



Reliability in distinguishing murder from accidental event with current forensic criteria in traumatic head injury

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ABSTRACT

Discovering a body displaying signs of multiple head trauma requires a thorough examination by the forensic pathologist, and a multidisciplinary approach is recommended. However, determining the manner of death is not always possible. We present a case in which the body of a 60-year-old man was discovered lying face down on the floor of his apartment, partially unclothed, surrounded by blood and vomit, and presenting numerous head injuries. The autopsy concluded that the cause of death was a result of post-traumatic brain injury. Nevertheless, applying current criteria made it challenging to ascertain whether the trauma stemmed from an accidental event or an assault.

1. Introduction

Head injury is a generic term which includes external lesions to the face and the scalp. These damages comprise lacerations, contusions, abrasions, and fractures, not always associated with brain injury. Traumatic brain injury (TBI) is defined as impaired brain functionality presenting with confusion, altered consciousness, seizures, coma, sensory and/or motor neurological defects [1]. In the field of forensics, head injuries consistently prompt suspicion of homicide, given the challenge of distinguishing between deliberate assaults and accidental falls. This necessitates a thorough analysis of all available data to determine not only the cause but also the manner of death [2,3]. The forensic pathologist relies on multiple elements to provide scientific evidence - circumstantial data, on-site inspection, necropsy, histology, and toxicology - and a list of criteria, available in forensic literature, can be used even if their application is challenging.

Herein, we describe a case of a man found dead at home, partially naked, with multiple head traumatic injuries, a whole scenario highly suspicious for inflicted blows and violence. All the available information (circumstantial data, necropsy, histological, and toxicological findings) is presented and discussed to evaluate the reliability of the current forensic criteria for the differential diagnosis between murder and accidental death.

2. Case report

The body of a 60-year-old man was discovered in his apartment after concerned neighbors, unable to reach him for nearly a day, alerted law enforcement. A forensic pathologist conducted an on-site inspection. The apartment, located on the third floor, comprised a main corridor, a bedroom, a restroom, a small living room with a couch, and a kitchen. The living space was in disarray, with overturned chairs and numerous broken objects strewn across the floor. Doors and windows were secured from the inside, showing no signs of forced entry. A substantial pool of vomit was present at the transition between the living room and the kitchen (Fig. 1a). Various traces of dried blood were mainly located on the floor, pieces of furniture, the refrigerator, and the walls between the corridor and the living room showing at blood stain analysis a transfer and wipe patterns without evidence of impact or projection spatter (Fig. 1b). The body, partially unclothed and surrounded by a mixture of blood and vomit, was discovered in the corridor near the main door (Fig. 2). Dried blood covered the entire body, revealing multiple head lacerations. The apartment contained various medications, including antihypertensives, pump inhibitors, and anxiolytics, as well as scattered bottles of wine. In the living room, a container of "Bromazepam" 2.5 mg/ml without a cap was also found. Analysis of circumstantial data revealed that the deceased had been experiencing depression, leading to

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a period of isolation in the final stages of his life. His medical history included hypertension, carotid stenosis, hyperlipidemia, chronic hepatitis C, and HIV infection. Previous treatments consisted of aspirin, atorvastatin, amlodipine, ramipril, venlafaxine, tamsulosin, perfenazine, bromazepam, lansoprazole, and bicittegravir/emtricitabine/tenofovir alafenamide.

Two years before the victim suffered a right hemispheric transient ischemic attack (TIA), followed by the angiographic detection and treatment of an anterior communicating artery aneurysm with angioembolization and stent insertion one year later.

Concerning the period leading up to the discovery of the body, neighbors unanimously reported hearing a loud thud around 3 a.m., accompanied by sounds of furniture being rearranged. By 6 a.m., a neighbor passing by the door noticed a “snoring” sound. At 8p.m., the same neighbor and another resident attempted to contact him by phone, receiving no response, and assumed he may have left. The morning of the next day, the neighbors unable to contact the victim, called the emergency medical assistance. Due to the suspicious nature of the scene, law enforcement was notified, and a medico-legal autopsy was arranged by the Public Prosecutor.

