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Article

Haemorrhagic Artefacts Produced by Ant Activity on Human Cadavers in the Early Post-Mortem Period

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Abstract: Forensic entomology is primarily focused on using carrion blow flies and beetles (Diptera and Coleoptera) to estimate the time since death. However, insect artefacts, such as footprints, defecations, regurgitations, and splatters are also considered within the disciplines of bloodstain pattern analysis (BPA), and ants (Hymenoptera: Formicidae) have been studied in forensic pathology for their potential to alter bodies. Although ant activity has been mostly reported as "dry marks" (abrasions) on decomposing bodies, their colonisation of congested or hypostatic anatomical regions can produce alterations that mimic active or recent haemorrhages. Therefore, if a body exhibits external haemorrhage/s without any apparent origin, artefacts caused by insects, such as ants, should be considered. This study describes ten cases of post-mortem ant activity observed in the Andaman and Nicobar Islands (India), and analyses the resulting external haemorrhagic artefacts, which exhibit different patterns of morphology, distribution, and location. The study proposes a classification system to aid in identifying bloodstain patterns caused by ant activity, assisting in determining the mechanism/s of the lesions, the original position of the body, and any subsequent interactions with the surrounding environment. Ultimately, this classification can improve the accuracy of reconstructing the events that occurred during the early post-mortem period, as well as the circumstances surrounding death.

Keywords: bloodstain pattern analyses (BPA); forensic entomology; insect artefacts; external haemorrhage; ant bites

