FORENSIC SCI SEM
Received 11 May 2016
Received in revised form 28 May 2016
Accepted 2 June 2016
Available online 29 June 2016
Peer Reviewed
2157118X.6.1.P3

Forensic Analysis of Impact Injection Trace Evidence under Ballistic Viewpoints

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Abstract The offender-victim position in space is usually one of the central issues of a forensic trail of blood sample distribution analysis. This is based on the experience-based analysis of the individual blood trail complexes. Furthermore, geometric calculation models of stroke injection marks an essential part of the analytical reconstruction of the spatial position of a source of bleeding at the time of the violence. Taking into account the biophysical properties of blood different, based on the fluid mechanics and ballistics calculation models can be installed and reconstructed as a possible position in space. This paper provides an introduction to the ballistic aspects of stroke injection marks and shows how the interpretation of such blood track pattern can be substantially improved by involving calculation models.

Keywords: Blutspur pattern distribution analysis; Blood Biophysical properties; Surface tension; Documentation; Forensic science.

If there is a contact between an accelerated drop of blood and a surface, it will take in response to Antragungsrichtung, angles and composition of the underlying different kind of shapes. This knowledge is fundamental for the forensic trail of blood sample distribution analysis. In many cases, a simple linear approximation of the trajectory of a blood quantum is not enough. Then has the ballistic calculation qualified, scientifically based evaluation option. Here, the experience and the physical background knowledge of the appraiser are required.

1 Background

To reconstruct the position of a victim at a crime scene, is one of the central tasks of the forensic trail of blood sample distribution analysis. Accurate measurement, shape analysis and categorization of bloodstains, incurred in connection with acts of violence against the human body, in this case form the basis for the application of secondary mathematics and analytical methods [1]. Taking into account the biophysical properties of blood equations of fluid mechanics to calculate the specific Flugballistik can be applied by drop of blood. The resulting derived mathematical models complement the experience-based to a large extent interpretation of blood trace patterns. This paper gives an introduction to the fundamentals of mathematical ballistic calculations of impact injection marks and shows the practicing forensic pathologist the advantages of this methodology.

As used hereinafter the impact injection traces describes spatter typical trace patterns that occur when a subject to a blutbenetzte surface (z. B. a wound o. Ä.) Blunt force exerted.

2 Biophysical properties of blood

To better understand the capabilities and limitations of forensic trail of blood pattern analysis and also to be able to understand you have to deal [3] with the biophysical properties of blood, such as adhesion, viscosity and surface tension [2] and the therefrom derived mathematical calculation models.

Blood is a complex composite body fluid from cellular components and a liquid plasma fraction. Due to its inhomogeneity blood is one of the so-called. Non Newtonian fluids. Unlike water or air, it has a load-dependent viscosity that can not be explained by Newton's law of inertia. Viscosity describes the flow characteristics of a fluid and results v. A. Of the internal

Table 1. Biophysical basis properties of different liquids

Liquid (temperature)	Density (g/l)	Viscosity (mPa.s)***	Surface tension (mN / m)
Blood (37°C)	1060 [3]	4,0 [3]	50.0 [3]
Blood (20°C)	1055 [4]	6.3 [7]	61.0 [7]
Water (20°C)	1000 [3]	1.0 [3]	72.5 [3]
Ethanol (20°C)	780 [6]	1.2 [3]	22.3 [3]
Milk (20°C)	1030 [6]	3.0 [3]	44.0 [5]

* Average (MW) over the entire main period (day 1-28)
** Average (MW) of 22-28 days the main period
*** Mean feed intake per hen per day amounts to 120 g feed

friction of the individual blood components. It defines the degree of viscosity and is expressed in force per unit area times time with the SI unit Pascal second (Pa • s) indicated. Undergoes blood by external forces, deformation, the structure changes in the liquid so that smaller interparticle interactions occur. This phenomenon is ultimately primarily responsible for the compared to other liquids partly somewhat delayed momentum with appropriate force.

By the surface tension, or commonly known as interfacial tension, the property of the surface or the interface between a liquid and its surroundings will be described. The acting in this field cohesive lead to the endeavor of fluids to keep their surface as small as possible. This results in a flying drop of blood of defined size and in the absence of interference from other forces (apart from air resistance) a (oscillating) spherical shape. The surface tension is given in units of Newtons per meter (N / m).

