

Forensic homicidal strangulation in women: Case series and systematic literature review

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ABSTRACT

This systematic review explores women's homicidal strangulation using PRISMA method. A total of 40 Google Scholar, 26 PubMed and 4 manual searching articles were analyzed, while other sources were excluded due to lack of full texts, irrelevance, or outdated content. Review highlights gender violence as an underestimated issue and provides a socio-demographic analysis. Diagnosing strangulation can be challenging, particularly in absence of visible asphyxial signs in the external examination. Judicial authorities' collaboration and reliance on circumstantial evidence are crucial in forensic investigations. Strangulation is statistically prevalent in sexually motivated crimes and employs various methods. We reported four different strangulation cases at the Institute of Forensic Medicine, University of Palermo, to emphasize findings, forensic characteristics, and interpretation difficulties. The primary goal of this review is to shed light on homicidal strangulation's specific characteristics, given its underreported nature, and to stress the importance of mechanical asphyxia in forensic differential diagnosis. Distinguishing strangulation from other asphyxial deaths is difficult, as is identifying potential third-party involvement. This review also aims to provide key indicators that assist forensic pathologists in differentiating strangulation from other asphyxial causes of death. Future perspectives highlight the use of specific protocols, using artificial intelligence (AI), and instrumental investigations to support forensic pathologists in performing differential diagnoses and providing compatibility assessments.

1. Introduction

Violence against women is a critical public health issue worldwide. Femicide (women homicide), the most extreme form of violence against women, is one of the leading causes of premature death among women and a significant medico-legal concern [1]. Gender-based violence often occurs in domestic environments, where a power dynamic exists between one party in a position of authority and the other in a state of dependency and subordination. Among the forms of gender-based violence, the most severe is undoubtedly homicide, which can be carried out using various methods [2]. One of the most common mechanisms is strangulation, which falls under the broader mechanical asphyxia category. Mechanical asphyxia is one of the most challenging topics for forensic pathologists and medical examiners, as it can sometimes be difficult to determine whether third-party involvement

occurred and thus establish homicidal versus suicidal intent. Deaths resulting from mechanical asphyxia vary; for example, while hanging often provides clear external signs to guide medico-legal diagnosis, this is not always the case with strangulation [3–6]. A careful analysis of circumstantial evidence, the crime scene, and autopsy findings can help orient the diagnosis, despite the current lack of specific operational protocols [7]. Gender-based violence and deaths resulting from strangulation remain among the greatest challenges for any forensic pathologist, particularly in cases where external injuries are not clearly indicative [8].

2. Materials and methods

For this purpose, a thorough review of the most recent sector-specific scientific literature was conducted in October 2024. Three keywords

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(MeSH terms) were used to perform searches on databases: PubMed and Google Scholar. The chosen keywords were “strangulation,” “homicide,” and “woman.” The selection of these keywords, particularly “homicide” and “woman,” was based on a preliminary investigation highlighting the correlation between homicidal intent and gender-related crimes, with women being the primary victims. Boolean operators, specifically “AND” and “OR,” were applied to refine the search terms (Fig. 1). The PubMed search yielded 79 articles; full texts were available for 57, of which 40 were accessible, and 26 were relevant to the research. The Google Scholar search returned 15,100 results, of which 737 were scientific articles, 222 fell within the 2020–2024 timeframe, 154 were accessible, and 40 were deemed relevant to the research. Additionally, the review extended to examining relevant websites and conducting citation searches, focusing on subjects pertinent to our study.

Following sector-specific literature review, a comparison was conducted with four different strangulation cases handled by the Institute of Legal Medicine at the University of Palermo to highlight their characteristics and to shed light on the challenges and complexities forensic pathologists face in cases of mechanical asphyxia resulting from strangulation.