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1. Introduction

The process of decomposition of human cadavers in a temperate terrestrial environment is often mediated and facilitated by the presence of macro- and micro-scavengers [1]. Arthropods, especially carrion insects such as blow flies, flesh flies, and coffin flies (Diptera: Calliphoridae, Sarcophagidae and Phoridae), are the most prevalent and active on remains in the first stages of decomposition, whether outdoors, indoors, or in limited-access spaces, such as trash bins and shallow burials [2]. Depending on the type of surrounding environment and the time elapsed since death, the colonisation of a cadaver may become more complex. Insects can feed directly on the corpse (necrophagous species), alongside species with predatory or parasitic habits, adventive and opportunistic species interested in feeding on either the body or different colonizing species, or use the body as a shelter [3]. If correctly collected, identified, and aged according to environmental parameters, the insect assemblage associated with a cadaver can be used successfully by forensic entomologists to estimate the time since death (also known as post-mortem interval, PMI), obtain toxicological and biomolecular data, and provide evidence of possible secondary disposal [4–6]. However, insect-feeding activity and insects' high mobility at the death scene can cause artefacts that, if misinterpreted, could affect the overall course of the investigation. Insects at the death scene have been described as being able to produce different types of bloodstains, either ex novo (e.g., regurgitation and faecal elimination of ingested body fluids), or as modifications of already existing bloodstains (e.g., transfer and translocation of body fluids) [7]. Alterations of both soft and hard tissues caused by species of ants, beetles, cockroaches, wasps, termites, moths, and crustaceans have been described with regard to human cadavers [8]. Ants (Hymenoptera: Formicidae) feed on organic waste, other insects and carrion, and have been described in the context of forensic casework involving both cadavers and carcasses, as well as in decomposition/insect succession trials performed around the world [8]. While generally more present in suburban and outdoor environments, ants are also found at death scenes occurring in city apartments, especially in the case of poor hygiene and in the presence of trash and food scraps [9–11]. Ants can be present at all stages of decomposition, although they are typically observed shortly after death or during the early PMI [12]. In the southern parts of the United States, the red imported fire ant (RIFA) *Solenopsis invicta* (Smith) (Hymenoptera: Formicidae) has reached bodies placed in the external environment within 10–20 min [13]. Ants have been described as having different roles in the process of decomposition, as well as different interactions with bodies [14]. They have been observed predating fly eggs and larvae, and producing nests near/under the body [2]; constructing soil structures near the natural orifices, blocking access to typical necrophagous insects, causing delays to the decomposition process [15,16]; feeding and foraging, starting from the body natural openings (cloaca, mouth, nasal and ocular orifices) and moving inward [17]; and producing lesions to the body surface using their strong mandibulate mouth parts designed to cut, tear, crush, and chew the food items [18]. The presence of ants near a corpse can disrupt the abundance of other species and hinder other colonisations by preferentially feeding on distinct life stages or species. Therefore, it is crucial to document the presence of ants in the vicinity of a cadaver, and collect samples to be stored for future morphological or molecular identification [19]. The feeding action of ants can cause multiple, irregular, serpiginous, and scalloped skin abrasions, as well as small punctate or multifocal areas of skin loss and striated lacerations, with limited or no bleeding [8,20]. If clothing obstructs the ants' movement, such artefacts can be found along the clothing edges, and in some circumstances, artefacts may provide clues about the original state or location of the body [21]. For example, the favourite site of colonisation of RIFAs is the skin–clothes interface. In many instances, RIFAs specimens are transported inside the body bag together with the clothed body, and in the time between the observation at the death scene and the autopsy, they can alter the body preservation despite the low temperatures kept in the mortuary [13]. Generally, the absence of bleeding connected to skin abrasions is used to differentiate them from ante-mortem lesions; however, and more rarely, bleeding has also been observed post-mortem on fresh cadavers, especially when abrasions occur in congested or hypostatic anatomical regions [8]. The observation of ant artefacts is facilitated on light-skinned and relatively fresh cadavers, and on experimental animals with light skin and thin hair coverage. Upon arrival of the investigators, ants may have left the body or may be overlooked, non-photographed, or non-collected, as only fly larvae are typically considered to hold forensic relevance. Without the presence of ant samples as evidence, the discovery of a body with such artefacts may appear suspicious, and the lesions may be misinterpreted as being caused by blunt force, abrasions caused by glass or grit, burn scars due to acid or cigarette ends, or manual or ligature strangulation marks [8,22]. In such cases, the confirmation of ant activity on the body should be sought from an expert entomologist, working in collaboration with a forensic pathologist. This task is facilitated by several scholarly articles describing body alterations produced by ants [8,10,20,22]. However, the majority of the available literature in the fields of forensic pathology and entomology is primarily focused on "dry" alterations, that is, alterations that are non-haemorrhagic in origin, or when blood has been washed away. In contrast, multiple minute haemorrhages caused by post-mortem ant activity are only briefly mentioned, and not characterised [8]. Post-mortem haemorrhages caused by ants are also rarely mentioned in the context of bloodstain pattern analyses (BPA), a discipline that studies the haemorrhage patterns on the body of a victim and of the suspected perpetrator/s, and on objects present at the death scene, in order to reconstruct the dynamics of the death event [23,24]. While insect footprints, defecations, regurgitation, and splatter are commonly considered insect artefacts in BPA due to their connection with blood, traumatic alterations of the body caused by insects that result in haemorrhages in the form of blood droplets, drops, stains, striped trails, and pools are often overlooked. This can lead to potential misinterpretations of the evidence [7]. This study provides a comprehensive description and categorisation of haemorrhages produced by ants on fresh human cadavers which, to the authors' knowledge, has not been previously documented. Details of ten forensic cases with associated external haemorrhagic artefacts and their patterns are reported. This information is highly valuable to experts in forensic entomology, pathology, and BPA, as well as to crime/death scene investigators, as it can assist with the interpretation of bloodstain evidence, and create a comprehensive record of the case. This can be used in conjunction with video and photographic materials to support the subsequent forensic analyses focused on, for example, the original body position of the cadaver, the cause, and the time of death. This observational study contributes to a better understanding of the role of ants in forensic investigations, and highlights the importance of considering all possible causes of bloodstains at a crime/death scene. By providing a greater understanding of the activity of ants on human remains, this study contributes to the development of forensic science, with crucial implications for the investigation of criminal cases.

2. Materials and Methods

Ten cases of human cadavers presenting external haemorrhagic artefacts with different patterns, observed in association with the presence of ants, are reported in Table 1. The cases occurred between 2015–2021 in the Andaman and Nicobar Islands, Union Territory (India), specifically on the South Andaman district (Figure 1). All cases were investigated by the Mobile Forensic Unit of the Forensic Science Laboratory, which operates under the purview of the Police of Andaman and Nicobar Islands. Upon initial examination of bodies at the scene, external haemorrhagic artefacts were observed despite the absence of any evident lesion, blood flowing from natural body openings, or any blood transfer from distinct sources. Presumptive analyses of the blood were carried out at the scene using the BLUESTAR® IDENTI-HEM Rapid Test for the detection of human hemoglobin. The presence of ants in association with the body was documented in the crime/death scene report and, where possible, through photographic evidence taken with a Nikon digital single-lens reflex camera (DSLR camera, make Nikon, model D 5100, AF-S DX NIKKOR 18–55 mm F/3.5–5.6 G VR). Autopsies were performed on each body, and based on the forensic pathologist's assessment of the macroscopic appearance of the lesions associated with external haemorrhagic artefacts, no additional analyses (such as histological, histopathological, or immunohistochemical) were required. Toxicology analyses were only carried out if deemed necessary, for example when the involvement of alcohol or drugs in the cause of death was suspected. The estimation of the time of death was based on circumstantial evidence (e.g., the last time the person was seen alive) and on the cadaver's thanatological signs, with a particular focus on rigor mortis (stiffness). Livor mortis (cadaveric lividity) was only considered in its anatomical distribution, especially in relation to the position of the body, but its mobility, or fixity, was not taken into account, resulting in less meaningful conclusions regarding the PMI. Similarly, the algor mortis (cadaver body temperature) was reported only as 'cooler than the normal body temperature' without comparison to the environmental temperature and without using calibrated thermometers or data loggers.