The post-mortem examination revealed multiple lacerated and contused wounds, accompanied by ecchymosis and excoriations on the skin of the skull. These injuries were in the left temporo-parietal region (Fig. 3a), the right frontal region near the midline, and at the lateral third of the left eyebrow (Fig. 3b). Additionally, an extensive red–purple bruise with swelling of the underlying soft tissues was observed in the right *peri*-orbital region. Wide ecchymoses were also found on the left iliac crest and on the anterior surface of the right knee. Layer-by-layer dissection of the head revealed significant blood infiltration in the soft tissues of the central and left occipital region (Fig. 4a). Upon opening the skull, a large subdural hematoma was observed on the right cerebral hemisphere, exerting pressure on the underlying parenchyma (Fig. 4b). Additionally, minor subdural hematomas were present in the left fronto-temporal and parietal-occipital areas. Upon brain extraction, small subdural hematomas were also evident within the three cranial fossae (Fig. 4c). The basicranium exhibited a fracture line in the left occipital bone, oriented antero-posteriorly, with a bony avulsion toward the foramen magnum (Fig. 4d). Following the removal of the extensive right subdural hematoma, small subarachnoid hemorrhages were bilaterally observed in the anterior part of both frontal lobes (more extensive on the right) and the rostral area of the temporal lobes (Fig. 4e). The cerebellum showed a small subarachnoid hemorrhage in the lateral part of the left hemisphere. The surgical stent within the anterior communicating artery was appropriately positioned, with no identified

hemorrhages or tears. Additionally, the *peri*-vertebral soft tissues exhibited bloody infiltration, coupled with a minor fracture of the C4 vertebral body (Fig. 4f). Histology of the brain disclosed multiple microhemorrhages within the mesencephalon with neutrophils and fibrin (Fig. 5). Many subarachnoid hemorrhages with intracortical blood extravasation (i.e. cerebral contusions), accompanied by fibrin and neutrophils, were diffusely located on the cerebral surface (Fig. 6). In the right basal ganglia, a lacunar infarct was detected, likely a residual damage of the previous documented TIA (Fig. 7a). The whole cerebral cortex presented diffuse ischemic changes with neuronal shrinkage and basophilic cytoplasm (Fig. 7b). Regarding the other organs, myocardiosclerosis and pulmonary edema were overall extensive. No other relevant findings were histologically observed (Fig. 8).

Toxicological analyses were conducted in blood samples by UPLC-MS/MS (illicit drugs and pharmaceuticals) and GC-FID (alcohol), resulting positive for bromazepam (193.7 ng/mL), venlafaxine (339.9 ng/mL), and a small amount of alcohol (0.12 g/L).

3. Discussion

In cases of fatal traumatic head injuries, autopsy findings assume a crucial role in either confirming or complementing investigative information. It is particularly significant to establish the cause of death even if the manner of death assessment can be extremely challenging.

In the presented case the autopsy allowed to establish that the primary cause of death was cerebral anoxia resulting from post-traumatic intracranial and external hemorrhages. Blunt force injuries were identified involving the occipital region, the left temporo-parietal region, the mid-frontal region, the right and the left orbital regions, the left iliac crest, and the right knee.

The impact on the occipital region was particularly noteworthy, sufficient alone to determine the mechanisms leading to death. Despite not causing evident external injuries, the contusive action resulted in hemorrhagic infiltration in the soft *peri*-cranial tissues of the occipital region, a linear fracture of the occipital bone, vertebral fracture at C4, contusions on the brain parenchyma of the frontal and temporal lobes, and subdural, subarachnoid, and intra-parenchymal hemorrhages.

