



An Analysis Study of Diagnostic Quality and Accuracy of Post Mortem Magnetic Resonance Imaging as An Alternative to Autopsy in The Diagnosis of Death : A Comprehensive Systematic Review

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ABSTRACT

Background: Virtual autopsy, or VA, is a non-invasive method that supports traditional autopsy (CA) by utilizing cutting-edge technologies including computed tomography, magnetic resonance imaging, and X-rays. In cases of pathological post-mortems (PMs) where cultural or religious restrictions limit the use of CA, VA can be employed. Comprehending the correlation between diagnostic quality and the precision of postmortem magnetic resonance imaging as a substitute for traditional autopsy might be advantageous in formulating strategies and mitigating the difficulty of precisely determining the cause of death in certain cases. **Methods:** Following PRISMA 2020 guidelines, this systematic review concentrated on full-text English literature

published between 2014 and 2024. Editorials and review articles that appeared in the same journal as the submission were not accepted without a DOI. Several websites, including ScienceDirect, PubMed, and SagePub, were utilized to gather the literature. **Result:** Based on credible sources such as Science Direct, SagePub, and PubMed, the analysis looked at more than 1,500 articles. After it was decided that eight publications needed to be looked at further, the entire article was examined in greater detail. **Conclusion:** PMMR is a high-sensitivity diagnostic tool that provides detailed information about structural abnormalities and fetal disease processes. It is crucial for neuroradiological examination in perinatal post-mortem settings and demonstrates high diagnostic accuracy. Combining PMCT and PMMR has demonstrated high sensitivity in identifying skeletal injuries and cardiomyopathies, but requires specialized training to minimize over-interpretation of non-specific findings.

Keyword: Virtual autopsy, post-mortem, PMMR, diagnostic, accuracy

INTRODUCTION

Since the 1300s, autopsies, also known as necropsies, have been conducted as part of death investigations for medical and legal purposes.¹ Over the last three decades, the progress of technology has significantly influenced the development of autopsy methods. Richard Dirnhofer pioneered the concept of "virtual autopsy (VA)" or "virtopsy" by integrating state-of-the-art technology with conventional autopsy (CA). This non-invasive autopsy technique utilizes imaging modalities such as computed tomography, magnetic resonance imaging, X-ray, and others.¹ While autopsies are widely recognized as the gold standard for determining the cause of death, there are instances where a less invasive radiological approach may be preferred, particularly in cases of cultural or religious objections to internal body examination.²⁻⁴ VA can be utilized in various ways to complement CA, highlighting CA results and enabling focused, system-specific CA. In instances where cultural, religious, or other constraints limit or impede the conduct of CA, VA can substitute for CA in pathological post-mortems (PMs).⁵

Some specialized centers have moved beyond the traditional "all or nothing" approach to post-mortem examinations by offering a variety of post-mortem imaging procedures known as "less invasive autopsies" (LIAs) or "minimally invasive autopsies" (MIAs). These procedures may include image-guided or laparoscopic surgical biopsies of organs.⁶ Postmortem CT (PMCT) methods are particularly well-suited for investigating traumatic deaths, acute hemorrhages, lung diseases, calcifications, pneumothorax, and conditions associated with free air, as well as for personal identification, due to their ability to provide enhanced visualization of bone structures, gas/fluid spaces, foreign bodies, and superior resolution through 3D volume rendering techniques.^{2,7,8} In comparison, postmortem magnetic resonance (PMMR), although less commonly used, offers valuable insights into the cause of death and is particularly effective in studying soft tissues.^{2,7}

Nevertheless, there exists a significant distinction in the application of virtual autopsy (VA) in adult and pediatric populations due to the differing disease pathologies in each group. Pediatric

deaths can result from a variety of factors, including syndromic diseases, congenital structural abnormalities, and other conditions, necessitating the use of radiographic techniques for a comprehensive investigation. However, parents and family members are often hesitant to authorize a full traditional autopsy in these cases. As a result, a less invasive virtual autopsy is often the preferred option.⁹ The evidence supporting these examinations has primarily focused on diagnostic accuracy trials and comparisons between imaging modalities. Some specialist societies have even issued consensus expert opinions on the implementation of various imaging tests for perinatal deaths, and a few guidelines have been proposed. For radiologists and clinicians looking to provide post-mortem imaging or less invasive autopsy services, determining where to begin and what steps to take can be daunting.⁶ Understanding the link between diagnostic quality and the accuracy of postmortem magnetic resonance imaging as an alternative to conventional autopsy can be valuable in developing plans and easing the burden of diagnosing the exact cause of death in certain patients.

