliability and have the largest permanent wound cavity of any of the four bullet types.

FRANGIBLE ROUND SUMMARY

Frangible bullets are designed to break apart, fragment or disintegrate into small pieces upon striking any solid object either immediately on target contact or after minimal penetration. Frangible rounds were created to minimize penetration and to be less likely to cause injury or damage to unintended objects. They are designed to create large diameter wounds and not penetrate deeply. During testing in all cases the frangible rounds did not penetrate the required 12 inches of ballistics gel, except for the core of one type of round (accidental). Each fragment path must be included in the calculation of the PWC. Frangible rounds tend to create large wound cavity areas but shallow wound penetration. The overall Permanent Wound Cavity (PWC) is generally less than a non-fragmenting round due to the smaller mass of each fragment, larger surface area after fragmentation resulting in greatly increased drag. Since most critical body parts reside deep inside of the thoracic cavity a superficial wound that does not encounter and destroy critical organs/blood vessels and CNS tissue does little in the way of incapacitation. Given that the FBI and DoD protocols call for a minimum gel penetration of 12 inches with a goal of around 18 inches, low penetrating frangible rounds do not qualify.

1. Penetration. Frangible rounds are not designed to penetrate deeply and they don't. None averaged anywhere close to 12 inches in IWBA calibrated ballistic gel.

2. Reliability and Consistency. All had extremely consistent numbers and reliably opened on every test. One gimmick round displayed erratic results.

3. Barrier Performance. Frangible rounds are supposed to be barrier fail rounds. All properly opened in contact with barriers.

4. Permanent Wound Cavity. Frangible rounds PWC size calculations are extremely difficult to measure because in gel the multiple fragments/projectiles produce many tiny hard to measure wound paths and in tissue most of the rounds Did Not Exit (DNE) the media, so measuring wound exit diameters was problematic. The measurements calculated were generally smaller than the hollow point rounds and much smaller than the solid coppers.

Overall, if minimal penetration or absolute barrier failure is desired than frangible rounds are designed for that task.

PENETRATION GRADING CRITERIA SUMMARY

Penetration is the overall distance traveled by the bullet through the selected media or target and is considered the most important characteristic of projectile wounding.

The best penetration depths were observed by the solid copper rounds in all calibers and consistently penetrated between 15 – 20 inches with and without barriers. Hollow points penetrated the second best, but were the most unreliable and inconsistent. FMJs very reliably and consistently over-penetrated. Frangible rounds all under penetrated as designed.

RELIABILITY AND CONSISTENCY GRADING CRITERIA SUMMARY

All involved agencies in recent tests stressed how important reliability and consistency are and demanded that they be addressed and reported. Many tests do not reference this critical benchmark.

Reliability was defined and graded as to whether the round performed as designed or failed to function properly. Function depended on the type of round. Failure to perform as designed (Failure to open/tumble, accidental fragmentation and jacket separation).

1. Hollow Points. They are designed to expand, stay linear (not tumble) and retain weight. Failure to do so, regardless of the cause, caused penetration depth and permanent wound cavity (PWC) size to be greatly affected. Of all 4 types of rounds tested hollow points recorded the worst reliability. Hollow point bullets fail approximately 25-30% of the time. Reliability continued to be degraded as barriers were added. Failure factors include the caliber, velocity, target media, barriers and bullet design.
    a. Failure to expand was particularly noted for low-speed rounds less than 900 fps. Barriers also caused failures to expand especially in the 9mm and less so as the caliber and velocity were increased.

   b. Fragmentation was noted in high-speed hollow points like the 357 SIG and 10mm resulting in much smaller PWC. Also, the smaller the caliber the more cases of fragmentation that occurred.
2. Full Metal Jacket. These rounds are not designed to do anything except retain weight and not tumble (stay linear). Failures are rarely noted since FMJs seldom fragment or deform enough to alter the results.
3. Solid Copper Rounds. Failure from these rounds comes from tumbling and not creating the designed tissue tearing. This was not noted in any of the tests. These rounds reliably and consistently perform as designed.
4. Frangible Rounds. These rounds open and fragment as designed with very little rate of failure.

Consistency was defined and graded as to whether the round’s performance was persistent. A standard deviation for each shot tested was used. Large changes in the values showed rounds to perform differently from shot to shot which was deemed as low consistency. Obviously, failure rates were the largest cause of inconsistency but some rounds were inconsistent even while functioning. Generally speaking, hollow points, exhibited the lowest consistency. The FMJs and solid copper rounds were the most consistent.

Overall, reliability to function on target as designed cannot be overstated. Choosing a round with excellent characteristics really doesn’t matter if it fails to function. Round reliability rates under 80-90% are serious problems. Consistency is also important but less so then reliability. There were some rounds that were extremely reliable (nearly 100%) and very consistent in the solid copper and FMJ categories.