The force exerted on the occiput caused direct pressure at the occipital level but was also capable of producing, through a mechanism of flexion–extension of the head, the cervical fracture at C4. Through a combination of traction and contusion, it also damaged the bridging veins running in the subarachnoid and subdural spaces, as well as the intraparenchymal vessels; this event can also be associated with the contusion of the frontal and parietal lobes through a coup–contrecoup



Fig. 1. The death scene: (a) pool of vomit between the living room and the kitchen; (b) traces of dried blood found in the living room.

mechanism. A subject exposed to a head injury can develop a brain lesion at the impact site (coup injury) or damage to the cerebral surface diametrically opposite (contrecoup injury). When a freely moving head is struck by an object, the site of maximum cortical contusion is usually found below the impact point or on the same side of the brain. However, when a moving head is suddenly decelerated, as in the case of a fall, although a lesion may be found at the impact site, cortical damage is more often present on the opposite side of the brain (the so-called contrecoup injury). The most common sites of contrecoup injuries are the anterior prominences and lower portions of the frontal and temporal lobes, and they can be symmetrical if a fall impact occurs on the occiput.

In our case, the occipital injury, ultimately leading to death, could result from a backward fall of the subject with a consequent impact on the floor.

Nevertheless, the other injuries responsible for copious bleeding were likely the result of at least 3 or 4 different impacts between a blunt object and the affected skin surface and raised suspicion requiring the adoption of other forensic criteria to clarify the manner of death.

The autopsy findings alone could not exclude the involvement of a perpetrator in the causation of these injuries and two different hypotheses were formulated: accidental multiple falls or repeated struck in the face and head with blunt objects as brass knuckles, small clubs, or kicks and punches.

One of the most often used criteria to discriminate falls from homicidal blows in blunt head injuries is the HBL rule. According to this rule, wounds located above the HBL are more likely caused by blows, while those inside the HBL are often associated with falls. However, this rule faces three main challenges: (I) a lack of standardized anatomical landmarks for the HBL, (II) ambiguity regarding its applicability to fractures, lacerations, or both, and (III) a scarcity of studies assessing its validity. Various definitions of the HBL have been proposed, ranging from overly general and non-replicable to more precise but impractical on dry skulls. For instance, definitions like “prominent areas of the head, like the forehead, the occipital pole, and a line bridging these areas” [4] or “the level where the brim of a hat would lie” [5,6] lack the precision needed for replication. Erhlich and Maxeiner [2] suggested a more precise definition: a band-like area of approximately 3 cm, running from the top of the eyebrows, around the upper margin of the auricle, to the occipital pole at the back. However, this definition faces challenges in forensic anthropology when applied to dry skulls lacking ears and eyebrows.

Another criterion introduced in a study by Kremer et al. [7] involves side lateralization, suggesting that left skull fractures are more linked to blows, while right skull fractures favor falls. This could be attributed to

the dominance of right-handed perpetrators in cases of blows. Similarly, the right-side lateralization of fractures in falls may be explained by individuals instinctively attempting to shield themselves with their right hand during a fall, making the right side of the head more prone to impact.

A third criterion that could be adopted in those cases is that ground-level falls typically result in limited external injuries, with lacerations being uncommon, mostly restricted to scalp contusions or abrasions [8]. The rarity of lacerations in falls was considered as a criterion in distinguishing falls from blows by Erhlich and Maxeiner who demonstrated that falls are associated with a small number of lacerations (four or fewer), while blows commonly present multiple lacerations [2], a finding corroborated by Kremer et al. [7].

In a retrospective study Guyomar’h et al. [9] found additional useful criteria in the distinction of falls from blows that generally present laceration length of 7 cm or more, presence of comminute or depressed calvarial fractures, more than four facial contusions or lesions, presence of ear lacerations, presence of facial fractures, presence of postcranial osseous and/or visceral trauma [9].

In our case, the presence of multiple lacerations in the left temporo-parietal region, the right frontal region near the midline, and at the lateral third of the left eyebrow, the presence of more than four facial lesions and the presence of postcranial lesions including the vertebral fracture, were indicative of an external assault, suggesting a homicide in consideration of number of lesions and lateralization.

On the other hand, the linear fracture on the left occipital bone, would be suggestive of a fall on the ground, as the main point of impact was within the HBL and the fracture was linear. Moreover, scalp lacerations were smaller than 7 cm and no ear lacerations were detected.

