

CQ 10: Is Postmortem CT and MRI Useful for Estimating the Cause of Death?

Recommendation Grade: C2*

**Grade C1 if minimally invasive autopsy including MRI is appropriately performed in fetuses and infants.*

Postmortem CT and MRI can provide a certain degree of information useful for estimating the cause of death and identifying major anatomical abnormalities. The combination of postmortem imaging with minimally invasive autopsy techniques—especially including MRI in fetal and infant cases—can significantly improve the accuracy of cause-of-death determination. However, it is important to note that postmortem imaging has strengths and limitations depending on the organ system and underlying pathology, and careful interpretation is required.

Explanation

● Background

As autopsy rates have declined worldwide, various non-invasive and minimally invasive methods for estimating the cause of death using imaging have been developed. These include postmortem CT and MRI, as well as minimally invasive autopsy (MIA) techniques. MIA refers to a simplified autopsy approach that does not involve full or partial dissection, but instead relies on procedures such as blood testing, angiography, and image-guided biopsy—all of which are low in invasiveness. In recent years, MIAs combined with postmortem imaging (CT and MRI) have been increasingly introduced as a means of determining cause of death.¹ Such approaches are particularly well accepted in the case of fetuses and infants, for whom less invasive methods of postmortem investigation are often preferred by families.²

● Diagnostic Performance of Postmortem CT and MRI for Estimating Cause of Death

According to a recent meta-analysis evaluating postmortem CT, postmortem CT angiography, and postmortem MRI, the sensitivity for determining cause of death was reported as follows:³

- Postmortem CT: 0.67 (based on 20 studies, 1,879 cases)
- Postmortem CT angiography: 0.79 (3 studies, 59 cases)
- Postmortem MRI: 0.71 (6 studies, 123 cases)

In the same report, the sensitivity for combined CT and MRI was somewhat lower, ranging from 0.51 to 0.60 (2 studies, 44 cases). Nevertheless, the combination may still offer improved diagnostic accuracy compared to either modality alone. In a robust prospective cohort study, the discordance rates between postmortem imaging and conventional autopsy were:⁴

- 32% for postmortem CT alone
- 43% for postmortem MRI alone
- 30% when both modalities were combined, suggesting improved performance

In the same study, the proportion of cases judged by radiologists not to require autopsy was: ⁴

- 34% with CT alone
- 42% with MRI alone
- 48% with the combined approach

Another systematic review (non-meta-analysis) reviewing 13 studies reported that the combination of postmortem CT and MRI resulted in a cause-of-death identification rate of approximately 70%, indicating meaningful utility.⁵

It is important to note that the diagnostic accuracy of postmortem imaging varies significantly depending on the organ system and underlying pathology. In the aforementioned meta-analysis, the sensitivity of CT and MRI findings, respectively, was: ³

- 0.65 and 0.73 for soft tissue and organ lesions
- 0.86 and 0.41 for bone fractures
- 0.76 and 0.83 for hemorrhage

Combining CT and MRI improved sensitivity across all categories

For sudden cardiac death, one study reported that postmortem cardiac MRI reached a diagnostic accuracy of 81%.⁶ However, it should be noted that the cause of sudden death is often missed on postmortem imaging.⁴ In a prospective cohort study of adult forensic death cases, the concordance rate between postmortem CT and conventional autopsy was reported to be 85.9%.⁷ The causes of death most frequently missed by imaging included ischemic heart disease, pulmonary embolism, pneumonia, and intra-abdominal pathologies.⁴ A systematic review comparing postmortem CT and autopsy concluded that CT has advantages in detecting: ⁸

- Fractures
- Fluid in airways
- Gas in internal organs
- Massive hemorrhage
- Fatty liver
- Stones
- Bullet fragments

However, postmortem CT may be less reliable in identifying: ⁸

- Cardiac and great vessel injuries
- Microscopic vascular lesions

• Improved Diagnostic Accuracy for Cause of Death Using Combined Postmortem Imaging and Minimally Invasive Autopsy

