Bullet Entry Holes in Fabric: Fibers, Facts, and Fallacies

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ABSTRACT

Common small arms projectiles passing through fabric often produce characteristics which can be used to distinguish entry from exit defects. The most reliable characteristic is the presence of "bullet wipe," a carbonaceous and lead deposit surrounding the margin of the defect. Bullet wipe can be detected visually and/or with the use of a colorimetric reagent but there are cases in which bullet wipe is not detectable and other methods of analysis must be used. A bullet perforating fabric may generate a large number of severed fibers protruding in a common direction around the margin of the bullet hole. The direction of these fibers may or may not indicate the direction of bullet travel. In cases in which fabric alone is perforated, the fiber direction may indicate the bullet direction, but when fabric is backed by a human body, the fibers are subject to significant movement opposite the bullet's direction of travel. Fibers may actually extend away from the body and back toward the source of the shot. While counter-intuitive, this phenomenon has been studied and documented through high speed videography. The same cloth or garment struck by the same type of bullet at comparable impact velocities while free-hanging or un-shored by soft tissue or a tissue simulant does not show this effect.

Introduction

Identifying a hole or other defect in fabric as an entry or exit is often simple when the garment or cloth item is the first object struck by the bullet. In this situation, the well-known phenomenon of *bullet wipe* offers the definitive solution. This paper will discuss bullet wipe and other indicators useful in the entry/exit determination and the sometimes unreliable use of fiber direction.

Fiber Direction

The direction of the protruding fabric fibers around the margins of bullet holes in clothing worn by gunshot victims has occasionally been relied upon by investigators, forensic pathologists, firearms examiners and criminalists to determine the direction of the bullet. The outward protrusion of fibers around the margin of a bullet hole in garments or other items of woven or knit cloth would seem to be a clear consequence of an exiting bullet and the inward protrusion of fibers the consequence of a bullet entry. But what seems intuitively obvious is very apt to be wrong as will be explained and illustrated in this paper.

Research presented in this paper demonstrates that fibers can -- and often will -- protrude outward on the entry side of a bullet hole. Until the analyst knows more about the characteristics of the garment or cloth, and the characteristics of what, if anything, was supporting the material and the terminal ballistic performance (behavior) of the responsible bullet, the analyst would be well advised to reserve drawing conclusions regarding the direction of fire based on the appearance of severed fibers around the margin of a bullet hole. The directional determination is often easy and straight forward where the garment or cloth item is the first object encountered by the bullet. In this situation, the well-known phenomenon of bullet wipe offers the definitive solution. But for those cases where bullet wipe is absent or its presence equivocal, the analyst may view the noticeable protrusion of numerous fibers around the margin of a bullet hole as a means of determining the direction of fire.

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Bullet Wipe

Bullet wipe is a form of gunshot residue (GSR) generally consisting of the visible dark carbonaceous deposits around the margin of a bullet hole. The carbonaceous bullet wipe substance may also contain bullet metals such as copper and zinc, lead from either lead bullets or lead-containing primer mixtures which often include barium and antimony. This material is transferred from the gun barrel to the bullet which is then deposited -- "wiped off" -- during *initial* bullet contact. The first object contacted by a bullet will "wipe-off" the carbonaceous material. The bullet's secondary impact will not likely transfer any GSR. Bullet wipe is most often grossly visible as a dark ring surrounding the margins of the hole [1]

The amount of bullet wipe surrounding an entry hole will vary from a dark, dense ring to much lighter deposits. The variances are related to the type of fabric, the composition of the bullet (e.g., plain lead vs. jacketed bullets) and to the sequence and timing of a series of shots [2]. Knit fabric may show much more of the bullet wipe GSR transfer because of the characteristics of the knit yarn to stretch and elongate when contacted by a bullet. This deformation can produce a "tunneling" of the bullet thru the fabric which will increase the amount of wiping contact between the bullet and the fabric. Woven fabric is more dense and will not deform as readily

thereby limiting relative contact with the bullet [3].

