

CONTENTIOUS ISSUES

ARE INVASIVE POSTMORTEM EXAMINATIONS STILL THE 'GOLD STANDARD' IN DIAGNOSING THE CAUSE OF DEATH?

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ABSTRACT

For many years, the foundations of both its art and science in medicine grew from the observations made at the autopsy table. The observations of the pathologists formed the pathologic basis and manifestations of disease, which further advanced the development of therapeutics. For most of the 18th and 19th centuries, morbid anatomy (autopsy pathology) was considered the science of medicine. Today, the autopsy and the knowledge that derives from it do not hold the position they once did in the profession's history. There is a belief among the medical community a complete autopsy is necessary to find out the answers when someone dies. In some jurisdictions, the forensic pathology community is reluctant to follow the targeted or minimally invasive approach in postmortem examinations due to a lack of understanding of the process. With a complete external examination, trace evidence collection, total body computed tomography (CT) scan, and minimally invasive/targeted dissection with a collection of samples for further analysis, almost all answers can be provided in hospital and medicolegal autopsy settings. We must collaborate with sister disciplines, such as experts in radiology and the legal community, to educate them on the importance of this new approach using advanced technology.

Continuously evolving modern radiological imaging has remarkably increased the accuracy of clinical diagnosis. Conventionally, when you hear the word postmortem examination, people think it includes an external examination and dissection of all body cavities. In the 21st century, most questions raised by the family, clinicians, the coroner (medical examiner), courts, and law enforcement agencies can be answered with a complete external examination of the body, total body CT scan +/- magnetic resonance imaging, and targeted dissection or minimally invasive approach incorporated with sample collection for further testing. This is cost-effective and can produce reviewable data.

Keywords: *Minimally invasive autopsy; postmortem CT scan; postmortem examination; targeted dissection*

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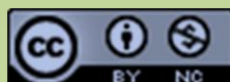
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INTRODUCTION

For decades, the foundations of art and science in medicine grew from the observations made at the autopsy table. The observations and the findings of the pathologists formed the pathologic basis and manifestations of disease, which further advanced the development of therapeutics. For most of the 18th and 19th centuries, morbid anatomy (autopsy pathology) was considered the science of medicine. Today, the autopsy and the knowledge that derives from it do not hold the same position it once did in the profession's history.

Conventional autopsies have been a longstanding method for investigating the cause of death and understanding underlying pathologies. The following are the key aspects of a conventional/traditional autopsy:

- 1. Systematic Approach:** Conventional autopsies follow a systematic approach that has been refined over centuries. This method involves a comprehensive examination of the deceased individual, both externally and internally. It includes reviewing clinical history, conducting ancillary tests (such as histology, toxicology, biochemistry, and microbiology), and assessing relevant clinical/pre-autopsy information¹.
- 2. Diagnostic Accuracy:** Conventional autopsies are recognized as the gold standard for detecting findings that indicate the cause of death. Pathologists can identify abnormalities, diseases, and injuries contributing to the demise of the individual by meticulously examining organs, tissues, and bodily systems².
- 3. Healthcare Quality Control:** Autopsies play a crucial role in healthcare quality control. They provide valuable feedback to clinicians, enhance medical knowledge, and contribute to improving patient care³.
- 4. Challenges and Declining Rates:** Despite their significance, autopsy rates have declined globally. To address this,

researchers are exploring alternative methods, such as non-invasive or minimally invasive autopsies, which aim to achieve similar diagnostic accuracy while respecting cultural and individual preferences³.

Although conventional autopsies remain invaluable for understanding the intricacies of natural deaths, ongoing research aims to develop feasible alternatives that balance the accuracy and the quality.

Continuously evolving modern radiological imaging has remarkably increased the accuracy of clinical diagnosis⁴. Every physician has experienced the power of radiological diagnosis in our technologically advanced era. In the 21st century, mainly based on these arguments, the non-medicolegal autopsy rate in hospitals worldwide has declined to a mere fraction of previous times⁵. The decline has been most evident in the last 20 years and correlates with the rise in the prominence of the radiological/epidemiological/molecular approach to medicine. However, the number of medicolegal autopsies is increasing.