Other relevant elements emerged from circumstantial data, on-site inspection, histology, and toxicology.

First of all, doors and windows were secured from the inside and the bloody trails on the floor didn’t show shoe prints or evidence of impact and projection spatter, being suggestive of body dragging and crawling by the agonizing victim, as blood stain analysis assessed.

Although the intentional action of a third party might have not been completely excluded, the victim’s past clinical history pointed more towards a loss of consciousness, followed by standing up attempts, and repeated falls or bumps against the furniture.

The victim had an history of right hemispheric transient ischemic attack, reported, and evidenced histologically by a residual lacunar infarct in the basal ganglia. Moreover, there was diffuse myocardiosclerosis, a predisposing condition to cardiac ischemia and arrhythmia.



Fig. 2. The position of the body during on-site investigation: (a) upper body; (b) unclothed lower body.

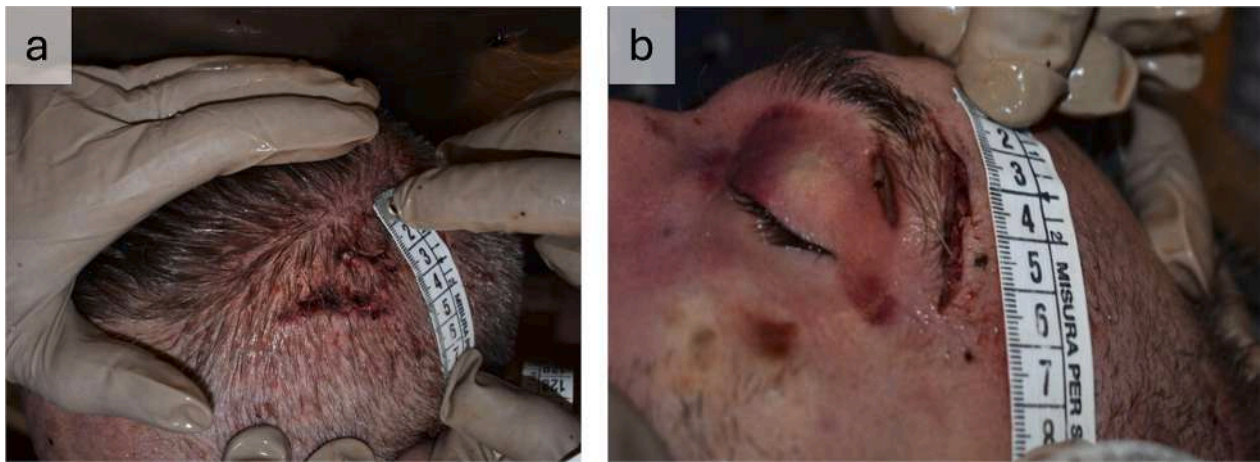


Fig. 3. Scalp injuries: (a) left temporo-parietal region; (b) lateral third of the left eyebrow.

