

A Comparative Observational Study of Postmortem Computed Tomography and Traditional Forensic Autopsy Findings in Hanging Cases

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Abstract

Background: The use of advanced radiological techniques is rising in the field of forensics to supplement and validate the evidence. Postmortem Computed Tomography (PMCT) is now used as a standard procedure in many institutions to augment traditional autopsy findings. The application of PMCT in hanging cases will greatly reduce the number of invasive traditional autopsies, as hanging is the most common method of suicide in Northern parts of India. Therefore this observational study was conducted to compare PMCT with traditional autopsy in fifty hanging cases.

Result: Out of 50 cases, the age of the subjects ranged between 14 years and 70 years. PMCT with the help of 3D reconstruction was able to detect external ligature marks on the neck in 92% (N=46) of cases giving a sensitivity of 92% (CI = 80.77% to 97.78%). Skin and subcutaneous tissue desiccation were identifiable in 96% (N=48) by PMCT, giving a sensitivity of 96% (CI= 86.29% to 99.51%). The muscle hemorrhage was identified in 4% (N=2) of the cases in traditional autopsy while the authors found difficulty in interpreting the muscle hemorrhage in PMCT. In detecting thyroid cartilage fracture, the sensitivity of PMCT was found to be 100% (CI= 15.81% to 100.00%) and specificity of 100% (CI=92.60% to 100.00%). In detecting hyoid bone fracture, the sensitivity was 100% (CI= 2.50% to 100.00%) and specificity of 100% (CI=92.60% to 100.00%). In addition, there was a great degree of agreement between the two observers for these findings suggesting the reproducibility of the result.

Conclusions: A consistency in findings of both the PMCT and traditional autopsy was found. However, CT was unable to detect muscle hemorrhages, compared to traditional autopsy. Authors suggest the use of CT angiography to overcome this shortcoming, till then CT can only augment invasive autopsy findings not replace it.

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INTRODUCTION

Hanging is a form of asphyxia where there is constriction of the neck and this constricting force applied to the neck comes from the gravitational drag of the weight of the body or a

part of it.¹ These asphyxia deaths though common are quite complex and need meticulous examination by an autopsy surgeon. In such a situation any tool or investigation supporting the findings will be of immense help. Internal injuries such as fractures and dislocations of hyoid and thyroid cartilage, and neck muscle hemorrhages are of significant value in forensic pathology, so as to better understand the constrictive force over the neck and to estimate the intensity of the force applied. The severity of internal neck injuries can not be estimated by solely looking at the external findings.² The external lesions may only be discreet or sometimes even absent, which further necessitates the requirement to apply advanced radiological techniques. Currently, for hanging cases, the traditional invasive autopsy is considered the gold standard. It is not just time consuming, but also requires a lot of precision and experience.³ But even then the fractures of the thyroid and hyoid may be missed or misinterpreted due to artifacts produced by the dissection, therefore using additional radiological tools to augment the traditional autopsy findings is very much needed.⁴

The use of CT and MRI in the field of forensic medicine has been validated and its usefulness is established by many studies in routine medicolegal death investigations.⁵⁻⁷ Implementing these diagnostic tools would greatly increase the standard and quality of autopsy, which could be reproducible evidence to the legal system. In addition, the correlation of macroscopic, microscopic, and radiological findings will enhance the scientific validity of forensic evidence. There have been several studies in the past discussing radiological neck findings in cases of hanging and ligature strangulation. Wallace et al described the cervical spine abnormalities and subarachnoid hemorrhage in two cases of judicial hanging.⁸ Hayashi et al in their study reported a case of hangman's fracture in non-judicial hanging detected by PMCT among his 32 cases of hanging.⁹ Kemper et al in their study claim that the use of post-mortem Multislice Computed Tomography (MSCT) along with the thorough external examination and crime-scene investigation can further guide a need for more invasive investigation.² All these studies highlighted the importance of radiological investigation in hanging cases. Therefore, the authors compared the traditional autopsy and Postmortem MSCT internal neck findings in 50 hanging cases. The authors aim to validate the PMCT findings to determine the cause and manner of death in comparison with

Traditional autopsy and to replace traditional invasive autopsy with the PMCT in future cases.

METHODS

Study Population

In the month of August and September, 50 hanging cases were done at the Department of Forensic Medicine and Toxicology, AIIMS, New Delhi which were taken for this study. These 50 cases had the cause of death as asphyxia due to hanging. All presented some form of ligature mark on the neck. Out of the total 50, 74% (N=37) were male and 26% (N=13) were females.