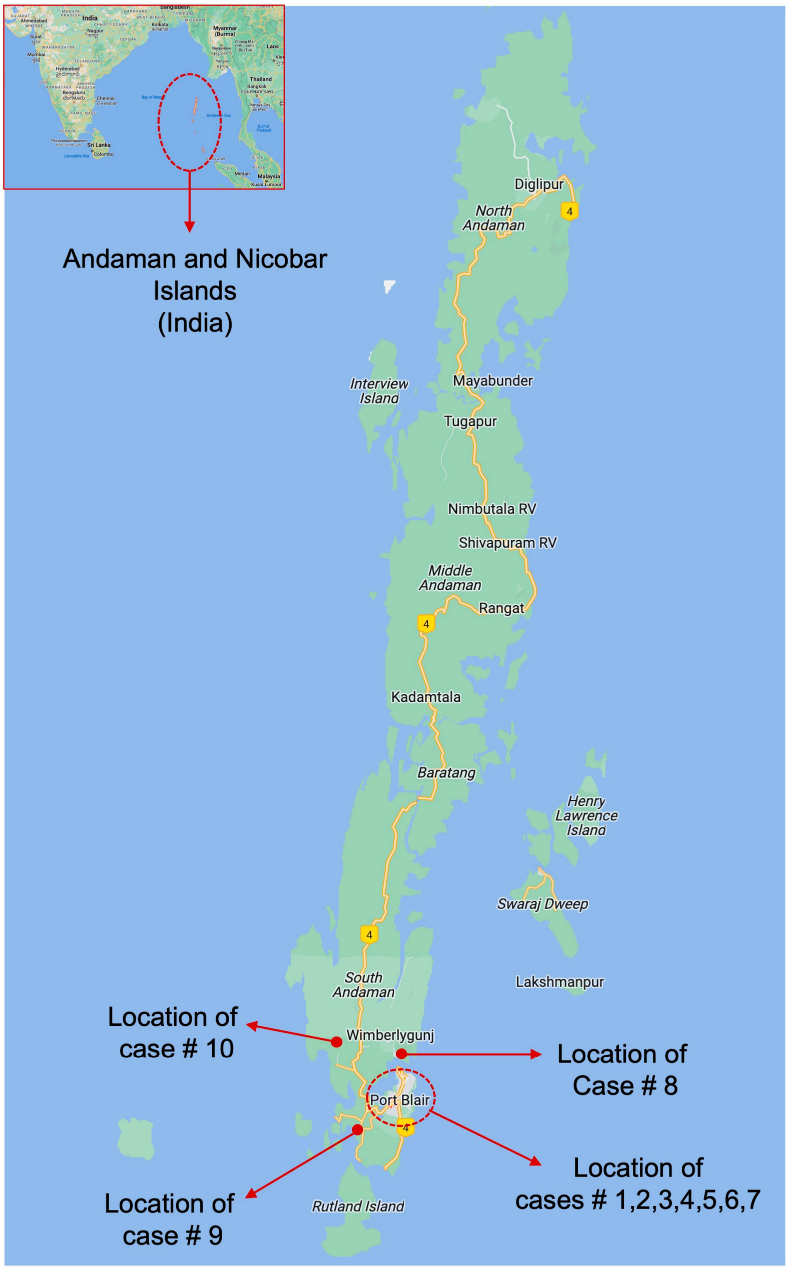


Figure 1. Locations of ten cases of human cadavers presenting external haemorrhagic artefacts observed in ant-associated incidents in the South Andaman district of the Andaman and Nicobar Islands, India, between 2015–2021. The cases and the case numbers are reported in Table 1.

