Data in Brief 22 (2019) 269–278

Contents lists available at ScienceDirect

Data in Brief

journal homepage: www.elsevier.com/locate/dib

Data Article

A data set of bloodstain patterns for teaching and research in bloodstain pattern analysis: Gunshot backspatters

Daniel Attinger [a,*], Yu Liu [b], Ricky Faflak [a], Yalin Rao [c], Bryce A. Struttman [b], Kris De Brabanter [b,c], Patrick M. Comiskey [d], Alexander L. Yarin [d]

[a] *Mechanical Engineering, Iowa State University, 50010 Ames, IA, USA*
[b] *Department of Computer Science, Iowa State University, 50010 Ames, IA, USA*
[c] *Department of Statistics, Iowa State University, 50010 Ames, IA, USA*
[d] *Department of Mechanical and Industrial Engineering, University of Illinois at Chicago, 842 W. Taylor St., Chicago, IL 60607-7022, USA*

ARTICLE INFO

Article history:
Received 10 September 2018
Received in revised form
9 November 2018
Accepted 12 November 2018
Available online 20 November 2018

ABSTRACT

This is a data set of blood spatter patterns scanned at high resolution, generated in controlled experiments. The spatter patterns were generated with a rifle or a handgun with varying ammunition. The resulting atomized blood droplets travelled opposite to the bullet direction, generating a gunshot backspatter on a poster board target sheet. Fresh blood with anticoagulants was used; its hematocrit and temperature were measured. The main parameters of the study were the bullet shape, size and speed, and the distance between the blood source and target sheet. Several other parameters were explored in a less systematic way. This new and original data set is suitable for training or research purposes in the forensic discipline of bloodstain pattern analysis.

* Corresponding author.
E-mail address: attinger@iastate.edu (D. Attinger).

https://doi.org/10.1016/j.dib.2018.11.075

Specifications table

Subject area	*Legal Medicine, Engineering*
More specific subject area	*Forensics – Bloodstain Pattern Analysis (BPA)*
Type of data	*Images of 68 backspatters from a gunshot, each in an individual folder with text file listing the experimental conditions*
How data was acquired	*Blood spattered backward from a bullet impact, as described in the manuscript. Spatters were collected on cardstock poster board, and scanned with a flatbed scanner*
Data format	*Images were scanned at 600 dots per inch (about 42.3 μm per pixel) and saved as a .jpg with minimum compression (10% compression max)*
Experimental factors	*Spatter images with dimensions of maximum 1.36 m × 1.1 m, scanned in a piecewise manner and reassembled with image processing software*
Experimental features	*Blood volume of 2.5–175 mL was either contained in a closed cavity or soaking a porous foam (sponge). Blood source was impacted normally by a bullet travelling horizontally; bullet velocities ranged between 285 and 987 m/s. Horizontal distances between the vertical target and blood source ranged from 10 cm to about 120 cm; fewer spatters on horizontal targets. Muzzle gases have been screened out with a diffuser plate for most spatters, to minimize their interaction with the backspatter;*
Data source location	*Ames, IA. Physical Targets have been preserved*
Data accessibility	*Electronic data set is with this article, as a set of five split .zip files*

