Federal Ministry
Republic of Austria
Interior

Federal Police Academy

SIAK-Journal – Journal for Police Science and Practice

Brodbeck, Silke M.C. (2021):

The Formation of Bloodstains Following Head Injuries. Gross, Piotrowski and the first blow

SIAK-Journal − Journal for Police Science and Practice (International Edition Vol. 11), 4-11.

doi: 10.7396/IE_2021_A

Please cite this articel as follows:

Brodbeck, Silke M.C. (2021). The Formation of Bloodstains Following Head Injuries. Gross, Piotrowski and the first blow, SIAK-Journal − Journal for Police Science and Practice (International Edition Vol. 11), 4-11, Online: http://dx.doi.org/10.7396/IE_2021_A.

Note: A hard copy of the article is available through the printed version of the SIAK-Journal published by NWV (http://nwv.at).

published online: 09/2021

The Formation of Bloodstains Following Head Injuries

Gross, Piotrowski and the first blow

SILKE M.C. BRODBECK,
Head of the Blutspureninstitut, Usingen, Germany.

The formation of bloodstains following head injuries shows all possible bloodstain patterns and is multifactorial. The earliest systematic publications on bloodstains can be found in Hans Gross (Gross 1893, 1) and Eduard Piotrowski (Piotrowski 1895, 2), although Piotrowski's work deals specifically with head injuries in rabbits. 126 years after the work of Hans Gross and 124 years after the work of Eduard Piotrowski, the progressive development of bloodstain pattern analysis and neurosurgery makes it necessary to reconsider the question of when bloodstains form in cases of head injuries and on which factors they depend. This is the purpose of this work.

THE DEVELOPMENT OF VOLUME OVER THE COURSE OF EVENTS

It may seem trivial, but the prerequisite for the formation of bloodstains is an injury to the vascular system. Since these are always accompanied by injuries to the body, bloodstains have, in contrast to other forensic evidence (e.g. DNA, footwear marks, fingerprint traces), the advantage that in most cases they are automatically connected to the incidents and that this connection does not have to be presented by the investigation.

Hans Gross already referred to a substantial fact in his handbook, when he wrote in the first edition of his Handbook for Examining Magistrates (1893): “Of course, not only the largest and most conspicuous stains, but also the small inconspicuous stains, and maybe the most important ones must be protected in the same way” (Gross 1893, 450). This still applies today and often reveals the layperson who analyses bloodstain patterns at the scene of the crime, who concentrates on large, eye-catching bloodstains and ignores the smaller ones in his or her work.

This may be illustrated by an example. In crimes involving a perpetrator shooting a person lying in bed, usually only the victim's DNA is found in the bed itself. The probability of the presence of perpetrator DNA in the bloodstains found in the immediate vicinity of the corpse is virtually zero.

A firearm is a legally restricted ranged weapon, which usually does not lead to an injury to the perpetrator if it is handled properly. For this reason, adequate forensics in such situations can be limited to taking a maximum of one or two spatter samples of the same origin and sending them to the DNA laboratory only when specific questions regarding these stain samples arise from the investigations or from the judicial point of view.

In some cases, the beginning of a fight is not or only marginally documented in the bloodstains, because an injury must have occurred before the formation of bloodstains. Therefore, in many cases the beginning of the incident is not documented in the bloodstains, but this should not be equated with the fact that bloodstains can never occur in the early stages. The same also applies to fighting resulting in blunt-force trauma during direct confrontation. In some cases, there are also only distinct bloodstains at the beginning, which are often overlooked, but can become particularly important in terms of the question concerning the onset of an incident or self-defence.

For this reason, the small traces are the significant traces in many cases and must not be ignored in forensics, even if the large areas of evidence often appear visually more concise.

BASAL ANATOMY OF THE CEREBRAL VESSELS

The skull is divided into two parts, the facial skull (viscerocranium) and the brainpan (neurocranium). Nature has placed the arterial vessels supplying the brain to the depths of the anatomical structures. Thus the two main arteries running laterally along the neck and the spinal arteries enter the brainpan through the skull base. Nature has thus given these vital structures maximum protection, since the arterial supply to the brain at the skull base is protected in depth by the bone.

