ORIGINAL ARTICLE

# Post-mortem Computed Tomography (PMCT) Imaging Compared to Conventional Autopsy in Establishing Cause of Death in Adults

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**ABSTRACT**

**Introduction:** The aim of this study was to determine whether the post-mortem computed tomography (PMCT) findings are able to correlate well with the cause of death on conventional autopsy. **Materials and methods:** From January 2008 until September 2016, total of 60 bodies underwent PMCT scans in the radiology department, followed by conventional autopsies conducted in the forensic department. The radiological findings were interpreted, which were then correlated with the cause of death based on conventional post-mortem autopsy and/or pathological diagnosis. **Results:** The PMCT findings correlated well with the conventional autopsies. In 28 cases (46.7%), the cause of death was diagnosable based on PMCT alone, in nine cases (15%) the cause was suggestive but required additional information, and in 23 cases (38.3%) the cause was not diagnosable based on PMCT alone. Diagnosable cases included those involving gunshot wounds, sharp and blunt injuries, and lung infections. Causes that could not be diagnosed through PMCT alone included acute myocardial infarction, burns, asphyxiation, drug intoxication and septicemia. **Conclusion:** PMCT proves to be a valuable and excellent tool for documenting and illustrating bone fractures, abnormal air and fluid accumulation compared to soft tissue injuries, which are better detected in autopsies. However, PMCT alone cannot replace conventional autopsy, which remain the gold standard for establishing the cause of death. Nevertheless, PMCT can serve as useful adjunct in forensic investigations.
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## INTRODUCTION

Conventional autopsy consists of external examination, evisceration, dissection of major organs to identify the macroscopic pathology or injury, and histopathology for microscopic pathology [1]. It has long been considered the gold standard for postmortem evaluations to identify the cause of death. Nevertheless, there has been a notable the decline in the number of autopsies conducted on adults in most developed and developing countries in the latter half of the 20th century and beyond. In recent years, family members have increasingly refused autopsies, often due to emotional reasons [2].

The standard of autopsies is highly variable across many countries. In a UK-wide audit revealed that one in four autopsy reports were deemed poor or insufficient [3]. While post-mortem reports can be reviewed and audited, but it is difficult to assess the adequacy and thoroughness of the procedure. For example, tissue sample is retained for histological examination in only a few autopsies, and even fewer photographic record for the macroscopic pathologies; in most cases, there is no standardized method for reviewing these findings. The destructive nature of the conventional autopsies hinders the reproducibility of pathological diagnoses. Pathologists conducting a second autopsy frequently arrive at different conclusions than those from the initial examination. Therefore, autopsy cannot be assumed to be superior than imaging. In contrast, imaging provides a permanent record, making it a valuable tool for auditing autopsy practices. In addition, post mortem imaging surpasses autopsy in detecting certain fractures, intracranial pathologies and pneumothorax [1].

These challenges can be addressed through the non-invasive post-mortem imaging. The conventional approach involving X- rays is sufficient to detect foreign bodies, gross osseous lesions and gas, albeit in a two-dimensional image. However, over the past decade, post-mortem radiology has evolved from a simple autopsy-assisting X-ray to computed tomography (CT) when it was first introduced by Hounsfield and Cormack in the early 1970s. The first PMCT scan was conducted on a victim of a gunshot head injury, dates back to 1977 [4]. With the advent of spiral CT scanners, two-dimensional and even three-dimensional reconstructions of radiological images in various planes became possible.

To evaluate the feasibility of using PMCT in determine the cause of death in adults, PMCT scans were performed on 60 bodies before conducting conventional autopsies. The demographic distribution and category of PMCT cases were analyzed. Additionally, the consistency of the PMCT findings with the cause of death determined through conventional autopsies were assessed.

## MATERIALS AND METHODS

Research was approved from University Kebangsaan Malaysia (UKM) Hospital Research Ethics Committee with the project code: FF-2015-131. Procedure involved in this study was the practice and ordered by Forensic Medicine Department, UKMMC. There was neither additional autopsy procedure nor any human tissue collection for the purpose of this study.