Value of the data

- The data set can be used by researchers. One research purpose is to test crime scene reconstruction models [1–3]. Briefly, these models pursue at least two purposes. First, they classify patterns with respect to their generation mechanism (e.g. beating vs. shooting [4]). Second, they determine the region of origin of the blood spatter [5,6]. Recently, the US National Academies emphasized [7] the need to develop more accurate bloodstain pattern analysis methods, with stronger fluid dynamics foundations. Accessibility to large amounts of bloodstain patterns produced under controlled conditions is thus important for the development of the needed science base. The data in this manuscript addresses the above issues by systematically documenting the experimental conditions. Data of this manuscript can also inform studies investigating conditions for the presence of spatter stains on the firearm or the shooter [8,9].
- The data helps dissemination of blood spatters for teaching and instructional purposes. Indeed, generation and transport of blood spatters is cumbersome. A large space, the size of a habitation room, is needed to generate a realistic blood spatter; and care should be taken to have reproducible and realistic experimental conditions. Shooting comes with its own strict safety rules, and is best done at an indoor shooting range to prevent draft from atmospheric winds. Blood sourcing and handling is not trivial either. Blood needs to be used under strict safety conditions because of the risk of blood-borne diseases and pathogens. Since travelling across borders is common for BPA instructors, both alternatives of travelling with blood spatters through customs or having the blood spatters prepared at the site and time of the workshop involve logistic efforts, costs and safety risks. Also blood ages within days [10]. All the experiments here use blood drawn less than 3 days before the experiment and spiked with anticoagulant. This database provides BPA instructors with a safe set of spatters ready to be printed at high resolution for their classes.
- This data set is new and original, and the data has not been published elsewhere.
- The experimental design and methods described in this manuscript can be readily reproduced and used to generate additional blood spatters. Note that there is still no consensus on which experimental setup is best to simulate the complexity of gunshot spatters in realistic conditions, where blood is located within a complex structure involving body tissues and blood vessels,

covered by skin. Head of calves have been used [11], a human cadaver filled with blood [12], foams or sponges soaked in blood [4,13], or cavities filled with blood have been used [14]. Experiments reported here used both soaked foams and cavities filled with blood as the blood source, and the information on which blood source was used is specified.

1. Data

Blood spatters are a subset of bloodstain patterns, with stains generated when an impacting object causes drops to go airborne [1–3] before hitting the surface of a solid object called the target. Gunshot backspatters are spatters where blood is atomized by a bullet, in a direction opposite to that of the bullet [2]. Discussion and physical description on the dynamics of a fluid impacted by a high-speed projectile can be found in Ref. [15]. Those events of atomization and airborne transport are rarely observable in a crime scene, and distinguish spatters from other bloodstain patterns, such as transfers where stains are produced by contact between the blood source and the target. Fig. 1 shows a typical gunshot blood spatter, as provided in this work.

Fig. 2 describes the geometry and setup used to generate the spatters. Most spatters were produced on a vertical target, with the bullet hole indicating the bullet impact location. The travel direction of the bullet was perpendicular to both the blood source and the target. For such a system, the visible location of the bullet hole and the orientation of the image – the image width corresponding to the horizontal direction of the experiment – defines the geometry. For the cases where muzzle gases were allowed to interact with the spatter process, the barrel of the gun was perpendicular to the cardstock target, and at the same distance from the blood source as the target, centered into a cutout of about 1 in. in size. The cutout in the cardstock is also visible in the scans, and determines the geometry of the spatter. Few spatters were produced on horizontal targets, where the angle between the bullet trajectory and a horizontal line was varied between 0° and 60°.

The conditions of each experiment are documented in a text file located in the same directory as the spatter image. For spatters on a vertical target, the conditions are summarized in Table 1, with the range of each parameter, and the reason for documentation of each parameter. Fig. 3 provides a synthetic view of the main variables investigated, the velocity of the impact that atomized the blood, and the distance between blood source and spatter target. For spatters on a vertical target, each test was denoted using the nomenclature described in Fig. 3. For spatters on a horizontal target, each test was denoted using the nomenclature in Table 2. The investigated conditions are summarized in Table 2. Some spatters names end with a number in parenthesis which our research team has used as an alternate name. Note that some spatters have been described in a general manner and compared to numerical models in Refs. [16,17].

