CQ51. Can postmortem imaging in children provide diagnostic information equivalent to autopsy?

Recommendation Grade

Assessment of condition: C1

Determination of cause of death: C1

Among postmortem imaging modalities, postmortem MRI is considered to have the highest diagnostic capability. When combined with minimally invasive biopsy, it may provide anatomical information comparable to that of conventional autopsy. High concordance rates with autopsy findings have been reported in the central nervous system, heart, urinary tract, and musculoskeletal system. While the sensitivity of MRI is lower for detecting pulmonary infections and gastrointestinal abnormalities, its specificity is high, and a negative postmortem MRI can largely rule out major abnormalities.

CT is effective for identifying traumatic findings. Ultrasonography also demonstrates high diagnostic performance, particularly in the detection of congenital anomalies.

Explanation

● Postmortem Imaging in Childhood Deaths

Because the causes of death in children differ significantly from those in adults, the utility of postmortem imaging for determining cause of death may also vary accordingly. When using concordance with conventional autopsy as the reference standard, it is important to assess the diagnostic accuracy of various postmortem imaging modalities—such as plain radiography, postmortem CT, postmortem ultrasonography, and postmortem MRI. In particular, the diagnostic performance of postmortem MRI should be evaluated in terms of how it varies by organ system and pathological condition.

● Plain Radiography in Neonates

A single-center study conducted postmortem plain radiography in all neonatal and infant death cases to diagnose and evaluate skeletal dysplasia, fractures, and other bone abnormalities. The study included 1,027 cases and reported an abnormality detection rate of 12.3%, including 33 incidental findings, 19 clinically significant findings, 20 diagnostic findings, and 2 false positives[1]. However, only 2 findings (0.27%) out of 739 cases were determined to be undetectable without routine imaging. Based on this, the study concluded that performing radiography in all cases is not cost-effective and that rational selection criteria for postmortem imaging should be established[1]. It should be noted, however, that this study focused on conditions with relatively low prevalence—such as skeletal dysplasia and bone abnormalities. The low detection rate reflects the low pre-test probability and does

not directly represent the sensitivity or specificity of the imaging modality.

● Limitations of Postmortem CT and Its Utility in Trauma Cases

The concordance between postmortem CT and autopsy in pediatric cases varies considerably depending on study design, age group, and the type of case included (forensic cases, presumed natural deaths, or a combination of both). In general, pediatric postmortem CT demonstrates lower accuracy in determining the cause of death compared to autopsy. It is difficult to obtain detailed anatomical information, such as coronary artery anomalies, and thus postmortem CT cannot serve as a complete substitute for autopsy.

A retrospective study conducted at a single center in the United Kingdom compared postmortem CT findings with autopsy results in children under 16 years of age. The cohort included both cases with no suspicious circumstances and unnatural deaths. Among 136 cases, the cause of death was determined by autopsy in 77 cases (56.6%). Of these, postmortem CT correctly identified the cause of death in only 55 cases (71.4%). The sensitivity of postmortem CT relative to autopsy was particularly low for findings in the heart (31.3%, 95% CI: 14.2–55.6%) and abdomen (53.8%, 95% CI: 29.1–78.6%)[2].

On the other hand, postmortem CT shows a certain degree of utility in detecting traumatic findings. In particular, in pediatric cases with an undetermined cause of death, fractures are a crucial finding that may raise suspicion of physical abuse. Several studies have supported the superiority of postmortem CT over autopsy in the detection of fractures.

One study conducted in Switzerland compared the detection of abnormal findings between postmortem CT and autopsy. In this retrospective study of 26 pediatric cases (aged 0–12 years) handled at a forensic medical center, 96 out of 102 fractures (94%) were detected by postmortem CT, whereas only 62 (62%) were identified by autopsy[3].

Thus, one potential application of postmortem CT in pediatric deaths is to screen for evidence of trauma that may suggest underlying cases of physical abuse.