### Patients

This cross-sectional study was carried out at the Radiology Department of the University Kebangsaan Malaysia Medical Centre (UKMMC) between January 2008 until September 2016. During this period, total 60 bodies underwent PMCT scans at the radiology department followed by conventional autopsies performed at the Forensic Department were included in the study. The probable cause of death was subsequently correlated with the findings from the conventional post-mortem autopsies or pathological diagnoses. Skeletal remains, cases with unknown cause of death due to pending laboratory investigations and ongoing court case were excluded from this study.

### Image Acquisition

All of the bodies who necessitating CT were scanned using 64-slices multidetector CT scanner (Siemens Somatom). Bodies were imaged in sealed body bags in their natural position, without manipulation. No contrast medium was administered. Contiguous volumetric scans were obtained from the vertex to the distal point allowable by table travel at 120 kV with 40-50 mAs, a pitch of 0.9 and acquisition thickness of 0.6mm. Images were reconstructed to 1mm slices thickness with soft tissue, lung and bone algorithm.

### Image analysis

With the given clinical history, the PMCT was interpreted by a senior consultant radiologist using Osirix workstation. An autopsy was later performed by pathologist after the PMCT imaging. All data was analyzed by using SPSS version 23.0.

## RESULTS

### Patient Demographics

The analysis in this study was focused on 77 consecutive forensic autopsy cases that were examined in the department between 2008 and 2016. Out of these 77 cases, 17 were excluded because inability to determine the cause of death post-autopsy either due to pending laboratory investigations in 4 cases or unavailability to retrieve the autopsy reports due to ongoing court case in 13 cases.

As a result, total 60 cases in which the cause of death had been established by conventional autopsy were reviewed and correlated with this study. Among these 60 cases, 46 cases (76.7%) involved fresh or non-decomposed bodies, while 14 cases (23.3%) involved decomposed bodies (Figure 1). Among the 14 decomposed corpses, there were 5 in bloating status, characterized by the putrefactive gases formation within the organs and subcutaneous tissue (8.3%), 2 in active decay status (3.3%), 6 in advanced decay status (10%) and 1 in dry or mummified status (1.7%).

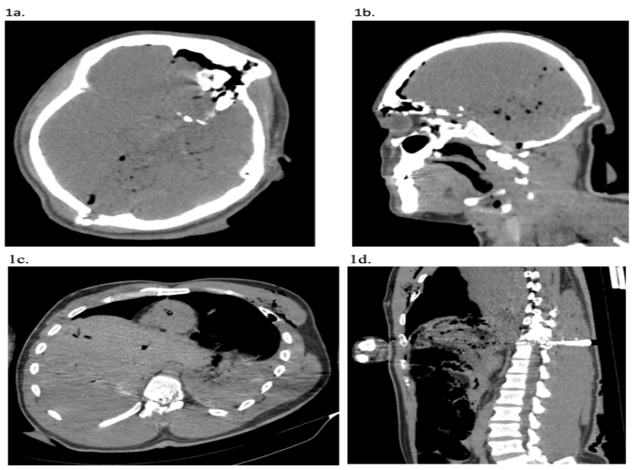


**Figure 1: a, b: A gun shot wound with its entry point at left orbital roof exiting through right occipital; c, d: Another entry at left chest wall, penetrating downward and inward, and exit through T10 vertebra.**

The study population consisted of 45 males and 15 females (Figure 2). The age ranged from 19 to 78 years (Figure 3). There were 7 Malays (11.7%), 15 Chinese (25%), 10 Indians (16.7%), 25 non-Malaysians (41.6%) comprising 14 Indonesians, 5 Burmese, 3 Bangladeshis, 2 Nepalese and 1 Pakistani, and 3 with unknown ethnicities (5%) (Figure 4).