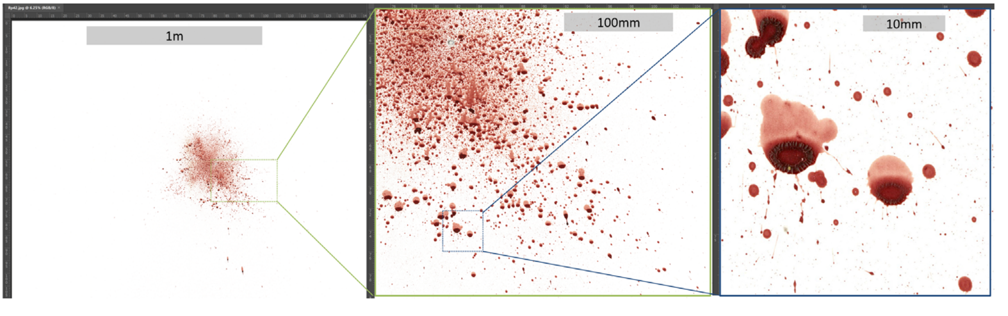


Fig. 1. Example of blood spatter Rp42, with scale on top. The size of the target cardstock board is 140 cm × 110 cm, left. The high resolution of the stain edges is well visible, as well as the bullet hole in the middle picture, top left. Image segmentation software such as the one used in Ref. [16] can count and measure more than 10,000 individual spots in the image, within a few minutes of processing time.

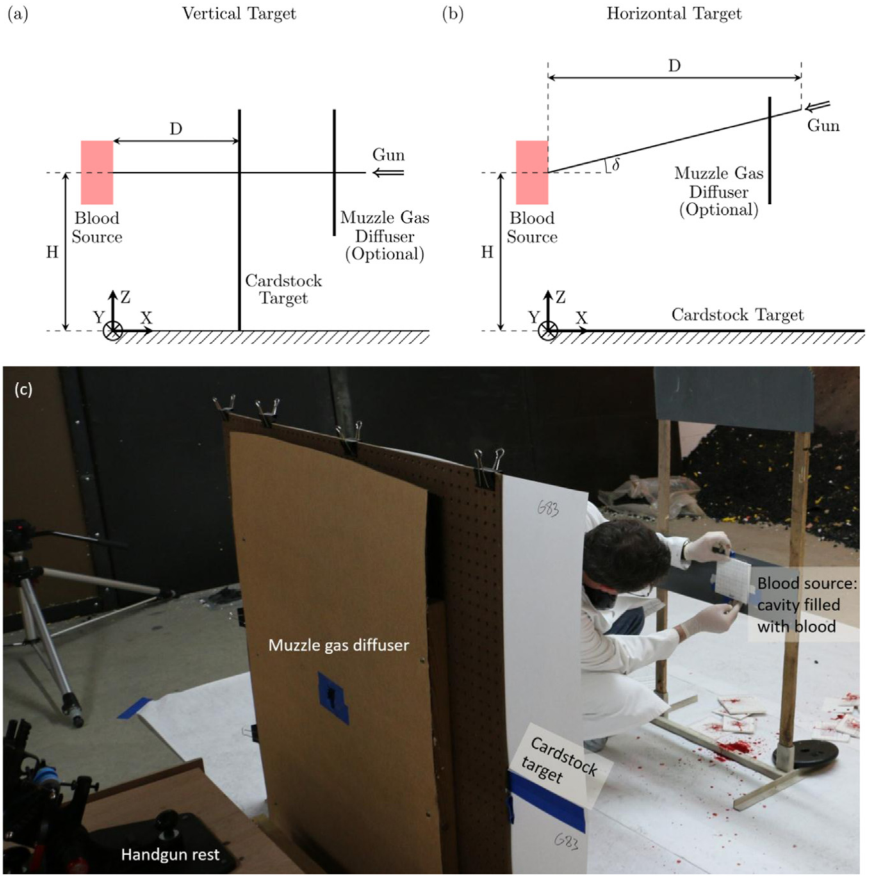


Fig. 2. Description of the experimental geometry used to generate spatters on a vertical cardstock target (a) and on a horizontal one (b). Picture (c) shows the preparation of a vertical backspatter from a handgun, using a cavity filled with blood and the muzzle gas diffuser.