3. Results and Discussion

After death, the blood circulation ceases due to the arrest of the cardiac muscle. As a general rule, blood completely coagulates after approximately twelve hours, and loses any possibility of movement (fixed lividity, or livor mortis) except due to gravitational pull. Several factors, such as temperature, humidity, body size and weight, clothing, presence of drugs (e.g., anticoagulants), underlying health conditions (e.g., dehydration), and the causes of death (e.g., asphyxia) can influence the blood coagulation, and, as a consequence, the necessary time to achieve lividity fixation [25]. While blood is still fluid, insects can produce lesions to the cadaver's soft tissues, such as tiny abrasions or, more rarely, lacerations, causing minute haemorrhages. The appearance of such haemorrhages may be influenced by the listed factors, as well as by post-mortem variables, such as the position of the body, the decomposition stage, and the timing of recovery. In fact, blood can retain the original location, dry out, or be washed away. The insects that caused the lesions may still be active on the body, may have left it, and/or may still be present in the surrounding environment. Ants can cause haemorrhages on fresh cadavers by biting the skin and the mucous membranes (mucosae) with their sharp mandibles [18,26]. The species of ants that cause this type of injury are often correlated with the biogeography of the surrounding environment, and if collected and correctly identified, they can confirm the body provenance.

This study reports ten cases of external haemorrhage caused by ant activity on human cadavers that occurred in various locations throughout the South Andaman district, which are part of the Andaman and Nicobar Islands (India) (Figure 1, Table 1). All cadavers were found in the fresh stage of decomposition, with an estimated PMI between 4 h and one day. With the exception of the cause of death (e.g., asphyxia), no ante-, peri- or post-mortem factors potentially influencing the fluidity of blood were identified, either at the autopsy or through ancillary investigations.

Andaman and Nicobar are a chain of 836 islands, islets, and rocks located in the Bay of Bengal in the Indian Ocean. The islands have a tropical maritime climate that is strongly influenced by the Indian Ocean, with temperatures ranging between 23 °C and 30 °C on average, with peaks of 34 °C in April and high humidity throughout the year, ranging from 60 to 90 percent. The South Andaman district is characterised by its dense tropical forests, mangroves, and extensive coastlines. Port Blair, the main city of South Andaman and capital of the Andaman and Nicobar Islands, is located on a flat plain of the south-eastern coast, which is fringed by a narrow beach and a dense tropical forest [27]. The district has a population density of approximately 350 people per square kilometer, with Port Blair being the most densely populated area. The living conditions of some areas in the South Andaman district are relatively poor, with limited access to basic amenities such as clean drinking water and adequate healthcare. Alongside natural death and fatalities caused by accidents, according to data published by the National Crime Records Bureau (NCRB) in 2021, the rate of suicides in India increased from 9.9 to 12.0 between 2017 and 2021. The Andaman and Nicobar Islands recorded 159 suicides in 2021, compared to a total of 164,033 in India, making the suicide rate in the Andaman and Nicobar Islands 39.70, much higher than the all-India average of 12.0 [28]. The number of reported homicide cases in the Andaman and Nicobar territory fluctuated substantially in recent years, but tended to increase between 2016 and 2021, with 14 cases reported in 2016, 9 in 2017, 11 in 2018, 13 in 2019, 5 in 2020, and 16 in 2021 [28,29].

In India, there are currently over 100 known genera of ants [30], with several species known for their aggressive behaviour and venomous bites, such as the Asian weaver ant (*Oecophylla smaragdina*, Fabricius) (Hymenoptera: Formicidae). In the Andaman and Nicobar Islands, 40 genera of ants have been reported [31]. Although some zoological surveys were conducted in the islands in 1976 and in subsequent years [31–36], recent studies on the current status and distribution of insect species in this area are lacking, and Formicidae remain largely neglected [31].

The ant-induced alterations observed on the human cadavers in this study were predominantly found on exposed soft tissues and the edges of clothing, consistent with reports in the published literature [8,20,22].

The overall appearance of the haemorrhagic artefacts produced by an ant-biting action is due to several factors [37]. Firstly, the basic physics of blood, including its fluid properties, surface tension, and coagulation, play a significant role in shaping the haemorrhagic artefact and the resulting bloodstain. Additionally, the size and depth of punctures made by ant mandibles vary according to ant species, the number of specimens, their behaviour, the energy of the bite, and the anatomical region of the body [18]. The flow of blood from these lesions is further affected by ante-, peri- or post-mortem conditions (e.g., causes of death involving asphyxia) that may alter the blood fluidity. It is also influenced by the position of the body, the presence and type of clothing, as well as the biological tissues and anatomical structures (e.g., hairs) surrounding the bite. Furthermore, other factors, such as post-mortem displacement and repositioning of the body, the PMI, the timing of recovery and environmental factors, such as rain, can all contribute to the final appearance of the bloodstain pattern initially caused by the ant bite. Understanding these factors can aid in interpreting the haemorrhages and the resulting bloodstains, providing valuable information to forensic investigations.