● Comparison Between Postmortem CT and Postmortem MRI

A study comparing diagnostic performance among autopsy, postmortem CT, and postmortem MRI evaluated 82 cases (53 fetuses and 29 children), focusing on major pathological abnormalities related to the cause of death and all diagnostic findings across five organ systems[4]. Postmortem MRI provided an accurate diagnosis in 24 of 55 cases (43.64%, 95% CI: 31.37–56.73%), outperforming postmortem CT, which yielded accurate diagnoses in 18 of 55 cases (32.73%, 95% CI: 21.81–45.90%). The diagnostic performance of postmortem CT was particularly low in fetuses under 24 weeks' gestation, at only 28.6% (95% CI: 8.1–46.4%)[4].

● Evaluation of the Utility of Postmortem Ultrasonography

In clinical pediatric imaging, ultrasonography is a principal diagnostic modality, and its usefulness in postmortem imaging has also been anticipated. A study comparing postmortem ultrasonography

with autopsy in 75 fetal cases for the detection of congenital anomalies reported a sensitivity of 81.5% (95% CI: 63.3–91.8%) and a specificity of 97.9% (95% CI: 89.1–99.6%) for detecting brain abnormalities. Notably, in fetuses under 24 weeks' gestation, both sensitivity and specificity reached 100%[5]. For abnormalities in the lungs, heart, abdomen, and urinary tract, sensitivity varied widely between 18.2% and 100%, while specificity was consistently reported as 100%[5]. On the other hand, another study reported that in fetuses over 20 weeks' gestation, postmortem ultrasonography showed lower diagnostic performance than postmortem MRI for detecting abnormalities in the brain, thorax, heart, and abdomen[6]. These findings highlight the need to recognize the limitations of ultrasonography in postmortem examinations.

● Postmortem MRI in Fetal and Pediatric Deaths

The most systematic evaluations of postmortem imaging in fetal and pediatric deaths have been conducted in the United Kingdom, particularly through a series of studies on postmortem MRI[7,8].

A systematic review aimed at assessing the accuracy, acceptability, and cost-effectiveness of postmortem MRI extracted eligible data from nine studies out of 539 screened articles, including 146 fetal, 11 pediatric, and 24 adult cases[8]. The sensitivity and specificity of postmortem MRI in detecting the cause of death or clinically significant findings were 69% and 95%, respectively, in fetuses; 28% and 64% in children; and 28% and 64% in adults[8]. These results suggest that while postmortem MRI demonstrated relatively high sensitivity and specificity in fetal cases, its diagnostic performance was much lower in postnatal pediatric and adult cases.

The findings of this systematic review also indicated that the existing published data on postmortem MRI are limited in number, heterogeneous in nature, and often of low methodological quality. Furthermore, data on consent rates and economic feasibility were found to be insufficient. As a result, a large-scale prospective study was subsequently conducted to more rigorously evaluate the diagnostic value of postmortem MRI and to assess whether it could serve as an alternative to conventional autopsy when combined with limited minimally invasive procedures[7].

● Results of a Large-Scale Prospective Study Using Postmortem MRI

At two centers in London, whole-body postmortem MRI was performed over a period of four and a half years in fetuses and children under the age of 16. In addition to MRI results, clinical history, ante- and postmortem laboratory tests, and other imaging studies were combined to evaluate how closely postmortem MRI could replicate the major pathological findings identified by conventional autopsy[7].

A total of 400 cases were included—277 fetuses and 123 children. Among these, postmortem MRI findings were concordant with those of conventional autopsy in 357 cases (89.3%, 95% CI: 85.8–91.9%). When stratified by age, concordance was highest in younger cases: 175 of 185 fetuses ≤24 weeks' gestation (94.6%, 95% CI: 90.3–97.0%), 88 of 92 fetuses >24 weeks (95.7%, 95% CI: 89.3–98.3%), 34 of 42 neonates (81.0%, 95% CI: 66.7–90.0%), 45 of 53 infants older than one month (84.9%, 95% CI: 72.9–92.1%), and 15 of 28 children aged 1–16 years (53.6%, 95% CI: 35.8–70.5%)[7].

In 165 cases (41.3%), conventional autopsy was deemed unnecessary based on imaging and clinical data, yet autopsy was nonetheless performed. In these cases, postmortem MRI findings matched those of conventional autopsy in 99.4% of cases[7].