3. Case series

Forensic autopsy is a fundamental tool in the analysis of suspicious or violent deaths. Dissection procedures and histological examinations provide detailed information on injuries, pathogenetic mechanisms, and any substances present in the body, contributing to the reconstruction of events and the determination of the cause of death. In all four cases examined, autopsies were performed following standardized protocols. After a thorough external inspection of the body, subungual scrapings, biological swabs, and samples of body fluids were collected for subsequent toxicological analysis. A systematic dissection and macroscopic examination of the internal organs were then carried out. For the histological analysis, the collected samples were fixed in formalin for an adequate period of time, dehydrated in alcohol, cleared in xylene, and

embedded in solid paraffin. Thin sections were then cut, placed on slides, and stained with hematoxylin and eosin for examination under a light microscope. In parallel, toxicological screenings were conducted to identify any drugs of abuse (e.g., barbiturates, benzodiazepines, cocaine, methadone, morphine, buprenorphine, THC) and medications (such as Citalopram, Promazine, Aripiprazole).

4. Autopsy findings

In the first case, involving a 35–40-year-old woman of African descent, the victim was discovered under circumstances strongly indicative of a violent homicide. The external examination showed findings consistent with mechanical asphyxia combined with blunt trauma to the head and face, including bilateral “butterfly-shaped” periorbital hematomas, protrusion and ecchymosis of the left eye, conjunctival hemorrhages, and the presence of blood at the nasal level. There was a clear sign of soft-material strangulation on the neck, appearing depressed and pale, accompanied by related abrasions; tongue protrusion suggested significant compressive force. No foreign material was detected in subungual samples, and no genital or anal lesions were found. Toxicology for common drugs of abuse was negative. The internal examination revealed frontal-parietal subscalp hemorrhages and moderate cerebral edema, with extensive hemorrhagic infiltration of the neck tissues and an intact hyoid bone. The lungs displayed emphysema and focal alveolar rupture, with areas of intra-alveolar hemorrhage, while subepicardial hemorrhages were noted in the right atrium. Histological analysis confirmed vascular congestion and micro-hemorrhages in the alveoli, consistent with an asphyxial mechanism due to strangulation. Craniofacial trauma may have rendered the victim incapable of defense, contributing to the fatal outcome. The cause of death was therefore deemed violent mechanical asphyxia, exacerbated by concurrent craniofacial trauma.

In the second case, a 44-year-old Caucasian woman with a psychiatric history was found deceased under circumstances indicative of homicide by strangulation, reportedly carried out by her mother. The