An increasing number of reports have described the combination of postmortem CT or MRI with MIA techniques such as image-guided biopsy, suggesting that such approaches can achieve diagnostic accuracy comparable to conventional full-body autopsy.¹ A systematic review comparing the

diagnostic accuracy of non-invasive or minimally invasive autopsy to that of traditional autopsy in adult natural deaths found that the best diagnostic concordance with autopsy (90.9%) was achieved when postmortem CT, postmortem CT angiography, and biopsy were combined.⁵ A meta-analysis evaluating the sensitivity of postmortem MRI combined with image-guided autopsy reported sensitivity values of: ⁹

- 0.82 in adults (5 studies, 107 cases)
- 0.73 in pediatric populations (8 studies, 953 cases)

A robust prospective cohort study assessing diagnostic accuracy of postmortem MRI and MIA(including blood testing) in fetal and pediatric deaths reported concordance with traditional autopsy findings as follows:¹⁰

- Overall: 89.3%
- Fetuses \leq 24 weeks gestation: 94.6%
- Fetuses $>$ 24 weeks gestation: 95.7%
- Neonates (\leq 1 month): 81.0%
- Infants ($>$ 1 month and \leq 1 year): 84.9%
- Children ($>$ 1 year and \leq 16 years): 53.6%

These findings suggest that MIA including MRI can provide equivalent diagnostic accuracy to conventional autopsy in cases of fetal, neonatal, and infant death. However, the diagnostic performance tends to decrease with increasing age in children. When pathologists and radiologists work closely together to carefully select appropriate cases, MIA can achieve diagnostic accuracy approaching that of full autopsy.¹⁰

Column: Advances in Imaging Technology

In recent years, advancements in imaging technology have gained increasing attention in the field of forensic medicine. In particular, dual-energy CT (DECT) offers material differentiation capabilities that hold promise for detailed analyses that were difficult or impossible with conventional single-energy CT (SECT).

SECT has limitations in that materials with different densities or compositions may produce identical CT attenuation values if their linear attenuation coefficients are the same.¹¹

In contrast, DECT acquires images at two different energy levels, allowing for material discrimination based on differences in X-ray absorption. This enables generation of advanced image sets such as virtual monochromatic images, electron density maps, and effective atomic number images.

Compared to clinical (antemortem) CT, postmortem DECT offers several advantages:

- There are no radiation exposure concerns, making full-body scanning feasible.
- The absence of cardiac and respiratory motion allows for high-resolution imaging.

A notable application is in traffic accident investigations, where DECT has been used to differentiate environmental materials such as gravel, concrete, and sand adhered to the body, as well as vehicle components such as metal fragments or glass. This may aid in identifying the crash scene or matching the vehicle involved.¹² DECT has also been explored in body packer cases for drug identification.¹³ While drugs like cocaine and heroin have similar CT densities depending on concentration, making them difficult to distinguish on SECT, spectral analysis with DECT has shown potential for their differentiation.¹⁴

However, DECT is not without limitations. It may help identify dental implant materials, which has potential applications in personal identification, but high-density materials like metals may cause artifacts, reducing accuracy.¹⁵ Moreover, cost remains a barrier to widespread adoption.

In 2022, Japan introduced its first photon-counting CT (PCD-CT) system. Unlike traditional energy-integrating detector CT (EID-CT), PCD-CT can discriminate the energy of individual photons as they are detected. This allows for material differentiation in a single scan, without changing tube voltage, and enables the acquisition of multi-energy data, rather than just two energies as in DECT. With the spread of PCD-CT, full-body material characterization in forensic imaging could become achievable with a single scan, offering exciting potential for future forensic research.

While DECT's material differentiation capabilities offer new possibilities in forensic science, further research is needed to clarify both its strengths and limitations.¹⁶ The technology is expected to make significant contributions to cause-of-death investigations and personal identification in the years to come.