The study concluded that, although diagnostic accuracy of postmortem MRI decreases with increasing age, it provides anatomical detail comparable to conventional autopsy in fetuses, neonates, and infants when combined with clinical information and laboratory data. Moreover, postmortem MRI is more likely to be accepted by families and may serve as an alternative to conventional autopsy when appropriately selected[7].

● Diagnostic Accuracy of Postmortem MRI by Organ System

In the cohort of 400 cases from this study, diagnostic accuracy by organ system and disease category was evaluated using concordance with conventional autopsy as the reference standard. The results are summarized in the corresponding table[9–13].

For the central nervous system, postmortem MRI showed high diagnostic accuracy for both malformations and hemorrhage. However, the sensitivity for detecting antemortem ischemic changes was only 68.0% (95% CI: 48.4–82.8%)[9].

In the thoracic region, diagnostic accuracy for congenital heart defects was very high[10]. A separate study comparing 3T MRI findings with autopsy results in 222 stillborn fetuses between 12 and 41 weeks of gestation reported a sensitivity of 87.8%, specificity of 97.9%, and an overall concordance rate of 95.3% for detecting congenital heart disease[14]. On the other hand, the sensitivity for detecting pulmonary abnormalities was low at 39.6%, and particularly low for infectious lung diseases at just 12.5% (see table)[10]. However, when evaluated by lesion type, specificity and negative predictive value for pulmonary abnormalities were close to 100%, indicating that a negative postmortem MRI of the lungs can effectively exclude most significant thoracic pathologies identified at autopsy[10].

In the abdominal region, the sensitivity for detecting gastrointestinal abnormalities was low at 50%, but specificity and negative predictive value exceeded 90%. The overall concordance with autopsy findings was 87.4% (95% CI: 83.6–90.4%), supporting the conclusion that postmortem MRI is a useful alternative or complementary method to autopsy for identifying anatomical abnormalities in the abdomen[12].

For the musculoskeletal system, sensitivity was relatively low at 51.1% (95% CI: 37.0–65.0%), but specificity and negative predictive value were high at 98.2% (95% CI: 96.2–99.2%) and 93.8% (95% CI: 90.8–95.9%), respectively. This suggests that postmortem MRI has a high potential to rule out abnormalities when negative. Furthermore, there have been cases in which MRI detected abnormalities in regions not routinely examined by autopsy, some of which, although not directly related to the cause of death, may hold clinical significance[13].

◯ Literature Search Strategy and Selection (December 17, 2023)

【PubMed】

#	Search formula	Number of articles
1	Search ((("postmortem imaging") OR "postmortem CT") OR "postmortem MRI") OR "postmortem computed tomography"	1,086
2	Search (("infant") OR "child") OR "adolescent"	4,379,214
3	Search (#1) AND #2	252

■References

1) Arthurs OJ et al：Routine perinatal and paediatric post-mortem radiography：detection rates and implications for practice. Pediatr Radiol 2014；44：252-257（level 5）
2) Shelmerdine SC et al：Diagnostic accuracy of postmortem CT of children：a retrospective single-center study. AJR Am J Roentgenol 2019；212：1335-1347（level 4b）
3) Krentz BV et al：Performance of post-mortem CT compared to autopsy in children. Int J Legal Med 2016；130：1089-1099（level 4b）
4) Arthurs OJ et al：Comparison of diagnostic performance for perinatal and paediatric post-mortem imaging：CT versus MRI. Eur Radiol 2016；26：2327-2336（level 4a）
5) Tuchtan L et al：Diagnosis of congenital abnormalities with post-mortem ultrasound in perinatal death. Diagn Interv Imaging 2018；99：143-149（level 4b）
6) Kang X et al：Postmortem fetal imaging：prospective blinded comparison of two-dimensional ultrasound with magnetic resonance imaging. Ultrasound Obstet Gynecol 2019；54：791-799（level 4b）
7) Thayyil S et al：Post-mortem MRI versus conventional autopsy in fetuses and children： a prospective validation study. Lancet 2013；382：223–233（level 4b）
8) Thayyil S et al：Diagnostic accuracy of post-mortem magnetic resonance imaging in fetuses, children and adults：a systematic review. Eur J Radiol 2010；75：e142-148（level 4a）
9) Arthurs OJ et al：Diagnostic accuracy and limitations of post-mortem MRI for neurological abnormalities in fetuses and children. Clin Radiol 2015；70：872-880（level 4a）
10) Arthurs OJ et al：Diagnostic accuracy of post-mortem MRI for thoracic abnormalities in fetuses and children. Eur Radiol 2014；24：2876-2884（level 4a）
11) Taylor AM et al：Postmortem cardiovascular magnetic resonance imaging in fetuses and children：a masked comparison study with conventional autopsy. Circulation 2014；129：1937-1944（level 4a）
12) Arthurs OJ et al：Diagnostic accuracy of post mortem MRI for abdominal abnormalities in foetuses and children. Eur J Radiol 2015；84：474-481（level 4a）
13) Arthurs OJ et al：Diagnostic accuracy of postmortem MRI for musculoskeletal abnormalities in

