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Indian Journal of Forensic and Community Medicine

Journal homepage: <https://www.ijfcm.org/>

Case Report

Study of delayed deaths in hanging: Unravelling post-obstructive pulmonary oedema as the primary cause of death

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ARTICLE INFO

Article history:

Received 05-09-2024

Accepted 25-09-2024

Available online 23-10-2024

Keywords:

Hanging fatalities

Post-obstructive pulmonary edema (POPE)

Near-hanging

Delayed death hanging

Intensive care unit admission

Acute respiratory distress syndrome

Respiratory complications

Oxygen therapy

Hypoxia

ABSTRACT

Background: Suicide by hanging is a significant public health concern globally, with delayed deaths presenting unique challenges in understanding the underlying pathophysiology. In this observational study, cases of suicidal hanging resulting in delayed death were isolated, and comprehensive analyses were performed. Data collection included detailed histories of the suicidal attempts, circumstances surrounding the events, medical treatment records, and thorough autopsy examinations, including histopathological analyses.

Aim and Objective: This study aims to investigate cases of delayed death by hanging and analyse the associated pathophysiological mechanisms.

Results: Three cases of delayed death by hanging were identified and analysed in this study. Each case involved individuals who initially survived the suicidal attempts and received medical treatment. Despite efforts, all three individuals succumbed to their injuries after a period of time. Autopsy findings revealed characteristic signs of hanging, along with evidence of post-obstructive pulmonary edema as the cause of death in each case.

Conclusions: This study highlights the occurrence of delayed deaths following suicidal hanging and underscores the importance of understanding the pathophysiological mechanisms involved. The identification of post-obstructive pulmonary edema as a significant contributor to mortality in these cases emphasizes the need for timely and effective medical interventions to mitigate adverse outcomes in individuals who survive hanging attempts.

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1. Introduction

Suicide has emerged as a pressing global and national public health concern due to an increase in reported cases. In 2022, India's National Crime Record Bureau documented 1,70,924 suicides, with hanging constituting 58.2% of these cases.¹ Medico-legally, three main types of asphyxia associated with neck compression hold significance: manual strangulation, ligature strangulation, and hanging.² Hanging is defined as death resulting from external pressure on

the neck when a ligature is applied to a wholly or partly suspended individual and the constricting force is the body's weight.³ Hanging is mostly suicide in nature; however, few accidental cases have been reported in the literature.⁴ While most cases result in instantaneous death, there are documented instances in the literature where death occurred after a certain period or where patients survived following prolonged resuscitative efforts.^{4,5} Hanging is often regarded as a painless method of suicide, resulting in immediate death caused by reflex vagal inhibition, anoxia, or cerebral ischemia.^{2,6–8} However, despite the common belief that, once initiated, hanging cannot be reversed, there

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are instances where individuals survive and are promptly rescued, termed “near-hanging”.^{2,3,7,8} Those who survive may die at a later stage, referred to as “delayed death by hanging”.^{2,3} Near-hanging incidents accounted for only 2.7% of documented para-suicides and less than 1% of intensive care unit admissions.

Death by hanging occurs because of cerebral ischemia and anoxia caused by obstruction of the carotid or cervical arteries, airway obstruction leading to respiratory insufficiency, jugular venous compression, reflex vagal inhibition, or fracture dislocation of the cervical vertebrae.^{2,9–11} Survivors of attempted hanging may experience secondary effects, such as hemiplegia, epileptiform convulsions, amnesia, dementia, cervical cellulitis/retropharyngeal abscess, and parotitis.¹² Respiratory and neurological complications, including pulmonary or neurogenic edema, post-obstructive pulmonary distress, aspiration pneumonitis, acute respiratory distress syndrome (ARDS), seizures, hypotension, neck vessel compression, cerebral hypoxia, and multi-organ failure, can emerge as fatal complications of hanging.^{8,13,14}

