Bullet shape, velocity determine blood spatter patterns

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Blood spatters are hydrodynamic signatures of violent crimes, often revealing when an event occurred and where the perpetrator and victim were located, and researchers have worked toward better understanding the fluid dynamics at play during gunshot spatters. In the Physics of Fluids, they propose a model for the disintegration of a liquid due to an arbitrarily shaped projectile. Their model focuses on providing predictive models of gunshot blood atomization and droplet flight and spattering. These are images of the bullets used in the experiments: the .45 auto bullet (left) and the 7.62 39 mm bullet (right). Credit: Alexander Yarin

Blood spatters are hydrodynamic signatures of violent crimes, often revealing when an event occurred and where the perpetrator and victim were located at the time of the crime.

A group of researchers from the University of Illinois at Chicago and Iowa State University realized that gaining a better physical understanding of the fluid dynamical phenomena at play during gunshot spatters could enhance crime scene investigations.

In the journal *Physics of Fluids* they propose a generalized model for the chaotic disintegration of a liquid due to an arbitrarily shaped projectile. Their model focuses on providing theoretical, predictive models of gunshot blood atomization (in particular, blood droplets) and droplet flight and spattering to provide physical insights that could enhance current bloodstain pattern analysis.

"Bloodstain pattern analysis in forensics implies a physical relation between blood droplet formation, trajectory, and impact into a solid surface," said Alexander Yarin, a distinguished professor at the University of Illinois at Chicago. "The formation of blood spatters involves a rheologically complex fluid—blood—and a nontrivial atomization process affected by the bullet shape and velocity."

One of the basic physical concepts involved in the study is the Rayleigh-Taylor instability phenomenon associated with denser blood accelerating toward lighter air. It is accompanied by a cascade of instability phenomena triggered by the original Rayleigh-Taylor instability—think of a water layer dripping from the ceiling. The researchers examine the viscoelasticity of blood, which affects ligament formation, the blood droplet spray propagation within air, and blood deposition on the floor, accounting for gravity and air drag forces, with the latter being diminished by the collective effect related to the droplet-droplet interaction. With that information, deposition on the floor or other surfaces is predicted.

The group's previous theory of forward blood spatter included the prediction of backward blood spattering caused by slender and blunt bullets and of forward blood spattering caused by a bullet shaped like a blunt ovoid (egg). In their present work, the latter was generalized for a bullet of arbitrary shape, because many different bullet shapes exist.

By doing this, the researchers were able to predict the fragmentation of the blood-filled target within the framework of percolation theory, which studies the filtration of liquid through a porous medium.

"Our results revealed that bullet shape and velocity determine the blood spatter patterns, because they dictate the velocity field in the blood body," said Yarin. "When this approach is incorporated into bloodstain pattern analysis in forensics in the future, hopefully it can help crack tough questions."

The group's technique for forensics "will allow a more accurate determination of the origins of blood spatter, as well as potentially facilitate investigators' conclusions about the weapon used for cases in which a bullet is not found," Yarin said.

More information: Hydrodynamics of forward blood spattering caused by a bullet of general shape, *Physics of Fluids* (2019). DOI: 10.1063/1.5111835

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