○ Literature Search Strategy and Selection (February 5, 2024)

【PubMed】

| # | Search formula | Number of articles |
|---|---|--------------------|
| 1 | ((((((((((postmortem)OR post-mortem)OR "post mortem"))AND imaging))OR((((postmortem)OR post-mortem)OR "post mortem"))AND CT))OR((((postmortem)OR post-mortem)OR "post mortem"))AND "computed tomography"))OR((((postmortem)OR post-mortem)OR "post mortem"))AND MR))OR((((postmortem)OR post-mortem)OR "post mortem"))AND "magnetic resonance"))OR((((postmortem)OR post-mortem)OR "post mortem"))AND MDCT))OR((MSCT)AND(((postmortem)OR post-mortem)OR "post mortem")) | 31,168 |
| 2 | ((autopsy)AND((correlation)OR(validation)OR(performance)) | 4,282 |

| | | |
|---|--|---------|
| | OR(accuracy))) AND((magnetic resonance) OR(MR) OR(computed tomography)OR(CT)) | |
| 3 | cause of death | 224,697 |
| 4 | #1 and #2 and #3 | 452 |

【医中誌 Ichushi-Web (Japan Medical Abstracts Society Database)】

| # | Search formula | Number of articles |
|----|---|--------------------|
| 1 | (死後/AL) and ((FT=Y) and PT=原著論文,会議録除く and CK=ヒト) | 5,100 |
| 2 | (死亡時/AL) and ((FT=Y) and PT=原著論文,会議録除く and CK=ヒト) | 990 |
| 3 | ((画像診断/TH or 画像診断/AL)) and ((FT=Y) and PT=会議録除く and CK=ヒト) | 369,108 |
| 4 | ((X線 CT/TH or X線 CT/AL)) and ((FT=Y) and PT=会議録除く and CK=ヒト) | 146,742 |
| 5 | ((MRI/TH or MRI/AL)) and ((FT=Y) and PT=原著論文,会議録除く and CK=ヒト) | 116,691 |
| 6 | #1 or #2 | 5,786 |
| 7 | #3 or #4 or #5 | 380,702 |
| 8 | #6 and #7 | 1,493 |
| 9 | 死因推定/AL or 死因診断/AL or (検査予測値/TH or 正診率/AL) | 13,354 |
| 10 | #8 and #9 | 24 |

●Additional Sources Not Captured by the Search Strategy

References [11] , [12] , [13] , [14] , [15] , [16]

■References

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- 2) Lewis C et al : Minimally invasive autopsy for fetuses and children based on a combination of post-mortem MRI and endoscopic examination : a feasibility study. Health Technol Assess 2019 ; 23 : 1-104 (level 4a)
- 3) Ampanozi G et al : Postmortem imaging findings and cause of death determination compared with autopsy : a systematic review of diagnostic test accuracy and meta-analysis. Int J Legal Med 2020 ; 134 : 321-337 (level 1)
- 4) Roberts IS et al : Post-mortem imaging as an alternative to autopsy in the diagnosis of adult