When we hear the word postmortem examination, it comes to mind that this procedure includes an external examination and the dissection of all body cavities. As we discussed earlier, due to the increased workload of a hospital pathologist and the available modern medical technology, hospital autopsy rates have come down to the lowest level⁴. Compared to autopsy pathology, advanced medical technologies are extensively used in other medical disciplines. Radiology techniques are incorporated into autopsy practice in many parts of the world, including Canada, the United States, Asia, Australia, and Europe. There is a well-established understanding and coordination between the clinicians and the pathologists regarding minimally invasive biopsy procedures such as Fine Needle Aspirations (FNA) and skin and endoscopy biopsies of patients for diagnostic purposes. In most parts of the world, when it comes to hospital and medicolegal postmortem examinations, they still perform total body dissections despite available technology.

The authors want to share the experience that we have learned in our forensic pathology unit for the last ten years, where we perform about 7000 autopsies annually, and about 99% of autopsy cases are subject to pre-autopsy computed tomography (CT) scanning, with some cases going through magnetic resonance imaging (MRI) scanning before autopsy.

DISCUSSION

Undoubtedly, the traditional postmortem examination served as a valuable tool in quality control and quality improvement in inpatient care. The main reasons for the rapid decline of the hospital autopsy included lack of interest of clinicians and next of kin due to the confidence in medical diagnostics, the refusal and reluctance of family members to provide consent due to the extent of the dissections, lack of trained pathologist and the unwillingness of the pathologists for the time-consuming procedures, cultural and religious beliefs preventing dissections, refusal and lack of interest of hospital authorities for the autopsy due to funding issues. As a result, alternative autopsy methods, such as non-invasive/minimally invasive/targeted dissections, were developed.

The two main types of postmortem examinations are the hospital (consent/clinical) autopsy and the medicolegal (forensic) autopsies. For a hospital autopsy, the main reason for asking for an autopsy is to find out the extent of the disease and the effects of the therapy. There are 5 questions the coroner (medical examiner) needs to answer in investigating death for medicolegal purposes. These five questions are⁶:

1. Who was the deceased (identification)?
2. Where did the death occur?
3. When did the death occur?
4. How did the death occur (i.e., the medical cause)?
5. By what means did the death occur (i.e., the classification or manner of death)?

The two main questions that need to be answered at the end of the autopsy are identity and the medical cause of death. For most cases,

to answer these questions, you do not need to perform a complete dissection as technological advances can be used to identify and document any findings with 21st century technology.

There has been no significant transformation in the instruments and the dissection methods used in traditional postmortem examination for the last 2 centuries. New radiological imaging methods such as high-resolution postmortem computed tomography (PMCT), digital X-ray, and MRI are now becoming the main diagnostic tools in forensic pathology in modern forensic pathology units in North America, Europe, and Asia.

PMCT has been well documented in the radiology and forensic pathology literature in the last decade, and more studies into these radiological technologies continue to develop. Recent publications show convincing data about the utility of PMCT in improving the documentation and diagnosis of the autopsy process⁵. With these new radiological advancements, the injuries and organ pathology of the total body can be viewed and documented. Using postmortem CT and MRI, imaging-guided targeted biopsy or a targeted dissection are performed to identify the injury and pathology and obtain tissue for histologic examination and other ancillary testing. In addition, CT angiography can be completed in some instances. These methods are already incorporated into routine autopsy work to support or substitute for medicolegal death investigations in many parts of the world. In perinatal autopsy practice, these non-invasive or minimally invasive procedures are utilized for autopsies of fetuses, newborns, and infants. This type of clinical practice is reported to have gained wide acceptance with parents, clinicians, and the public. However, these principles are not uniformly applied in adult autopsies in most autopsy centers. In most traditional autopsy centers, the dissection methodology has not undergone any major transformation since the 19th century. However, new radiological imaging methods such as multidetector computed tomography (MDCT) and MRI can potentially become the main diagnostic tools in forensic pathology.

