Chapter 249

Forensic reconstructive hematology: Analysis and reflections on its development and applications in Brazilian forensic cases

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ABSTRACT
Reconstructive Forensic Hematology is the discipline responsible for the morphological study of bloodstains found at the crime scene, to infer the dynamics of the criminal act. This study aimed to conduct a narrative literature review to learn about Brazilian studies in Forensic Reconstructive Hematology. A search was performed in the Google Scholar database with the combination of descriptors: "bloodstains", "hematology", "forensics" and "patterns". No specific period was estimated and only national works that were available in full and that dealt with theoretical or practical works on reconstructive Forensic Hematology were selected. It can be seen that most of the works included case reports of police incidents, abstracts or conclusion works, and few experimental or observational works. With this, it was possible to conclude that the discipline is young in the country and needs more research incentives in the area and police appreciation, having the potential to help justice and society.

Keywords: Hematology, Bloodstains, Forensic Sciences, Forensic Medicine.

1 INTRODUCTION

Forensic Hematology corresponds to an important area of Forensic Sciences. According to Barros et al. (2021), "Forensic sciences employ scientific knowledge and various techniques to investigate crimes and other legal matters – civil, criminal or administrative. Its main function is to facilitate investigations related to civil and criminal justice, aiming to clarify issues of the public security system". In this context, Forensic Hematology can contribute a lot.

"Blood is an important biological trace found at the crime scene of a homicide, as its characteristics allow the expert to make valuable assessments" (Botteon, 2018). According to Almeida & Dias Filho (2022), the study of blood is divided into identifying Forensic Hematology, which aims to identify the biological characteristics of blood traces, and Reconstructive Forensic Hematology, which analyzes the characteristics of blood traces to infer the dynamics of the fact.

Forensic Reconstructive Hematology is the discipline responsible for studying the morphology of bloodstains found at crime scenes to infer the dynamics of the criminal act (Silva et al., 2021). The study

of bloodstain patterns involves knowledge from different areas, such as physics, biology, and mathematics, and its analysis can be done indirectly through photographs of a crime scene, analysis of the scene itself, or both (James, Kish & Sutton, 2005).

Bloodstain pattern analysis includes impact angle analysis; calculation of the area of convergence and origin to reconstruct the relative position between victim and aggressor; the inference of probable movements between aggressor and victim and eventually the probable instruments used during the criminal act (James, Kish & Sutton, 2005).

Through morphological analysis, it is possible to assess whether the event is a homicide, suicide, or accident, and serve as a basis for comparing any testimonies made during the process (Silva et al., 2021). It is also possible to obtain an estimate of the number of blows inflicted on the victim, if there was any kind of displacement in the location of objects or people and if there was a change in the position of the victim (Gomes, 2019). The central procedure for performing all these analyses is the classification of bloodstains (Bevel & Gardener, 2008).

According to Dias Filho et al. (2022), there are many classification systems used and proposed in the literature. Some examples of pattern classification are cast-off (blood thrown from an object), transfer pattern (blood mark in the shape of an object on a surface), drip (from an individual or object), and pool (accumulation of blood by gravity) (Bevel & Gardener, 2008). Other nomenclatures and classification methods can be found, such as the one based on the flow of events diagram that tries to infer actions in the investigated fact by combining classifications already recognized as cast-off with the diagram (Wonder, 2007).

Another form of classification is based on the relationship between speed and strength, in the so-called impact patterns, which can be low impact, medium impact, and high impact (James, Kish & Sutton, 2005). In Brazil, studies in Forensic Hematology are scarce (Dias Filho & D´Ávila, 2022). According to the Institute for Applied Economic Research (Ipea, 2021), the number of homicides in the country in 2019 was 45,503, showing how frequent this type of trace is in crime occurrences.

In Brazil there is no specific legislation regarding the regulation of this specialty; it is exercised by official experts through obtaining public office. Experts are responsible for carrying out forensic examinations and any expertise required by the competent authorities to prepare and sign an expert report (Vanrell, 2019).

This study aimed to carry out a narrative literature review to learn about Brazilian works in Forensic Reconstructive Hematology and to provide a reflection on the discipline in the country.

2 METHODOLOGY

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3 RESULTS AND DISCUSSION

Publications of theoretical works, articles with experimental research, case reports, observational research, and some institutional advances were found, presented in Chart 1.

Table 1 – Summary of articles selected for review.