The scanned images of the spatters are provided electronically in the appendix. Some of the spatters contain well over 10,000 stains, each produced by the same single bullet. The high resolution of the stain edges is well visible. Image segmentation software such as the one used in Ref. [16] can count and measure more than 10,000 individual spots in the image, within a few minutes of processing time.

2. Experimental design, materials and methods

Most backward spatters were generated at the Izaak Walton League Park indoor shooting range (Ames, Iowa, USA) and a few spatters at an indoor range used by the Fort Dodge (Iowa, USA) Police Depatment. The air was quiescent.

The rifle was held in position with an ad hoc metallic structure. The handgun was mounted in a fixed position with a Ransom rest (Master Combo Series, Ransom International Corp.). Ammunition and gun description is in Table 3.

Most blood spatters were generated on flat cardstock poster board sheets (UCreate, Walmart Inc., each 22 in. × 28 in.). Targets of larger sizes were assembled by juxtaposing several poster board sheets using masking tape at the back of the joints. The smooth side of the cardstock was used. An

Table 1
Description of the variables documented. Ranges of parameters are indicated, and parameters that have been systematically varied during the investigation are in bold. Most commonly used values of parameters are underlined.

Parameter and unit	Reason for documentation	Range or typical values, and uncertainty
Gun and bullet	Bullet shape, speed and diameter influence atomization; muzzle gas can interfere with backspatter [18]	**Rifle or Handgun; bullets with pointy, round or flat nose**, and diameters between 5.66 and 9 mm. In most experiments the muzzle gases have been suppressed by adding a diffuser between gun and blood source.
Geometry	Spatial information needed for reconstruction	Horizontal distance between blood source and vertical target (cm): **10–120** $\pm$ 2 cm Height of blood source above horizontal target: 50–70 cm
Image scale, DPI (dots per inch)	Spatial information needed for reconstruction	600
Blood temperature, T (°C)	Blood physical properties depend on temperature [19]	14.5–37 $\pm$ 1
Relative humidity, %	Evaporation rates [20] might affect stain shape or structure	39–70 $\pm$ 5
Hematocrit, %	Physical properties of blood depend on hematocrit [19]	37–46 $\pm$ 1
Type of target	Controls the spreading, deformation and splashing of the drops [19,21–23]	Smooth cardstock poster board (1.2/1.56), butcher paper (5.8/7.35). In parenthesis is Ra/RMS roughness, both in μm.
Blood source	Might influence atomization	Cavity filled with blood (2.5–10 $\pm$ 1 ml), polyurethane foam soaked in (10–15 $\pm$ 1 ml) blood, or sponge soaked in blood ($\sim$175 $\pm$ 10 mL)

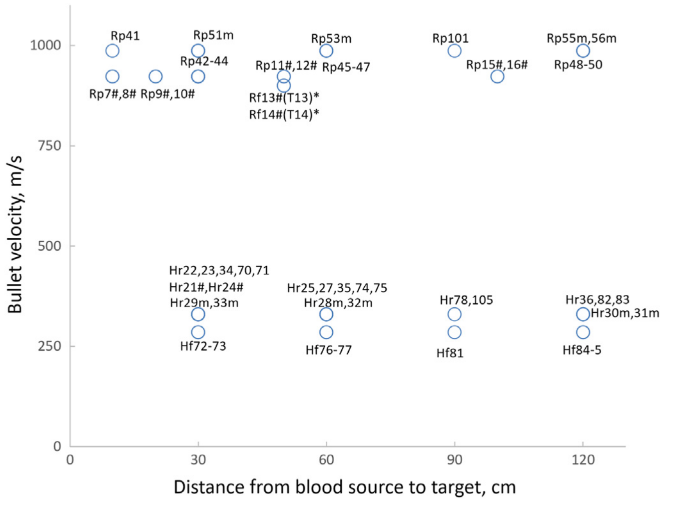


Fig. 3. Synthetic view of the spatters on vertical targets. *X*-axis is the horizontal distance between blood source and cardstock target; *Y*-axis is velocity of the bullet. Blood spatters are designated with symbols R (rifle), H (handgun), p (pointy bullet), f (flat tip bullet), r (round tip bullet). Symbols after spatter number are m (muzzle gases interacting with spatter), h (horizontal spatter), # (blood source in soaked foam). The asterisk denotes spatters analyzed in an earlier study on the fluid dynamics of backspatters [16].