In a single fabric layer such as a curtain or clothing item, the entry side will have the bullet wipe ring and the exit side will not. If the fabric was not shored (backed) by a human or animal body, the direction of the fibers will indicate the direction of bullet travel: The loose broken fibers around the margin will remain in their "pushed out" position.

The fiber direction method can also be reliably utilized with a two (or more) layer fabric object such as hat, pant leg, or jacket in which the bullet did not strike an intervening object such as a head, leg, torso: human tissue or similar items. **Figure 7** shows a denim pants leg with typical entry and exit holes – the pant leg was empty when shot. The margins of the cloth surrounding the entry shows an inward direction while the exit hole shows an outward protrusion of broken fibers. This is expected with cloth not backed by human tissue.

When a bullet perforates a fabric layer without a shored object such as human tissue, the bullet pushes into and through the fabric, crushing and stretching the fabric threads and then dragging some of the broken fibers surrounding the hole in the direction of bullet travel. In situations when a fabric is not in contact or close proximity with any other objects, the broken thread/fiber direction will likely indicate the bullet path direction, e.g. a bullet perforating a hanging fabric item in a left-to-right direction will have the fibers protruding to the right, "pointing" towards the bullets direction of flight.

However, when fabric is held or worn and in contact or near contact with human (or animal) tissue, the dynamics affecting the broken threads/fibers are very different. While the perforating bullet does initially push and drag the loose fibers along in the direction of travel, the wound ballistics phenomena of temporary cavitation [4], during which a cavity is created by the bullet's sudden displacement of tissue, will draw air into the body and also "pull" loose fibers at the bullet hole towards or inside the body. But this cavity – which may be visualized as a "bubble" – only exists for a few thousandths of a second before it collapses. This collapse occurs when the displaced tissue suddenly rebounds back into its original form, displacing the air-filled cavity. The cavity collapse forcefully expels air out of the entry (and any other) defect. When this happens the rushing air will push the loose fibers outward reversing their previous direction.

Figure 8 shows very high speed photo (1/1,000,000 sec) of the temporary cavity as it is expanding in size. Created in tissue simulant by a .45 ACP, 230gr, JHP. This cavity will collapse and expel air.

A high speed video system was used to investigate how the temporary cavitation dynamics affects the fiber direction. In the sequence below, a denim fabric shored by a block of tissue simulant behind it shows the "puff out" of the fabric as the temporary cavity collapses, expelling air and causing the outward movement of the fibers. (See **Figures 9, 10, & 11**)

High speed video recordings of this dynamic effect also shows that after the first temporary cavity creation and collapse, there is a further series of smaller, oscillating cavity-collapse cycles. Each of these cycles can affect the fabric fiber direction.

Video of this phenomena is available for viewing online [5].

Figure 1: Bullet wipe on knit fabric

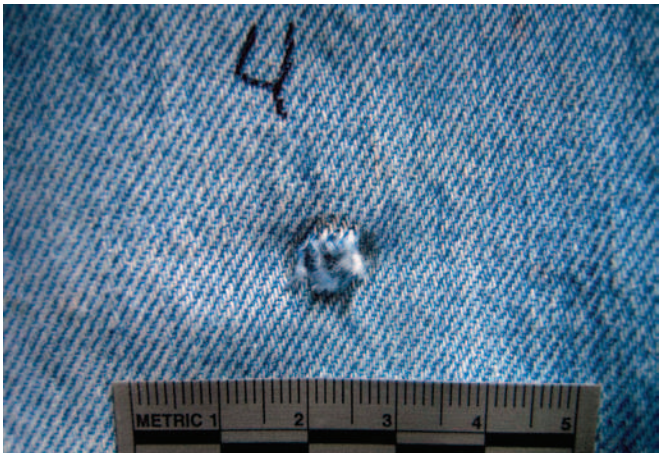


Figure 2: Bullet wipe on woven fabric

Figure 3: Elongation of knit fabric increases bullet-to-fabric contact (high speed image)