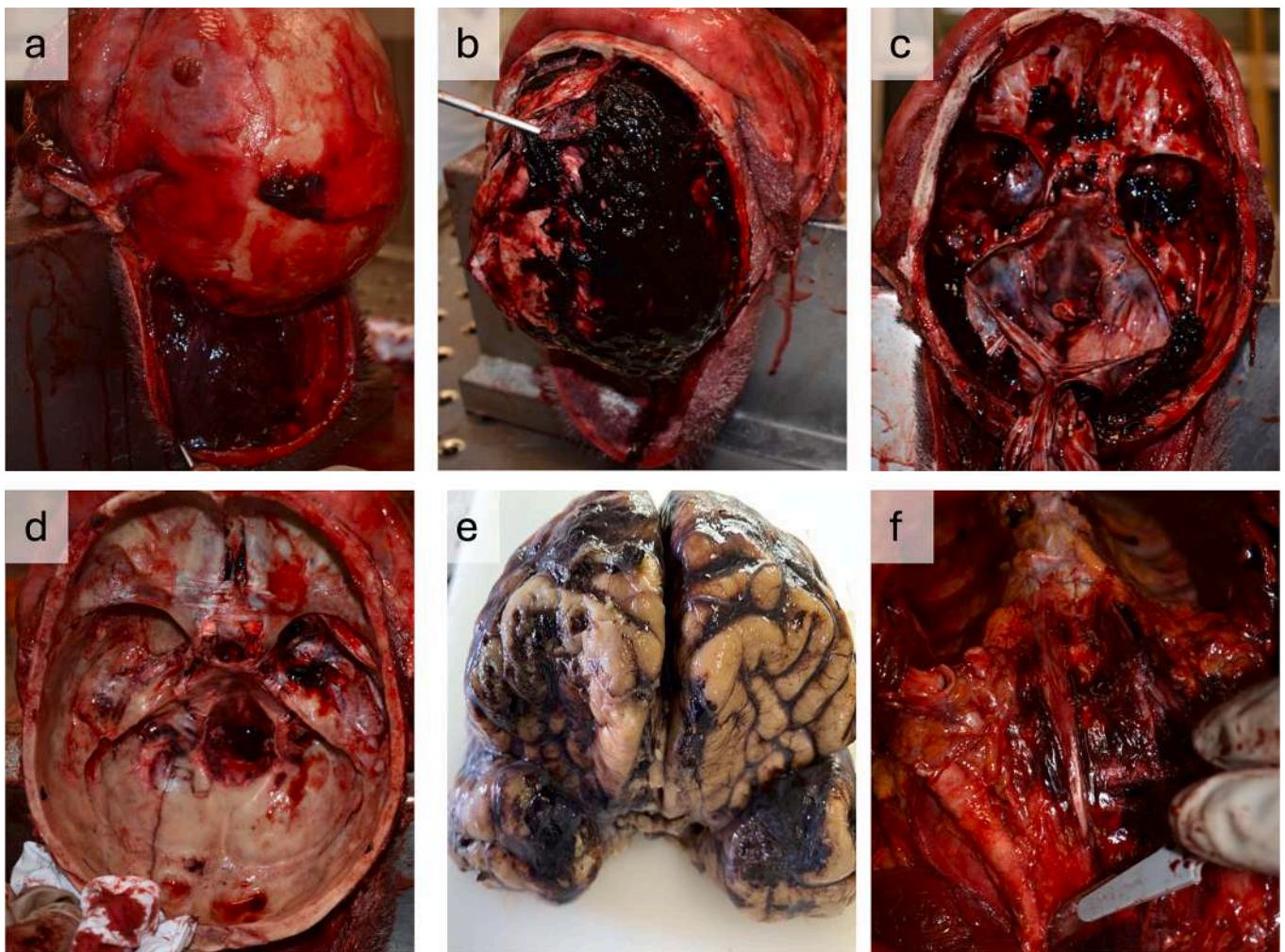


Fig. 4. Head injuries: (a) blood infiltration in the soft tissues of the central and left occipital region; (b) subdural hematoma on the right cerebral hemisphere; (c) small subdural hematomas within the three cranial fossae; (d) a fracture line in the left occipital bone; (e) bilateral subarachnoid hemorrhages; (f) bloody infiltration with a minor fracture of the C4 vertebral body.

Histological exams also allowed dating the brain damage to a few hours before death, supporting the hypothesis of a prolonged agonizing period during which the subject could experience multiple falls.

Toxicological analysis revealed bromazepam, venlafaxine, and a small amount of the metabolite desmethylvenlafaxine in the blood, in

ranges below toxicity levels. Since these medications, particularly in mutual interaction, may depress consciousness and reflexes, a systemic ischemic event might have easily been worsened [10,11]. The intake of central nervous system depressant drugs in a condition of cerebral edema and ischemia could also contributed loss of balance, repeated