The adhesion or attachment force describes the physical-mechanical cohesion of two interfaces. They are a measure of the "stickiness" of blood again and is responsible for the good transferability in contact a target surface with a quantity of blood.

Comparing the spray behavior of various liquids, such as water, ethanol and dairy, so indeed, individual parallels are drawn with regard to the respective morphology with blood. Due to the different biophysical properties has blood but a generally sluggish reactivity, which is due v. A. At the correspondingly high viscosity at too high relative density (Tab. 1).

3 Flugballistik whipped spray tracks

Acting on a wetted with blood surface a whatsoever form blunt force: a (physically a shock), various amounts of blood of different size and shape radially from the center of the source of bleeding accelerated outward in excess of the viscosity or surface tension of the originally cohesive track , Meeting then flying drops of blood on a surface, they blow injection tracks are here called according to their incidence in the sense. Ready. Investigations with a high speed camera have shown that at a stroke on a wetted surface with blood from the center of the initial trauma large amounts of blood are displaced as a gush-fan shape to the rim portion. Depending on the acceleration and the braking force her counteracting this blood surge splits into shock injection traces of different sizes in the course. The greater is the acting energy, the smaller the resulting blood splatter can

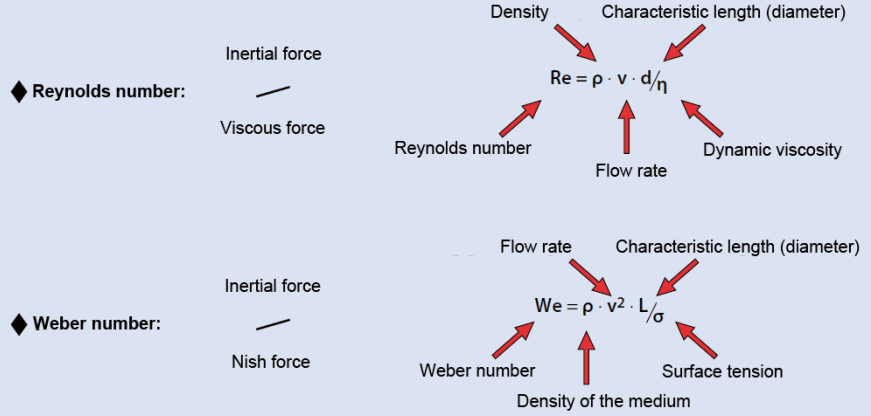

Figure 1. Reynolds and Weber number as the essential characteristics of fluid mechanics

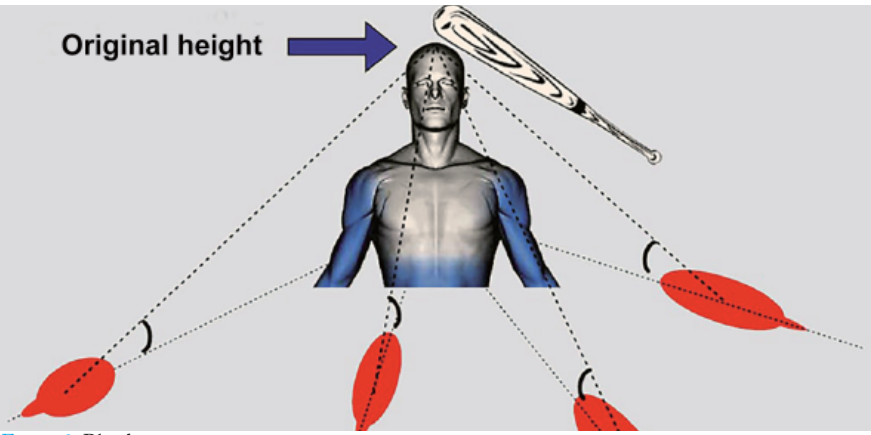

Figure 3. Bleeding positioning.