**Figure 2: A stab wound seen at the back of body penetrating into the left kidney.**


**Figure 3: a,b: A big slash wound over left side of neck causing neck vessels laceration and cervical spine fracture.**

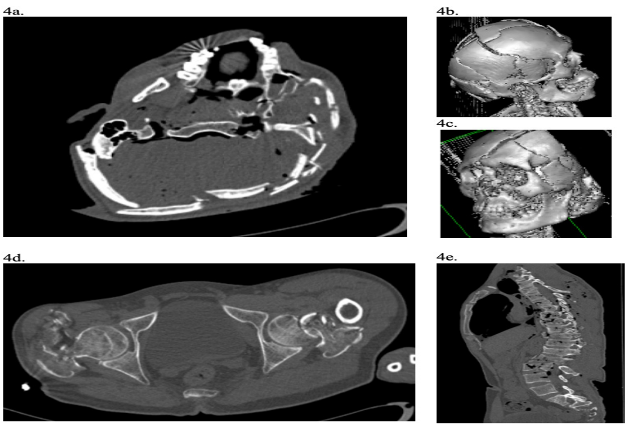


**Figure 4: Multiple fractures involving the skull (a, b, c), pelvis (d) and spine (e) and in a case fall from height.**

## Categorization of Results

Interpretation of the PMCT findings was conducted by a board-certified radiologist and two board-certified forensic pathologists. Each PMCT image was classified into one of the following three categories [5] - (1) Diagnosable: In cases where the cause of death was diagnosable from PMCT findings alone; with no need for additional information. (2) Suggestive: In cases where the PMCT findings provided clues regarding cause of death but were to sufficient on their own, necessitating additional information. (3) Non-diagnosable: In cases where the cause of death could not be ascertained from the PMCT findings.

The causes of death observed in this study encompassed a range of categories, including sharp or penetrating injuries (17 cases, 28.3%), gunshot wounds (14 cases, 23.3%), falls from height (10 cases 16.7%), blunt injuries (6 cases, 10.0%), coronary artery disease (5 cases, 8.3%), burns (3 cases, 5.0%), asphyxiation (2 cases, 3.3%), drug intoxication (1 case, 1.7%), lung infection (1 case, 1.7%), and septicemia (1 case, 1.7%) (Table I). Among the 60 cases, 28 cases (46.7%) are consistent with conventional autopsy, 9 cases (15%) were suggestive, and 23 cases (38.3%) not diagnosable on PMCT (Table II).

**Table I:. Causes of death based on PMCT findings**

| Causes | n (%) |
|---|---|
| Sharp injury (stab/slash wound) | 17 (28.3%) |
| Gun shot wound | 14 (23.3%) |
| Fall from height | 10 (16.7%) |
| Blunt injury | 6 (10.0%) |
| Coronary artery disease | 5 (8.3%) |
| Burn | 3 (5.0%) |
| Asphyxiation | 2 (3.3%) |
| Drug intoxication | 1 (1.7%) |
| Lung infection | 1 (1.7%) |
| Septicemia | 1 (1.7%) |
| Total | 60 (100%) |

**Table II:Classification of PMCT findings in 60 cases**

| Causes | Diagnosable | Suggestive | Non-diagnosable |
|---|---|---|---|
| | (number, proportion%) | | |
| Sharp injury | 10/17 (58.8%) | 1/17 (5.9%) | 6/17 (35.3%) |
| Gun shot wound | 13/14 (92.9%) | 0/14 (0%) | 1/14 (7.1%%) |
| Fall from height | 1/10 (10%) | 8/10 (80%) | 1/10 (10%) |
| Blunt injury | 3/6 (50%) | 0/6 (0%) | 3/6 (50%) |
| Coronary artery disease | 0/5 (0%) | 0/5 (0%) | 5/5 (100%) |
| Burn | 0/3 (0%) | 0/3 (0%) | 3/3 (100%) |
| Asphyxiation | 0/2 (0%) | 0/2 (0%) | 2/2 (100%) |
| Drug intoxica-tion | 0/1 (0%) | 0/1 (0%) | 1/1 (100%) |
| Lung infection | 1/1 (100%) | 0/1 (0%) | 0/1 (0%) |
| Septicemia | 0/1 (0%) | 0/1 (0%) | 1/1 (100%) |

## Gunshot

In 13 out of 14 cases, PMCT was able to localize the projectile and visualize the bullet tract. These results matched the results obtained from autopsies, regarding the number of bullets, the bullet track, the location of entry and exit wounds, as well as the detection of bullets and bullet fragments within the body, and major injuries (Figure 1). However, in 1 particular gunshot case, PMCT failed to detect the gunshot wound as the chest injury was exceptionally extensive, leading to consideration the cause of death to be a sharp or penetrating injury instead.