Table 2
Description of the spatters on horizontal targets. The first position denotes the gun (*H* standing for handgun, and R, for rifle); the second position indicates the initial inclination angle δ between bullet trajectory and the horizontal (e.g., a0 denotes a zero bullet inclination angle $\delta = 0°$), and the third position describes the horizontal distance *D* from the gun barrel exit to the blood source in cm. The height *H* is measured from the center of the blood source to the floor. For example, H-a0-D300 stands for a horizontal cardstock target (placed on the floor) with an initial bullet inclination angle $\delta = 0°$ and a distance from the gun barrel exit to the target of 300 cm. Trial numbers for each test case were appended at the end of the experimental nomenclature, e.g., as −1 and −2. Muzzle gases were either allowed to interact with the spatter or suppressed with a diffuser plate. The asterisk denotes spatters analyzed in our earlier study on the fluid dynamics of backspatters [17].

Spatter designation	**δ [deg]**	***D* [cm]**	**Gun**	**Bullet**	***H* [cm]**	**Muzzle gases interacting with spatter**	**Blood source**
H-a0-D300-1	0	300	Glock 23	Gold Dot (flat)	67.5	Yes	Sponge
H-a0-D300-2*	0	300	Glock 23	Gold Dot (flat)	**67.5**	Yes	Sponge
H-a0-D200-1 (93)	*0*	200	Smith & Wesson 9 mm	AE9AP (round tip)	**63**	No	Cavity
R-a0-D200-2 (96)	0	200	Rock River Arms rifle 0.223”	AE223 (pointy)	**63**	No	Cavity
R-a0-D200-3 (102)	0	200	Rock River Arms rifle 0.223”	AE223 (pointy)	**63**	No	Cavity
H-a0-D200-4 (106)	0	200	Smith & Wesson 9 mm	AE9AP (round tip)	**63**	No	Cavity
H-a30-D270-1	30	270	Glock 23	Gold Dot (flat)	**66.5**	Yes	Sponge
H-a30-D270-2	30	270	Glock 23	Gold Dot (flat)	**66.5**	Yes	Sponge
H-a45-D200-1	45	200	Glock 23	Gold Dot (flat)	**67.5**	Yes	Sponge
H-a45-D200-3	45	200	Glock 23	Gold Dot (flat)	**66.5**	Yes	Sponge
H-a60-D150-1*	60	150	Glock 23	Gold Dot (flat)	**66.5**	Yes	Sponge
H-a60-D150-2*	60	150	Glock 23	Gold Dot (flat)	**66.5**	Yes	Sponge
H-a60-D150-3	60	150	Glock 23	Gold Dot (flat)	**66.5**	Yes	Sponge

optical profilometer (Zygo Newview 6300) measured the roughness of the target, with results reported in Table 1. Spreading correlations, which link drop sizes, stain sizes and impact velocities together, have been characterized on this substrate according to the methods in Ref. [19].

The blood source was either a foam or sponge soaked with blood, or a closed blood filled cavity reservoir. The latter was prepared as follows. A section of paper was peeled back from one side of foam board (Elmer's, USA). The foam board in a central cylindrical section (either one or two in. in diameter) was then removed; the cavity was filled with blood. Clear packaging tape was utilized to affix the paper back over the blood-filled cavity. This latter setup became the source of choice because of apparent improved reproducibility of the spatters, in comparison with the ones obtained with the soaked foam or sponge. The type of blood sources are in Table 2 and Fig. 3, with details in the text files describing the individual spatters provided as supplementary documentation.

