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A Comparative Forensic Assessment of Hanging and Strangulation with Reference to Autopsy Findings

Azra Kamal[1], Himjay Kumar[2] and Md. Matloob Raza Khan[3]

[1]Assistant Director, [2]Director Incharge [3]Assistant Director
Forensic Science Laboratory, C.I.D (Police), Patna-800023, Bihar, India.

Abstract

Hanging and strangulation are the two most frequently encountered forms of asphyxial death in forensic practice, yet their differentiation remains a critical medico-legal challenge with profound implications for determining the manner of death. Hanging results from suspension of the body by a ligature, where the constricting force is the weight of the body, whereas strangulation is caused by external compression of the neck independent of body weight, either by a ligature or by manual force. Both mechanisms share overlapping external and internal features, often complicating interpretation at autopsy. This review synthesizes current evidence from 2022–2025 to provide an integrated, evidence-based framework for distinguishing hanging from strangulation. Epidemiological data highlight hanging as the most common method of asphyxial suicide worldwide, including in India, while strangulation is more often associated with homicide. Mechanistic differences give rise to characteristic patterns of ligature marks, internal neck injuries, and associated trauma. Recent advances, including multivariate statistical analyses, postmortem imaging, histopathology, and immunohistochemical evaluation of biomarkers such as heat-shock proteins (HSP27, HSP70, HSP90), ubiquitin, caspases, and hypoxia-related markers (HIF-1α, VEGF), have significantly improved the objective assessment of wound vitality and antemortem neck compression. Strangulation is typically associated with pronounced localized stress, ischemia, and apoptotic markers, whereas hanging more often demonstrates markers of generalized hypoxic response. The combined interpretation of molecular findings with gross autopsy features and scene investigation enhances diagnostic accuracy, even in decomposed bodies. A multimodal approach is essential to reduce subjectivity, strengthen medico-legal conclusions, and ensure accurate classification of the manner of death, thereby supporting justice delivery, public health surveillance, and family closure.

Keywords- Hanging; Strangulation; Asphyxial death; Forensic pathology; Immunohistochemistry.

1. Introduction-

Hanging is a form of asphyxial death caused by suspension of the body by a ligature (such as a rope, cloth, or dupatta) encircling the neck, where the constricting force is the weight of the body, either fully or partially while Strangulation is a form of asphyxia caused by compression of the neck by a force other than the weight of the body, resulting in obstruction of blood vessels and/or air passages. It may be:

Ligature strangulation**:** compression by a ligature material, or Manual strangulation (throttling)**:** compression by hands, fingers, or forearm. Asphyxial deaths constitute 5-10% of all medico-legal autopsies and rank among the most frequently encountered forensic challenges globally (1). Among asphyxial mechanisms, hanging and strangulation are prevalent, particularly in cases of suicide and homicide respectively. The distinction between hanging and strangulation is not merely academic; it carries profound legal implications for determining the manner of death (suicide, homicide, accident, or undetermined), establishing criminal culpability, and guiding investigative direction (2).The traditional challenge lies in overlapping pathological features—both mechanisms involve ligature compression of the neck with resulting asphyxia and vascular compromise. However, fundamental mechanistic differences exist. Hanging involves suspension where the weight of the body generates the compressive force, whereas strangulation involves application of external force (ligature or manual) independent of body weight (3). These mechanistic differences produce distinct patterns of injury that forensic pathologists must meticulously recognize. Recent advances in forensic pathology have transformed this field. Multivariate statistical analyses (Crudele et al., 2024) analyzing 399 autopsies with contingency tables and logistic regression provide robust quantification of diagnostic value for traditional signs (4). Immunohistochemical examination of heat-shock proteins (HSP27, HSP70) and ubiquitin expression offers objective determination of wound vitality, distinguishing antemortem from postmortem injuries (5)(6). Additionally, comparative studies from Dhaka Medical College (2022) and multi-center European analyses have established criteria with 97% sensitivity and 92% specificity for manner-of-death determination (7).This review synthesizes 2022-2025 evidence to provide forensic practitioners with evidence-based frameworks for differentiating hanging and strangulation, integrating external findings, autopsy pathology, and emerging molecular techniques.