Authors publication year	Job category	Main goal
	Theoretical work	
Guazzelli (2018)	Theoretical work/Review article.	Evaluate how the detailed analysis of bloodstains can help the criminal expert in elucidating the dynamics of the facts of a crime when examining a location.
Gomes (2019)	Theoretical work/Specialization Completion Work/Revision.	Promote a brief criminological analysis of the offender until the classification of bloodstains through Forensic Hematology
Silva (2021)	Theoretical work/Review article.	Rebuilder.
Alves & Boaventura (2021)	Theoretical work/Review article.	Carry out a study on the importance of the interaction of drops of blood subject to the influence of vortices generated in firearm shots.
	Experimental Research/Article	
Finez & Chiarato (2019)	Experimental research/Article.	Perform an experimental procedure related to dripping blood perpendicular to a fixed height, on different surfaces, and analyze format, diameter , and the basic characteristics when touching a surface.
Dias & Carvalho (2018)	Experimental research/Article.	To present a comparison between the results obtained for angles of impact of blood spatter obtained through the traditional method of measuring the stains and calculating the angle and through a proposed method of digital processing of images made from the blood stains.
Godói, Quiles & Rocha (2011)	Experimental research/Article.	Create solutions for the classification and evaluation of bloodstain patterns using computer vision and machine learning techniques.
	Case report/Expertise/Congress summary	
Mamedes, Nóbrega & Eloy (2017)	Case report/Expertise/Abstract in congress.	Clarify the dynamics of the crime and, mainly, determine the position of the victim about the aggressor, to corroborate or refute the possible investigative theses.
Botteon (2018)	Case report/Expertise/Abstract in Congress.	To report the analysis of bloodstains present in a place classified as disreputable, in a case of consummated homicide, perpetrated using firearm projectiles.
Anjos Júnior (2019)	Case report/Expertise/Abstract in Congress.	Carry out an analysis of bloodstains at a scene of feminicide to reconstruct possibly criminal events from photos captured at the scene of the fact.
Almeida (2021)	Case report/Expertise/Abstract in Congress.	Demonstrate the importance of crime scene analysis from the MS perspective associated with necroscopic examination information, and genetic and residuographic profiles for confirmation or refutation of suicide or homicide hypotheses in cases involving the death of a woman reported by family members as missing.
	Observational research	
Gamba et al. (2016)	Observational research/Dentistry/Bloodstains/Article.	Check the dentist's level of knowledge about aspects related to the forensic effect of scenographic blood on

		different surfaces, as well as confirm the reproducibility of stain models, varying angles of incidence, and surfaces.
Carneiro & Botteon (2021)	Observational research/Dentistry/Bloodstains/Article.	Carrying out an epidemiological analysis of homicides in Brazil, from the perspective of the analysis of bloodstain profiles, added to a multidisciplinary approach in the scientific investigation of crime.
	National advance	
Machado (2018)	National advancement/Article/Book Review.	Conduct a book review: "Bloodstain Profiles: from the crime scene to the Preparation of the Report."
São Paulo, (2021)	National advancement/Ordinance of the Scientific Police of the State of São Paulo.	Establish a standard classification for standardizing the report in the analysis of blood stains.
Ursini et al. (2022)	National Advance/Book	Unravel the analysis of bloodstains.

Source: Own elaboration.

Theoretical works

According to Guazzelli (2018), Forensic Hematology, nationwide, has little literature when compared to other countries, such as the United States. The author exemplifies some national criminal cases in which experts used morphological analyzes of bloodstains, which were fundamental to understanding the dynamics of the crime. Gomes (2019) also emphasizes the importance of this specialty, listing some possibilities with its application, such as positioning the victim, confirmation of weapons used, comparison of testimonies of those involved with the analyzed spots, and general dynamics of the facts that occurred.

Silva (2021) presents a theoretical review work on the interference of the ballistic vortex (gases that escape in firearm shots) and interfere with the drops of blood, and the author calls attention to this aspect being considered for the analysis of bloodstains during expertise, being crucial the knowledge of the expert about this type of interference for these standards. Alves & Boaventura (2021) suggest that the use of these analysis methods must be encouraged in Brazilian expertise, and also that the judiciary allocates resources for the area to be developed. Bevel & Gardener (2008) report that the theory that supports the analysis of blood stains is linked to fluid dynamics, where external forces such as surface tension, air resistance, and gravity are physical conditions that will act together to form patterns of blood stains. Thus, they are reproducible, having the potential to prove not only the possible mechanisms that will lead to such a pattern but also to contextualize them about other traces of the crime scene. They corroborate the conclusions of the Brazilian theoretical works presented, concerning the importance of the dynamics of crime, institutionalization, and investment in knowledge.