On the other hand, the blood in the brain flows through the venous conductors, which are known as sinuses in the brain. There is the superior sagittal sinus, the inferior sagittal sinus, the sinus rectus, the two transverse sinuses and the rectus sigmoidei sinus in the brain.

The superior sagittal sinus is of greater forensic importance because it is located under the calvaria between the two halves of the cerebrum. Its walls are formed by the dura mater. This vein structure located on the surface is of particular importance, because it can be injured after the first blow and then, depending on other factors (hair, clothing), it can result in the formation of

Source: Juha Öhman

Figure 1: Radiological presentation of the left carotid artery with one surgically treated and one untreated aneurysm. The large arterial vessels pass through the skull base. Note the left eye socket[1] above the sign to compare sizes

Source: Gray 1918, 7

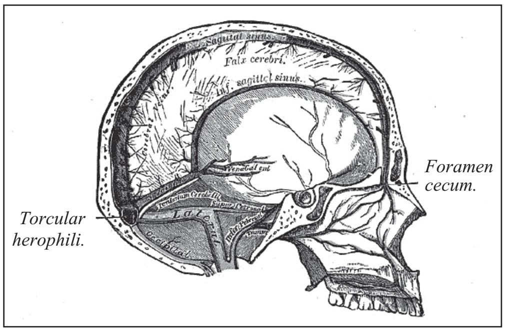


Figure 2: Representation of the venous vascular system by Henry Vandyke Carter in Gray (1918)

massive bloodstains immediately after the first injury.

FORMATION OF BLOODSTAINS OVER THE COURSE OF EVENTS

In many court cases, the question of whether bloodstains can develop during the initial impact on a skull plays a role.

These questions usually arise only for the effects of blunt force. In gunshot injuries to the skull, which for example run medially along the skull base, bleeding usually occurs within a very short time via the internal carotid artery. This is irrespective of whether or not there is an exit wound. Here, it is also particularly important that not only the deformed skull bone should be photographed, but also the damage to the brain surface. In blunt skull injuries, the first blow using blunt force can lead to massive bleeding over the course of time and thus also to the development of large bloodstains, although this does not necessarily have to be the case. Both variants are possible.

The question of whether one of the major blood vessels was damaged in the injury and was able to bleed outwards is relevant for the formation of bloodstains with the first blow. This circumstance is of particular importance and even today it still leads to erroneous expert statements in court, as Piotrowski's work is often misquoted in this context (Piotrowski 1895).

Source: Blutspureninstitut

Figure 3: Spatter created by the single impact of a murder weapon on a skull[2]

Piotrowski's work was written in 1895, at a time when it was not possible to see the formation of bloodstains. Since the 1990s, the formation of bloodstains has been documented in several projects using high-speed video, beginning with a film by New Scotland Yard "Blood in slow motion".

At that time, Piotrowski killed rabbits and struck dead rabbits with different tools (hammer, axe, stone). He described the bloodstains that were left behind in his work. It remained Piotrowski's only work on the subject and it revealed shortcomings in standardisation at relevant points. One of the major problems is the comparison between a human brain and a rabbit brain. A rabbit's brainpan (neurocranium) is significantly smaller and therefore its vessels are also much smaller. The study also does not describe a standardisation of the localisation of injuries on the animals or even the injuries suffered by the animals.