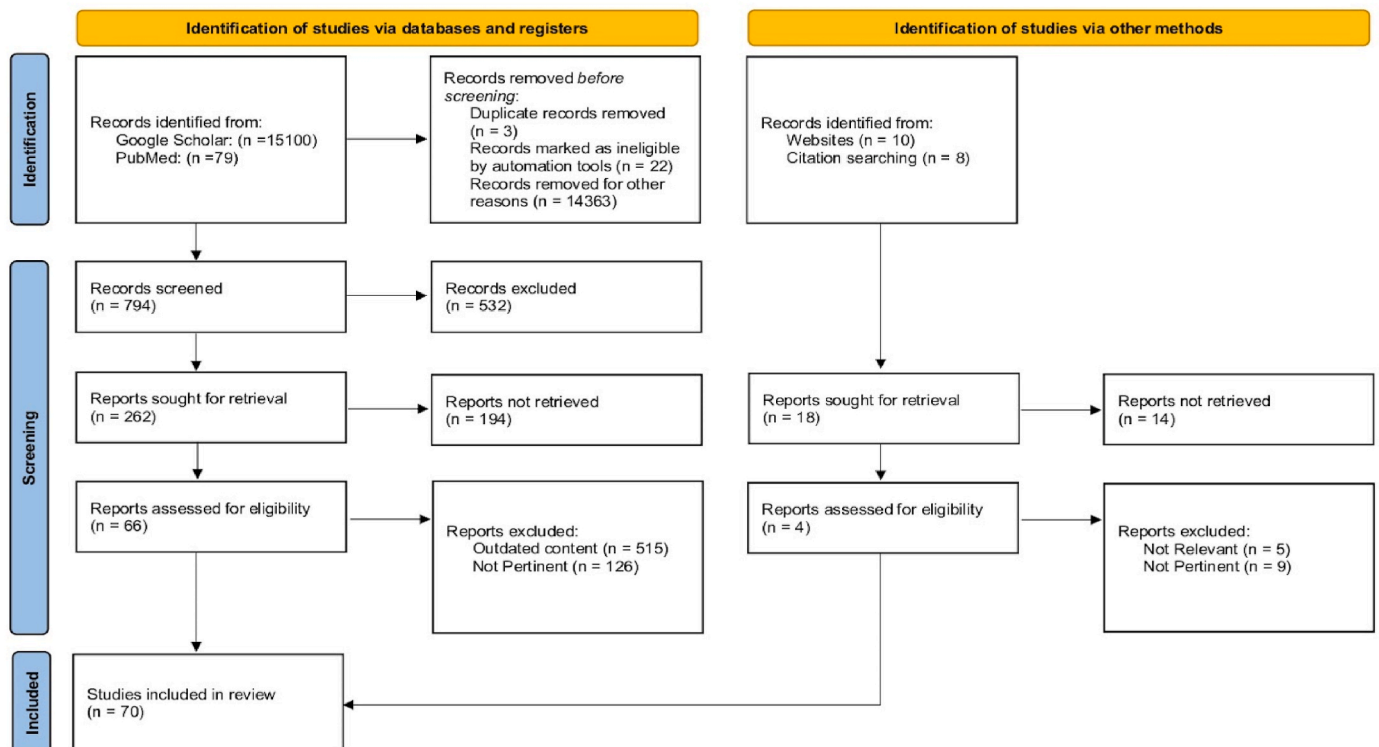


Fig. 1. PRISMA Flow Diagram. 70 articles were included in the systematic review. Irrelevant, duplicate and non-recent articles have been eliminated.

external examination revealed numerous petechial hemorrhages on the face and beneath the eyelids, alongside a reddish-purple ligature mark, approximately 6 mm wide, running horizontally across the anterior neck and becoming discontinuous posteriorly. A “mantle-like” edema was evident in the upper thoracic area, and there were abrasions on the volar surfaces of both forearms, marked subungual cyanosis, bruising and erythematous areas on the left thigh, minor abrasions on the left calf, and hematomas in the lumbar region. Internally, subcentimeter scalp bruises were detected without notable skull lesions; small hemorrhages were found in the hippocampus and basal nuclei, while only mild hemorrhagic infiltration involved the sternocleidomastoid muscles. The hyoid bone was intact. The lungs were heavily congested and produced a hemorrhagic foam, with alveolar septal rupture (acute emphysema) and cerebral edema indicated in the histological findings. Toxicological tests revealed elevated levels of Citalopram (toxic but sub-lethal) and Promazine (potentially toxic), along with therapeutic levels of Aripiprazole. This pharmacological combination likely caused confusion, sedation, and respiratory depression, reducing the victim’s capacity to resist, thus facilitating asphyxiation. Based on all these findings, the cause of death was identified as mechanical asphyxia by strangulation, exacerbated by the psychotropic effects of the medications.

In the third case, a 28-year-old Caucasian woman was found dead at home by her husband. Initial assessment by emergency medical personnel revealed no significant injuries beyond a small abrasion on the neck at the level of the thyroid cartilage. However, upon arrival, the forensic pathologist decided to conduct a full autopsy to further investigate. The external examination revealed small contused-abrasive injuries on the face, bilateral conjunctival injection, and extensive hemorrhagic injuries in the cervical region. Bilateral subungual cyanosis was noted, and numerous active and passive defensive wounds were documented on the upper limbs. Dissection uncovered a laceration of the left sternocleidomastoid muscle and extensive hemorrhagic infiltration along the entire left neck pillar, as well as congested and hemorrhagic lungs. Hemorrhagic infiltration was also observed in the esophageal wall and in the left sub-hyoid region, and a fracture was found in the left horn of the hyoid bone. Histological examination revealed cerebral neuronal edema and acute emphysema due to alveolar septal disruption. These findings led to the conclusion that death resulted from mechanical asphyxia by manual strangulation with homicidal intent. The multiple defensive injuries and internal lesions identified at autopsy proved the violent nature of the incident, contrasting with the initial impression of the paramedic.