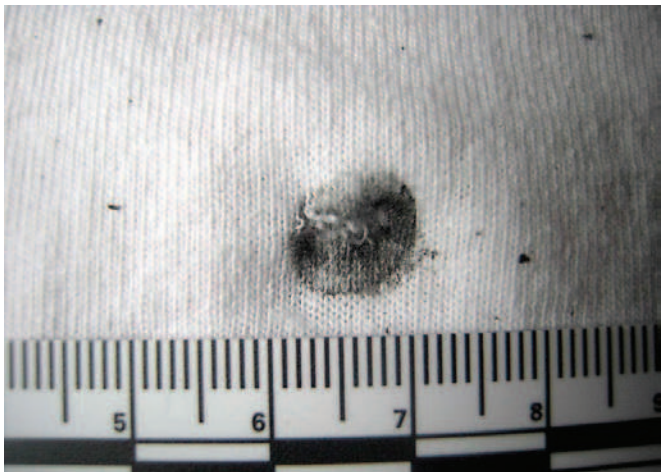


Figure 4: Bullet wipe on knit fabric

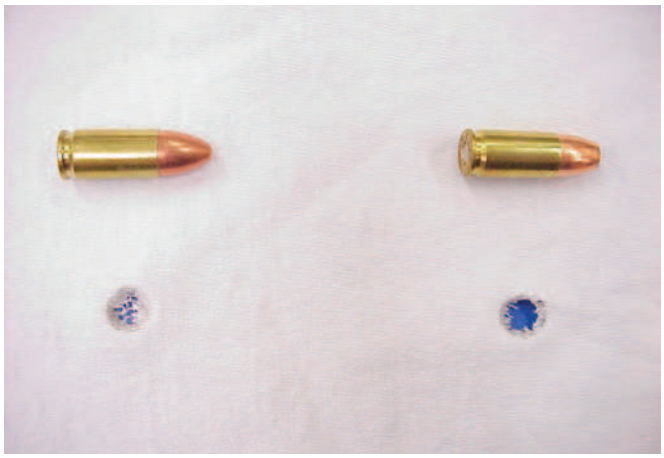


Figure 5: Entry side shows bullet wipe

Figure 6: Exit side does not show bullet wipe

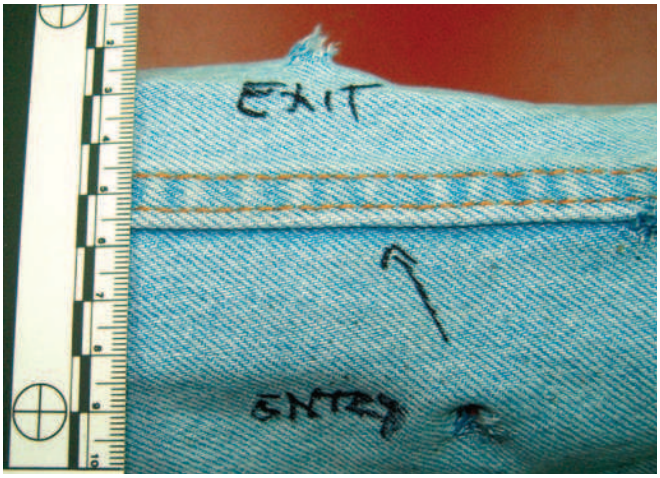


Figure 7: Bullet entry and exit holes in empty denim pants leg

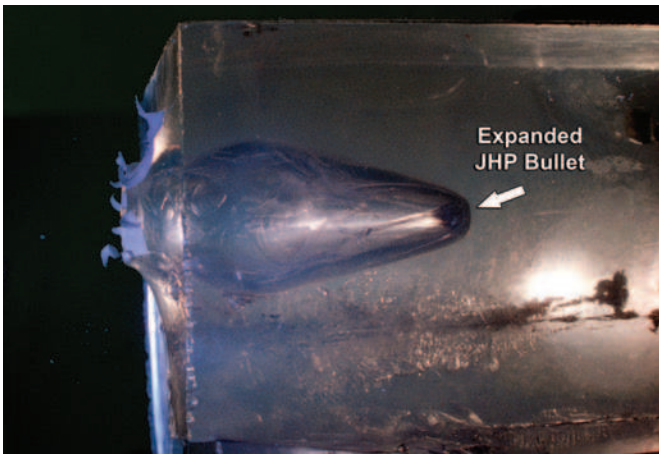


Figure 8: Temporary cavity in ballistics gelatin

Summary

The demonstrative tests shown here should be sufficient to warn the reader of the perils of rendering opinions as to the direction of fire (entry vs. exit) based on the protrusion of fibers around the margin of a bullet hole in cloth or clothing.

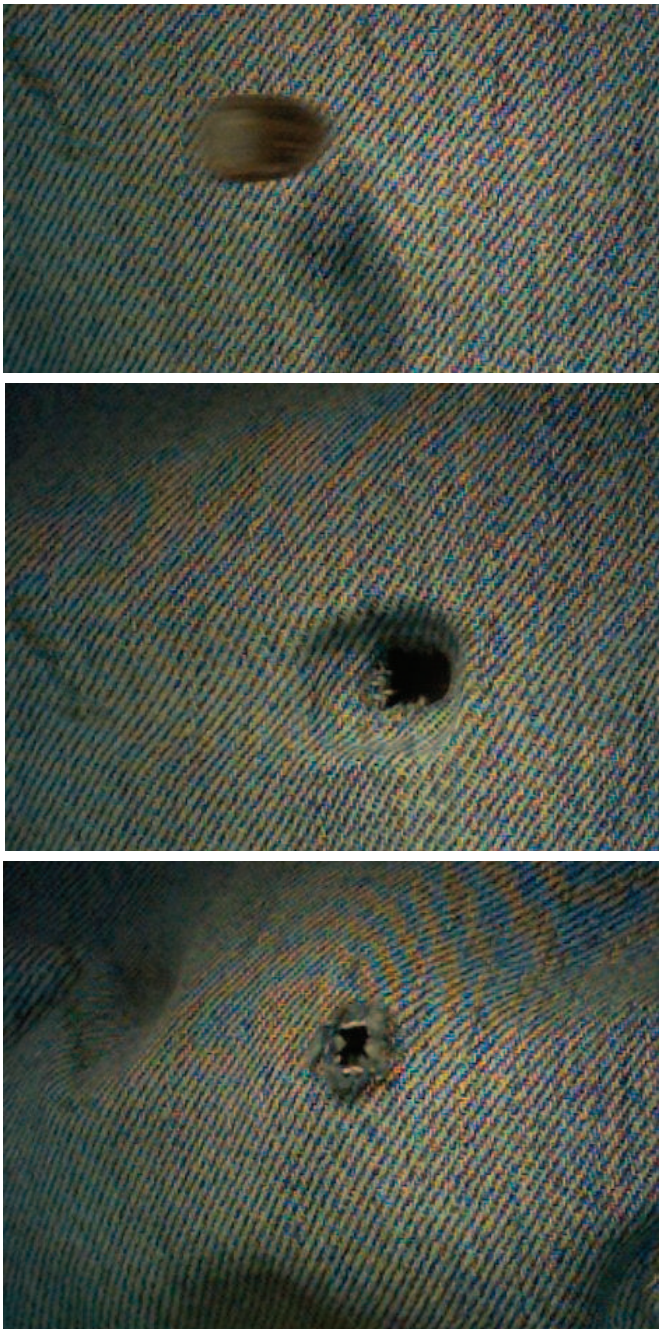
The fact that such protruding fibers can be, and often are present around the margin of an *entry* bullet hole in cloth or clothing is counter-intuitive. Relying on the direction of such protruding fibers as a determinator of the direction of bullet travel in the absence of other critically important information is clearly ill-advised and can result in a serious error. Other factors such as the presence or absence of any material shoring or supporting the cloth or garment or the garment's proximity to other objects can play a deciding role in which way the fibers extend; back toward the approach path of the causative bullet or along the departure (exit) path of the bullet.