In most cases, postmortem CT has critical practical advantages compared to traditional dissection alone. It is less time-consuming and easy to detect specific pathologies like skeletal trauma, intracranial hemorrhages, tension pneumothoraces, ruptured aortic dissections, and ruptured heart due to myocardial infarction. There is resistance by some of the traditionally trained forensic pathologists and the legal community to targeted or minimally invasive approaches for medicolegal cases. The time has come for autopsy pathologists to utilize minimally invasive procedures and targeted dissections while incorporating contemporary technology, such as PMCT scans and MRI scans, in clinical and medicolegal autopsy practice. The cooperation between radiologists and pathologists is not a new concept for surgical pathology and hospital autopsies. For decades, pathologists provided consultations for skin, stereotactic (ST), endoscopic biopsies, and FNA for diagnostic purposes performed by clinicians. In hospital (non-medicolegal) autopsies, targeted dissections were carried out to determine the extent of the disease and the effects of treatments per the request of the family and the clinician. Recent studies show most sudden natural adult deaths investigated by coroners could be managed by an external examination and a minimally invasive approach utilizing PMCT and PMCT with angiography (PMCTA). The gold standard of postmortem investigations should include both PMCT and autopsy for an accurate diagnostic system⁹. In the field of medicolegal autopsy practice, due to the lack of availability of qualified and trained forensic pathologists and the increased caseload due to pandemic situations and increased deaths related to drug toxicity it has come forensic pathologists have to perform a large number of autopsies now. The modern forensic pathologist has to respect the wishes of the families and the decedent's beliefs, with an increasingly diverse population with different cultural and religious beliefs. It is our experience that some cultural and religious groups oppose invasive procedures and dissection of the body, while some request to avoid opening the head or demand a bloodless autopsy. Studies show less invasive autopsy

offers a viable alternative to many Muslim and Jewish parents in the United Kingdom who currently decline a complete autopsy¹⁰. Compared with the traditional autopsy, CT is a more accurate imaging technique than MRI for providing a cause of death in certain situations¹¹.

Detecting bleeding, organ damage, and vascular pathology

Cerebral aneurysm ruptures and the exact location of the bleeding can be well located and documented by PMCT incorporated with angiography (PMCTA). Ischemic bowel due to mesenteric artery pathology can be well demonstrated with PMCT and PMCTA. Vascular pathologies such as calcification, aneurysm ruptures, stenosis, and soft plaques can be detected. Contrast material can be injected through plastic tubes inserted into the coronary arteries, and the blood vessel wall plaque can be visualized with Dual Energy imaging¹².

Several studies and publications about postmortem imaging and targeted and minimally invasive approaches are available. One such study states the performance of a minimally invasive autopsy in detecting the cause of death was similar to that of a conventional autopsy; however, a minimally invasive autopsy has a higher yield of diagnoses¹³. Another study shows a minimally invasive autopsy, consisting of CT, MRI, and CT-guided biopsies, performs well in answering clinical questions and detecting primary diagnoses¹⁴.

Dealing with infectious cases

The minimal invasive autopsy (MIA) is very helpful when dealing with a potential death following an infectious condition such as COVID-19. One study found that MIA findings are almost identical to complete autopsy findings in COVID-19 cases¹⁵.

One more study shows MIA is a procedure with high diagnostic performance for detecting common causes of death such as pneumonia and sepsis. However, MIA failed to

demonstrate certain cardiac diseases, such as acute myocardial infarction and endocarditis¹⁶. In our experience, PMCT can diagnose coronary artery calcifications, cardiomegaly, ruptured myocardial infarctions, and ruptured aortic dissections.