Epidemiology and Public Health Context

Hanging is the most frequently used method of asphyxial suicide worldwide and shows clear epidemiological trends (8)(9). In Bihar, it has consistently been the leading mode of suicide, accounting for about 50–60% of cases. NCRB and state police data indicate that hanging deaths rose from roughly 1,800 in 2008 to over 2,500 by 2018. Males predominated throughout the decade (75–80%), with a male–female ratio of about 3:1 to 4:1. Young adults were most affected, particularly those aged 21–30 years (35–40%), followed by 31–40 years (20–25%). Female cases were more frequent in rural settings and often linked to family issues, whereas male suicides were commonly associated with unemployment and financial stress(10). Autopsy-based regional studies corroborate these NCRB patterns. A 2022 retrospective autopsy study from two Bihar medical colleges (Patna and Madhubani) reported strangulation in 20 of 421 unnatural deaths (4.8%), ranking seventh after road traffic accidents, violence, poisoning, hanging, burns, and drowning. Strangulation was slightly more common in females than males (11). Post-mortem findings in Bihar court cases typically describe death due to asphyxia from strangulation, supported by external injuries (nail marks, bruises on the neck/face) and internal evidence such as hyoid bone fracture (12).

Mechanisms of Death: Mechanistic Framework-

Hanging Mechanism - In hanging, suspension of the body by a ligature around the neck creates variable compression depending on:

- **Suspension angle and knot position**: Knot typically placed over lateral neck (mastoid), producing oblique ligature mark.
- **Body weight**: Force applied continuously through suspension; heavier individuals show greater neck compression.
- **Duration**: Asphyxia develops gradually over seconds to minutes
- **Possible mechanisms of death**: 1. airway closure (most common); 2. carotid artery compression with cerebral hypoxia; 3. vagal reflex-induced cardiac arrhythmia (rare) (13).

Strangulation Mechanism- In ligature strangulation, external force (typically manual or via ligature) compresses the neck independent of body weight:

- **Force vector**: Applied horizontally, often from behind or laterally
- **Agressor control**: Force can be varied, sustained, or intermittent
- **Compression pattern**: Typically more uniform, encircling compression with horizontal ligature mark
- **Mechanism of death**: (1) airway obstruction (less common than hanging due to flexibility); (2) bilateral carotid compression with rapid cerebral ischemia; (3) venous obstruction with raised intracranial pressure

Manual strangulation produces similar vascular compromise without ligature mark, but commonly leaves fingernail marks, bruising of larynx, and evidence of struggle.

Antemortem and Postmortem Findings

External Ligature Marks: Pattern and Characteristics

The ligature mark—impression of ligature material on neck skin—provides crucial differentiation:

Hanging Pattern (14,15)

Characteristic	Suicidal Hanging	Homicidal Strangulation
Mark Direction	Oblique (typically 45°)	Horizontal/slightly diagonal
Continuity	Non-continuous, often one side deeper	Complete encirclement
Location	Above thyroid cartilage	At/below thyroid level
Knot Position	Lateral (mastoid 56%, occipital 7%)	Multiple knots or irregular
Margin Definition	Pale, parchmentized edges	Dark, bruised, hemorrhagic
Underlying Tissue	Glistening white fascia	Extensive extravasation of blood

Associated Bruising	Minimal or absent	Extensive, multiple levels
Predictive Value	Sensitivity 97%, Specificity 100%	N/A

Antemortem vs. Postmortem Determination: Molecular Markers (16,17)

Development of multiplex immunohistochemistry assays enabling simultaneous assessment of multiple biomarkers for robust antemortem/postmortem and mechanism differentiation.