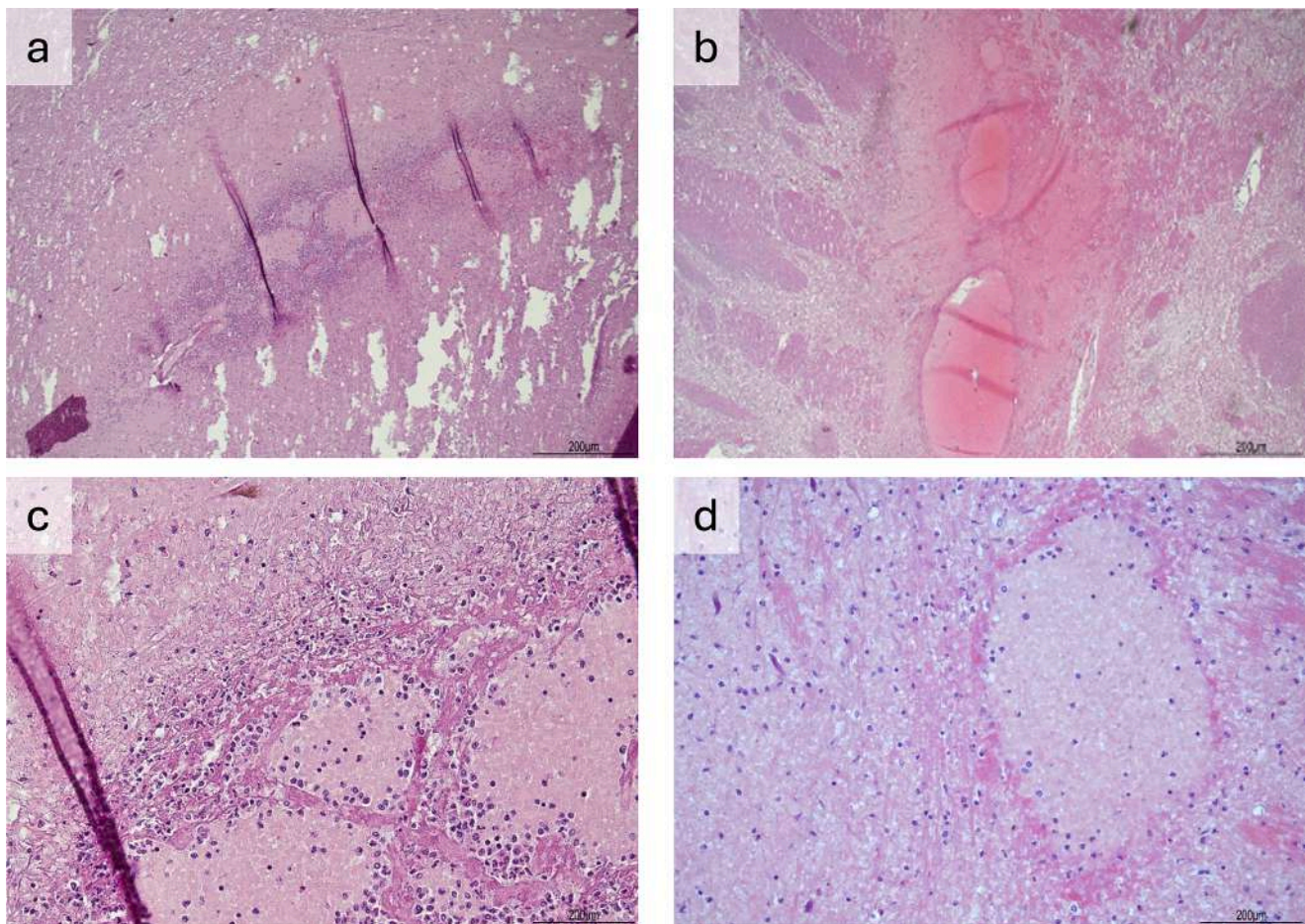


Fig. 5. Mesencephalon: (a–b) multiple microhemorrhages associated with vascular dilatation and congestion; (c–d) fibrin and neutrophils within the blood extravasation.