be. Mathematically can this relation between the resulting top speed, flight distance and letztlicher picture size of a blood spray track constitute the basis of mathematical models. The Weber number is used in this connection, as a measure for the droplet deformation and to characterize the atomization of a liquid (Fig. 1). The Reynolds number is the ratio of inertial to viscous forces is (Fig. 1). These two indicators of fluid dynamics describe the inertial force of liquid in relation to the toughness or surface force. Based on accelerated in the air drops of blood define these two variables, the trend of a drop of blood, during the flight to change its shape or to divide itself. With regard to the evaluation of spray tracks is important that a direct dependency between the droplet size and its maximum possible speed at which it to a fragmentation and thus reduction in size of the original droplet comes (Fig. 1 and 2), can be derived. Experimentally it has been determined that there is a partitioning a liquid quants in Weber numbers that exceed the value of the thirteenth From this it can be the maximum achievable rate of drop of blood given size restrict (at the basis of typical values of air density and the surface tension of blood,[8]). From the physical relationships arises that smaller drops of blood reach higher maximum speeds than larger drop of blood; This is also confirmed by experimental measurements [9]. Nevertheless, smaller blood quantum achieve shorter distances from the blood source. The reason for this is the drag force exerted by a relatively greater impact on smaller blood quantum. (Smaller blood quanta are strongly slowed down by the air.)

4 Reconstruction of the origin area

If there is a contact between an accelerated drop of blood and a surface, it will take in response to Antragungsrichtung, angles and composition of the underlying different kind of shapes. The greater the horizontal acceleration (along the target surface) as compared to the vertical action component (perpendicular to the target surface), the flatter is the angle of incidence and the more ovoid-oblong, the resulting blood trail. Vertically downwards falling or ortho degree impinging drops leave a circular track configured on the contact surface. . Ovoid bloodstains with so-called bear claws like outgrowths occur at an angle of incidence between about 40 ° and 60 °; ausrufezeichen shaped configurations can be seen in shallow impact angle between about 10 ° and 30 ° [10].

By latitude and longitude measurement of blood to their incidence can be determined using trigonometric relationships using the following formula [11]:

$$\alpha = arcsin \times width / length$$

One Extends addition, the longitudinal axes of several, the same complex associated impact injection marks, the so-called. Convergence region of this blood trail complex can be determined. Use the tangent method in a next step-off on this convergence area of origin of the complex trail of blood isolated [12]. Here, the actually parabolic trajectory of a drop of blood is reduced to a linear airline and the object to be determined point (the original height) retrograde developed (Fig. 3). The flatter in this regard is the trajectory of a drop of blood, the more true this approximation matches the actual trajectory. In addition, should preferably blood spraying tracks are used which have a Antragungsrichtung from bottom to top for angle determination on larger objects or walls.

Figure 4. head injuries of the dead.

At relatively obtuse angle of the blood trail analyst for level determination of the source of bleeding must incorporate more bloodstains in his calculations. Particularly round, d. H. Plumb is transmitted to the wall of blood spraying tracks here are a great help. By horizontal displacement can be carried out using these traces of blood a height determination. To avoid misinterpretation, care must be taken when applying this method advises that relied on interpretation bloodstains actually attributable to the assessed event and are not passed through a thereof independent action through the appropriate channels.

Because it can happen at the time of the trauma and the onset of stroke injection marks on relative movements of the victim, may have different areas of convergence position changes of the victim during a show of force. For this reason, the source area of a source of bleeding can be found usually just enough so that a differentiation between a standing, kneeling or sitting or lying position is possible. But this is enough for reconstruction purposes in respect of the crime in a rule.

5 Practical application examples

To a forensic trail of blood analysis include a structured crime scene with

Figure 5. Reconstructed position of the deceased at the time of trauma (not to scale).

detailed tour of all spatial conditions, a systematic study and survey of all existing traces of blood or blood trail complexes and a standardized written and photographic documentation[13,14]. Impact injection traces are often here in the center of the analytical reconstruction of a source of bleeding at the time of the violence.