Experimental research

A work involving practical research issues in the study of bloodstains is that of Finez & Chiarato (2019). The authors carried out a study of dripping patterns by reproducing experiments with a fixed height, using different types of surfaces (cardboard, styrofoam, floor, wooden floor, marble, and sheet) to analyze the diameter and observable characteristics. The authors warn about the importance of a single nomenclature for the classification of blood traces, and state that in Brazil this type of study is still very restricted, due to a lack of investments. The lack of a standard classification is not just a Brazilian problem

but also occurs in many countries. Nogueira's dissertation (2013) brings a literature review evaluating the main classifications used by blood analysis professionals, weighing points of equality and differences in each classification taxonomy. Thus showing that Brazilian researchers are also aware of this issue.

Godói, Quiles & Rocha (2011) present a proposal for the creation of a computational tool based on computer vision and machine learning that can help in the process of classifying bloodstain patterns using digital photographs. According to the authors, this tool could help minimize context bias at the crime scene. Two North American works that emphasize the production of digital photographs are those by Attinger et al. (2018), who produced impact spatter bloodstains for teaching and research, and by Attinger et al. (2019), who produced gunshot spatter patterns. Both kinds of research could serve as a basis for training and application in Brazilian expertise and the reproduction of experiments in laboratories. The use of computational tools has been observed in other areas of Forensic Sciences in the national territory, such as Forensic Palynology (study of pollen grains). According to Gonçalves et al. (2022), neural networks for recognizing pollen grains and mapping cities with satellite images have been used in real cases involving expertise in Forensic Palynology.

Dias & Carvalho (2018) experimented with drips of bovine blood on a sheet of paper at different angles, to test the traditional method of measuring the angle of impact (“cord method") with the digital method of image processing, using Matlab® software to calculate the impact angle by measuring measurements from digital images. The authors concluded that image processing procedures are more efficient than the traditional method, in addition to providing faster analysis. The use of image processing techniques has been researched by foreign authors, as in the work of Arthur et al (2017), in which the authors propose a methodology with the combination of various image processing techniques using Matlab® software to characterize bloodstain patterns, thus presenting proposals to minimize subjectivity, improve the measurement of patterns for their eventual classification. With this, it is evident that the use of these techniques in Brazilian expertise is a technological advance to be considered both in the field and in research, and must be replicated in the field and laboratory. Also, the satisfactory use of images has been reported in Forensic Dentistry which, according to Barros et al. (2021), is a useful tool for human identification, providing faster, more objective, and efficient expertise. Therefore, the use of images in general in Brazilian forensics should be used and improved. Not only in forensics but also in the teaching of Forensic Sciences in general, the use of technologies such as software, and 2D and 3D images, can be effective for learning. According to Roncato et al. (2022), it was effective in teaching human anatomy in health courses. In addition, it is a fundamental area for human identification and forensic sciences.

Case reports

Mamedes, Nóbrega & Eloy (2017) present a case report of an expert report by the scientific police of João Pessoa -PB, of homicide by firearm in which rope techniques were used to infer the relative positioning of the victim and the aggressor. The technique analysis was crucial to understanding the

dynamics of the criminal event.

Botteon (2018) presents an expert report of a homicide case in the interior of the state of São Paulo, in which the preservation of the scene was impaired, and the analysis of bloodstains helped to reconstruct a good part of the dynamics as the victim's position at the time. homicide and accidental traces that were not connected with the occurrence, highlighting the analysis potential of Forensic Reconstructive Hematology.

Anjos Júnior (2019) presents the report of a case of feminicide that occurred in the state of Amazonas, in which the police authority requested the analysis of bloodstains to help in a conflicting statement, using digital photographs with photogrammetry techniques for analysis of the stains. The importance of using digital image processing techniques is reported by Canadian authors Boos et al. (2019) in a study of the characteristics of dripping patterns about environmental variables, where digitized data of dripping patterns were produced with the subsequent possibility of digital qualitative and quantitative analysis for a better understanding of the mechanisms that produced them. The use of new technologies in forensic expertise has been observed and according to Silva, (2020), several computational tools have been incorporated into Forensic Sciences, consolidating yet another area - the so-called Digital Forensic Sciences or Forensic Computing. Almeida (2021) reported the case of an investigation that took place in the interior of the state of São Paulo, where the analysis of bloodstains was crucial to assess whether the death was homicide or suicide. According to Vanrell & Scaglia (2019), this important process implies the legal diagnosis of death, and bloodstains can eventually bring invaluable subsidies for research concerning this legal issue of death. Therefore, accurate knowledge of this type of trace is crucial.