A classification of the bloodstain patterns observed in the present case studies is outlined below.

3.1. Droplet Pattern (Minute Haemorrhages with Droplet-Shaped Pattern)

In BPA, droplets can be formed by various mechanisms, such as blood dripping, spattering, or expirating, and their features can vary depending on the velocity, angle, and height of the source, as well as properties of the target surface [23,24]. In addition, blood droplets can result from the abrasions of ant mandibles on the skin or mucosal surfaces of a cadaver, and the appearance of droplets can reflect the extent of insect feeding activity. For droplets to maintain their shape, they need to form on a flat surface parallel to the ground and exposed to the air. Therefore, the presence of droplets suggests that the body position has remained undisturbed since the insect activity, providing a stable flat surface for the formation and maintenance of such patterns. Droplets have been observed on the protruded tongues of cadavers in complete (full) hanging, that is fully suspended without touching the ground [25,38] (Table 1, Figure 2). The protrusion of the tongue is a common occurrence in cases of asphyxiation by hanging or strangulation, and it is caused by the pressure applied to the neck's soft tissues and blood vessels. The soft and exposed tissues of the protruded tongue may attract ants, and the pressure on the surrounding tissues and blood vessels may result in external haemorrhages.

Figure 2. Droplet pattern observed on the tongue of a body found outdoors, fully hanging from a tree (Table 1, case 5).

Droplet patterns have also been observed in cases of incomplete (partial) hanging, where anatomical regions of the body, usually the lower limbs, are in contact with the ground. Depending on the final position of the body, which can range from sitting, stooping, kneeling, and lying, droplets can be found in different anatomical regions, as long as they are free from clothing, and are flat and parallel to the ground. Examples are provided in Figure 3a, where the individual's feet were touching the ground, and Figure 3b, where the almost fully prone position of the body allowed droplets to be produced in the gluteal region.

(**a**) (**b**)

Figure 3. Droplet pattern (**a**) observed on the feet of a body found indoors, partially hanging (Table 1, case 1); (**b**) mixed with stripe pattern observed on the gluteal region of a body found indoors, partially hanging (Table 1, case 7).

Furthermore, Figure 4 shows that the presence of body hair can help maintain the droplets' shape and prevent dripping.

Figure 4. Droplet pattern mixed with stripe pattern observed on the scrotum of a body found indoors, partially hanging (Table 1, case 7).

3.2. Stripe Pattern

Stripe patterns are a common occurrence in hanging cadavers (Figure 5), and in BPA they are described as a linear arrangement of bloodstains in a series or a row. When blood drips or is projected onto a surface in a direction perpendicular to the surface, elongated bloodstains can result in a stripe pattern that is narrower at its ends and wider in the middle section. The length, width, and distribution of the stripes can provide important information for reconstructing the originating event/s [23,24].

Figure 5. Stripe pattern observed on the lower limbs of a body found outdoors, hanging from a tree (Table 1, case 10).

Stripe patterns can also be caused by ant bites produced directly, or following the break of the superficial tension of droplets, which causes the blood to flow along the gravitational pull. As a result, a mixed pattern of droplets and stripes may be present (Figures 3b, 5 and 6).

Figure 6. Stripe pattern mixed with droplet pattern observed on the lower limbs of a body found indoors, partially hanging (Table 1, case 1).

The position of the body, as well as the initial location of ant bites (Figure 7a), can influence the shape and the distribution of the stripe pattern (Figures 5 and 7b). Additionally, clothing or other items in contact with the body can also affect the stripe pattern, as some blood may be absorbed, resulting in saturation stains.

(**a**)