In the fourth case, a 38-year-old Caucasian woman was discovered dead at her home, naked and lying on the bed, with a plastic bag over her head and adhesive tape around her neck. The external examination documented bilateral “butterfly-shaped” periorbital ecchymoses, lip cyanosis, conjunctival hemorrhages, and a discontinuous ligature mark around the neck that varied in depth and color, suggesting strangulation.

Multiple bruises on the arms and hands indicated a struggle, while other bruises and abrasions were found on the legs. Redness and small abrasions to the vulva, along with hemorrhagic spots and abrasions around the anal region, suggested recent sexual activity, though it was insufficient to conclusively confirm sexual assault. The internal examination revealed diffuse cerebral edema with hemorrhagic changes, hemorrhagic infiltration of the neck muscles extending to the larynx and trachea, and fractures of the hyoid bone and thyroid cartilage. Histological analysis confirmed acute pulmonary emphysema, neuronal edema, and focal necrosis. It was determined that the victim died from acute mechanical asphyxia caused by manual strangulation, further complicated by both suffocation (the plastic bag) and ligature strangulation (the adhesive tape). The fractures and hemorrhagic infiltration confirmed violent compression of the neck, while the external, internal, and histological findings pointed to multiple asphyxial mechanisms acting concurrently. A summary of the four cases analyzed is presented below (Table 1).

In all the cases described, the integration of external examination, internal autopsy, and histological analysis, together with toxicological findings and information regarding the circumstances in which the bodies were found, was essential for understanding both the dynamics and the cause of death.

5. Discussion

Strangulation is a critical area of forensic investigation due to its often controversial mechanisms. Historically, strangulation was attributed solely to asphyxia caused by airway obstruction [9]. However, the rapid onset of death in many cases suggests that hypoxia alone cannot fully explain the lethality. This discrepancy necessitates exploring alternative mechanisms like vagal inhibition and pressure on the carotid arteries. Differentiating between manual and ligature strangulation is crucial. Manual strangulation is frequently observed in domestic violence cases, sexually motivated homicides, and child killings perpetrated by adults. It is predominantly a male-on-female crime, owing to the significant strength differential typically required [10,11].

Forensic findings often include localized signs of violence, such as discoid bruises clustered around the neck, abrasions caused by fingernails, and defensive scratches. Bruises distribution pattern may vary depending on the victim’s struggle and can suggest the assailant’s handedness, although this is not conclusive. Additionally, death mechanism is indicated by hallmark features such as petechial hemorrhages, vascular congestion, and internal muscle bruising. Internal injuries commonly involve bruising of the platysma, sternocleidomastoid, and strap muscles, often accompanied by subcutaneous hemorrhages, providing further evidence of the assault. Ligature strangulation occurs when an object is used to constrict the neck and is predominantly associated with homicidal cases, while accidental or suicidal instances

Table 1

Schematic representation of the findings emerging from forensic investigations on the four examined cases.

Case no.	Age	Strangulation Method	Main External Signs	Main Autopsy Findings	Toxicological Results	Results and Consideration
1	35–40	Strangulation by a soft medium	Periorbital ecchymosis, tongue protrusion, pale furrow around the neck	Cerebral edema, alveolar hemorrhages, hemorrhagic infiltration of neck tissues	Negative	The faint furrow and absence of defensive injuries suggest the victim was incapacitated during the event.
2	44	Strangulation by an electric cable	Diffuse facial petechiae, defensive injuries on forearms	Hemorrhagic infiltration of sternocleidomastoid muscles, pulmonary congestion	Toxic levels of citalopram and promazine	The presence of toxic drug levels may have contributed to reduced resistance of the victim.
3	28	Manual strangulation	Abrasions and defensive injuries, facial contusions	Fracture of the left horn of the hyoid bone, hemorrhages in neck muscles	Negative	The presence of defensive injuries and hyoid bone fracture supports the hypothesis of a violent attack with victim resistance.
4	38	Strangulation by adhesive tape and plastic bag	"Butterfly-shaped" periorbital ecchymosis, suspected sexual violence signs	Fracture of the thyroid cartilage, acute pulmonary edema	Not performed	The combination of strangulation and suffocation suggests a premeditated action to maximize lethality.

