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Bloodstain patterns can help to lead crime-scene investigators to the truth — but mistakes can be made.

CRIMINOLOGY

Written in blood

Bloodstain pattern analysis is used by forensic scientists to help reconstruct violent crimes. Efforts are underway to root the often subjective practice in science.

BY SUJATA GUPTA

On 28 September 2000, David Camm, a former police state trooper from Indiana, United States, returned home after playing basketball to discover his wife and two children, aged 5 and 7, in the garage, dead from apparent gunshot wounds. The police took Camm's T-shirt, which was stained with eight small spots of blood, as evidence and showed it to crime-scene analyst Robert Stites. Stites alleged that blood from one of the victims spattered onto the T-shirt when the gun was fired, a theory that placed Camm at the crime scene. On 1 October, the police charged Camm with murder.

Camm argued that the blood got on his T-shirt when he held a family member, but the jury still found him guilty. He was sentenced to 195 years in prison.

Evaluating bloodstains to piece together the events of a violent crime is known as bloodstain pattern analysis (BPA). BPA is used to determine a victim's location and position, the weapon used, and the angle and force with which the victim was hit. But, in 2009, the US National Academy of Sciences published a report[1] that blasted many techniques used in forensic science, including BPA. The authors noted that, "In general, the opinions of bloodstain pattern analysts are more subjective than scientific," and their report triggered the growth of research on the practice of BPA.

"It was a massive wake-up call," says Niki Osborne, a researcher in forensic psychology at the University of California, Irvine.

BLOODIED RABBITS

Bloodstains were first studied as a way to interpret crimes in the late 1800s, when Eduard Piotrowski, a physician and researcher in Kraków, Poland, covered the corner of a room with white paper and beat rabbits to death to observe how their blood spattered. One of Piotrowski's findings was that blood typically doesn't appear until the second blow. Over the next few decades, researchers determined that by measuring the angle at which a victim's blood splattered, they could identify the perpetrator's general location and position, as well as calculate the victim's location when attacked.

Despite progress over the past century, however, BPA remained heavily reliant on the experience of forensic investigators, rather than a clear understanding of the underlying science. And until the past decade, says Michael Taylor, a forensic scientist at the Institute of Environmental Science and Research in Christchurch, New Zealand, "there was very little scientific research happening because most people in the discipline were up to their eyeballs in casework".

A PROBLEM OF BIAS

When Camm was put on trial in 2002, prosecutors brought up his numerous affairs — prompting the Indiana Court of Appeals to rule, in 2004, that the jury had been prejudiced against him. The court then overturned Camm's conviction. When police reopened the case a year later, they took a closer look at a sweatshirt found under the body of Camm's 7-year-old son. They found that DNA on the sweatshirt matched that of Charles Boney, an ex-convict who had served time in prison for armed robbery. Boney was sentenced to 225 years in prison as an accomplice to the murders.

Camm's second trial, held in 2006, featured testimonies from duelling experts in BPA.

Camm's legal team noted that Stites had failed to complete an introductory course on BPA and that he had never previously conducted a bloodstain analysis independently. But other experts in BPA corroborated Stites's claim that the bloodspots got onto Camm's T-shirt when a victim was shot at close range. Analysts brought in by Camm's legal team backed up their client's claim that the blood transferred to his T-shirt after the murders had taken place. The similarity between bloodstains from transfers and spatters would be explained years later, at a 2014 symposium of forensic scientists in Adelaide, Australia, but by then it was too late. The jury again found Camm guilty. Results from the BPA did little to change Camm's fate. He was sentenced to life in prison without parole. But by this point, some who were following the case closely had begun to question his guilt — and the accuracy of BPA.

Identifying bloodstains by their size, shape, location and distribution lies at the heart of BPA. But what happens when the patterns are unclear? Taking his cue from the National Academy of Sciences report, Taylor began to investigate the reliability of BPA in current practice. His findings were troubling[2].

To investigate the accuracy of BPA for interpreting bloodstain patterns on hard surfaces, Taylor and his team recruited 27 experts in BPA from North America, Europe, Australia and New Zealand. Using donated human blood, Taylor's team created more than 400 sample bloodstains by varying the type and spatial extent of the patterns, as well as the surface on which the blood landed. For instance, to imitate blood flying off different weapons, the team swung a wrench drenched in blood or a knife lightly coated in blood. Each analyst received 15 or 16 of the samples and was asked to determine what caused the pattern.

"We're always trying to get more and more information out of any stain."

But analysts rarely enter a crime scene blind. "In BPA, you can't ignore the body on the floor, the mess in the house," says Osborne, a collaborator on Taylor's project. "You can't operate in a vacuum." To mimic this reality, the researchers paired each sample with a vignette containing information that could bias the analysts towards the right or wrong answer. In one such vignette, the police find the badly beaten body of a 23-year-old man in a dark alley outside a nightclub. They later discover bloodstains on the club door. The owner of the club says that he didn't observe the attack but came outside after the man had died. He tells the police that the bloodstains appeared after the victim coughed up blood. In other words, the vignette leads analysts to attribute the pattern to coughed-up blood.