Observational research

Gamba et al. (2016) bring research into the scope of Forensic Dentistry, where patterns of bloodstains (dripping, dripping, spreading, puddle, impregnation) were reproduced on fabric and paper surfaces with scenographic blood. A questionnaire was applied to verify the knowledge of dentists on the subject. The authors concluded that the dentists who participated in the research had partial knowledge of the subject. Forensic dentistry plays a fundamental role in cases of human identification (Gioster-Ramos et al., 2021), and dentistry professionals need to be aware of different forensic aspects and possibilities.

Carneiro & Botteon (2021) present an epidemiological overview of homicides in Brazil from the perspective of bloodstain analysis, exemplifying through some case studies that it was possible to establish the victim's positioning elements, movements that were performed, whether the scene was changed and even the authorship of the crime. Epidemiological studies can be of great value to forensic sciences in general, as Leite (2022) concluded that the following areas can be covered: Forensic Toxicology in establishing a causal link, suicide with knowledge of the characteristics of victims, incidence and common aspects of a certain region, traffic accidents, domestic violence, thus constituting forensic epidemiology, which for the study by Carneiro & Botteon, (2021) about bloodstains was no different and that such

knowledge should be aggregated and applied in the reasoning of the bloodstain analysis.

Some advances in the national territory

An important work for the Brazilian context on the subject, according to Machado (2018), is the book "Perfis de Manchas de Sangue: Do Local de Crime à Elaboration of the Report" by the federal criminal expert Antônio Augusto Canelas Neto, where the author presents the apparatus of this type of expertise and examples of cases in a national context. Another national book on the subject is that of Ursini et al. (2022), entitled "Forensic Hematology: from identification to the analysis of Bloodstains", which brings together examples of the application of methods and techniques in the analysis of bloodstains applied to Brazilian expertise. Regarding basic books, Brazil is still taking its first steps in publishing Forensic Reconstructive Hematology. A vast North American literature can be listed, according to James, Kish & Sutton, (2005): 1989 Interpretation of Bloodstain Evidence at Crime Scenes Published; 1990 Bloodstain Pattern Analysis—Theory and Practice Published; 1993 Bloodstain Pattern Analysis in Violent Crimes Published; Bloodstain Pattern Interpretation Updated to Bloodstain Patterns, among others. However, the national material found is based on a large part of North American publications, making it clear that there is already some institutional consolidation of the discipline. This shows that Brazil is moving slowly but in the right direction.

A considerable advance for the area occurred in the Technical-Scientific Police of the State of São Paulo, which established a Commission for Expert Analysis on Blood (CAPS) (SPTC Ordinance No. for the Brazilian reality. Subsequently, Ordinance SPTC nº 173, of August 13, 2021, was published, which described the classifications of the standards that must be added to the expert technical report of the police of the state of São Paulo (São Paulo, 2021). The first attempt to institutionalize the discipline by the São Paulo Scientific Police, with the discussion of the adoption of a standard nomenclature for the issuance of expert reports involving traces of blood, is in line with international studies and discussions, such as James, Kish & Sutton, (2005), with the suggestion of classification by speed; by Wonder, (2007), with the flow of events diagram for inference of actions; with Bevel & Gardener, (2008), based only on the first observable characteristics and only later inferring the bloodstain formation mechanisms and also on later works, such as Nogueira (2013) to analyze differences and convergences of each method of classification. Thus, looking for ways to institutionalize, research, and promote an area of Forensic Sciences that is so necessary for a country with high rates of violence, in which the hematic trace is so present.

4 FINAL CONSIDERATIONS

Considering the presented scope of Forensic Reconstructive Hematology at the national level, it can be considered that it is still in the initial process of development in the country. The expertise of the state of São Paulo has been advancing in terms of structuring and standardizing the discipline, with the proposition of a standardized nomenclature for preparing the report. In the works analyzed, there are studies

of specific cases in the expertise of the state and federal police, communicated as a way of showing the importance of the application of this area.

Despite this effort, the number of national works found dealing with research in Forensic Reconstructive Hematology was negligible, considering the potential of the area presented by the authors in the case studies, and the possibilities of working with new technologies, such as image processing, algorithms machine learning, digital photography, photogrammetry, etc.

Therefore, it is essential in a country like Brazil, which has high rates of violent crimes, that public policies be created to encourage teaching, research, and application of this specialty that encompasses Forensic Sciences, investing in new technologies so that scientific police can exercise Forensic Reconstructive Hematology with expertise, and thus contribute with technical reports that will enhance the importance of this trace, contributing to justice and society. It can be suggested that more research be carried out on national soil, especially experimental ones involving the use of digital photographs, photogrammetry, image analysis software, and 3D scanning. More specifically, we suggest experimental work with digital photographs of bloodstains for quantitative analysis of patterns through image processing methods.

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