Post-obstructive pulmonary edema (POPE), characterized as a form of non-cardiogenic, non-neurogenic pulmonary edema, is uncommon but potentially life-threatening and rapidly develops without warning, typically within seconds to minutes after the relief of severe upper airway obstruction caused by factors such as tumors, strangulation, or near hanging.¹⁵ The precise mechanisms underlying POPE development in delayed death by hanging remain unclear, with proposed theories attributing it to the hypoxia-induced release of vasoactive mediators, damage to the pulmonary capillary membrane, or abrupt relief of acute upper airway obstruction.^{7,8} The incidence of POPE after non-lethal suicidal hanging is poorly documented, with most reports comprising isolated cases in the literature.

The objective of this study is to identify cases of delayed death caused by hanging and analyse the underlying pathophysiological mechanisms leading to death. Understanding the pathophysiological process involved in delayed deaths by hanging can contribute to improved medical interventions and patient outcomes in similar cases in the future.

2. Materials and Methods

This observational study was conducted at the Forensic Medicine and Toxicology Department of a tertiary care hospital in Surat, India, spanning from October 2023 to December 2023. The study focused on autopsies performed on suicidal cases, involving hanging as the method of suicide, specifically including cases where the individual survived and received medical treatment. Detailed information was collected regarding the timing and circumstances of the suicide attempt, including who first

witnessed it and how the individual was transported to the hospital. Medical records were reviewed to document the treatment received and the patient's condition throughout the course of treatment. During autopsy, both external and internal examinations were conducted, and tissue samples were collected for histopathological analysis. The study encompassed individuals of all ages, genders, and races, with no exclusion criteria based on demographics.

3. Results

Between October and December 2023, there were 29 reported autopsies of suicide by hanging. Among them, three cases of delayed death by hanging were isolated, wherein individuals received medical treatment following the suicide attempt. Below, individual case details are provided, beginning with the suicidal attempt, followed by the treatment received, subsequent death, and concluding with autopsy findings and histopathological examination results.

3.1. Case 1

A 33-year-old married woman, who was undergoing treatment for depression, committed suicide by hanging herself with cloth material at home in the morning. Her husband discovered her hanging, promptly removed the ligature, and lowered her down, although the duration of the hanging remained unknown as there were no witnesses to the event. The woman had last been seen 25 minutes before she was found. She was rushed to the nearest hospital where she arrived unconscious, with excessive frothing from the mouth and heavy breathing, along with very low oxygen saturation levels (Spo2) of 81% with room air. Consequently, she was admitted to the intensive care unit (ICU) and received all necessary resuscitative measures. Oxygen therapy was initiated, and vital signs were closely monitored. Various supportive treatments were administered to the patient. However, during the course of treatment, the patient developed severe hypoxia, acidosis, and haematuria. The patient was subsequently intubated and placed on mechanical ventilation. Despite repeated suctioning, the endotracheal tube continued to be filled with copious pink frothy secretions. Intensive therapy has been employed to enhance tissue oxygenation, reduce intracranial pressure, and prevent neurological complications. Unfortunately, her respiratory and neurological status deteriorated, and she succumbed to her injuries 48 hours after the suicide attempt. A post-mortem examination was conducted to rule out the cause of death. External examination revealed a reddish-brown partial ligature mark measuring 29 cm in length, predominantly visible on the left lateral aspect of the neck (Figure 1 A) with a width of 3.5 cm, and faint marks on the front and right sides of the neck (Figure 1 B, C) measuring 2 cm in width. The ligature mark appeared hard

and parchmented. A bluish discoloration was observed on the nails and lips. Internally, there was evidence of blood extravasation into the subcutaneous tissues and muscles of the left lateral aspect of the neck. Subcutaneous tissues (Figure 1 E) beneath the ligature mark appeared dry, white, and glistening. The hyoid, thyroid, and cricoid cartilages were intact, whereas the larynx and epiglottis exhibited severe edema and petechial haemorrhage (Figure 1 F). The left and right lungs (Figure 1 D) weighed 491 g and 543 g respectively, and showed congestion, edema, and frothy fluid mixed with blood upon sectioning. Histopathological examination of the tissue samples revealed pulmonary edema in both lungs and zonal necrosis around the central veins of the liver.