Case 1

In this case, a 69-year-old woman with multiple fatal head injuries caused by a blunt or partly sharp object (Fig. 4) was found dead in her apartment. The cause of death is a central regulatory failure was diagnosed in the presence of a massive open craniocerebral trauma with Teilenthirnung. During the police investigation, a hatchet was identified as the murder weapon. As it turned out by the trail of blood pattern analysis, it was in locating position also to the position of the victim at the time of ultimately leading to death acts of violence against the skull (Fig. 5). The body of the deceased was in a supine position in the living room. The head was located directly behind the doorstep of tiled transition area to the laid out with dark gray carpet living room (approximately corresponding to the position of the blood-soaked towel in Fig. 6).

In order to reconstruct the events concerned one of the key issues the positions of the injured during the confrontation. In particular, it should be clarified whether the victim had taken a more passive role in the dispute, or whether a highly dynamic process with multiple changes of position of the parties present. The background to the question was whether the perpetrator and the victim were close and the victim had therefore may not initially defended. In the first step the usable for this question bloodstains were machined out of the whole complex. An important Blutspur complex was the transition area from the hallway to the living room. Here a significant collection of typical for a striking mechanism spray traces could be found on the doorstep. Based on the shape of the tracks, d. H. The presence of single barbed or bear claws shaped, fine linear outgrowths and taking into account the immediate vicinity the respective Antragungsrichtung and the longitudinal diameter of individual randomly selected bloodstains were examples found (Fig. 6). The sectional area of elongated longitudinal diameter finally yielded a convergence area directly behind the door sill on the carpet in the living room (Fig. 6). By measuring the width to length ratios of individual stroke injection marks on the outside and inside of the door threshold could be calculated for being transferred here bloodstains the respective incidence (Fig. 7). The retrograde extension of the flight axes gave an origin area at a height 15 to 27 cm above the point of convergence, which with a lying position agrees well (Fig. 5, 7). A random survey further blow injection traces with appropriate calculation of their incidence showed

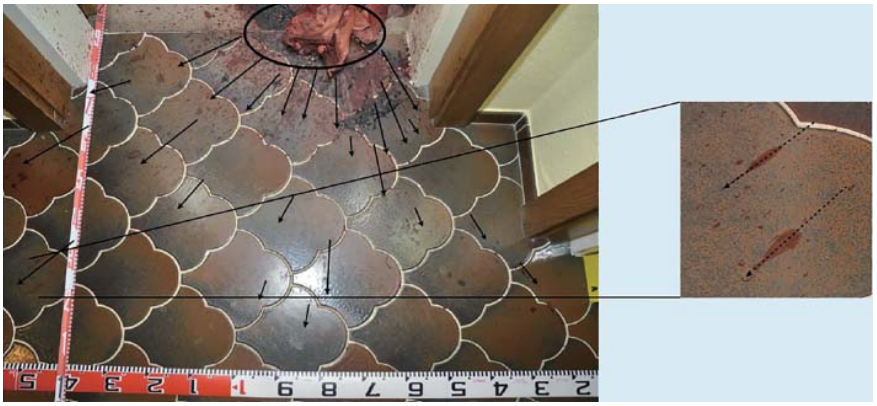

Figure 6. Blow spray footsteps in the corridor in front of the living room.

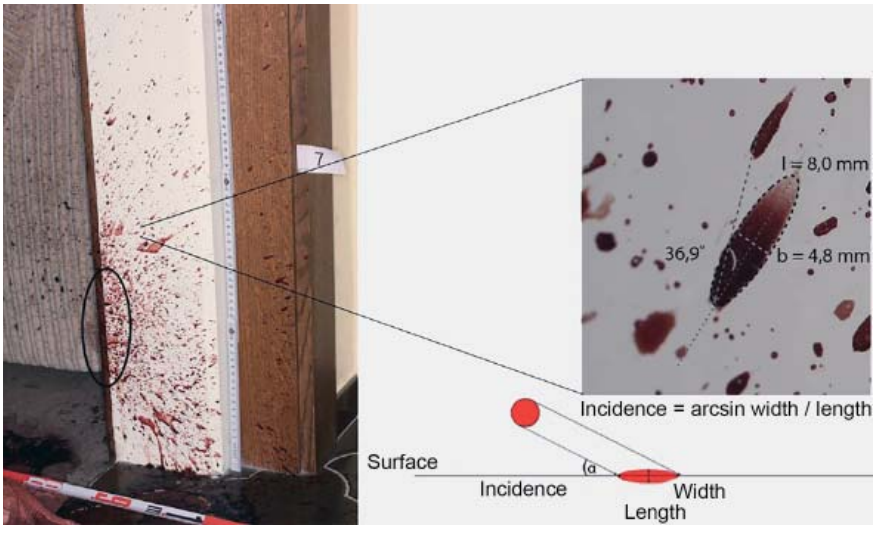

Figure 7. Blow spray marks on the outside of the door frame to the living room, right Rechenbeispiel.