Spatters on vertical targets were generated as follows: A cardstock target was used to collect the backward spattered drops and was placed vertically between the muzzle of the gun and the target (see Fig. 3a). The bullet trajectory was parallel to the ground at a height of typically 50–70 cm. Spatters on horizontal targets were generated according to the geometry described in Fig. 3b and [17], and summarized in Table 2.

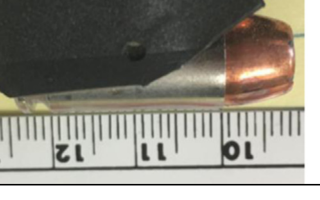
To suppress or at least minimize the interaction of the muzzle gases with the back spatter process, a high-density fiberboard diffuser plate pierced with a hole twice the diameter of the bullet was placed between the gun and the target. For a few spatters, interaction with muzzle gases was allowed by removing the diffuser plate; for vertical spatters, the gun barrel was placed at the same distance from the blood source as the cardstock target, in a cutout made at the center of the cardstock target.

Table 3
Guns and bullets used in the experiments with manufacturer number. Velocities are either as per manufacturer data (and preceded with the symbol "~") or measured with a chronograph at the shooting range. The grain is a measure of mass, and can be converted to SI units as 1 grain ≅ 64.8 mg. Pictured ruler has cm units.

Gun label	**Description**
Rock River Arms rifle .223 in.	LAR-15 16 in. barrel length M-4, .223 caliber (5.66 mm), with Yankee Hill YHM Phantom 223 suppressor
Smith & Wesson 9 mm	Smith & Wesson M&P caliber 9 mm,with 4.25 in. barrel length
Glock-23, 0.40 in.	Glock G23, 0.40 in. caliber, with 4.02 in. barrel length

Bullet label (tip shape)	**Velocity [m/s]**	**Full description**	**Picture**
XM193 (pointy bullet)	922	Full metal jacket (FMJ) rifle rounds, Federal Ammunition #XM193, bullet mass 55 grain, 5.56 mm caliber.	
AE223 (pointy)	~987	FMJ rifle rounds, Federal Ammunition American Eagle #AE223, bullet mass 55 grain, .223 rem.	

Table 3 (*continued*)

BEE (flat)	897	Custom produced rifle round Bullet: Hornady .224 cal 45 grain HP BEE #2229) of 45 grain mass, Case: .223 Rem brass case Powder: 26.5 grain BLC-2 Primer: Winchester Small Rifle Primer.	
AE9AP (round)	330	Full metal jacket (FMJ) round nose handgun ammunition American Eagle #AE9AP, 124 grain, 9 mm.	
AE9FP (flat)	285	FMJ flat nose handgun ammunition, Federal Ammunition American Eagle #AE9FP, 147 grain, 9 mm.	
Gold Dot (flat)	~312	Hollow-point bullet (Speer Gold Dot #53962) caliber 40 Smith & Wesson 180 grain bullet weight.	

The experiments utilized ethically-sourced swine blood with an anticoagulant of either heparin or ACD. The blood was drawn less than 72 h prior to any experiment. The blood was placed on a rocker and was at room temperature. Hematocrit was measured with a dedicated centrifugation device (STI, HemataStat-II). Room temperature and relative humidity were measured with a Mannix PTH8708 temperature-humidity pen.

The choice of swine blood can be explained as a compromise between safety and relevance to BPA in a public university laboratory. Indeed, human blood is a biohazard, requiring extensive testing and handling precautions to avoid risks such as HIV (human immunodeficiency virus) and hepatitis B and C, which can be deadly if untreated. Artificial blood is still in a development phase, and it is not clear whether it will ever be able to match all the complex – and still partly unknown [24] – characteristics of actual blood [3]. Among available animal blood, swine blood is the closest to human blood in terms of comparable physical properties [25], such as hematocrit range, shear viscosity of whole blood and plasma, and erythrocyte aggregation behavior. Since swine blood has not been associated with risks of HIV or hepatitis B, it is a safer substitute to human blood. Thus, swine blood was drawn from healthy pigs screened for zoonotic diseases at the Ames USDA facilities. Blood was stored refrigerated when not in use and allowed to reach room temperature before use. Personal protection equipment for the biohazard while producing the spatters included coveralls, gloves, face shields, surgical masks, and goggles, while gloves were used for manipulating dried spatters, e.g. during scanning.