are rare. Type of ligature employed plays a significant role in forensic interpretation, as ligature marks often exhibit patterns corresponding to the material's texture, such as cords, ropes, or cloth. If substantial force is applied, bruises or abrasions may extend beyond the neck. Compared to manual strangulation, internal injuries are generally less severe, although fractures of the hyoid bone or thyroid cartilage can occasionally occur. The mechanism of death often involves vagal reflex-induced cardiac arrest or classical signs of asphyxia, such as cyanosis, petechial hemorrhages, and facial congestion. Death resulting from mechanical asphyxia, particularly strangulation, represents one of the most challenging fields for forensic pathologists and medical examiners [12]. A thorough and meticulous external examination, combined with circumstantial evidence in collaboration with judicial authorities, is essential to distinguish between homicidal and suicidal hypotheses and to identify any third-party involvement, gathering the necessary evidence. Such deaths are often linked to domestic violence, although studies conducted in Mozambique suggest that deaths by strangulation are more commonly associated with out-of-control erotic practices or filicide [13]. Another study conducted by Vij et al. highlights strangulation as one of the primary mechanisms of killing; in eight documented cases of strangulation, seven of the victims were women [14]. Similar findings emerged from a retrospective study conducted in Taiwan, which analyzed femicides between 2000 and 2010 [15]. Over the ten years, 220 cases of femicide were reported, and in cases where the perpetrator had a sentimental relationship with the victim, strangulation was the main killing method, followed by stabbing. The same trend was observed in sexual homicides. The physical disadvantage of female victims often leads to failed resistance, as most offenders are male, and manual strangulation is one of the most common methods. Similar data were reported in England and Wales. In forensic investigations of suspected strangulation deaths, it is crucial to search for biological traces on the body, as studies indicate this death method as often associated with sexual assault [16]. Abraham et al. noted an 11-fold higher risk of association between strangulation and suspected rape homicides compared to other causes of death in femicide cases without evidence or suspicion of rape [17]. Strangulation, along with asphyxia, demonstrated a high positive predictive value for sexual elements in the crime. Additionally, neck injuries were identified in 58.2 % of suspected rape-homicide cases compared to other homicides, further highlighting the correlation between strangulation and sexual elements [18]. Given these findings, the implementation of standardized protocols during autopsies is critical for detecting potential biological traces that could confirm or rule out sexual assault suspicion [19]. Training health workers in recognizing such injuries would be highly beneficial. Disseminating this information is essential because women who are victims of violence, particularly strangulation, may survive and present to emergency departments. Victims may not always disclose their experiences, making it vital for healthcare professionals to recognize injuries that might suggest abuse, violence, or attempted strangulation. Healthcare providers should look for signs and symptoms in patients suspected to be strangulation victims. These symptoms may include neck pain, hoarseness, respiratory difficulty, dysphagia, and petechiae on the face and eyes. Fiber-optic laryngoscopy, CT scans of the neck, chest X-rays, and other instrumental assessments are recommended in such cases to identify visceral injuries. Not all cases of strangulation are fatal. Scientific studies reveal that strangulation is one of the most common and significant methods in intimate partner violence, often serving as an early warning sign of potential homicide [20]. They highlight the role of strangulation as both a lethal mechanism and an expression of extreme control and dominance in abusive relationships [21,22]. Non-lethal strangulation has been identified as a key predictor of intimate partner homicide (IPH) [23]. This method is prevalent when the perpetrator seeks to assert physical and psychological control over the victim [24,25]. Female victims often report strangulation as part of a continuum of physical and psychological abuse that can escalate to homicide [21,26–29]. Forensic analysis of strangulation requires a