no other origin area. Notes (possibly even multiple) changes in position of the victim were not found in a review of the entire crime scene. Also, no traces of blood could be detected, which could be compatible with relative movements of the injured during acts of violence.

The forensic trail of blood pattern analysis distribution came along with the findings of the autopsy to the conclusion that the deceased had at the time of the acts of violence in only one position, namely in the supine position directly, found in the area of doorstep. Based on these findings it was considered polizeilicherseits of a Beziehungstat in immediate family environment of the deceased; the victim was attributed to a more passive role in the overall picture in the facts of the case.

This assumption was ultimately confirmed in further investigations and the grandson of the deceased are transferred as perpetrators.

Case 2

A 57-year-old woman was charged with 4 scalp through separations in the left temporal / parietal region including comminuted fracture of the cranium dead in her marriage bed lying found (Fig. 8). The cause of death is a central regulatory failure was diagnosed in the presence of a massive left-sided open craniocerebral trauma. The murder weapon, a crowbar lay at the foot of the bed.

It could as part of the trail of blood sample distribution analysis 4 major areas of Schlagspritz- (Fig. 9, no. 1 and 4) and skid marks (Fig. 9, no. 2 and 3) are worked out. Due to the fan-shaped arrangement of the traces of blood spatter typical of the region 4 and their overall relatively steep Antragungswinkel this area was a blow injection traces comprising interpreted (Fig. 10).

The blood skid marks of the areas 2 and 3 were each successively or

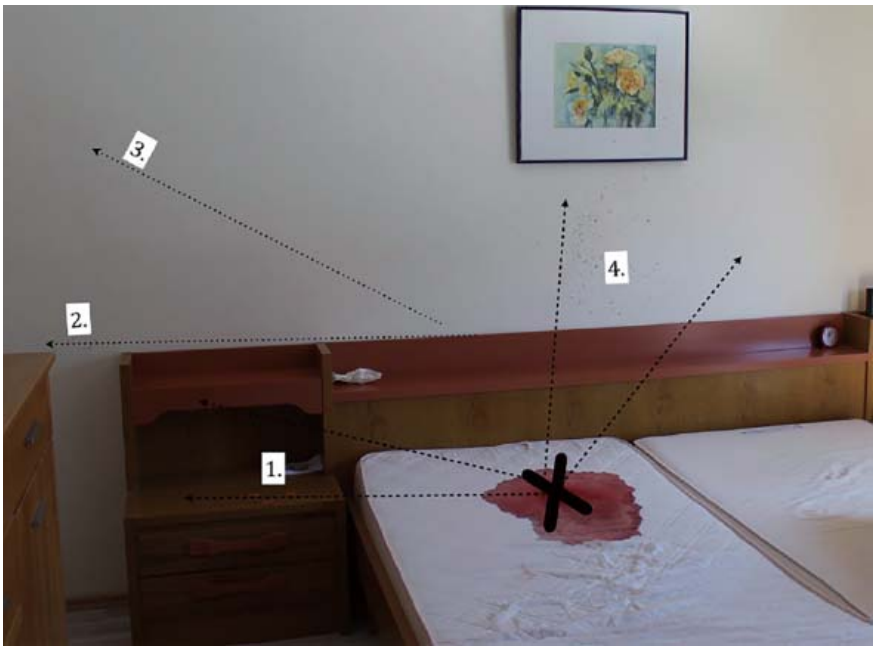

Figure 9. Distribution of Schlagspritz- and skid marks.

Figure 10. Blow spray marks on the head near the wall of the bed.