Taylor's team found that, on average, the analysts misclassified samples 13% of the time. But the error rate dropped to 8% when the vignette helped analysts to select the correct answer and ballooned to 20% when the vignette threw them off track.

In unpublished results, Taylor's team suggests that a way to overcome such bias might be to use two skilled people to interpret the results. One would go to the crime scene and receive all of the case information to reach a conclusion, and the other would look at photos of the crime scene without any extra information. "Hopefully their answers are the same," Taylor says, but "if there's any discrepancy, then that's explored further."

QUANTIFYING BPA

At a meeting of the International Association of Bloodstain Pattern Analysts in Jachranka, Poland, in June 2017, Jennifer Guest presented her findings on mimicking bloodstain patterns that result from arterial wounds — those gory, spurting wounds beloved by film producers. Guest, a forensic scientist at the University of Greenwich, UK, says that, at present, experienced analysts use their best judgment to determine how blood gushing from an artery will behave. But does the size of the wound matter, for instance? And what about the type of clothing that the victim is wearing? Such information is crucial when determining whether a bloodied person standing about two metres away from a victim with an arterial wound is an innocent bystander or a murder suspect.

So Guest is developing a realistic model of human skin and tissue that will let analysts test patterns from specific wounds. Her team is working with a company that makes synthetic blood vessels of various sizes, which are embedded in a pad of synthetic skin and subcutaneous fat. Guest cuts down into the layer below the artery to create a wound and then uses a pump to generate a pulse that pushes blood out of the body.

"Arterial patterns tend to be big," says Guest, "and show a pulsing with the heart." It's early days, but her preliminary work indicates that the set-up can replicate those characteristic bloodstain patterns.

Guest's research is part of a broader effort to quantify the ways in which blood spatters. Ultimately, researchers hope to automate the entire observation and interpretation process.

For such a pattern-recognition system to work, says Taylor, the BPA lexicon will need to be re-evaluated. The terms used to describe bloodstain patterns, such as spatter and transfer, are intertwined with the cause of the injury, Taylor explains. A neutral classification system would describe the pattern first and then interpret the results. To that end, Ravishka Arthur, a graduate student at the University of Auckland, New Zealand, who is studying BPA under Taylor's supervision, has been working to define and measure the features of bloodstain patterns, including how straight they are, the colour intensity and the angle of the blood's impact. Those values could then be plugged into an automated system, Arthur says.

THE LIMITS OF BPA

When researchers who were inspired by the Camm case investigated the similarities between transfer and high-impact spatter patterns, they found that blood trickling down fabric can leave behind a trail of small beads. When those beads come into contact with another piece of fabric — such as during an anguished embrace — the patterns that result appear almost identical.

That's not surprising, says Stephen Michielsen, a polymer scientist at North Carolina State University in Raleigh, who was not involved with the bead study or the Camm case. Fabrics contain an array of yarns and are made using a variety of manufacturing processes. For instance, sports clothing designed to wick moisture away from sweaty areas of the body could also transport blood to unexpected locations. And once fabrics return home, people wash them with different detergents. They may wear the items several times before washing them again. The fibres in the clothes wear down. "If blood is on a hard, non-absorbent surface, we're in good shape," Michielsen says. "When blood is on an absorbent surface" — that is, just about any type of clothing or shoes — "forget it."

In fact, when Taylor extended his BPA reliability study to fabrics[3], the average sample misclassification error rate jumped to 23%. "We're always trying to get more and more information out of any stain," Michielsen says. "It's a question of how far we can go before we get outside of what we know."

In 2009, the Indiana Supreme Court demanded a second retrial for Camm — this time, because the prosecution had prejudiced the jury by suggesting that Camm had sexually molested his daughter. At Camm's third trial, in 2013, the bloodstains on his T-shirt were again called into question. Robert Shaler, a forensic scientist who led DNA testing to identify victims of the terrorist attacks in New York on 11 September 2001, noted that the number of stains was too small to make a clear determination and that analysis of the evidence lacked rigour. "The Camm case hinged entirely on bloodstain evidence," says Michielsen. But, he adds, "textiles are complicated."

This time, the jury found Camm not guilty. He had been in prison for 13 years. ■

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2. Taylor, M. C., Laber, T. L., Kish, P. E., Owens, G. & Osborne, N. K. P. *J. Forensic Sci.* **61,** 922–927 (2016).
3. Taylor, M. C., Laber, T. L., Kish, P. E., Owens, G. & Osborne, N. K. P. *J. Forensic Sci.* **61,** 1461–1466 (2016).