combination of physical examinations, toxicological studies, and detailed reconstructions to determine intent and the sequence of events [30]. Preventive interventions should include stricter protective policies for victims reporting episodes of strangulation, educational programs addressing gender inequalities, and efforts to counter the culture of relational violence [31,32]. Healthcare professionals, not just forensic pathologists, should document evidence of suspected gender-based violence by taking photographs and providing detailed descriptions of injuries. These measures are critical for assisting judicial authorities [33–36]. Detailed physical examinations, searching external signs of violence in both forensic and clinical contexts, are crucial but can be challenging, even for experienced forensic pathologists [8]. This difficulty arises because, in 97 % of strangulation cases, the means employed—hands or soft materials—often leave marks that are not easily identifiable on the victim (as noted in the aforementioned study). Strangulation is also a predominant mode of violence in cases of sexual violence against children [37–41]. Epidemiological data reveal that strangulation is frequently employed in such cases, underscoring the need for targeted prevention and intervention strategies. Strangulation, particularly through the use of hands and/or soft materials, requires special attention, and the examination of cases of forensic interest highlights key aspects [42–45]. In a study, Campobasso et al. analyzed 15 women killing methods in Southern Italy, three of whom were victims of strangulation by a foreign serial killer [46]. This method was used to prevent the victims from screaming and to cause death as quickly as possible. The external injuries observed included abrasions, contusions, and, at times, fingerprints on the neck region, which were not always clearly visible. These were accompanied by hemorrhages in the underlying soft tissues as well as petechiae on the mucosa and conjunctiva, indicative of acute asphyxia. In this case, attributing the blame to the serial killer, who was later convicted, was challenging due to the limited traces present on the corpse. A meticulous collection of circumstantial data, as well as evidence gathered from the body and the crime scene during both the investigation and the autopsy, played a crucial role [47]. To guide investigations, a key contribution by the forensic pathologist, in collaboration with the forensic toxicologist, involves searching for alcohol and psychoactive substances that may have altered the victim's and/or perpetrator's state of consciousness [48]. In this regard, a study provides valuable insight into the effects of synthetic drugs, such as 3-MeO-PCP—a dissociative hallucinogenic anesthetic [49]. Chronic abuse of this substance was detected in biological fluids, tissues, and hair. These findings highlight the potential impact of new synthetic drugs that induce hallucinations and dissociative states. The challenge for forensic pathologists, therefore, lies in gathering as much data as possible to determine the potential involvement of third parties and to provide comprehensive information for criminal proceedings. Strangulation, particularly using hands and/or soft materials, requires meticulous attention, and analyzing forensic cases helps highlight fundamental aspects [29].

Although strangulation often has homicidal intent, there are cases where death results accidentally, particularly in the context of paraphilic syndromes. These occur when cerebral hypoxia is induced to enhance sexual arousal, accidentally leading to death [50]. Such cases may involve the victim alone, with an autoerotic intent, or suggest the presence of a third party, framing death within shared sexual practices. In these rare instances, excluding criminal involvement is challenging. Forensic pathologists must collect as much evidence as possible, working with law enforcement to carefully examine the crime scene (e.g., the room's condition, locked windows). Collecting biological evidence at the scene and analyzing body injuries are also essential. In strangulation cases involving soft materials, evaluating the characteristics of any knots is important to determine, based on their shape, whether they were self-applied. A detailed study of accessory injuries, not just those on the neck, can reveal active or passive defensive marks, potentially indicating violent death with third-party involvement [51–53].