- deaths : a validation study. *Lancet* 2012 ; 379 (9811) : 136-142 (level 4a)
- 5) Blokker BM et al : Non-invasive or minimally invasive autopsy compared to conventional autopsy of suspected natural deaths in adults : a systematic review. *Eur Radiol* 2016 ; 26 : 1159-1179 (level 1)
 - 6) Mentink MG et al : Clinical relevance of unexpected findings of post-mortem computed tomography in hospitalized patients : an observational study. *Int J Environ Res Public Health* 2020 ; 17 : 7572 (level 4b)
 - 7) Hueck U et al : Forensic postmortem computed tomography in suspected unnatural adult deaths. *Eur J Radiol* 2020 ; 132 : 109297 (level 4a)
 - 8) Uthandi D et al : Effectiveness of post-mortem computed tomography (pmct) in comparison with conventional autopsy : a systematic review. *Curr Med Imaging* 2020 ; 16 : 669-676 (level 1)
 - 9) Ahmad MU et al : Assessing the use of magnetic resonance imaging virtopsy as an alternative to autopsy : a systematic review and meta-analysis. *Postgrad Med J* 2017 ; 93 (1105) : 671-678 (level 1)
 - 10) Thayyil S et al : Post-mortem MRI versus conventional autopsy in fetuses and children : a prospective validation study. *Lancet* 2013 ; 382 (9888) : 223-233 (level 4a)
 - 11) 日本放射線技術学会 監, 山口 功ほか 編 : CT 撮影技術学 改訂 4 版. オーム社, 2023
 - 12) Große Hokamp N et al : Technical background of a novel detector-based approach to dual-energy computed tomography. *Diagn Interv Radiol* 2020 ; 26 : 68-71
 - 13) Ruder TD et al : Material differentiation in forensic radiology with single-source dual-energy computed tomography. *Forensic Sci Med Pathol* 2013 ; 9 : 163-169
 - 14) Grimm J et al : Differentiation of heroin and cocaine using dual-energy CT — an experimental study. *Int J Legal Med* 2014 ; 128 : 475-482
 - 15) Kutschy JM et al : The applicability of using different energy levels in CT imaging for differentiation or identification of dental restorative materials. *Forensic Sci Med Pathol* 2014 ; 10 : 543-549
 - 16) Bolliger SA et al : Is differentiation of frequently encountered foreign bodies in corpses possible by Hounsfield density measurement? *J Forensic Sci* 2009 ; 54 : 1119-1122

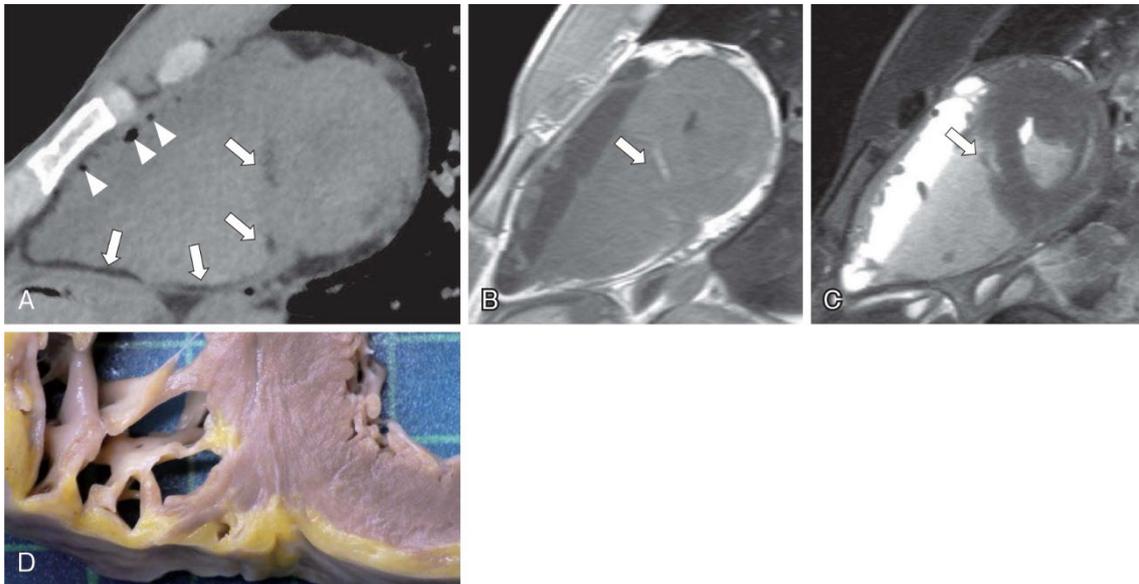


Figure. Male in his 20s – Arrhythmogenic Right Ventricular Cardiomyopathy (ARVC)

A: Postmortem CT B: Postmortem MRI (T1-weighted image) C: Postmortem MRI (T2-weighted image) D: Gross Specimen After Fixation

Fat-density areas are observed in the right ventricular myocardium and also within the interventricular septum (⇨). Gross examination shows fatty degeneration of the right ventricular wall myocardium. Gas in the right ventricle (△) is attributed to resuscitation efforts.