fetuses and children. Prenat Diagn 2014；34：1254-1261（level 4a）
14) Ulm B et al：Diagnostic quality of 3Tesla postmortem magnetic resonance imaging in fetuses with and without congenital heart disease. Am J Obstet Gynecol 2021；225：189.e1-189.e30（level 4b）

■ **Figures and Tables**

Table. Diagnostic Accuracy of Postmortem MRI by Organ System and Pathological Condition

	Sensitivity (%)	**Specificity (%)**	**PPV (%)**	**NPV (%)**	**Accuracy (%)**
All CNS abnormalities (Ref. 9)	87.5 (80.1-92.4)	74.1 (68.0-79.4)	62.8 (55.0-70.0)	92.2 (87.4-95.3)	78.6 (73.9-82.6)
Brain malformations	88.4 (75.5-94.9)	95.2 (92.1-97.1)	73.1 (59.7-83.2)	98.2 (95.9-99.2)	94.3 (91.3-96.4)
Intracranial hemorrhage	100.0 (83.9-100)	99.1 (97.2-99.7)	87.0 (67.9-95.5)	100.0 (98.8-100)	99.1 (97.4-99.7)
Ante-mortem ischemic changes	68.0 (48.4-82.8)	96.1 (93.4-97.8)	58.6 (40.7-74.5)	97.4 (94.9-98.7)	94.0 (91.0-96.1)
All cardiac abnormalities (Refs. 10,11)	72.7 (58.2-83.7)	96.2 (93.5-97.8)	72.7 (58.2-83.7)	96.2 (93.5-97.8)	- -
Congenital heart disease	92.6 (76.6-97.9)	99.1 (97.4-99.7)	89.3 (72.8-96.3)	99.4 (97.8-99.8)	- -
Non-cardiac thoracic abnormalities (Ref.10)	39.6 (31.0-48.9)	85.5 (80.7-89.2)	53.7 (42.9-64.0)	77.0 (71.8-81.4)	71.8 (67.1-76.2)
Pulmonary infection	12.5 (5.9-24.7)	92.6 (88.6-95.2)	25.0 (12.0-44.9)	84.2 (79.3-88.1)	79.3 (74.3-83.6)
Abdominal (Ref. 12)	72.5 (61.0-81.6)	90.8 (87.0-93.6)	64.1 (53.0-73.9)	93.6 (90.2-95.8)	87.4 (83.6-90.4)
Kidneys	80.0 (60.9-91.1)	98.6 (96.4-99.4)	83.3 (64.1-93.3)	98.2 (95.9-99.2)	97.0 (94.5-98.4)
Bowel	50.2 (23.7-76.3)	95.2 (92.1-97.1)	26.3 (11.8-48.8)	98.2 (95.9-99.2)	93.7 (90.3-95.9)
Musculoskeletal system (Ref. 13)	51.1 (37.0-65.0)	98.2 (96.2-99.2)	79.3 (61.6-90.2)	93.8 (90.8-95.9)	92.7 (89.7-94.9)

（lower row: 95%CI）