If you look at a rabbit brain, you can see that the surface vessels are very small (see Figure 4, page 7). They are therefore considerably smaller than human vessels. The larger a vessel is, the greater the volume of blood moving through the vessel in a given time, which can leak out in case of bleeding. Bleeding is therefore also directly dependant on the size of the injury and, in a broader sense, on the location of the injury. Smaller vessels lead to lesser bleeding due to their

Source: Tanja Lenz

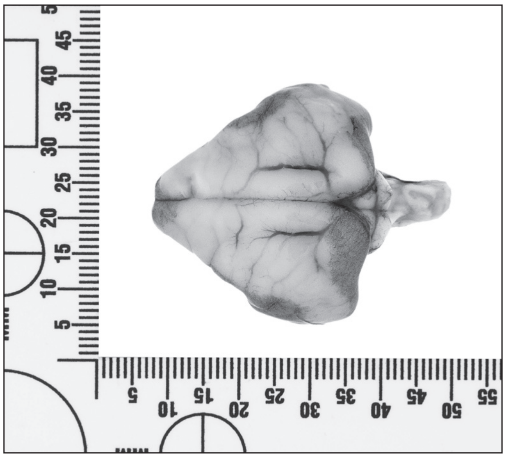


Figure 4: Surface of a rabbit brain

smaller diameters (Brodbeck 2007).

If we now look at an image of the human superior sagittal sinus from above (Figure 5), we can see that this vein has a considerably larger diameter, therefore, these structures will bleed more heavily in the event of an injury.

Piotrowski's work is an empirical description. He describes the circumstances of the blows he made. However, his observation remains an observation and does not reach the analysis stage. He describes that when a wound first develops, the injury to the rabbit's skull only begins to fill up and the second blow then causes the blood to accumulate.

Source: Gray 1918, 654

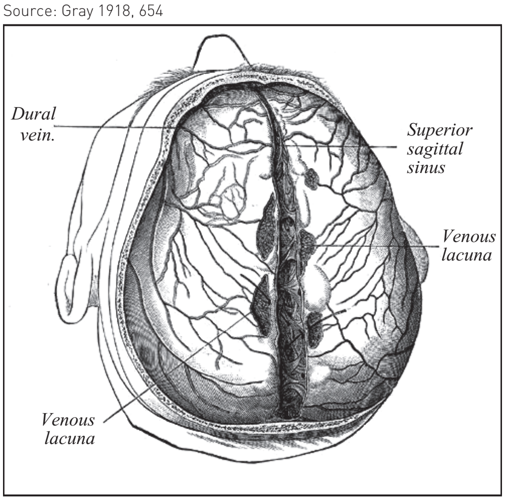


Figure 5: Representation of the superior sagittal sinus by Henry Vandyke Carter in Gray (1918)

These observations can also be made in everyday neurosurgery; they arise, for example, when the skin is cut at the beginning of the surgery. The smaller vessels are injured in the process and the bleeding is stopped by electrocoagulation or stapling. The situation is different with the bleeding from larger vessels. In this case, the large volume of bleeding results in a fast and almost immediate, larger volume discharge with immediate refilling or, depending on the pressure, in an ejection of blood.

Piotrowski described that in his experiments only insignificant bloodstains resulted after the first blow with a hammer. This cannot be transferred to humans. It must also be stated that he himself never specified that there was no bleeding after the first blow. Piotrowski described, for example, that during his hatchet attempt, bloodstains already formed after the first blow. Although, after several attempts with a hammer he attributed the first blow alone to the development of the wound (Piotrowski 1895)

From today's point of view, a major point of criticism regarding Piotrowski's work is also the lack of standardisation of the target object. This means that the rabbits' skulls were injured in different places, and it can also be seen that the vascular structures both in biological creatures and between individuals are not equally distinct in all parts of the brain. Contemporary scientific studies would also include adequate documentation of injuries, including a report on the findings of the skull, brain and vessels.