Careless or improper handling/packaging of clothing possessing bullet holes must always be of concern if this phenomenon in going to enter into an evaluation of the direction of fire. The prior manipulation of such garments by one or more individuals can easily alter the appearance and direction of any previously protruding fibers.

Crime scene investigators in shooting cases should be aware of the potential value of bullet defects in clothing. When possible, visible holes in clothing items should be documented photographically before the item is moved or touched. Medium and close-up photographs and descriptive written notes can be of value later in attempting to distinguish entry from exit based on fiber protrusion. While this documentation is of most value when accomplished at the crime scene, it should also be done in the initial stages of an autopsy, before the clothing is removed.

If the cloth or garment is the first object to be struck by the bullet, then 'bullet wipe' is the most reliable and definitive means of determining the entry side of the struck (perforated) object. If no bullet wipe can be detected on either side of the struck material, then a careful, cautious and considered evaluation of any substantial display of protruding fibers around the margin of the bullet hole may allow the offering of an opinion as to the direction of fire.

If at all possible, the authors would advise the readers to draw upon other, more reliable indicators for the direction of fire. Autopsy reports, for example, that clearly document entry and exit are a good example.



Figures 9, 10, and 11: This high-speed video frame series shows (top to bottom): a 9mm FMJ bullet in flight as it approaches the fabric shored by a tissue simulant; the fabric hole immediately after the bullet has passed through; and the puffing out of the fabric as the temporary cavity collapses. (Note that the fibers are pointing inward in Figure 9 and then outwards in Figure 10. The elapsed time from Figure 9 to Figure 10 is 0.023 seconds)

References:

[1] Levin, N. et al; "Bullet Wipe – Fact and Fiction" Presented at the 12th ENFSI Firearms WG Meeting, Olso, Norway, August-September 2005.
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[3] Haag, M.G., Haag, L.C. Shooting Incident Reconstruction, Chapters 4, 5, 2nd Ed, Elsevier, New York, 2011.
[4] Kneubuehl, B.P. et al, Wound Ballistics, 2nd Ed, Springer-Verlag Berlin Heidelberg, New York, 2011.
[5] Request link from: ajason@alexanderjason.com

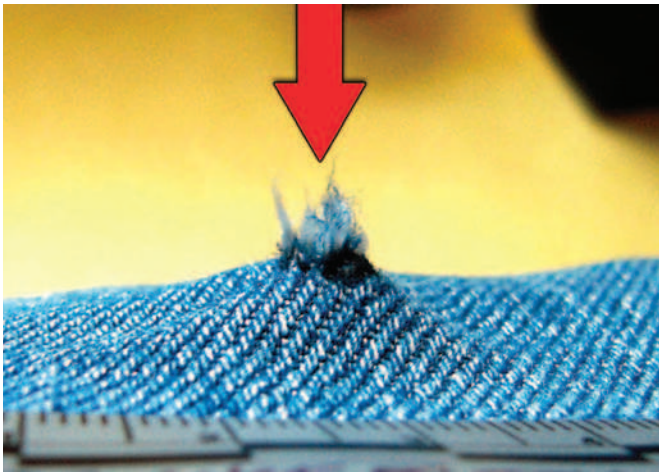

Figure 12: Entry hole after bullet strike. Arrow indicates direction of bullet travel. Fibers are protruding outward because of temporary cavity collapse from tissue simulant behind the fabric.