Post-mortem Imaging

In each case, an autopsy was preceded by a PMCT examination using a 16 slice MSCT spiral scanner, Canon, Aquillon Lightning TSX-035A CT. The scanning parameters used were 120kV and 70 mAs. 16 x 1 mm collimation was used for all the cases for data acquisition. All the raw data was processed into slices of 1mm thickness. Multiplanar and 3D reconstruction were also done. The processed data were assessed and reported at two dedicated workstations (Vitrea 6.9. and Vitrea 7.10). A group of forensic doctors with training in post-mortem radiological assessment interpreted the findings.

Traditional Autopsy

Following imaging, a standard traditional autopsy using the Letulles technique of dissection was conducted by forensic doctors. This method of the autopsy was chosen as it gives detailed layer wise dissection findings while retaining anatomical correlation. It has better compliance and can easily detect injuries.

Statistical Analysis

The sensitivity and specificity of each variable were calculated. In addition, to prove, the reproducibility of the data inter-observer tests were applied. For inter-observer variability cases were analyzed by another forensic doctor with prior training in radiology.

RESULTS

Descriptive Statistics

A total of 50 cases were analyzed in the study. The age of the subjects varied between 14 years and 70 years, with a median age of 44 years.

Sensitivity and Specificity of PMCT

An evaluation of the parameters (Table 1) showed that PMCT with the help of 3D reconstruction was able to detect external ligature marks on the neck in 92% (N=46) of cases giving a sensitivity of 92% (CI=80.77% to 97.78%). Skin and subcutaneous tissue desiccation were identifiable in 96% (N=48) by PMCT, giving a sensitivity of 96% (CI= 86.29% to 99.51%). The muscle hemorrhage was identified in 4% (N=2) of the cases in traditional autopsy where the authors found difficulty in interpreting

the same at PMCT. In detecting thyroid cartilage fracture, the sensitivity of CT was found to be 100% (CI=15.81% to 100.00%) and specificity of 100% (CI=92.60% to 100.00%). In detecting hyoid bone fracture, the sensitivity was 100% (CI=2.50% to 100.00%) and specificity of 100% (CI=92.60% to 100.00%). Out of the total 50 cases, 26% (N=13) had ligature material in-situ. Among the ligature material, the most commonly encountered was cotton cloth in the form of a bedsheet or dupatta (shawl) in 10 cases and the remaining 3 cases had a rope as presented in Table 2.

Table 1: Comparison of various parameters in Traditional Autopsy and PMCT

Parameter	Autopsy Findings present in	PMCT Findings present in
External neck ligature mark	100% (N=50)	92% (N=46)
Skin and Subcutaneous tissue desiccation	100% (N=50)	96% (N=48)
Intramuscular hemorrhage	4% (N=2)	0
Fracture of the Hyoid bone	2% (N=1)	2% (N=1)
Fracture of Thyroid cartilage	2% (N=1)	4% (N=2)

Table 2: Ligature Material In-situ

Case No.	Age	Gender	Ligature Material	Hounsfield Units(HU) on CT
1	70 years	Male	Nylon Rope	650-900
10	24 years	Male	Bedsheet	600-850
11	22 years	Male	Dupatta	500-700
13	60 years	Male	Nylon Rope	500-800
16	20 years	Female	Soft cloth	600-700
18	25 years	Male	Bedsheet	600-750
24	17 years	Male	Bedsheet	750-850
32	59 years	Male	Nylon Rope	600-700
34	21 years	Male	Bedsheet	800-1000
39	29 years	Female	Bedsheet	800-1000
44	52 years	Male	Bedsheet	600-700
47	44 years	Male	Cotton Cloth	600-700
50	44 years	Male	Cotton Cloth	500-650

INTEROBSERVER ANALYSIS

An interobserver agreement analysis was

performed to calculate the intraclass correlation coefficient (ICC) between the first and the second observer for various variables observed. (Table 3)

Table 3: Interobserver analysis

Variable	Interobserver Cohen's kappa	Agreement %
External ligature mark	0.634	94%
Skin and Subcutaneous Tissue	0.789	97%
Thyroid fracture	0.657	98%
Hyoid Fracture	1	100%

DISCUSSION

The external ligature mark is mostly visible well on external examination, but if it could be recorded in Post-mortem CT then it could be a reproducible, reliable, and decision making tool at later stages also as it decreases the need for exhumation in disputed cases. The external ligature mark on 3D reconstruction was appreciated in 92% of all the cases (fig. 1). The presence of a faint external mark on the body in the remaining cases resulted in difficult detection on CT by the authors. This was observed in cases where the ligature material used was a soft cotton material like a bedsheet, which was also reported in previous studies.¹⁰



Fig. 1a: External ligature mark on Traditional autopsy.

Fig. 1b: External ligature mark on 3D reconstructed CT image.