Cost-effectiveness

There is an initial cost to install and maintain a TBCT scan. Once you have established it and fully incorporated it into daily use, the overall cost per autopsy can be saved. When it comes to the cost of the postmortem examination, MIA may be less expensive than a conventional autopsy. According to one study, a minimally invasive autopsy, including biopsies and CT-angiography, costs \$1649 to \$1945, whereas an autopsy costs \$2170 to \$2378. In Switzerland, each autopsy is preceded by at least CT¹⁷.

Most countries still prefer complete postmortem examinations in non-natural deaths¹⁸. Targeted and MIA are regarded as safer in contagious, higher-risk cases. The postmortem examination takes less time. With less information gathered at the targeted approach, the turnaround time can be shorter. MIA can be performed with fewer resources, making them less costly when it comes to resources. Also, partial autopsies may be reimbursed at a lower rate and cost the funding agency less¹⁹.

Problems encountered with interpreting subtle CT findings and relying on them

Certain findings are subtle, and it is difficult for the non-trained eye to interpret them, especially without contrast. If you rely on a CT scan without opening the body, there is a chance you miss the cause of death. For example, it is difficult to differentiate a subarachnoid hemorrhage with postmortem changes, a brain tumour without contrast, acute meningitis and encephalitis. If you rely on CT findings alone and decide not to open the head based on your interpretation, a significant cause of death, like subarachnoid hemorrhage, meningitis, or encephalitis, is likely to be missed.

Difficulties encountered by a pathologist interpreting CT findings

Most pathologists are not adequately trained in reading CT scans. Even if you are comfortable interpreting postmortem images based on your experience, it will be challenging in courts as one specialist steps out of the expertise.

Postmortem changes

Interpreting a PMCT scan is different from interpreting a CT of a living person. The radiologists and pathologists must be aware of these postmortem CT differences. The main differences are postmortem changes such as livor mortis and putrefactive decomposition. To avoid misinterpretation and misdiagnoses, the PMCT reader should be mindful of these postmortem changes when interpreting a PMCT scan²⁰.

Case examples

We want to share a few examples as a medicolegal center performs about 7000 autopsies annually, and about 99% of autopsy cases are subject to pre-autopsy CT scanning, with some cases going through MRI scanning prior to autopsy.

A few examples where we can perform External Examination (EE) and Targeted Dissection (TD), or MIA, utilizing TBCT +/- MRI scan are given below:

- Well documented suicidal hanging (EE +/- PMCT)
- A well-documented suicidal gunshot wound (EE with PMCT and TD +/- toxicology)
- Well documented suicidal descent from height (EE with PMCT +/- TD/MIA +/- toxicology)
- Train/subway fatality (EE with PMCT +/- TD/MIA +/- toxicology)
- Suspected toxicological death (EE, PMCT, TD of chest/abdomen, and toxicology)
- Sudden natural death (EE, PMCT, TD of chest/abdomen, +/- toxicology, +/- molecular pathology)

- Non-traumatic subarachnoid hemorrhage identified by CT (EE, PMCT, +/- PMCTA and open head to confirm ruptured berry aneurysm)
- Haemopericardium identified by CT (TBCT, open the chest with +/- abdomen to confirm the underlying diagnosis, such as ruptured myocardial infarction due to coronary artery disease or ruptured aortic dissection)
- The six cases illustrated in the images are some of the case examples that we have managed by external examination, TBCT scan, targeted dissection/Minimal invasive approach for sample collection with the agreement of the coroners and the families. We were able to provide all the answers the coroner and the family requested in these cases.

Figure 1 shows a 29-year-old male pedestrian who died of multiple blunt impact trauma. This image shows typical "bumper fractures" caused by the primary impact. 10 years before, we did time-consuming, extensive low erextremity dissections to demonstrate this type of injury.



Figure 1: A 29-year-old male pedestrian died of multiple blunt impact trauma. This image shows typical "bumper fractures".

Figure 2 shows a 38-year-old male subway train trauma with massive blunt impact head trauma. With a proper investigation, good history, and circumstances, including a subway station video review, we could manage this case with an external examination, sample collection, and TBCT scan.