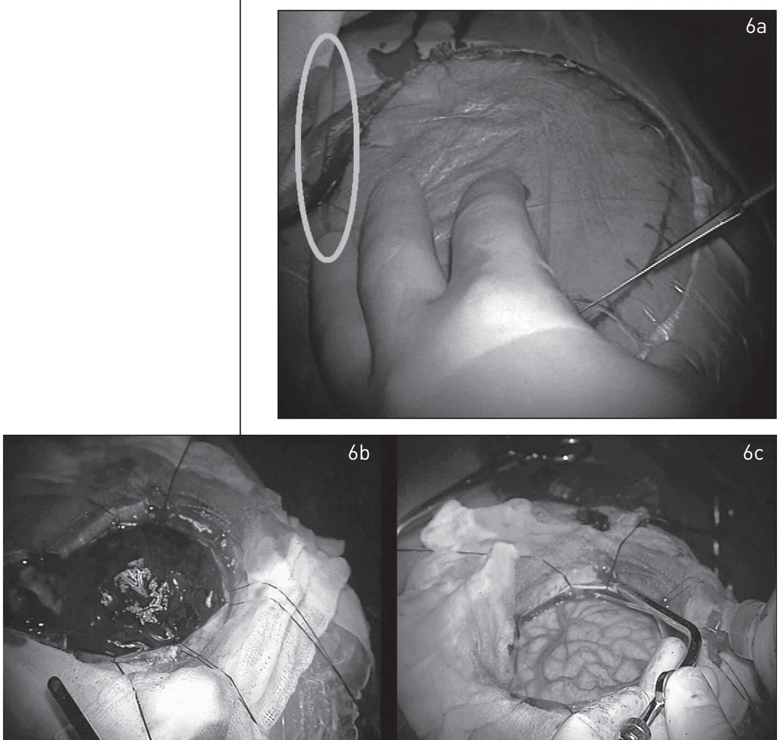
Another issue that often gains importance in court is the question of the force applied in the occurrence of skull injuries. From a scientific perspective, force alone is not the only factor responsible for skull injuries, but also the pressure caused by the weapon and the structure of the striking tool and the movement performed. Accelerations on circular paths are often encountered when striking with objects. The pressure is equal to the force per surface area. This is essential in considering skull injuries and, in particular, the effectiveness of weapons in this context.

The knights already knew this well, as they used battle hammers with extended handles when they fought on horseback, e.g. at Braunfels Castle[3]. The hammer is a ranged weapon and increases the distance between the attacker and the injured party. The small area of impact means that the force is concentrated. Hammer injuries are therefore very well suited to penetrating the skull and causing permanent damage to the brain.

In conclusion, it should be noted that bloodshed is quite possible after the first blow and it is subject to expert blood pattern analysis. It very often results from an injury to the superior sagittal sinus and is also dependent on external factors (see below).

Expert opinions, which make a general reference to the fact that there are no bloodstains after the first blow, should therefore be re-examined by a specialised senior expert.

Source: Juha Öhman



Figures 6a–c: Photographs of a brain operation to remove bleeding under the dura mater[4]

FACTORS AFFECTING THE FORMATION OF BLOODSTAINS FOLLOWING HEAD INJURIES

Anatomy and physiology are the foundations of bloodstain pattern analysis. While the location of the injury plays an essential role in the formation of bloodstains, wound morphology is usually not relevant here (see Figure 6). The figures show the beginning of a neurosurgical surgery involving the scalp being cut. The surgery is performed to remove a bleeding located under the dura mater. Figure 6a shows the beginning of the surgery involving the cutting of the scalp. Here, blood spurts out where a vessel has been injured. This blood would cause spatters due to dispersion if adequate surfaces were present. The blood accumulates in the other parts of the wound according to gravity and leads primarily to the formation of pools and flow patterns. The wound edges therefore have no effect on the formation of bloodstains.

Figure 6b shows the skull opening with a view of the haematoma and Figure 6c the surface of the brain after its removal. The significantly larger vessels can be seen in comparison to the rabbit brain and in relation to the instruments shown.

There are therefore factors in every sequence of events that remain unknown and influence the formation of bloodstains. These include:

- blood pressure and its changes during the incident,

- the discharged volume and the total blood volume of the damaged body,
- the area of the vascular injury, which depends on the physiological change in the vessel cross-section,
- and in most incidents, the most detailed movement sequences, as it is usually only possible to reconstruct the rougher sequences.