Beyond external neck injuries, pathognomonic signs of violent

asphyxial death should be investigated, such as hyoid bone fractures, which are the primary injury to assess. Hyoid or thyroid cartilage fractures, while indicative of violence, are not life-threatening by themselves [54]. Radiographic and histological examinations are crucial to confirm ante-mortem origin and exclude post-mortem damage. Virtopsy technology, which employs advanced imaging methods such as CT and MRI, has become invaluable in assessing asphyxial deaths involving airway obstruction. This technology facilitates the efficient identification of airway blockages and trauma before traditional autopsy procedures [55]. CT scans have proven effective in evaluating neck compression-related deaths, such as strangulation, throttling, or ligature constriction. For instance, Decker et al. [56] demonstrated that CT is comparable to conventional autopsy in detecting hyoid fractures and soft tissue hemorrhages, with superior sensitivity in identifying microfractures. Similarly, Fais et al. [57] highlighted micro-CT potential in identifying microfractures in ossified thyroid cartilage, which are difficult to detect with traditional methods. MRI studies complement this by providing detailed imaging of hemorrhages in subcutaneous fat, neck muscles, and lymph nodes, as well as injuries to the larynx and pharynx. Schulze et al. introduced the “gas bubble sign” as a radiological indicator of laryngeal fractures, frequently observed in hanging cases on post-mortem CT [58]. This sign demonstrated a sensitivity of 79.2 % and an accuracy of 83.0 % for diagnosing fractures. CT imaging also frequently identifies laryngeal deformities or dislocations (LDD), which are strongly correlated (83 %) with fractures. These findings remain undetected in conventional autopsies due to mechanical distortions during procedure. Distinguishing between post-mortem artifacts and ante-mortem injuries poses a significant forensic challenge, requiring the correlation of hemorrhagic patterns and histological evidence with circumstantial data. Despite advancements, a lack of specific protocols for crime scene analysis and the examination of injuries on the victim’s body remains a major issue.

Another study highlights uncertainties arising from external examinations of neck injuries, which can create doubt. The literature sometimes reports controversies regarding injury characteristics observed on victim’s body [59]. In mechanical asphyxia cases review—including typical and atypical hanging, strangulation, and ligature strangulation—the authors noted neck injuries as more pronounced in individuals with higher age, weight, and BMI [60]. In cases involving normal BMI and the absence of gravitational force, such as in strangulation, external injuries were less clear. Neck injuries, particularly to the hyoid bone, are more common in women due to its smaller size and lower bone density compared to men. Hyoid fractures are more frequent in manual strangulation cases, with risk factors including age-related decreases in bone density and sexual dimorphism, as women have wider hyoid angles, affecting force distribution during trauma. Given these findings, the legal-medical examination of neck injuries is critical to understanding the circumstances of death [61–64]. Standardized protocols for autopsies and toxicological analyses are urgently needed to improve the identification of causes and methods of death in suspected neck compression cases [65,66].

6. Results

From the systematic review of the most recent scientific literature and the analysis of four forensic cases from our dataset, four distinct modes of strangulation were highlighted to illustrate their different characteristics. As noted, the findings from external examination must be contextualized based on the specific mode of strangulation. It is evident that in such cases, attention is predominantly focused on neck injuries. Equally important, however, is the initial careful collection of circumstantial evidence and crime scene analysis, along with the proper collection and preservation of biological evidence. Ensuring the integrity of the chain of custody is essential for legal proceedings. Similarly, collecting biological fluids as early as possible, even during judicial inspections, is crucial to conducting appropriate analyses and minimizing