**Sharp / penetrating injury**
Fatal injuries resulting from sharp objects like stabs (Figure 2) or slashes (Figure 3) are commonly encountered, whether in homicides, suicides, or accidental incidents. These injuries lead to internal damage and exsanguination of blood vessels. In 10 cases, PMCT sufficed in diagnosing injuries to the lung, heart and abdomen. In one case, sharp injury was suggestive after further correlation with the available history. However, PMCT failed to detect this injury in 6 cases (4 affecting the neck, one the lung, and one the heart).

**Blunt injury**
Total 6 cases of blunt injury causing fatal death. PMCT was able to detect 3 cases, however, failed to detect in 3 cases of blunt injury to the head.

**Fall from height**
One case was diagnosable as fall from height as evident from the presence of multiple fractures involving the skull, body and limbs (Figure 4), along with multiple internal hemorrhages depicted. In contrast, 8 cases were suggestive with the given history and the injuries were consistent with autopsy findings, revealing fatal injury to head and multiple fractures of spine and limbs. However, in one case was unable to correlate to fall from a height (Figure 5).

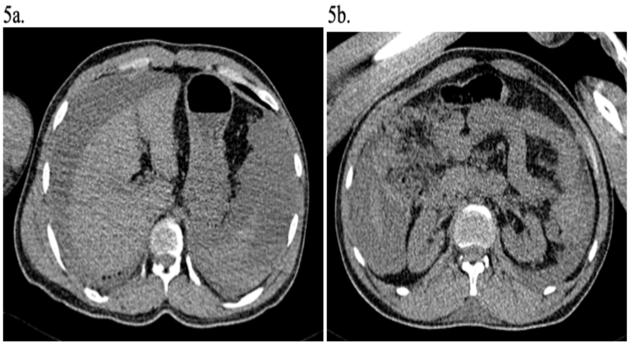


**Figure 5: A fatal abdominal injury in a case fall from height that unable to be detected on CT. The autopsy revealed lacerated liver (a) with multiple hematoma at greater omentum, mesenteric, retroperitoneum and bilateral perinephric (b).**

**Burn**
The diagnosis of burn-related deaths relies on specific indicators such as charred bodies, inhalation burns or carbon monoxide concentration in the blood, which cannot be determined through PMCT. Consequently, none of the 3 cases were identified in this study.

**Drug intoxication**
A drug intoxication case was diagnosed based on toxicological tests, making it beyond the capability of PMCT for detection.

**Asphyxiation**
In 2 cases of aspiration asphyxiation, both were undetectable through PMCT, as there was no evidence of cervical muscle injuries or lymph node hemorrhage.

**Coronary artery disease**
In 5 cases of acute myocardial infarction, the important findings such as coronary artery thrombosis were only uncovered during autopsy, and not apparent on PMCT, rendering these cases undetectable through PMCT.

**Lung infection**
Miliary lung nodules were observed in a case, consistent with the diagnosis of pulmonary tuberculosis.

**Septicemia**
A case of septicemia was not identified through PMCT. Instead it was diagnosed through blood and urine culture and sensitivity tests.

## DISCUSSION

In this study, PMCT were performed on 60 cases with the aim of identifying causes of death categorized as ‘diagnosable’, ‘suggestive of’ and ‘non-diagnosable’ through PMCT. The results of the conventional autopsies was still regarded as the gold standard for determining the cause of death.

The study indicated that fatal findings were diagnosable in 46.7% of cadavers on the PMCT. These cases included gunshot wounds, lung infections, as well as sharp and blunt injuries. PMCT proved particularly effective in gunshot cases, providing insight into entry and exit points of bullet tracks and the trajectory of injuries. The utility of PMCT in gunshot cases has been previously described and is significant for screening in certain regions [6].