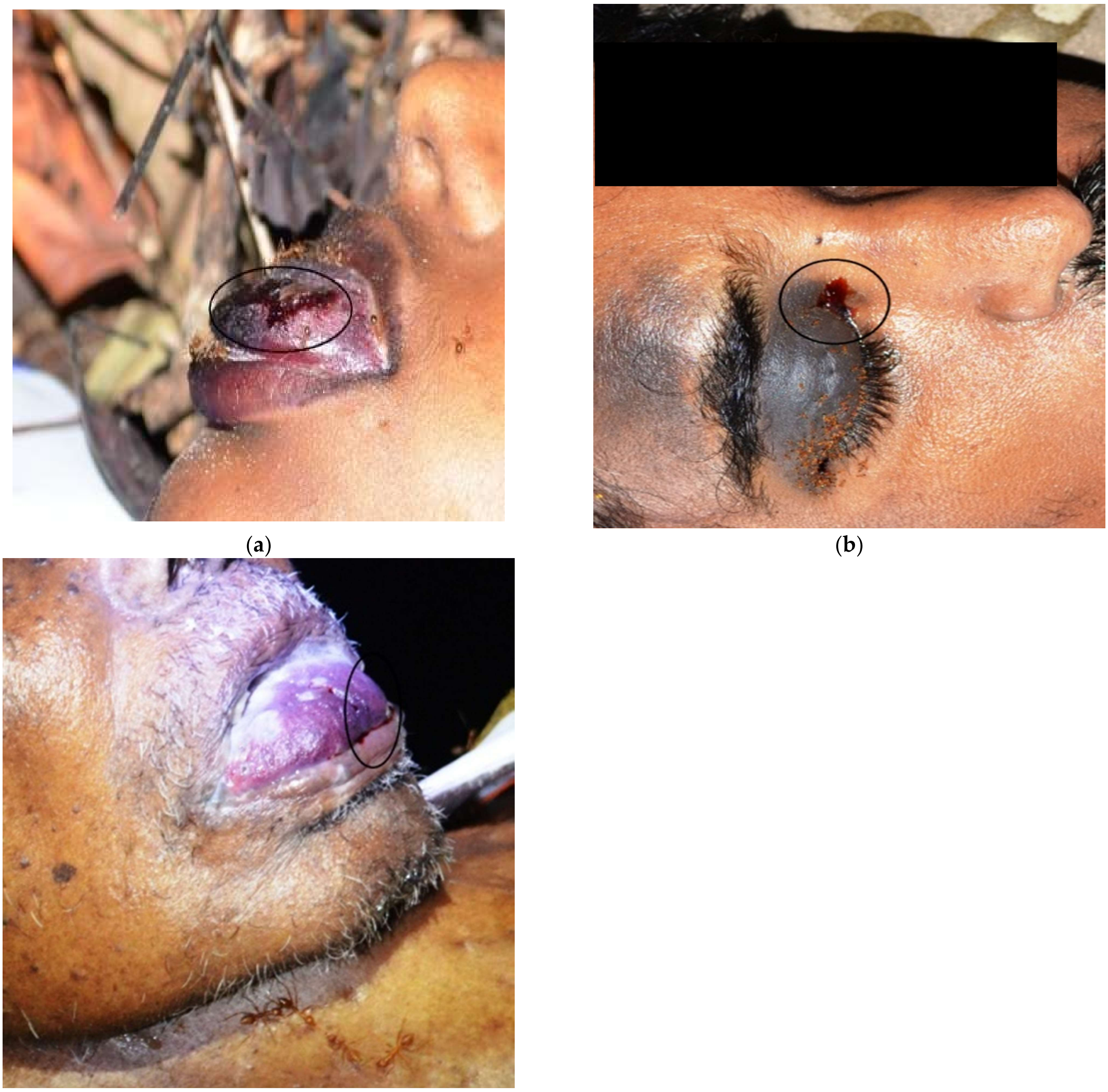
(**b**)

Figure 7. Stripe pattern (**a**) and ants observed on the scrotum of a body found outdoors, partially hanging. Stripes are short and close to the initial location of the ant bites (Table 1, case 8); (**b**) observed on the lower limbs of a body found indoors, partially hanging (Table 1, case 9). The clothing shows the presence of saturation stains.

Overall, the presence of a mixed pattern of droplets and stripes can indicate recent insect activity, particularly if the blood is still fresh, and provide information on the original position of the body. A pattern made of stripes distributed in different directions and the presence of saturation stains (Figure 7b) can provide clues about changes to the body position since the time of death.

3.3. Pool Pattern

In the context of BPA, a pool pattern refers to a pool of blood that has accumulated on a surface [23,24]. The appearance of a pool pattern can vary depending on the surface and the amount of blood involved, and can result from different circumstances, such as blood from a wound or pooling due to changes in body position. Analyses of the pool pattern considers multiple factors, such as the shape, diameter, and depth of the blood pool, as well as the texture and the porosity of the surface on which it has formed. This information can provide valuable insights into the nature and timing of the haemorrhage, and can be useful in criminal investigations. When ants are active in a confined area of the body, such as the palpebral commissures or the upper surface of the tongue, they may produce a large number of blood droplets that merge into small pools or large blood stains (Figure 8a–c). Depending on the posture of the body and the area colonised by the ants, the blood pool can be found on the body surface, under the body, or associated with clothing. The pool pattern can be primary or secondary, depending on whether it remains where it was produced by the ants' activity, or if it pooled on a lower surface (e.g., under the body) following gravitational pull. In the latter case, a single stripe from the primary to the secondary area may be present. The presence of a secondary pool may be due to any changes in the position of the body that caused the primary pool to yield to gravity.