METHODS

Protocol

The chosen technique was carefully constructed to produce accurate and coherent research outputs, and the author of this work has followed the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 criteria to ensure compliance with all requirements.

Criteria for Eligibility

This paper offers a thorough review of studies done in the last ten years about the relationship between diabetes mellitus and psoriasis. The goal of this initiative is to clarify and improve patient care practices through in-depth data analysis. This thesis' main goal is to highlight the importance of important subjects that appear in a range of literary works.

Strict inclusion and exclusion criteria were put in place to guarantee the accuracy of the data used in this investigation. For consideration for inclusion, an item needs to have been published in English between 2014 and 2024. Published reviews, editorials, submissions without a DOI, and duplicate journal entries are among the exclusion criteria.

Search Strategy

The study's keywords include "magnetic resonance imaging, autopsy, post mortem, diagnostic, accuracy, diagnosis, death, alternative, quality". For this research, the following Boolean MeSH keywords were entered into the databases: (((“Magnetic Resonance Imaging”[MeSH Terms] OR “post mortem magnetic resonance imaging”[All Fields] AND “autopsy”[All Fields]) OR (“MRI”[MeSH Terms] OR “post mortem MRI”[All accuracy] AND “autopsy”[All Fields]) AND (“diagnosis”[MeSH Terms] OR “death”[All Fields] OR “alternative”[All Fields] OR “autopsy”[MeSH Subheading] OR “quality”[All Fields] OR “autopsy”[All Fields]))).

Data retrieval

The writers carefully considered the relevancy of each article based on its abstract and title before starting this in-depth analysis. Greater weight was only given to research that matched the inclusion criteria and the goals of the article. After several searches, a distinct and consistent pattern became apparent. The only language that was approved for full-text entries was English. The most stringent screening procedure produced content that met all predefined inclusion criteria and had a direct bearing on the topic of the study. Studies that did not meet these standards were typically ignored, and their conclusions were not given much weight. Numerous pieces of information were included in the assessment, such as factors, titles, authors, dates of publication, locations, and study procedures.

Quality Assessment and Data Synthesis

The authors themselves carefully read through the titles and abstracts of each article to decide which ones need more research. Subsequently, every document that was initially eligible for the examination had to be carefully examined. The selection of the review papers was based on the evaluation findings. This criterion allowed for a quicker selection of publications for additional examination, which in turn allowed for a more comprehensive assessment of earlier studies and the conditions that called for their review.