Figure 1: External and internal findings of case 1. A, B and C shows left, front and right side of neck. Internal examination shows edematous lungs (D), internal findings of neck (E) and edema and haemorrhagic spots over larynx, epiglottis and trachea (F)

3.2. Case 2

A 23-year-old married woman hung herself with a soft towel cloth in the afternoon. Her husband discovered her and promptly removed the ligature, bringing her down from suspension. The patient was then transferred to the nearest hospital. As the event was unwitnessed, the duration of hanging remained unknown. The woman had last been seen 20 minutes before she was found. On arrival at the hospital, she was unconscious and unresponsive to painful stimuli, with saliva and frothy fluid dribbling from her mouth. She was admitted to the ICU, where her oxygen saturation level (SpO₂) on room air was 88%. Oxygen therapy and other supportive measures were also initiated. Bilateral crepitation sounds were detected during chest auscultation. As her SpO₂ level continued to

decline, she was intubated and placed under mechanical ventilation. Despite intensive treatment, she succumbed to her injuries 30 hours after the suicide attempt. A post-mortem examination was conducted to determine the cause of death. External examination revealed a partial ligature mark measuring 31 cm in length, more prominent on the left side of the neck (Figure 2 A) with a width of 3 cm, and gradually fading on the front and right sides of the neck (Figure 2 B, C). Bluish discoloration was noted on the nails. The ligature mark appeared reddish-brown, hard, and parchmented. In addition, blood extravasation was observed in the muscles on the left side of the neck. The subcutaneous tissues (Figure 2 E) beneath the ligature mark appeared glistening, dry, and white. The hyoid, thyroid, and cricoid cartilages were intact, whereas the larynx, epiglottis, and vocal cords exhibited edema (Figure 2 F). The left and right lungs weighed 539 g and 602 g respectively, and showed congestion, edema (Figure 2 D). Histopathological examination revealed pulmonary edema in both lungs and bronchopneumonia in one lung. Hepatocyte degeneration and acute tubular necrosis were also observed.



Figure 2: External and internal findings of case 2. A, B and C shows left, front and right side of neck. Internal examination shows edematous lungs (D), internal findings of neck (E) and edema over larynx, epiglottis and trachea (F)

3.3. Case 3

A 24-year-old married man was found in hanging state with a scarf cloth material at home during the evening. Discovered by his mother, the ligature was promptly removed, and he was lowered down, though the duration of the hanging remained unknown as there were no witnesses. Last seen 40 minutes prior to discovery, he arrived at the nearest hospital in unconscious condition, exhibiting excessive jerky limb movements and heavy

breathing, with an oxygen saturation level (Spo2) of 88% on room air. Bilateral crepitation was noted on chest auscultation, and his heart rate was recorded at 152 beats per minute. Admitted to the intensive care unit (ICU), he received resuscitative measures, including oxygen therapy and close vital sign monitoring. Portable chest x-ray indicated changes consistent with ARDS. Despite various supportive treatments, he developed severe hypoxia, leading to intubation and mechanical ventilation. Copious pink frothy secretions persisted in the endotracheal tube despite repeated suctioning. Sadly, his respiratory and neurological status deteriorated, and he succumbed to his injuries 28 hours post-suicide attempt. A post-mortem examination was conducted to determine the cause of death. Externally, a reddish-brown partial ligature mark measuring 27 cm in length was evident on the front aspect of the neck (Figure 3 B), with faint marks measuring 3.5 cm in width on the left and right sides (Figure 3 A, C). Bluish discoloration was observed on the nails and lips. Internally, blood extravasation was found in the subcutaneous tissues and muscles of the right lateral aspect of the neck due to central line catheterization. The subcutaneous tissues beneath the ligature mark appeared dry, white and glistening (Figure 3 E). While the hyoid, thyroid, and cricoid cartilages were intact, severe edema was noted in the larynx and epiglottis (Figure 3 F). The left and right lungs weighed 502 g and 593 g respectively, and exhibited congestion, edema, and frothy fluid mixed with blood upon sectioning (Figure 3 D). Histopathological examination revealed pulmonary edema and changes consistent with ARDS in both lungs.