BARRIER PERFORMANCE GRADING CRITERIA SUMMARY

The main target area to stop/incapacitate a human target is the upper thoracic cavity and head. Bone protects over 70% of that area and in most conditions, clothes cover about the same percentage. Barriers are encountered on about 2 of 3 shots taken. Bone tissue is an excellent protective barrier and is similar but stronger than the plywood that was used as a consistent barrier IAW IWBA standards. Shot placement is NOT wound placement and where a shot hits the target does not always determine the path of the bullet through the target due to barriers (clothes, bones and outside items) and bullet performance/failures. Many common defensive rounds are easy to defeat/vector away from the original path of the bullet. Barrier performance is extremely important in judging whether a round will continue on its original path or be deflected/defeated and how much a round is degraded by going through barriers.

Barrier performance was graded by comparing the results in both media (IWBA calibrated gelatin and animal tissue). Each media had tests accomplished with a barrier and without. Comparing those yielded a barrier performance metric, where the only differences were the addition of a single ¾ inch thick AA fir plywood panel IAW FBI / DoD protocols.

Penetration and PWC degradation: Percent of penetration and PWC size lost from non-barrier shots to barrier shots.

1. Hollow Points.
    a. 9mm- 30% degradation due to barriers.
    b. 357 SIG- 35% degradation due to barriers.
    c. 40 S&W- 15% degradation due to barriers.
    d. 10mm- 20-25% degradation due to barriers.
    e. 45ACP- 10% degradation due to barriers.

2. Full Metal Jacket. No measurable degradation in penetration or PWC. Barrier Blind.

3. Solid Copper. Very minimal degradation on the order of 5% degradation in penetration and PWC regardless of caliber.

4. Frangible. Frangible rounds are supposed to be barrier fail rounds. All bullets performed as designed by functioning and opening due to contact with barriers.

Overall, the ultimate goal is for a round to be either barrier blind or barrier fail, that way the shooter will know the capability of the rounds and not have unexpected results. The solid copper rounds and all FMJs were barrier blind, while the frangible were barrier fail as designed. The hollow point results were erratic and it would be impossible to classify hollow points as either barrier blind or barrier fail. This is true for specific hollow points, not just the entire category or group.

PERMANENT WOUND CAVITY GRADING CRITERIA SUMMARY

Penetration was judged the most important characteristic of a defensive handgun bullet. Permanent Wound Cavity (PWC) is a mathematical calculation comprised of penetration depth and wound diameter converted to area and is expressed in cubic inches of destroyed material (Volume of Wound Index). Literally it's how big a hole was made by the bullet. Whereas this seems to be extremely important, there are four issues with concentrating solely on this number.

1. A large PWC that doesn't destroy any important body tissue because the wound is too shallow is virtually meaningless. Since the important organs are deep within the body this drives up the importance of penetration. Destroying a lot of skin and subcutaneous material does little to stop/incapacitate a human target.
2. Many rounds that create large PWC exhibit low reliability and consistency. Many of the hollow points that open extremely far tend to do it inconsistently or accidentally fragment often.
3. Most of the PWC calculations are done using IWBA gel. Human tissue is compressible and gel is non-compressible which creates results that don't represent reality. Using a media closer to human tissue is required to get actual realistic data.
4. About 70% of the target area of a human is covered by clothes and bones. So, 2/3^{rds} of the shots are going to encounter barriers which are not considered for

most PWC calculations. Barriers greatly lowered some PWC figures. That is why VWI is considered more valid because half of the calculation comes from barrier tests.

1. Hollow Points. The PWC of hollow points were some of the biggest seen along with the solid copper rounds. Caliber and weight had the largest bearing on hollow point PWCs with design being less important.

2. FMJ. The PWCs measured were the smallest of all 4 bullet types.

3. Solid Copper. The solid copper rounds produced the largest wound volumes. This was true in gel tests and animal tissue tests. This was true with and without barriers.

4. Frangible. Results varied depending on ammo. Some large wound channels were observed but difficult to measure due to fragmentation creating multiple wound paths. Also, since penetration depth was so low the overall PWC was smaller than the hollow points and solid copper rounds.

Overall, PWC is important but should not be overestimated and the data used should be from a realistic media, should include barriers and must take into account the reliability and consistency of the wounding by looking at a great many shots. Lastly, the PWC has to be deep enough to actually account for the destruction of important organs/material and not just superficial tissue.

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There are no conclusions in this report. All testing was accomplished only to provide raw data on a large scale with an enormous sample size on multiple media with 4 predetermined quantifiable grading criteria. Each agency should first determine which characteristics are important to them in order, before using the data for ammunition determination or for ballistics training.

Any agency wanting more information please make a request to viperweaponstraining@gmail.com