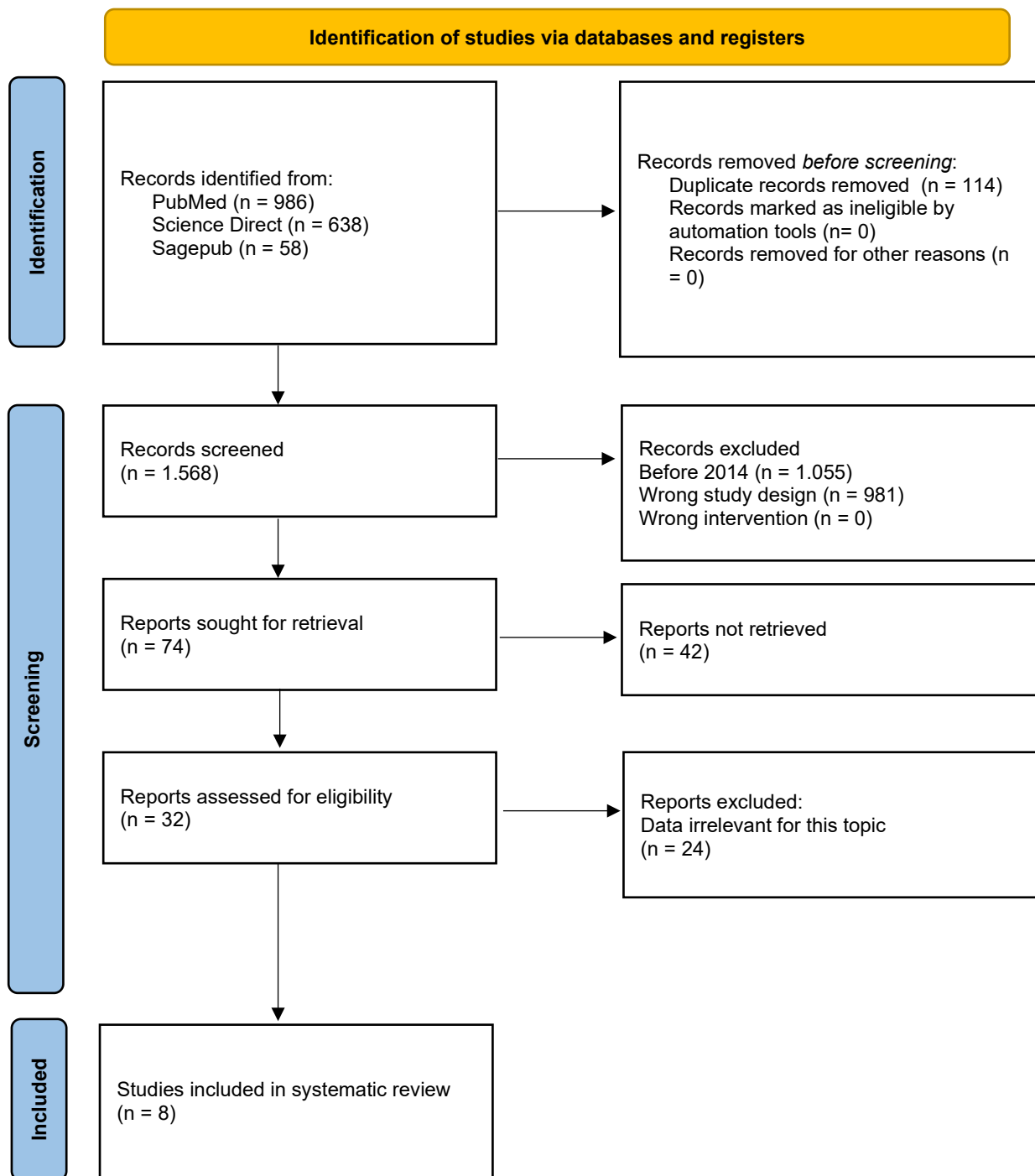


Figure 1. Article search flow chart

RESULTS

Early on in the study, our group meticulously assembled a sizable library of articles from reputable sources such as Science Direct, PubMed, and SagePub. Following a rigorous three-stage screening procedure, we identified eight papers that were considered extremely relevant to our current systematic study. After that, we focused on particular topics for more research and gave each manuscript a thorough evaluation. For your convenience, we've included a brief description of the assessed content in Table 1 to help expedite our study.

Table 1. The literature included in this study

Author	Origin	Method	Sample	Result
Vullo al.¹⁰ (2016)	Italy	Case Control	15 patients	Eight of the fifteen instances that were analyzed, both in the preliminary radiological examination and the typical autopsy, tested negative for illnesses and/or structural anatomical anomalies. The abnormal findings in the seven remaining cases were identified by PMMR and corroborated by autopsy data. PMMR can lead to better diagnostic results and offer helpful information on fetal medical issues.
Shelmerdine et al.¹¹ (2017)	United Kingdom	Review	-	The PMMR sequences and findings from post-mortem examination help readers understand abnormal developmental and acquired conditions, including neural tube defects, posterior fossa malformations, forebrain and commissural development,

				neoplastic, haemorrhagic, and infectious aetiologies.
Sonnemans et al.¹² (2018)	Netherlands	Literature Review	8 studies	Post-mortem radiology in Dutch settings is primarily performed using PMMRI, with MIA being the most common modality. PMCT is recommended for older children, while conventional autopsy is the preferred diagnostic method for foetuses, neonates, and infants. Post-mortem CR and ultrasonography play limited roles, with conventional autopsy remaining the preferred diagnostic method.
Ampazoni et al.¹³ (2019)	Switzerland	Meta Analysis	66 studies	The highest pooled sensitivity was found with PMCTA for soft tissue and organ findings, without evidence of between-study variability. The pooled sensitivity of PMCT+PMMR was very high in skeletal injuries, with no evidence of variability. The highest pooled sensitivity for detecting haemorrhages was found for PMCT + PMMR, with strong evidence of heterogeneity.
Perez-Serrano et al.¹⁴ (2021)	Spain	Review	-	MRI is a crucial tool for post-mortem foetal assessment, complementing autopsy methods. However, interpreting these findings requires familiarity with normal and abnormal findings, as well as