(**a**) (**b**)

(**c**)

Figure 8. Pool pattern observed (**a**) on the tongue of a body found outdoors, supine on ground (Table 1, case 3); (**b**) at the internal corner of the right eye of a body found indoors, supine on the floor of an apartment (Table 1, case 4); (**c**) on the tongue of a body found outdoors partially hanging; ants are visible in the neck area (Table 1, case 8).

3.4. Mixed Pattern

In BPA, a mixed pattern exhibits the characteristics of two or more of the other bloodstain patterns, and can occur when the crime/death scene was highly dynamic (e.g., struggle or altercation) or the body was moved early post-mortem, for example by first-aid responders [23,24]. The analyses of mixed patterns can be challenging, but its understanding provides critical information for the reconstruction of the perimortem and early post-mortem events. In this study, mixed patterns were often observed developing as a consequence of natural events (Figures 3b, 4 and 6), and on the posterior body regions of bodies due to non-standard recovery procedures.

Table 1. Descriptions of ten cases of human cadavers presenting external haemorrhagic artefacts observed in association with the presence of ants in the Andaman and Nicobar Islands (India), including date and season of the year, place of discovery, sex and age of the deceased, stage of decomposition and thanatological signs (rigor, livor, and algor mortis), last time the subject was seen alive, cause of death, position of the body, presence of clothing, anatomical region and type of artefact caused by ant activity, bloodstain pattern observed, and case number. The case number is used to map the locations in Figure 1.

Date and Season	Place of Discovery	Sex Age	Stage of Decomposition and Thanatological Signs: RM = Rigor Mortis [1] LM = Livor Mortis [2] AM = Algor Mortis [3]	Last Time Seen Alive	Cause of Death	Position of the Body	Presence of Clothing	Anatomical Region of and Type of Artefact Caused by Ants (HA [4], DH [5])	Bloodstain Pattern Observed	Case #
03.11.2015 Dry season (summer)	Body found indoors, at a house with good hygiene standards	M 30	Fresh RM = full LM = legs AM = cooler than normal body temperature	5 h before the police was informed	Suicide by hanging	Partial hanging, from the ceiling fan of the hall area of house	Yes	HA = lower limbs (Figure 6) HA = feet (Figure 3a) Presence of black ants on eyes, with no HA/DH associated	Mixed, stripe and droplet Droplet nil	1
15.03.2016 Dry season (summer)	Body found outdoors, in an area near bushes alongside a road	M 45	Fresh RM = full LM = back AM = cooler than normal body temperature	Last seen the night before; body found in the morning	Natural death in known history of chronic alcoholism. Alcohol test positive	Supine on the ground of a road side, surrounded by dry leaves	Yes	HA = middle and lower back DH = right arm and hand	Mixed Multiple small abrasions	2
19.03.2016 Dry season (summer)	Body found outdoors, in a forest area	F 16	Fresh RM = full LM = tongue AM = cooler than normal body temperature	1 day before	Suicide by hanging	Supine on ground of a forest area, surrounded by dry leaves	Yes	HA = tongue (Figure 8a) DH = area of the face and neck	Pool Multiple small abrasions	3
11.06.2016 Rainy season	Body found indoors, location in moderate hygiene standards	M 44	Fresh RM = full LM = back AM = cooler than normal body temperature	Last seen the night before; body found in the morning	Natural death in known history of chronic alcoholism	Supine on the house floor, in an apartment located at the first floor of a building	Yes (trousers only)	HA = internal corner of the right eye (Figure 8b)	Pool	4
29.10.2016 Dry season (summer)	Body found outdoors, in a forest area	M 26	Fresh RM = not yet developed LM = back AM = cooler than normal body temperature	5 h before	Suicide by hanging	Full hanging from a tree in an open forest area with low tree density	Yes	HA = tongue (Figure 2)	Droplet	5
12.11.2016 Dry season (summer)	Body found indoors, at a house with moderate hygiene standards	F 65	Fresh RM = full LM = hands and feet AM = cooler than normal body temperature	Last seen the night before; body found in the morning	Suicide by hanging	Partial hanging, from wooden ceiling beam of bathroom area of a house	Yes	HA = lower lip DH = upper lip area	Mixed Multiple small abrasions	6