Biomarker	**Antemortem Significance**	**Postmortem Behavior**	**Forensic Utility**
HSP27/70/90	Active stress response	No new synthesis	Vital reaction marker
Ubiquitin system	Compression & ischemia injury	Passive degradation	Differentiates vital injury
Caspases	Ischemia-induced apoptosis	No activation	Confirms antemortem ischemia
HIF-1α / VEGF	Hypoxia response	Stable but no expression	Supports asphyxia

The expression of stress proteins, apoptosis markers, ubiquitin system alterations, and hypoxia-inducible angiogenic factors represents vital cellular responses, making them highly valuable in distinguishing antemortem injuries from post mortem changes. Their combined use with histopathology and autopsy findings significantly enhances the accuracy of forensic timing and cause-of-death determination.

Comparison of Biomarker Expression in Hanging and Strangulation

Hanging and strangulation, though both categorized as asphyxial deaths, exhibit distinct patterns of cellular and molecular responses that can be evaluated using forensic biomarkers. In cases of strangulation**,** particularly ligature or manual strangulation, the application of intense and localized neck compression results in pronounced mechanical stress and ischemia, leading to marked upregulation of heat shock proteins (HSP27, HSP70, and HSP90) at the site of injury. This enhanced HSP expression reflects an active cellular stress response and is often accompanied by alterations in the ubiquitin–proteasome system**,** including depletion or abnormal accumulation of ubiquitinated proteins, indicative of antemortem compression. Furthermore, ischemia-induced apoptosis, evidenced by activation of caspases (especially caspase-3)**,** is more prominently observed in strangulation due to sustained vascular occlusion and tissue hypoxia. In contrast, hanging**,** particularly complete or typical hanging, is characterized by global hypoxia rather than focal compression, resulting in comparatively less intense local mechanical injury to neck tissues. Consequently, HSP expression and ubiquitin system alterations at the ligature mark may be less pronounced or patchy. However, hanging demonstrates stronger activation of hypoxia-responsive angiogenic markers**,** notably HIF-1α and VEGF**,** reflecting systemic oxygen deprivation and cerebral hypoxia. These markers indicate a vital hypoxic stress response occurring prior to death, even in the absence of extensive local tissue damage. Thus, while both hanging and strangulation show evidence of antemortem hypoxia, strangulation is more strongly associated with localized stress, ischemia, and

apoptotic biomarkers, whereas hanging predominantly exhibits markers of generalized hypoxic response**.** The combined interpretation of these biomarkers, along with histopathology and autopsy findings, enhances the forensic differentiation between hanging and strangulation.

Investigative Guidance

Autopsy findings guide investigative direction:

Autopsy Finding	Suggested Manner	Investigative Action
Oblique mark, no defense injuries, parchmentization	Suicide	Focus on victim's mental health, stressors
Horizontal marks, extensive trauma, defense injuries	Homicide	Identify potential assailants, motive, evidence
Mark with signs of struggle, varying pressures	Undetermined	Require additional evidence (scene, witnesses)
Postmortem suspension simulant	Determine actual cause	Investigate scene thoroughly

Recent Advances and Future Directions

Postmortem Imaging

Recent studies employ postmortem CT and MRI for neck examination: (18)

- **Advantages**: Visualize deep structures without artifact from dissection; preserve specimens.
- **Applications**: Detect fractures, vascular injuries, intracranial pathology.
- **Limitations**: 29.3% diagnostic disagreement with autopsy; some findings underreported in severe cases.
- **Future**: Integration of postmortem CT findings with autopsy and immunohistochemistry.