				understanding the strengths and limitations of the imaging method. This review provides an overview of the process.
Shelmerdine et al.⁶ (2022)	United Kingdom	Review	-	Post-mortem imaging, including MRI and other imaging modalities, is increasingly used to investigate perinatal deaths, but availability remains limited. Collaboration among multidisciplinary teams is crucial for successful service implementation, considering antenatal clinical findings when necessary.
Stassi et al.⁸ (2022)	Italy	Narrative Review	-	PMMR methodologies, particularly cardiac postmortem MR, are increasingly used in histologic investigations to detect and age infarcted areas and cardiomyopathies, offering a complementary approach to standard autopsy and histologic methods in diagnosing coronary artery disease.
Wickramasinghe et al.¹⁵ (2023)	Sri Lanka	Systematic Review	23 studies	Virtual autopsy outperforms conventional autopsy in detecting skeletal lesions, bullet trajectory, bleeding points, and air/fluid in body cavities. It's crucial for traumatic and firearm deaths, pulmonary thrombosis, foreign body aspiration, drowning, and metastatic malignancies. However, non-contrast imaging may lead to erroneous

				conclusions.
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Vullo's study showed that PMMR, a powerful tool for detecting structural abnormalities in the CNS, was more effective than traditional autopsy in finding pathological issues. PMMR was able to accurately assess brain anatomy, identify small amounts of cerebral hemorrhage, and detect major structural lesions in the lungs.¹⁰

Globally, perinatal autopsy using PMMR imaging has significantly improved, with Shelmerdine et al.'s findings highlighting the importance of parental consent for the process. The study found that perinatal autopsies included regular PMMR sequences, typical post-mortem findings, and abnormal developmental circumstances. Examples of abnormal findings included neural tube defects, posterior fossa malformations, forebrain, and commissural development, as well as neoplastic, hemorrhagic, and infectious causes.¹¹

Sonnemans et al. reported on the diagnostic accuracy of PMMRI in fetuses and neonates, comparing it to conventional autopsy. PMMRI showed high sensitivity and specificity for major and minor cardiac pathology, as well as structural and non-structural heart disease. However, it was challenging to identify non-cardiac and thoracic abnormalities, especially in cases of pneumonia.¹²

Ampazoni et al. examined 66 papers with a median age of 52.1 years, published between 1994 and 2018. The studies included various post-mortem imaging techniques such as PMMR, PMCT, PMCTA, PMCT + PMCTA, PMCT + PMMR, and PMMRI. The studies had an average of 23 participants, with a median percentage of 30% females, and utilized index tests like PMCT, PMCTA, and PMMR.¹³

Perez-Serrano et al. highlighted the importance of MRI as an imaging technique for evaluating fetal abnormalities but noted the lack of consensus on how to perform it. Previous protocols varied, with some using T1 and T2 sequences for anatomy and morphological alterations. Additionally, susceptibility-weighted imaging (SWI) and diffusion-weighted imaging (DWI) were found to be useful for detecting bleeding and cytotoxic edema.¹⁴

Shelmerdine's 2022 study revealed that MRI can provide high diagnostic accuracy for perinatal conditions, particularly in abnormalities of the heart, brain, and musculoskeletal system.

The largest prospective pediatric post-mortem imaging study, the 'MARIAS' study, found over 90% agreement with the autopsy, with higher concordance rates at higher field strengths.⁶

Stassi's study found that Postmortem Magnetic Resonance Tomography (PMMR) is superior to Postmortem Coronary Angiography (PMCTA) in detecting myocardial infarction and estimating infarction age. However, PMMR, autopsy, and histology were unable to identify signs of peracute ischemia or chronic infarction.⁸

Wickramasinghe's review of 23 studies on the detection of unnatural and natural deaths found that various techniques, including PM-MRI and PMCT, were used for virtual autopsy. While virtual autopsy was recognized as a crucial tool for unnatural deaths, it did not offer additional information.¹⁵