After the spatter was produced, the target was removed from the holding fixture and the bloodstains were allowed to dry. Spatters were then digitized with a flatbed scanner at 600 DPI. That resolution is slightly better than what has been obtained with high-end photography [4], and allows a clear definition of the edges of most stains. The use of a scanner also avoids issues of parallax, which are often present on crime scene photographs. The spatters were scanned in a piecewise manner, by cutting the tape joining the poster board sheets (tape was at their backside), because the maximum scanning area of the scanner was European A3 format (297 mm × 420 mm), significantly smaller than the largest target posters. Poster board sheets were never cut in that process. Scans were assembled using the image processing software Adobe Photoshop, and saved as high-quality JPG's. A sticker was placed at the center of each sheet, to allow precise assembly of the scans. Adobe Photoshop was used to remove most marks that were not stains, such as the sticker, tape, or pencil marks. On vertical targets, the bullet hole or the cutout for the barrel is visible. That hole and the fact that in the experiments with vertical targets, gravity goes vertically from top to the bottom of the scanned image fully describes the geometry of the spatter generation, because bullets travelled horizontally and normally through the vertical target and blood source. In experiments with horizontal spatters, the top of the scanned image correspond to the location of the blood source.

Acknowledgements

The authors acknowledge financial support from the US National Institute of Justice, United States (award no. NIJ 2014-DN-BX-K036). This work was also partially funded by the Center for Statistics and Applications in Forensic Evidence (CSAFE), United States through Cooperative Agreement No. 70NANB15H176 between NIST and Iowa State University, which includes activities carried out at Carnegie Mellon University, University of California Irvine, and University of Virginia. We acknowledge the contribution of Officer Darin Van Ryswyk and Sgt Christopher O'Brien who performed the shootings; the help of Sungu Kim, Prashant Agrawal, John Polansky and Reetam Das to perform the experiments; useful discussions with William Ristenpart, Craig Moore and Kevin Winer; and the roughness measurements by Ashraf Bastawros and Bishoy Dawood.

Transparency document. Supporting information

Transparency data associated with this article can be found in the online version at https://doi.org/10.1016/j.dib.2018.11.075.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at https://doi.org/10.1016/j.dib.2018.11.075.

References

[1] S.H. James, P.E. Kish, T.P. Sutton, Principles of Bloodstain Pattern Analysis: Theory and Practice, CRC Press, 2005.
[2] T. Bevel, R.M. Gardner, Bloodstain Pattern Analysis with an Introduction to Crime Scene Reconstruction, CRC Press, Boca Raton, FL, USA, 2008.
[3] D. Attinger, C. Moore, A. Donaldson, A. Jafari, H.A. Stone, Fluid dynamics topics in bloodstain pattern analysis: comparative review and research opportunities, Forensic Sci. Int. 231 (2013) 375–396.