Histopathological Examination

Microscopic analysis of ligature mark tissue distinguishes hanging from strangulation: (19)

Ligature mark histology findings (skin and subcutaneous tissue):

- **Compression findings**: Flattened keratinocytes, condensed collagen
- **Hemorrhage pattern**: Distinguishes vascular rupture (strangulation) from ischemic changes (hanging)
- **Inflammation/vital reaction**: Neutrophil infiltration confirms antemortem injury

Justice and Legal Applications

Correct distinction between hanging and strangulation has major legal and social consequences. It determines whether a death is classified as homicide, suicide, or accident**,** directly affecting criminal charges and sentencing. The certified manner of death also shapes the official death narrative for the victim's family**,** influences insurance claims where suicide exclusions apply, and ensures accurate public health data**,** which is essential for planning effective prevention strategies.

2. Discussion

Accurate differentiation between hanging and strangulation is crucial, as it directly influences the determination of the manner of death**.** Hanging generally reflects the victim's own act and is most often classified as suicide**.** Strangulation implies the involvement of another person and is typically categorized as homicide**.** Accidental hanging, though uncommon, may occur in situations such as autoerotic asphyxia or accidental entrapment (20). In cases where available evidence is inadequate or inconclusive, the manner of death is recorded as undetermined**.** Isolated findings rarely allow a definitive opinion; diagnostic accuracy improves markedly when autopsy results are interpreted together with scene evidence**.** Suicidal hanging is typically characterized by an oblique, incomplete ligature mark above the thyroid cartilage, parchmentization of the skin, absence of defense injuries, and lack of sedative or drug involvement. In contrast, homicidal strangulation is suggested by a horizontal, continuous ligature mark, marked internal neck trauma such as fractures and hemorrhage, presence of defense injuries, frequent detection of sedative substances, and scene findings indicating struggle or restraint. Therefore, a holistic evaluation of external, internal, toxicological, and circumstantial evidence is crucial for an accurate medico-legal diagnosis. Although classical features such as petechiae, facial congestion, cyanosis, and tongue protrusion are useful for forming an initial opinion, they have limited diagnostic specificity**.** Petechial hemorrhages are more frequent in hanging than in non-hanging cases, but their presence in a notable proportion of non-hanging deaths reduces their value as an independent diagnostic sign(21). Facial congestion and cyanosis result from impaired venous return and may be seen not only in hanging, but also in strangulation and other forms of asphyxia, making them unreliable for differentiation. Tongue protrusion**,** though commonly observed in hanging, is a non-specific finding and may be influenced by postmortem muscle relaxation or decomposition. Therefore, traditional signs should be interpreted in conjunction with other autopsy, histological, and scene findings**,** rather than relied upon in isolation. Emerging immunohistochemical approach like Immunohistochemical markers HSP27, HSP70, and ubiquitin, mark an important advancement toward an objective, molecular evaluation of vitality in cases of neck compression. These markers help differentiate antemortem from postmortem injuries, minimize the subjectivity associated with gross autopsy findings, and remain useful even in partially decomposed bodies, provided tissue integrity is maintained. In addition, characteristic expression patterns may assist in distinguishing hanging from strangulation. However, this approach has certain limitations. It depends on specialized immunohistochemistry laboratories, which are not widely available in many resource-limited settings. Accurate results also require proper tissue preservation, and overlap in marker expression between hanging and strangulation reduces its ability to provide a definitive distinction between the two mechanisms. Autopsy findings should always be correlated with scene investigation**.** Hanging scenes usually show body suspension with a ligature, while strangulation scenes often display signs of struggle,

restraint, and scene disturbance**.** The forensic pathologist must integrate postmortem findings with police and scene evidence and communicate them clearly to ensure accurate determination of the manner of death.

3. Conclusion

Distinguishing hanging from strangulation remains a major challenge in forensic pathology with important legal and public health implications. Future practice emphasizes a multimodal approach, combining postmortem imaging, histopathology, immunohistochemistry, and thorough scene investigation to improve diagnostic accuracy. Forensic pathology is thus evolving from a largely subjective assessment to an evidence-based science, strengthening justice delivery, supporting families, and enhancing understanding of asphyxial deaths.

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