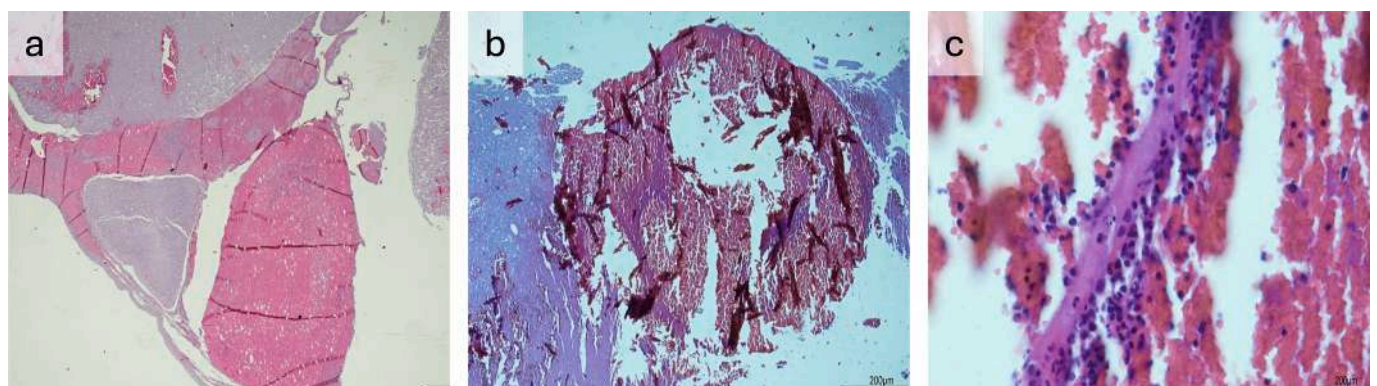


Fig. 6. Subarachnoid hemorrhages throughout the cerebral surface (a) with cortex involvement (b). Initial organization with fibrin and neutrophils (c).

falls on the ground and blows against the furniture, increased intracranial pressure generating vomit and undressing.

About undressing, either suspicious for violence or paradoxical undressing in hypothermia arose. Inflicted violence seemed unlikely as no defense wounds or other signs of violence were detected at autopsy, even in the genital or anal areas. Instead, the undressing seemed more related to the massive subdural hemorrhage, and not to body hypothermia as the room temperature was 16 °C. In fact, the indirect compression of the subdural hemorrhage on the hypothalamic temperature-regulating centers might have altered the sensation of warmth and induced the necessity to unclot [12].

In summary, integration and interpretation of circumstantial data, patient’s clinical history, inspection site information, autopsy, histological, blood stain pattern analysis, and toxicological findings, allowed to identify the cause of death as massive right subdural hemorrhage and the manner of death as most probably accidental.

The HBL Rule, the side of lateralization, the number of lacerations and other criteria can be helpful but are only partially indicative of the circumstances surrounding the injuries. As a matter of fact, at the present time, it is impossible to be extremely confident in the distinction of falls from blows by basing oneself solely on those criteria that do not consider falls from crouched or kneeling positions, the presence of