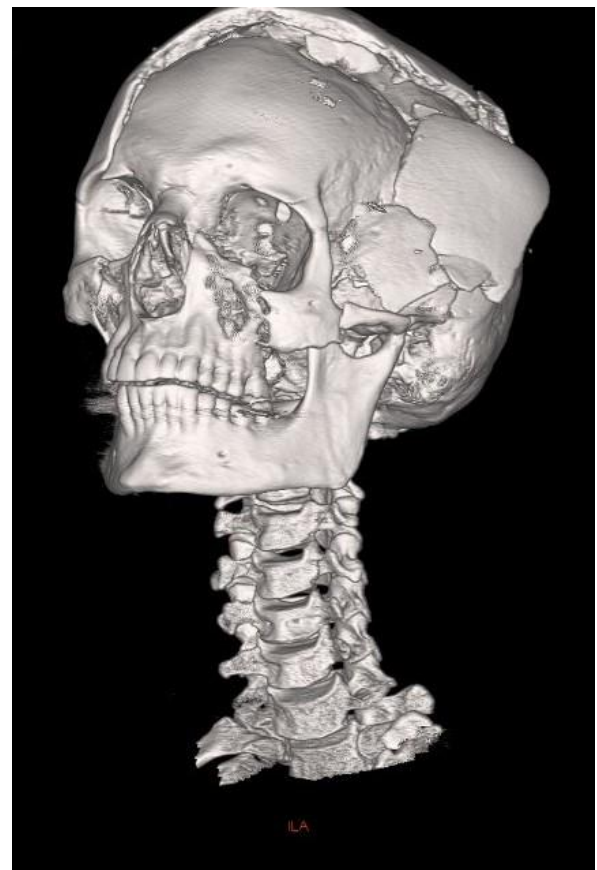


Figure 2: A 38-year-old male subway train trauma with massive blunt impact trauma of the head.

Figure 3 shows a 65-year-old male subway train trauma with massive blunt impact trauma, including decapitation. With a proper death investigation, good history, and circumstances, including a subway station video review, we could manage this case with an external examination, sample collection, and TBCT scan.

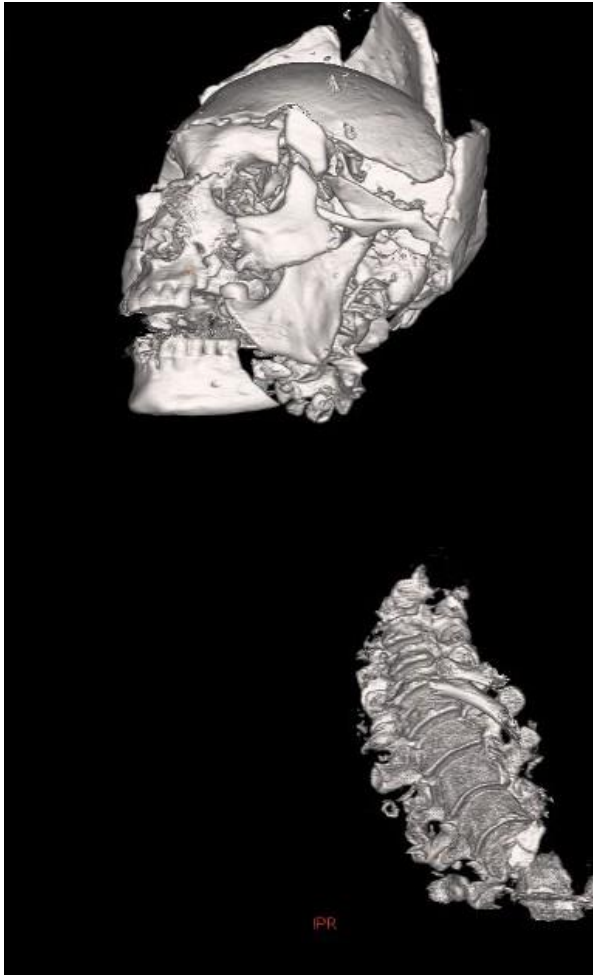


Figure 3: A 65-year-old male subway train trauma with massive blunt impact trauma, including decapitation.