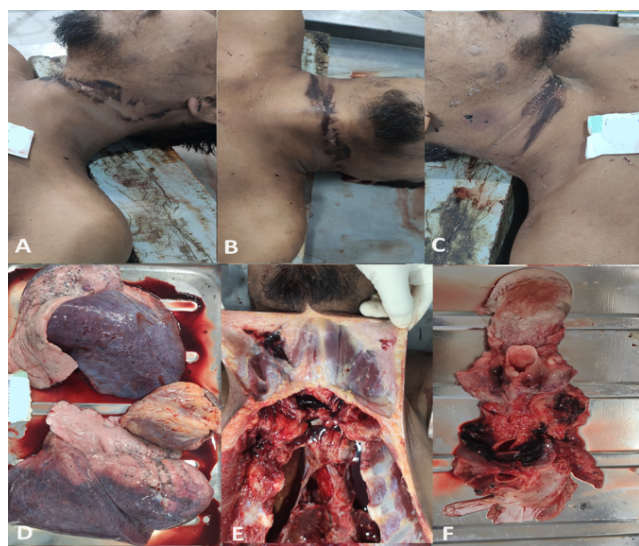


Figure 3: External and internal findings of case 3. A, B and C shows left, front and right side of neck. Internal examination shows edematous lungs (D), internal findings of neck (E) and edema over larynx, epiglottis and trachea (F)

4. Discussion

In India, hanging is increasingly recognized as a method preferred by adults for suicide attempts. Typical hanging occurs when the point of suspension is directly above the centre of the occiput, leading to maximal artery occlusion. Conversely, any other point of suspension is termed atypical hanging. While the majority of cases result in instantaneous death, there are documented instances in the literature where death occurred after a certain period or where patients survived following prolonged resuscitative efforts.^{5,13} Death by hanging occurs due to cerebral ischemia and anoxia caused by obstruction of the carotid or cervical arteries, airway obstruction leading to respiratory insufficiency, jugular venous compression, reflex vagal inhibition, or fracture dislocation of the cervical vertebrae.^{2,9–11} Survivors of attempted hanging may experience secondary effects such as hemiplegia, epileptiform convulsions, amnesia, dementia, cervical cellulitis/retropharyngeal abscess, and parotitis.¹² Respiratory and neurological complications, including pulmonary or neurogenic edema, post-obstructive pulmonary distress, aspiration pneumonitis, ARDS, seizures, hypotension, neck vessel compression, cerebral hypoxia, and multi-organ failure, can emerge as fatal complications of hanging.^{8,13,14}

POPE categorized as a type of non-cardiogenic and non-neurogenic pulmonary edema, is infrequent, but carries the potential for life-threatening consequences. It manifests rapidly and unexpectedly, often occurring within seconds to minutes following the alleviation of severe upper airway obstruction.¹⁵ POPE was initially documented in humans in 1973.¹⁶ It is classified into two distinct subclasses: type I, associated with forceful inspiratory effort during acute and severe airway obstruction such as epiglottitis, choking, laryngospasm, endotracheal tube obstruction, hanging, strangulation, and near drowning; and type II, which is linked to the relief of chronic partial airway obstruction (e.g., laryngeal mass resection, tumor, adenoidectomy, tonsillectomy).¹⁷ Instances of pulmonary edema following non-lethal hanging are exceedingly rare, likely due to the low survival rate among victims of suicidal or accidental hangings.¹⁸ The pathophysiology of POPE is multifaceted.¹⁷ The initial event involves the generation of significantly negative trans pulmonary pressure during forceful inspiration against a closed upper airway, hence the term "negative pressure pulmonary edema".¹⁹ This elevated pressure is transmitted to the interstitium and alveoli, resulting in an increase in the hydrostatic gradient, favouring fluid transudation from the pulmonary capillary to the interstitial space, leading to pulmonary edema.²⁰ Hypoxia and a hyperadrenergic state also contribute to POPE development. Hypoxemia due to upper airway obstruction increases pulmonary vascular resistance and capillary pressure, while the hyperadrenergic