In 15% of the cases, PMCT yielded suggestive cause that required clinical and background details, as well as injury mechanisms, to ascertain the definitive cause of death and rule out other possibilities. These cases were predominantly related to falls from heights. Findings included intracranial hemorrhage, ground-glass opacity in the lungs, pneumothorax, and multiple fractures. PMCT excelled in detecting pneumothorax and vertebral body fractures, which are limitations in conventional autopsies. However, PMCT struggled to identify soft tissue injuries like intramuscular hematomas, abrasions, superficial bruises, and contusions, highlighting the need for autopsies in determining the cause of death in this group [6, 7].

PMCT was non-diagnosable for the cause of death in 38.3% of the cases, as it did not reveal any significant findings. These cases encompassed coronary artery disease, burn-related deaths, asphyxiation, drug intoxication, and septicemia. The most common cause among these was coronary artery disease, including acute myocardial infarction (AMI) and coronary artery thrombosis. The results aligned with the findings from other studies, highlighting the challenge of diagnosing cardiac-related causes of death using PMCT [1, 8]. Although there might be indirect potential indicators to suggest underlying cardiac event, like coronary calcification, previous cardiac bypass surgeries, coronary artery stents, or calcified scars from prior myocardial infarctions, but this not able to be taken as the conclusive evidence for the cause of death [9]. This highlights a specific limitation of PMCT screening, which could potentially be addressed with cardiac post mortem MRI for AMI lesions and post mortem CTA coronary for arterial thrombosis [10].

Burn death was another pitfall in our study as PMCT only showed superficial and subcutaneous tissue edema, which can result from various causes. Some cadavers exhibited no superficial or subcutaneous changes, and charred bodies could not be visualized on PMCT, affirming the continued relevance of autopsies.

Another undiagnosable cause of death was asphyxiation, which may result from strangulation or hanging. The inability to detect this cause of death is another pitfall of PMCT. Fractures of thyroid cartilage and hyoid have been found on CT [11, 12], but were not detected in this study. A thinner collimation with multidetector-row CT might improve detection, but could still offer suggestive findings. MRI may have the potential to detect cervical muscular hemorrhage and lymph node hemorrhage [12], and thus postmortem MRI may be useful in this area.

For cases involving drug intoxication and septicemia, diagnoses were primarily reliant on laboratory results from blood and urine tests. There are no distinct features of sepsis on anatomy-pathology or radiology, possess the challenges in diagnosis cause of death in the bodies [13]. PMCT did not contribute to their detection, underscoring the essential role of autopsies in determining the cause of death.

PMCT has limitations in terms of standardized settings, as a uniform kV and mAs for window width and window length of the abdomen were used for whole-body PMCT scans in our center. Suboptimal window settings led to a failure to diagnose one intracranial hemorrhage through PMCT, although these were readily directly visible during conventional autopsy.

Decomposed body status added complexity to the interpretation of PMCT images, especially in active and advanced decay stages, where the remaining body tissue's condition became crucial in establishing the cause of death. In the presence of decomposition, gases form during the putrefaction process typically occurs within and along side the intestinal wall, mesenteric, and portal venous systems, which later permeates all vascular structures and potential anatomical spaces causing the body to bloat and loss of the body's normal configuration. This is followed by a decaying process with maggot infestation which manifest as linear or curvilinear soft tissue or surface irregularities on PMCT [14]. In the final stage, dry or mummified status, all soft tissues are removed, and only skeletal remains are left, requiring forensic anthropology to determine the cause of death at this stage [15].

## CONCLUSION

PMCT proves valuable in identifying the causes of death, particularly in cases of gunshot wounds and sharp injuries, and to some extent in blunt injuries. It also provides suggestive findings in fall-from-height cases, although misdiagnosis may occur due to a lack of related information. Nevertheless, PMCT does not offer diagnostic or suggestive value in various common forensic medicine cases, including asphyxiation, burn-related deaths, drug intoxication, acute myocardial infarction, and septicemia.


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