Figure 4 shows a 68-year-old female with COVID-19 pneumonia. Also, cardiomegaly due to hypertensive heart disease and coronary artery calcifications are seen here. After analyzing the history and scene information, external examination, sample collections including nasopharyngeal and throat swabs, and a lung biopsy, we concluded the diagnosis here.

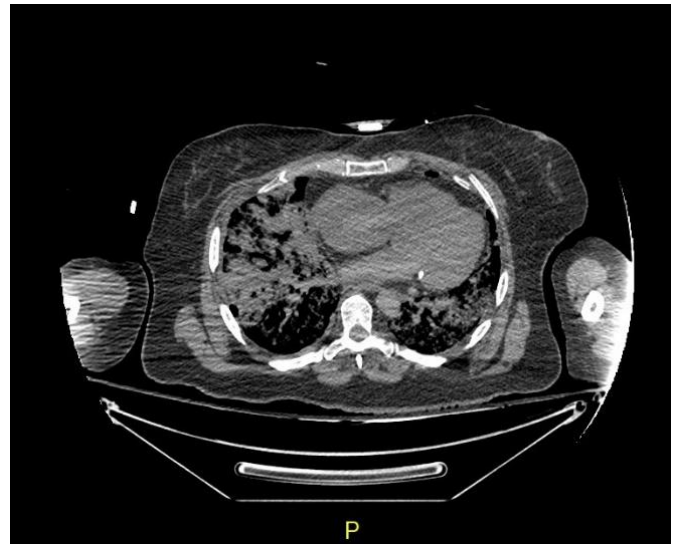


Figure 4: A 68-year-old female with COVID-19 pneumonia. Also, cardiomegaly due to hypertensive heart disease and coronary artery calcifications are seen here.

Figure 5 shows a 69-year-old male who died of massive blunt impact trauma after descending from height. With a thorough death investigation, external examination, TBCT scan, and sample collection, we concluded the diagnosis in this case.



Figure 5: A 69-year-old male died of massive blunt impact trauma after descent from height.

Figure 6 shows a 92-year-old male who died due to hemopericardium as a result of ruptured aortic dissection. Also, bilateral hemothoraces due to ruptured aortic dissection can be seen here. We could conclude the diagnosis with a careful death investigation, external examination, TBCT, and a targeted dissection to confirm the diagnosis.



Figure 6: A 92-year-old male died due to hemopericardium as a result of ruptured aortic dissection. Also, bilateral hemothoraces due to ruptured aortic dissection can be seen here.

CONCLUSION

The two main types of postmortem examinations are the hospital (consent/clinical) autopsy and the medicolegal (forensic) autopsies. For a hospital autopsy, the main reason for asking for an autopsy is to find out the extent of the disease and the effects of the therapy. There are 5 questions the coroner (medical examiner) needs to answer for the medicolegal autopsy. Continuously evolving modern radiological imaging has remarkably increased the accuracy of clinical diagnosis. Traditionally, postmortem examination refers to the external examination of the body and dissection of all body cavities. In the 21st century, most questions raised by the family, clinicians, the coroner (medical examiner), courts, and law enforcement agencies can be answered with a complete external examination of the body, total body CT scan +/-

MRI, and targeted dissection or minimally invasive approach incorporated with sample collection for further testing. This is cost-effective and can produce reviewable data.

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CONFLICTS OF INTEREST

The authors declared no conflicts of interest.

ETHICAL ISSUES

Not applicable.

SOURCES OF SUPPORT

None.

AUTHOR CONTRIBUTIONS

JCH: Conception and design of the work; acquisition, analysis, and interpretation of data for the work; drafting the work and reviewing it critically for important intellectual content; and final approval of the version to be published. **URH:** Acquisition, analysis, and interpretation of data for the work; drafting the work and reviewing it critically for important intellectual content; and final approval of the version to be published.

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