The next group includes factors that are often known and that influence the formation of bloodstains at crime scenes:

- head hair of the injured person,
- localisation of vascular injuries (if documented, in case of survival, it must be ensured that the operation report is available, because unlike the autopsy findings, the operation reports provide information on the vascular injuries treated; in autopsy reports this data is usually not available or is only slightly differentiated),
- headgear/clothing,
- three-dimensional spatial structure of the scene with surface textures.

The factors of the last group are usually known and can either be requested or investigated.

It is important to note that the formation of bloodstains also depends to a large extent on the existing life of the injured person, as blood pressure is a major factor in the formation of bloodstains.

Although Piotrowski used live and dead rabbits in some of his experiments, Piotrowski lacked experience with bleeding in living organism. He might then have been able to document the relationship between the amount of bleeding and the size of the vessels. However, it should also be noted that neurosurgery only developed in an own speciality after Piotrowski's work, and he was working in a theoretical, medical field at the time of his work, without any surgical practice on living people.

BLOODSTAIN PATTERNS AND HEAD INJURIES

Since bloodstain patterns are multifactorial, all known bloodstain patterns can also be caused by injuries to the skull, depending on the specific circumstances of the scene. Bloodstain patterns alone are not unique and bloodstain pattern analysis focuses on the possibilities of the formation and combination of different patterns as complex patterns.

Spatterfields resulting from damage to the skull in the region of the superior sagittal sinus, drip patterns, contact stains and all other stain patterns may occur in cases of skull injury. Especially in cases of head injuries to a head with hair, contact stains with finely chiselled shapes very often appear as a mark of hair covered with blood.

In this respect, it should be noted that the term "contact stain" is scientifically more precise than the term "transfer stain"[5] that is currently preferred in American literature. The word "transfer" is derived from the Latin word "transferre" and has various meanings of carrying over, directing, transforming, moving and shifting. It is not specific enough. In contrast, the word "contact" is derived from the Latin word "contingere", which can be translated as touching, grasping, wetting or staining,

Source: Gregor Haring

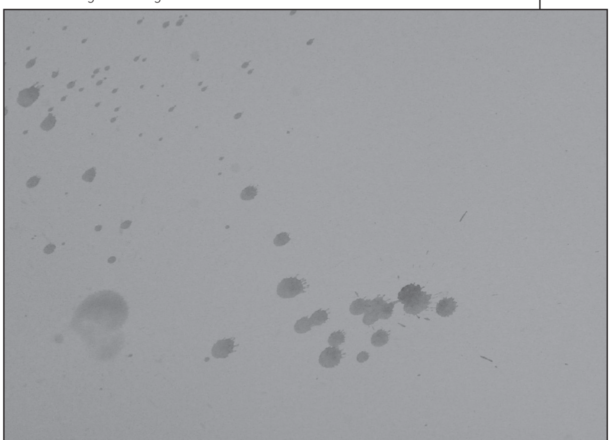


Figure 7: Diluted bloodstains with a reduced colour intensity due to an addition of cerebrospinal fluid

among other options. Since it is always a surface that touches the blood, the term "contact stain" is scientifically more precise than the term "transfer stain".

Although there are no specific bloodstain patterns for head injuries, the particular importance of diluted bloodstains in connection with skull injuries must be emphasized. Diluted bloodstains are found in cases where another fluid is added to the blood. In cases of head injuries, cerebrospinal fluid is often added following an injury to the dura mater, so that spatters with altered colour intensities as an expression of diluted bloodstains can be an indication of a head injury if the corpse is missing (see Figure 7, page 9).

CONCLUSION

After injuries to the skull, all forms of bloodstains can occur depending on the underlying crime-scene circumstances. The formation of bloodstains is directly dependent on the location and size of the injury. On the other hand, wound morphology plays only a minor role.

Injuries to the dura mater can cause blood and cerebrospinal fluid to mix, resulting in the formation of diluted bloodstains.

It is not the occurrence of single patterns that is essential for the assessment of bloodstains, but often the combination of different patterns as complex bloodstains.