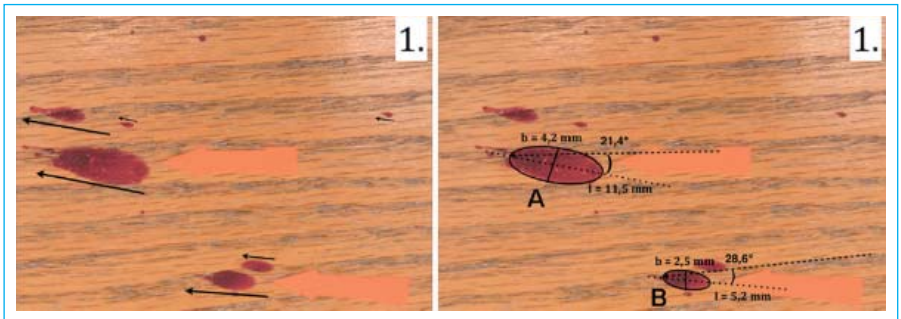

Figure 11. Rechenbeispiel a blow injection track. b width, length.

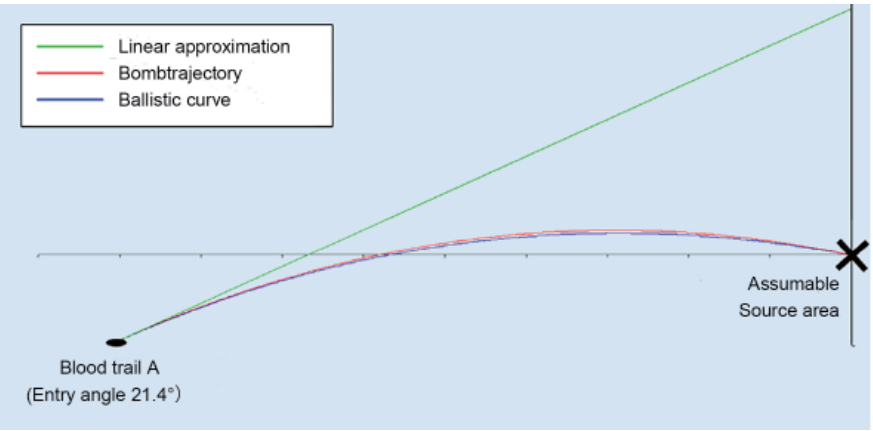

Figure 12. Movement paths of the blood traces a and b. Fig. 11 Comparison of 3 physical models.

slightly offset from each other located and could be assigned at the same time relevant distance 2 Ausholbewegungen. This type of blood stains typically arises in that with fast movements of a relatively thoroughly wetted with blood object single drop of blood inertia be thrown from the instrumentalities and be mapped so in accordance with the motion control of objects in the room or a corresponding projection.

Only the blood trail complex 1 could be assigned unequivocally initial neither a blood spinner track still a blow injection track. A random survey of traces of blood (Fig. 11) and calculating the incidence enabled a mapping of these tracks to their original source in the head area of the bed (mark "X" in Fig. 9). Thus, these traces could (not for injuries larger arteries, no accumulation of blood in the airways Anhalt) are identified and the morphological characteristics of the track image clearly as blow injection marks, including the injury. The spatially separated Blutspur complexes 1 and 4 could be assigned to the same source area.

The different reconstructions of the trajectories of the two in Fig. 11 illustrated blood spraying tracks whose Antragungswinkel is known based on the latitude-longitude relationship, visualized Fig. 12. Green are the approximations of the trajectory represented by a line, which accordingly in this case, the source area which is resting on the bed head of the victim (marked by cross, about 90 cm from the tracks and about 10 cm above the target surface located) are not compatible. In this approximation, both the gravity and the air resistance are neglected, resulting in a gross distortion of the result. Considering besides Antragungswinkel additional gravity, the trajectories shown in red in Fig. 12 can be calculated. If now also the air resistance into account, in addition, give the calculations shown in blue ballistic curves. The calculations show that a reconciliation of the tracks with the assumed source area is. In this case, only a small influence of the air resistance and therefore only a slight deviation of the ballistic curve of the trajectory (Fig. 12) result. are also conceivable constellations that would justify the high computational effort for the consideration of air resistance. Here the experience and physical background knowledge of the appraiser are required.