Table 1. *Cont.*

Date and Season	Place of Discovery	Sex Age	Stage of Decomposition and Thanatological Signs: RM = Rigor Mortis [1] LM = Livor Mortis [2] AM = Algor Mortis [3]	Last Time Seen Alive	Cause of Death	Position of the Body	Presence of Clothing	Anatomical Region of and Type of Artefact Caused by Ants (HA [4], DH [5])	Bloodstain Pattern Observed	Case #
25.04.2017 Dry season (summer)	Body found indoors, at a temporary house with moderate hygiene standards	M 63	Fresh RM = full LM = tongue, hands, and feet AM = cooler than normal body temperature	4 h before	Suicide by hanging	Partial hanging, from ceiling wooden beam of a temporary house (shed made of tin)	Yes	HA = genital area (scrotum, Figure 4);	Mixed, stripe and droplet	7
								HA = gluteal region and proximal medial thighs (Figure 3b)	Mixed, stripe and droplet	
07.05.2018 Rainy season	Body found outdoors, in a forest area	M 83	Fresh RM = in development LM = tongue, hands, and legs AM = cooler than normal body temperature	4 h before	Suicide by hanging	Partial hanging, from a tree in forest area	Yes	HA = genital area (especially scrotum) (Figure 7a)	Stripe	8
								HA = tongue (Figure 8c)	Pool	
18.03.2020 Dry season (summer)	Body found indoors, at a house with moderate hygiene standards	F 34	Fresh RM = full LM = palm of hands AM = cooler than normal body temperature	Last seen the night before; body found in the morning	Suicide by hanging	Partial hanging, from a wooden beam of a house/shed constructed between farms	Yes	HA = lower limbs (Figure 7b)	Stripe	9
								DH = neck and upper back area	Multiple small abrasions	
30.09.2021 Rainy season	Body found outdoors, in a forest area	M 44	Fresh RM = in development LM = palm of hands and soles of feet AM = cooler than normal body temperature	6 h before	Suicide by hanging	Full hanging, from a tree in a forest area	Yes	HA = genital area and lower limbs (Figure 5)	Stripe	10
								DH = area of the face and neck	Multiple small abrasions	

[1] RM = rigor mortis, cadaver stiffness recorded at the time of the arrival of the police at the scene of death. [2] LM = livor mortis, cadaver lividity considered in its anatomical distribution, not in its mobility or fixity. [3] AM = algor mortis, cadaver body temperature documented as 'cooler than the normal body temperature', without using calibrated thermometers. [4] HA = haemorrhage. [5] DH = dry haemorrhage.

4. Conclusions

Ant activity should be considered as a potential cause of haemorrhages when the origin of the lesion is unclear, even in the absence of visible insects. Understanding ant activity on bodies can provide valuable information for reconstructing the events that occurred in both the perimortem and early post-mortem periods.

The proposed classification can aid in identifying and describing ant-produced external haemorrhages, determining the body's original position and potential movement; these provide clues about the cause of death, and contribute to the estimation of the PMI. Such analysis enhances the investigations, and provides a comprehensive understanding of the circumstances of the death event.

It is important to train CSI personnel to recognize the role of ants in forensic investigations, as it is not only blowflies that interact with bodies and provide valuable information. A limitation of this study is the absence of ant collection associated with the cadavers; the lack of recent zoological studies on the identification, distribution, and ecology of ants in the Andaman and Nicobar Islands would have impeded their identification and use for provenance investigation. Another shortcoming of this study is the absence of ant collections associated with the cadavers, along with the unavailability of close-range photographs and written descriptions of the ant bites. However, recently released guidelines for forensic entomologists and their proxies (e.g., pathologist, law enforcement) [39] emphasise the crucial role of detailed documentation and analysis of insect activity in forensic investigations, enabling accurate identification, interpretation, and utilisation of entomological evidence in such contexts.

Accurate crime/death scene reports and comprehensive photo–video documentation are essential before the body is removed. This precaution helps prevent significant changes to the body between recovery and autopsy, which could otherwise introduce confounding factors into subsequent investigations (such as determining the manner of death). Furthermore, it is recommended to collect ants for identification, and to inspect body bags for their presence. Incorporating the role of ants in forensic investigations on human cadavers can lead investigators and forensic scientists to a more complete understanding of the events leading up to death and the early post-mortem period, potentially adding valuable evidence to legal proceedings. Lastly, alongside the forensic pathologists' assessment, the consideration of additional histological, histopathological, and immunohistochemical analyses may enhance the description of the lesion characteristics [40–42]. These analyses can help refine hypotheses regarding underlying pathologies, potential poisonings, exposures to toxins and infectious agents, or even narrow down the timelines of lesion/s development.

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