Historically, the first systematic work on bloodstains dates back to Hans Gross in 1893. He systematically dealt with securing bloodstains at crime scenes. The subsequent work by Eduard Piotrowski in 1895 dealt with the bloodstains on the rabbit skull following blunt force. To this day, Piotrowski's work is often misquoted by denying that the formation bloodstains appear after the first blow. It is correct that massive bloodstains can also form even after the first blow, namely when large vessels, such as the superficial sagittal sinus, are injured.

Paradoxically, the most important bloodstains at crime scenes are often very small, and this can apply not only to the bloodstains left at the beginning of an incident, but also, for example, to a slightly injured perpetrator. It is therefore a source of error if at crime scenes where bloodstain patterns are analysed, the patterns that are visually very obvious are preferentially secured and if a police or forensic medical forensics department fails to secure the most relevant evidence. This should be avoided.

Factors with a great influence on the formation of bloodstains are the location of the injury and especially the vascular injuries of the larger vessels, the hair on the head, clothing and surrounding surfaces in the three-dimensional environment of the scene. These should be forensically documented and also in autopsy photography, special attention must be paid to all damaged structures (not only the base of the skull, but also to damage to the brain and brain vessels must be photographed).

The blood volume discharged and the total blood volume of the injured body, the blood pressure and the exact size of the injury will always remain unknown, as the vessels are capable of changing their diameter in the living person; these changes are too small to be of influence on the bloodstain pattern analysis (Brodbeck 2007).

From a forensic perspective, even smaller stain areas should be photographically documented and DNA secured at crime scenes. This complies with the valid standards of forensics at crime scenes. However, this does not mean that all spatters in a spatterfield are photographed individually, but that independent bloodstain patterns are secured with at least one overview photograph, regardless of its size.

There is no such thing as too small to photograph and even small traces can have a significant impact!

It is not possible to make general statements on the formation of bloodstains after the first blow and these should be questioned by an expert in any case.[6]

[1] *Illustration of the left carotid artery with aneurysm of the left anterior common artery and a surgically treated media aneurysm. The large arterial vessels ran through the skull base. As a comparison for size please note the roundish structure of the left eye socket above the sign. The nose is visible at the lower left side of the image.*

[2] *Spatterfield, created by the single impact of a weapon on a skull. As a result of the weapon structure, high pressure was built up on the skull, directly causing an impression fracture and injury to the large venous blood vessel. The spatterfield spreads more than one metre. The textile saturation of the floor is caused by the injured person lying down after the distinct source of bleeding has developed.*

[3] *www.schloss-braunfels.de.*

[4] *Photographs of a brain operation to remove bleeding under the dura mater; 6a – in the image with blood shooting out from an injured vessel (see marking), 6b – in the middle the haematoma and 6c – the surface of the brain after removal.*

[5] *https://asb.aafs.org/wp-content/uploads/2017/1 l/033_TR_el_2017.pdf.*

[6] *Acknowledgements: The author would like to thank Tanja Lenz, Dr Gregor Haring and Prof. Dr Juha Öhman for kindly providing images and Dr Sinikka Brodbeck for critical discussions and comments.*

Sources of information

Brodbeck, Silke M.C. (2007). Arteries and Veins – a plea for spurt patterns, IABPA Newsletter, June 2007, 4 –14.

Gray, Henry (1858). Anatomy – Descriptive and Surgical, London.

Gray, Henry (1918). Anatomy of the human body, Philadelphia/New York.

Gross, Hans (1893). Handbuch für Untersuchungsrichter, Graz.

Piotrowski, Eduard (1895). Über Entstehung, Form, Richtung und Ausbreitung von Blutspuren nach Hiebwunden des Kopfes, Wien.

https://asb.aafs.org/wp-content/uploads/2017/11/033_TR_el_2017.pdf.

www.schloss-braunfels.de.

Further literature and links

Damulewicz, Anna (2017). Polish history go BPA, Presentation at the 6,h European IABPA Conference in Warsaw.

Richardson, Ruth (2016). Henry Gray, plagiarist, Clinical anatomy 29 (2), 135–9, doi: 10.1002/ca.22681.