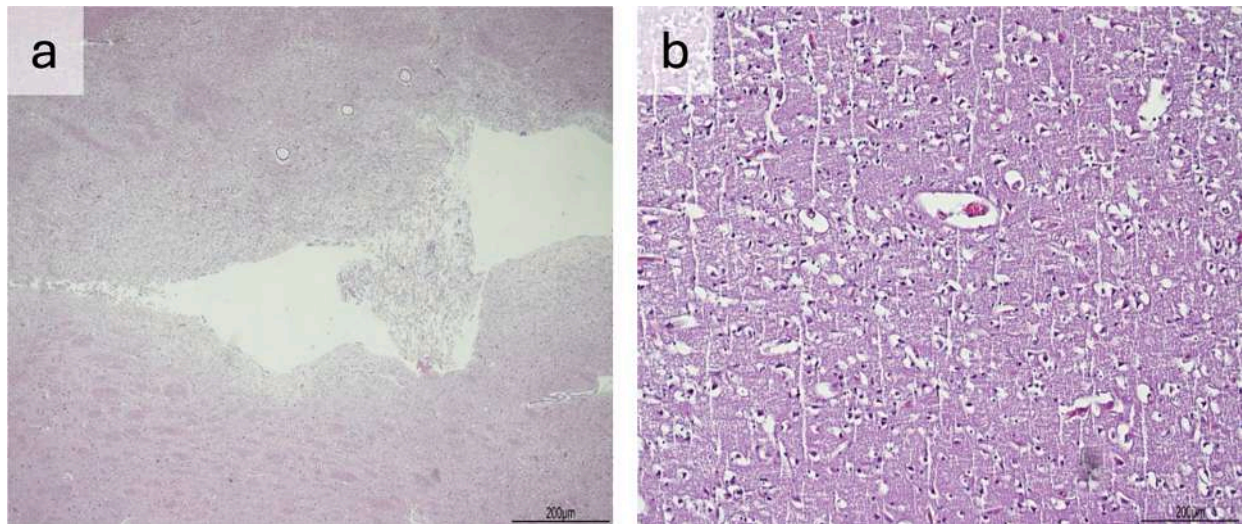


Fig. 7. Lacunar infarct of the right basal ganglia (a). Diffuse neuronal ischemic damage with nuclear shrinkage and cytoplasmic basophilia of the cerebral cortex showed (b).

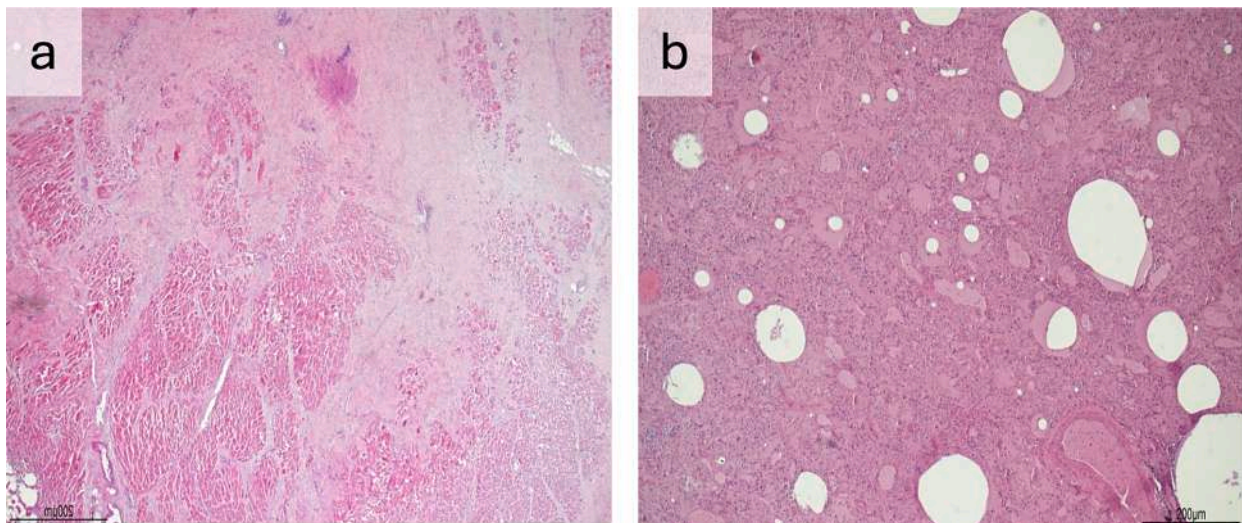


Fig. 8. Myocardiosclerosis (a) and pulmonary edema (b).

obstacles during the fall (furniture, stairs, other objects) and conditions such as intracranial hemorrhage, cerebral edema, and the influence of substances that can lead the individual to experience dizziness, blurred vision, lack of coordination, and multiple falls.

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Filippo Pirani: Writing – original draft, Conceptualization. **Maria Paola Bonasoni:** Formal analysis, Visualization. **Angela Cornacchia:** Investigation, Visualization. **Elena Lacchè:** Investigation, Visualization. **Arianna Giorgetti:** Methodology, Visualization. **Susi Pelotti:** Writing – original draft, Supervision; **Guido Pelletti:** Visualization, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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