The primary signs of hanging like skin changes and subcutaneous desiccation were found in almost all of the hanging cases in both the traditional autopsy and the PMCT. It is in concordance with the finding of Yen *et al.* who reported that 100% of cases have these signs.¹¹ M Pollacco *et al.* found the presence of ligature marks similar in both the traditional autopsy and that in PMCT.¹²

Detecting soft tissue or muscle hemorrhages in CT is difficult. According to D. Gascho *et al.*, PMCT has missed several hemorrhages in contrast to their presence in autopsy.¹³ G. Graziani *et al.* concluded that one of the most missed findings in CT neck was the soft tissue hemorrhage, the second being the thyroid nodules and superficial incisions.¹⁴ In our study, muscle hemorrhage was found in 2 of the 50 cases in traditional neck dissection, but none was interpreted by the authors in CT (fig. 2). MSCT-based post-mortem angiography can be used to not only detect vascular injuries but also to merit the contrast agent leakage to detect hematomas, which are missed on native PMCT.¹⁵ However, the authors could not find any findings or technique supportive of detecting very small hemorrhages using contrast agents, which could be a significant

finding in hanging cases. The absence of detection of the hemorrhage on CT makes it difficult to call any fracture antemortem or post-mortem, as the presence of hematoma validates its antemortem nature.



Fig. 2: External hemorrhage seen on Traditional autopsy.

Conventional autopsies may overlook or miss some hyoid or thyroid fractures. PMCT non invasively, adds information regarding the cartilaginous as well as bony structural lesions and abnormalities which is a definite merit of using CT.^{2,11} Many times anatomical variations of the larynx make it extremely difficult to detect fractures not only on traditional autopsy but also on PMCT. Schulze *et al.*, in his study described the detection of gas bubbles along with the fractures in laryngohyoid complex.¹⁶ The incidence of thyroid and hyoid fractures in Indian population is less which is evident in our study and the studies done previously as well.^{4,14} This can be attributed to the nature of ligature material used, as harder the material the greater would be increased local application of pressure over a small surface to the internal neck structures resulting in fractures.

In addition, the age of the subject plays an important role in defining the presence and absence of fracture, as younger individuals have slender built so more force is required for the same to occur. In our study the age group of more than 60 years was present in 2 cases, out of which both had fractures. Increased age causes ossification of the laryngeal structures, thereby increasing the chances of hyoid and thyroid fractures.^{18,19} Due to prevalence of sexual dimorphism, increased incidence of fractures in males compared to females is established in the literature and the same is evident. Hence the authors here report the presence of both fractures in

male subjects in concordance with the literature.¹⁹ According to Charoonnate *et al*, fractures of the hyoid and thyroid were present in 25% of the Thai population, and the incidence was more in the older age group.²⁰ Thali *et al* in 2003 detected hyoid fracture in 100% of its cases. According to a review by D Gascho *et al* out of a total of 26 hyoid fractures found in 126 cases, PMCT was able to detect 23 of them.¹³ In the present study the authors were able to find a unilateral greater horn fracture of hyoid in a 65-year-old male in both modalities (fig. 3A & 3B). A bilateral thyroid cartilage fracture was found in one case and is well appreciated in both PMCT as well as traditional autopsy (fig. 4A & 4B). In addition to this, one more fracture of thyroid was found on CT which could not be appreciated at traditional autopsy. The study of D Gascho *et al* showed that the thyroid fracture in 25 cases was found in CT as well, only one case was middle.¹³

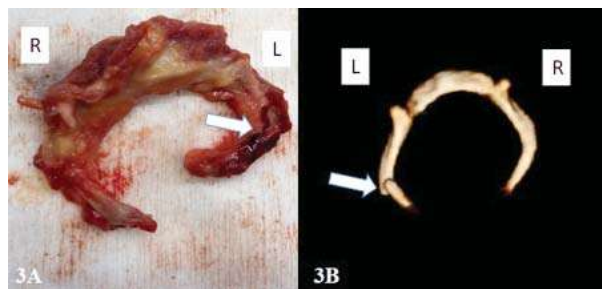


Fig. 3a: Unilateral hyoid fracture on Traditional autopsy.

Fig. 3b: Unilateral hyoid fracture on 3D reconstructed image of Hyoid.

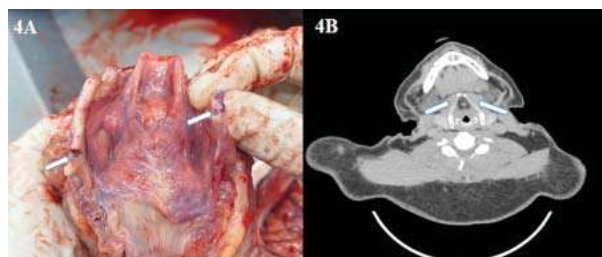


Fig. 4a: Bilateral Thyroid fracture on Traditional autopsy.