Note

Using the formula for the Weber number (and at the onset of specific values for P, = 13, ρ = 1.225 kgm-3, σ = 50 mNm^{-1}; Fig. 1) are obtained for the 4.2 mm wide track a maximum airspeed of about 11.2 ms^{-1} and for the 2.5 mm wide track a maximum airspeed of about 14.6 ms^{-1}. The calculated initial rates were about 4 ms^{-1} and about 3.5 ms^{-1}.

In regard to the results of the autopsy protocol, and on the basis of the configuration and distribution of blood stains a tod causative multiple blunt trauma was adopted against the head of the deceased in the present case, which had been taught her exclusively in near the head portion of the bed in a horizontal position. The offender was located here in a standing position in the head near third next to the bed. The trail of blood image took a total strikingly static events without evidence of a change in position of the injured party (a single origin area of blood injection track pattern on the wall and on the nightstand beside the bed).

The two presented cases have in common that the number of origin areas was (as weighty indication of any changes in position of the victim or the perpetrator / victim configuration) is of great importance. The reconciliation of individual tracks or track patterns with the identified areas of origin can play an important role in the workup; for example, could 1 single tracks in the classical reconstruction of the original range, a height above the convergence point of more than 20 cm result, be interpreted as evidence of effects on the not resting on the floor (but be higher located) head in the case. In such cases, a simple linear approximation of the trajectory of a blood quantum is not sufficient; a qualified, scientifically based evaluation provides a ballistic calculation. It can be checked whether at the given boundary conditions (Antragungswinkel the track localization of the convergence point, the size of the track) a concrete trajectory of the blood quantum find (physically calculate) leaves, which is compatible with a specific zone of origin. One can calculate the initial velocity, which must have had such a blood quantum to be discharged from the given region of convergence

under the given Antragungswinkel to the target surface. If this computed initial velocity does not exceed the maximum attainable level for the given track size, the blood trail with the emergence in concrete source area (or point) is compatible. If the calculated initial velocity of the track can be derived from the Weber number maximum speed, must be assumed by another source area. (The single track can physically have not reached this speed, because they would divide into smaller due to air resistance.) Such an approach has already been used successfully [9]. Specifically, based on Case 2 was determined by calculation that the initial rates are well below the calculated theoretical maximum. The ballistic calculations are not trivial, and since they are differential equations, the application of numerical methods is announced. For this, existing, specially developed for the trail of blood analysis programs specially or already used on the market.

Any calculation - with calculator and pencil and using a computer program - errors may occur. To avoid erroneous conclusions, it is necessary always to check the plausibility of the calculation results critically; This places high demands on the experience of the appraiser.

6 Limitations

Depending on the surface properties and the shape and location of an object may be inaccurate and therefore not always purposeful application of the trigonometric angle calculation due to thus caused variability of the track shape.

By relative movements of the victim may lead to blurring in the number and the extent of the areas of convergence. Therefore, in the application of mathematical calculation models for determining origin of bleeding source the overall picture of the bloodstains and their surroundings should be taken into account.

When moving or strongly inhomogeneous surfaces calculation models are not sufficient often to capture the complexity of the blood trace analysis. Rather, in the interpretation of such a track image and the experience of the bloodstains investigating coroner crucial and restraint is in addition to the mathematical and analytical methods v. A. Offered.

7 Conclusion for practice

The ballistic workup and calculation of impact injection traces should be performed by an experienced forensic pathologist.

The forensic trail of blood analysis a blow injection track allows the positioning of a bleeding source in the room and a differentiation between a standing, kneeling or bent or lying posture of the victim.

The mathematical calculation of impact injection traces is a partial aspect of the systematic analysis of all existing blood and should be included as such in the assessment of blood trace image.

The results of calculations should always be examined critically; Here the experience of the blood trail appraiser plays an important role.

Compliance with ethical guidelines

Conflict of interest

S.N. Kunz, C. Grove and J. Adamec indicate that no conflict of interest.

This post contains no studies on humans or animals.

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