DISCUSSION

Post-mortem magnetic resonance (PMMR) is an invaluable diagnostic tool that offers detailed information about structural abnormalities and fetal disease processes, providing diagnostic indications comparable to those obtained with conventional autopsy.^{9,10} PMMR is particularly effective in identifying intraparenchymal blood components due to the altered signals compared to surrounding healthy brain tissue. However, it does not entirely replace conventional radiology and requires a greater financial commitment than a standard X-ray examination.^{10,16} The correlation between PMMR, post-mortem examination, and related histological studies of the fetus-placenta unit could contribute to reducing the percentage of cases in which the cause of fetal death remains unexplained.^{17,18} PMMR is crucial for neuroradiological examination in the perinatal post-mortem setting, serving as an adjunct or alternative to conventional autopsy. PMMR demonstrates high diagnostic accuracy, although features associated with infection and central nervous system abnormalities remain challenging. A clear understanding and greater experience of the range of appearances on post-mortem imaging can be beneficial in cases of perinatal death, especially where normal findings may preclude intracranial tissue extraction.¹¹

Post-mortem radiology is recommended as a diagnostic method in cases where an autopsy is not performed, particularly in fetal, neonatal, and pediatric cases. Post-mortem MRI (PMMRI) is preferred for fetuses, neonates, and young children due to its superior soft-tissue contrast compared to PMCT.¹⁹ PMCT is favored for older children due to its widespread availability, cost-effectiveness, and shorter scan time compared to PMMRI. However, there is limited evidence to determine the age range at which PMCT and PMMRI have equal diagnostic performance.¹² Ultrasound is considered in selected cases where parents do not approve the use of PMCT or PMMRI.²⁰ A combination of imaging and minimally invasive tissue acquisition is expected to be increasingly utilized in the future, incorporating improved diagnostic techniques such as high-field PMMRI, post-mortem angiography, and post-mortem ventilation.¹²

Postmortem imaging techniques such as PMCT and combined PMCT + PMMR have demonstrated high sensitivity in identifying skeletal injuries. The combination of PMCT and PMMR showed the greatest sensitivity for detecting hemorrhages, followed by PMMR alone.¹³ PMCT is a reliable method for identifying skeletal injuries compared to autopsy, and it exhibited the highest sensitivity for detecting soft tissue and organ findings. PMMR alone demonstrated a lower overall sensitivity, and PMCT alone had notably low sensitivity.^{13,21,22} Post-mortem MRI and autopsy show promise for future research, as they exhibit strong macroscopic correlation and could serve as complementary techniques for evaluating the central nervous system (CNS).^{11,17,23} In cases of fetal death, post-mortem MRI may be routinely conducted before autopsy to enhance diagnostic information. Understanding the imaging characteristics of post-mortem fetal MRI is essential for achieving optimal results.¹⁴

PMMR has demonstrated superior efficacy in detecting myocardial infarction in postmortem situations, enabling the estimation of infarction age.⁸ Cardiac PMMR (PMCMR) has been studied for its potential to diagnose cardiomyopathies, particularly Hypertrophic Cardiomyopathy (HCM).²⁴ The diagnostic utility of PMCMR has been evaluated in clinical settings, with research indicating the ability to assess ventricle hypertrophy and dilation from both short and long-axis views. PMCMR has also been assessed for diagnosing Arrhythmogenic Right Ventricular Cardiomyopathy (ARVC).²⁵ VA serves as a valuable tool in investigating unnatural deaths, especially firearm-related

injuries and non-accidental injuries (NAIs).¹⁵ However, the VA encounters challenges in investigating natural deaths, including organ-specific sensitivities and the difficulty in differentiating AM injury from PM changes.^{17,26} The implementation of VA in routine practice necessitates specialized training and expertise to minimize the over-interpretation of non-specific findings.¹⁵

CONCLUSION

Post-mortem magnetic resonance (PMMR) is a valuable diagnostic tool that provides detailed information about structural abnormalities and fetal disease processes, providing diagnostic indications comparable to those obtained with conventional autopsy. PMMR is particularly effective in identifying intraparenchymal blood components due to altered signals compared to surrounding healthy brain tissue. However, it does not entirely replace conventional radiology and requires a greater financial commitment than a standard X-ray examination. PMMR is crucial for neuroradiological examination in the perinatal post-mortem setting, serving as an adjunct or alternative to conventional autopsy. PMMR demonstrates high diagnostic accuracy, but features associated with infection and central nervous system abnormalities remain challenging. Post-mortem radiology is recommended as a diagnostic method in cases where an autopsy is not performed, particularly in fetal, neonatal, and pediatric cases. PMMR and autopsy show promise for future research, as they exhibit strong macroscopic correlation and could serve as complementary techniques for evaluating the central nervous system.

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