Fig. 4b: Bilateral Thyroid fracture on Axial CT.

Apart from the age of the deceased, suspension point, the type of hanging (in terms of complete and partial) and ligature material also plays an important role in extent of internal neck injury. In this study the most common ligature material used was soft cotton cloth in the form of bedsheet or dupatta (shawl) (fig. 5A & 5B). Sharma *et al.*²¹, Ahmad and Hussian²² and Patel *et al.*²³ have reported the chunni/dupatta (soft cotton cloth) as the most common ligature material followed by the rope.

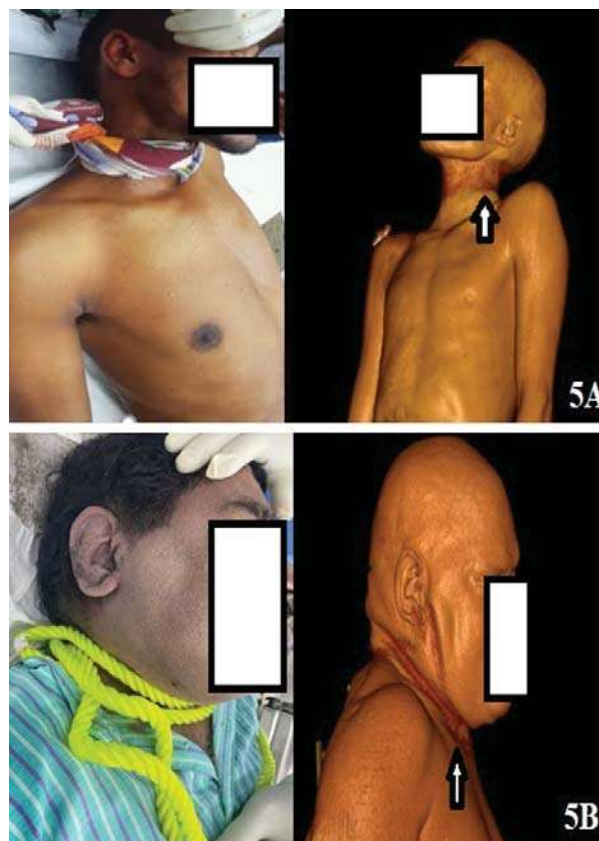


Fig. 5a: Traditional and 3D reconstructed CT image showing bedsheet as ligature material.

Fig. 5b: Traditional and 3D reconstructed CT image showing rope as the ligature material

In contrast Tumram *et al* reported nylon rope as the commonest ligature material.¹⁰ As a norm, in routine practice, hanging is always considered suicidal in manner till the contrary is proved.²⁴ In many jurisdictions, where Medical Examiner's or Coroner's systems of the inquest are in practice, the law allows handing over the deceased body without dissection if the preliminary investigation revealed no foul play.²⁵ PMCT is being used in many of these jurisdictions to avoid unnecessary dissections in cases with no possibility of future litigation.²⁵ In India, Section 174 of The Code of Criminal Procedure 1973 is a procedural law that categorizes deaths that need a preliminary investigation by the Police. The law directs the investigating officer to take the body to an empowered doctor for examining the body in all unnatural death cases and in cases without a medically certified cause of death. Thus, through usage PMCT in confirming the cause of death in combination with a detailed external examination, in nonsuspicious hanging cases, unnecessary internal dissection can be avoided.

RECOMMENDATIONS

Firstly, this study has a sample size of fifty, and the incidence of fractures of hyoid and thyroid is less in Indian population. Therefore, taking a larger sample size will further validate the results of the study. Secondly, this study is based on the concept of taking traditional autopsy as the gold standard. However, there are studies done previously which prove PMCT is better than Traditional autopsy in certain cases. Authors would suggest using a combination of thorough external examination and ruling out the possible internal injuries due to other causes like firearm, injuries due to blunt trauma etc at PMCT is sufficient enough to conclude a case of hanging. Even the instances where the presence of fracture in PMCT alone, was taken as falsely positive tarhettet examination of checking the thyroid under the electron microscope could solve the purpose. Improvising in these aspects in future studies would authenticate the findings.

CONCLUSIONS

There is a great degree of concordance in the findings of the PMCT with that of traditional autopsy in the case of skin, subcutaneous tissue desiccation, thyroid fracture, and hyoid fracture. Authors further intend to explore the implications of PMCT angiography for the identification of vessel injuries and resultant soft tissue haemorrhages, which would help in concluding nonsuspicious cases of hanging in a minimally invasive way.

LIST OF ABBREVIATIONS

PMCT: Post-mortem Computed Tomography

MSCT: Multi-Slice Computed Tomography

CT: Computed Tomography

ICC: Interclass correlation

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