the confounding effects of post-mortem processes. A detailed examination of the body can also help identify active or passive defense injuries on the victim, which may support the hypothesis of third-party criminal involvement. In *Case Report No. 3*, the presence of accessory injuries, including those attributable to defense, was pivotal. Contusions, bruises, and abrasions were common findings, particularly in *Case Report No. 1* and *No. 3*. Focusing on neck injuries, *Case Report No. 1* and *No. 3* revealed subtle signs, with compression marks weakly visible due to the use of soft materials that left no contusions, bruises, or abrasions on the body. In *Case Report No. 1*, external neck signs of strangulation were nearly absent. In such cases, the expertise of specialized forensic pathologists is critical, especially when the external examination is inconclusive. Meticulous searches for signs of asphyxial death are essential, and instrumental investigations often prove indispensable. Post-mortem CT scans and MRI could play a crucial role in identifying signs of asphyxial death and potential trauma to the hyoid bone. Additionally, 3D scanning techniques could help clarify neck compression characteristics and provide forensic pathologists with tools to assess compatibility with the instrument used for strangulation. In contrast, *Case Report No. 2* and *4* involved a more rigid material (an electric cable and tape) to strangle the victim. In *Case Report No. 2*, neck marks were easily identifiable, allowing for compatibility assessments with the instrument used. Moreover, the number of loops around the neck could be determined based on the strap-like marks visible on the victim’s neck. A particular challenge in such cases is differentiating between hanging with subsequent relocation of the body and strangulation. In this instance, evidence supporting homicidal intent included the absence of the pronounced congestion typically seen in hanging, the lack of injuries caused by the weight of the body and gravitational force opposing the suspension device (no abrasions, contusions, or excoriations in the groove), and the perpetrator’s confession. In *Case Report No. 4*, several injurious activities were involved: manual and ligature strangulation. The use of a plastic bag secured with tape, along with the injuries to the neck, left clearer marks despite the complexity of the injurious mechanisms. Despite the evident external neck signs, the forensic pathologist faced the challenge of differentiating between hanging and strangulation and thereby assessing homicidal or suicidal intent. Macroscopic findings from autopsy examinations allowed for the identification of hemorrhagic infiltrations in the neck’s soft tissues, varying based on the pressure exerted by the perpetrator and the strangulation method used. Histologically, typical signs of acute mechanical asphyxial death were observed. All these elements were present in the four cases, enabling conclusions regarding the ultimate cause of death. This highlights that the primary difficulty in case interpretation often lies in the external examination and the search for specific signs that guide diagnosis and compatibility assessments. The literature does not currently provide clear data to systematically classify neck injuries in strangulation cases, nor are there specific protocols to follow. Conducting careful studies tailored to the type of death and following guidelines could provide valuable direction for forensic pathologists. The availability and routine application of instrumental investigations in all suspected strangulation deaths could help identify specific and pathognomonic features, thereby ensuring diagnostic certainty [44].

7. Conclusions

Gender-based violence is an increasingly prevalent and often underestimated phenomenon. Survivors of violence frequently struggle to share their experiences and fail to receive the necessary help. This underscores the importance of adequate training for all healthcare professionals to identify potential signs of physical abuse [8,67]. The key elements of violence through strangulation should therefore be known not only by forensic pathologists but also by all healthcare workers [68]. From a medico-legal perspective, the interpretation of mechanical asphyxia presents a significant challenge. The characteristics of asphyxial deaths vary depending on the methods and instruments

used. Forensic pathologists are tasked with providing expert opinions to support judicial authorities and offering evidence crucial to legal proceedings [69].

It is essential to highlight that in cases where soft materials or hands are used for strangulation, the hyoid bone often remains intact. This creates a substantial challenge, as neck injuries are typically mild, complicating the ability to definitively determine the cause and mechanism of the trauma. In such cases, the absence of clear external or internal injuries underscores the necessity of advanced methodologies to identify subtle signs of compression and evaluate their compatibility with the suspected means of strangulation. Modern forensic practices increasingly rely on specialized tools, such as imaging technologies and biomechanical analysis, to detect these otherwise elusive injury markers. Given these complexities, the development of standardized protocols that integrate cutting-edge methodologies is crucial [70]. In this context, the integration of artificial intelligence (AI) could play a transformative role. AI-driven analysis can enhance the detection of patterns, correlation of findings, and generation of reliable conclusions in medico-legal investigations.

Establishing protocols supported by AI would not only improve the accuracy of forensic assessments but also ensure consistency across cases, thereby aiding the pursuit of justice. This multidisciplinary approach represents the future of forensic science, where technology and expertise converge to address even the most complex cases.

CRedit authorship contribution statement

Ginevra Malta: Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Investigation, Data curation, Conceptualization. **Maria Puntarello:** Writing – original draft, Resources, Investigation, Data curation, Conceptualization. **Mauro Midiri:** Writing – original draft, Resources, Methodology, Investigation, Conceptualization. **Tommaso D’Anna:** Methodology, Data curation, Conceptualization. **Stefania Zerbo:** Visualization, Data curation, Conceptualization. **Antonina Argo:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Data curation, Conceptualization.

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.–to proceed further.

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