response redistributes blood from the systemic veins to the pulmonary circuit, further increasing pulmonary vascular resistance.²¹ The etiological factors underlying POPE type II are less clear than those underlying type I. Type II POPE pathophysiology focuses on expiration against an obstructed airway, which is similar to the Valsalva manoeuvre. This results in positive alveolar and pleural pressure, decreased pulmonary blood volume, and venous return to the right side of the heart. Upon relief of the obstruction, such as in laryngeal mass resection or post-adenotonsillectomy, sudden release causes an abrupt fall in airway pressure, an increase in venous return, and subsequent elevation in preload, leading to increased hydrostatic pressure in the pulmonary circuit and pulmonary edema.^{20,22}

The occurrence of POPE following non-lethal suicidal hanging has been inadequately documented, with the literature mostly consisting of isolated case reports. This study presents three cases, detailing delayed deaths stemming from hanging, wherein POPE was determined to be the cause of death. In two instances, the individuals were unconscious upon arrival at the hospital, with frothing observed from the mouth. Despite intensive treatment efforts, all patients succumbed within 48 hours. Gross and microscopic examinations revealed pulmonary edema and pneumonia as significant findings. Therefore, pulmonary edema was identified as the cause of death in three cases. This study underscores the need for further research to elucidate the pathophysiology and incidence of POPE following non-lethal suicidal by hanging. More extensive studies could help to identify risk factors, improve diagnostic approaches, and develop targeted interventions to prevent or manage POPE in such cases. Healthcare professionals, particularly emergency responders and intensive care unit (ICU) staff, need to be aware of the potential development of POPE in hanging-related cases.

Overall, this study provides valuable insights into the complex clinical and medicolegal aspects of hanging-related deaths, particularly highlighting the role of POPE as a potential cause of mortality in such cases.

5. Conclusions

This study identifies three cases detailing delayed deaths resulting from hanging, wherein post-obstructive pulmonary edema (POPE) was identified as the cause of mortality. These cases underscore the multifaceted nature of hanging-related fatalities and highlight the potential for life-threatening complications, such as POPE. These findings emphasize the importance of recognizing and addressing diverse physiological mechanisms and complications associated with hanging, particularly in cases of delayed death. Healthcare professionals, including emergency responders and ICU staff, should be vigilant about the development of POPE in patients presenting with hanging-

related injuries and provide timely interventions to improve outcomes.

Overall, the findings of this study provide valuable insights into the complex clinical and medicolegal aspects of hanging-related deaths, with implications for research, practice, and policy in the fields of forensic medicine and public health. By raising awareness of the potential complications associated with hanging, this study aimed to improve patient care, inform decision-making, and ultimately reduce the incidence and severity of hanging-related injuries and fatalities.

6. List of Abbreviations

POPE: Post-obstructive pulmonary edema; ICU: Intensive care unit; ARDS: Acute respiratory distress syndrome.

7. Ethics Approval and Consent to Participate

Ethical approval and the need for informed consent were waived for this study as it utilized de-identified data and autopsy specimens. Institutional review board (IRB) approval was not required due to the use of existing de-identified data. All patient data used in this study were anonymised to protect patient privacy and confidentiality.

8. Source of Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

9. Conflict of Interest

The authors report there are no competing interests to declare.


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Cite this article: Kanani J, Sheikh MI, Tailor CI. Study of delayed deaths in hanging: Unravelling post-obstructive pulmonary oedema as the primary cause of death. *Indian J Forensic Community Med* 2024;11(3):130-135.