[4] S. Siu, J. Pender, F. Springer, F. Tulleners, W. Ristenpart, Quantitative differentiation of bloodstain patterns resulting from gunshot and blunt force impacts, J. Forensic Sci. (2017).
[5] A.L. Carter, The directional analysis of bloodstain patterns: theory and experimental validation, J. Can. Soc. Forensic Sci. 34 (2001) (173-173).
[6] F. Camana, Determining the area of convergence in bloodstain pattern analysis: a probabilistic approach, Forensic Sci. Int. 231 (2013) 131–136.
[7] Strengthening Forensic Science in the United States: A Path Forward, Committee on Identifying the Needs of the Forensic Sciences Community, National Research Council, The National Academies Press, Washington, DC. https://doi.org/10.17226/12589, 2009.
[8] B. Karger, R. Nüsse, H.D. Tröger, B. Brinkmann, Backspatter from experimental close-range shots to the head: 2. Microbackspatter and the morphology of bloodstains, Int. J. Leg. Med. 1997 (110) (1997) 27–30.
[9] S.N. Kunz, H. Brandtner, H.J. Meyer, Characteristics of backspatter on the firearm and shooting hand–an experimental analysis of close-range gunshots, J. Forensic Sci. 60 (2015) 166–170.
[10] T.C. de Castro, M.C. Taylor, D.J. Carr, J. Athens, J.A. Kieser, Storage life of whole porcine blood used for bloodstain pattern analysis, Can. Soc. Forensic Sci. J. 49 (2016) 26–37.
[11] M. Grabmuller, P. Cachee, B. Madea, C. Courts, How far does it get? The effect of shooting distance and type of firearm on the simultaneous analysis of DNA and RNA from backspatter recovered from inside and outside surfaces of firearms, Forensic Sci. Int. 258 (2016) 11–18.
[12] C. Rossi, L.D. Herold, T. Bevel, L. McCauley, S. Guadarrama, Cranial backspatter pattern production utilizing human cadavers, J. Forensic Sci. 63 (2018) 1526–1532.
[13] B.G. Stephens, T.B. Allen, Back spatter of blood from gunshot wounds, Obs. Exp. Simul. J. Forensic Sci. 28 (1983) 437–439.
[14] P.M. Comiskey, A.L. Yarin, D. Attinger, Theoretical and experimental investigation of forward spatter of blood from a gunshot, Phys. Rev. Fluids 3 (2018) 063901.
[15] A.L. Yarin, I.V. Roisman, C. Tropea, Collision Phenomena in Liquids and Solids, Cambridge University Press, Cambridge, 2017.
[16] P.M. Comiskey, A.L. Yarin, D. Attinger, Hydrodynamics of back spatter by blunt bullet gunshot with a link to bloodstain pattern analysis, Phys. Rev. Fluids 2 (2017) 073906.
[17] P.M. Comiskey, A.L. Yarin, S. Kim, D. Attinger, Prediction of blood back spatter from a gunshot in bloodstain pattern analysis, Phys. Rev. Fluids 1 (2016) 043201.
[18] M.C. Taylor, T.L. Laber, B.P. Epstein, D.S. Zamzow, D.P. Baldwin, The effect of firearm muzzle gases on the backspatter of blood, Int. J. Leg. Med. 125 (2011) 617–628.
[19] S. Kim, Y. Ma, P. Agrawal, D. Attinger, How important is it to consider target properties and hematocrit in bloodstain pattern analysis? Forensic Sci. Int. 266 (2016) 178–184.
[20] D. Brutin, B. Sobac, B. Loquet, J. Sampol, Pattern formation in drying drops of blood, J. Fluid Mech. 667 (2011) 85–95.
[21] L. Hulse-Smith, N.Z. Mehdizadeh, S. Chandra, Deducing drop size and impact velocity from circular bloodstains, J. Forensic Sci. 50 (2005) 54–63.
[22] B.L. Scheller, D.W. Bousfield, Newtonian drop impact with a solid surface, AICHE J. 41 (1995) 1357–1367.
[23] V. Balthazard, R. Piedelievre, H. Desoille, L. Derobert, Etude des gouttes de sang projete, in: XXIIe congres de medicine legale de langue francaise, Paris, 1939.
[24] A. Kolbasov, P. Comiskey, R.P. Sahu, S. Sinha-Ray, A.L. Yarin, B.S. Sikarwar, S. Kim, T.Z. Jubery, D. Attinger, Blood rheology in shear and uniaxial elongation, Rheol. Acta 55 (2016) 901–908.
[25] U. Windberger, A. Bartholovitsch, R. Plasenzotti, K.J. Korak, G. Heinze, Whole blood viscosity, plasma viscosity and erythrocyte aggregation in nine mammalian species: reference values and comparison of data, Exp. Physiol. 88 (2003) 431–440.