Original Research

NEWER DEVELOPMENTS IN AUTOPSY EXAMINATION

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ABSTRACT

High quality data on the cause of death are important to help prioritize health policies. This is particularly relevant in low- and middle-income countries where the mortality burden is high, information is poor, and most deaths are preventable. Complete diagnostic autopsies (CDA) is considered as the gold standard in the performance of post mortem examinations worldwide. The procedure entails invasive analysis, structured recording of comorbidities for the identification of important pathophysiological and molecular mechanisms in organs. The data can provide information that may have implications for future therapeutic interventions.

Many deaths occur outside the health system, bereft of even basic medical assistance, let alone postmortem evaluation that allows certification of death. Verbal autopsy is a structured interview administered to relatives of the deceased individual and serves as an alternative to overcome this problem in low- and middle-income countries. (1, 2)

Social and religious considerations, age of the deceased, mutilation considerations, emotional and economic liabilities, preclude consent for autopsies.

Healthcare professionals have the onerous task of convincing the next of kin of a deceased for the need for a post mortem examination and secure their informed consent. This delicate but essential task can pinpoint the cause of death and provide finality to the medical personnel and relatives.

To overcome the issues concerned, it has become essential to render CDAs less invasive and comprehensive to secure widespread acceptability. 'Virtopsy' is set to become the newe alternative in thanatology. (3)

Keywords: Autopsies, Minimal Invasive Techniques, Ultrasound, Post Mortem, Conventional Autopsy, COVID-19, Acceptability.

INTRODUCTION

A medical or forensic post-mortem is a medical examination of a corpse to determine the cause and manner of death, with a forensic post-mortem specifically focusing on cases with legal or suspicious implications.

Complete diagnostic autopsies, considered the gold standard, are rarely done in low resource settings to determine a person's cause of death. Many health centers lack the resources and infrastructure needed to carry out the complex procedure, which can also be considered culturally unacceptable in some contexts.

The objectives of an autopsy are:-

a) To establish the identity of the dead
b) To determine the cause of death
c) To assist in confirming or refuting the alleged manner of death, wherever possible
d) To estimate the time since death (postmortem interval)
e) For insurance and compensation in cases of drowning, hanging, burns and accidents
f) For inheritance related issues

In the case of a fetal autopsy or an autopsy of a neonate, the medicolegal objectives:

- To determine the intra-uterine/gestational age of the fetus, ultimately aiming to assess its viability.
- If viable, to determine whether it was a live birth or stillbirth.
- If born alive, to determine the period of survival after birth, the cause, and manner of death

In classic autopsy, the entire body is never dissected as, in most instances, the next of kin do not accept the extensive mutilation of the corpse

HISTORICAL ASPECTS OF POST MORTEMS

The concept of minimally invasive postmortems study to support cause of death determination is credited to Dr. Howard Atwood Kelly (1858-1943) a founding Johns Hopkins professor, pioneered "arm's length' methods to preform covert autopsies to harvest organs via natural orifices to circumvent autopsy consent regulations and procure specimens

www.ajmrhs.com
eISSN: 2583-7761

Date of Received: 11-01-2026
Date Acceptance: 21-01-2026
Date of Publication: 20-02-2026

for mounting as well as diagnose obscure cases that defied clinical diagnosis (4).

In 1930, Décio Parreiras and Werneck Genofre used needle- based postmortem examination during a yellow fever outbreak in Brazil. (5)

In 1990, Ros and co-workers investigated the potential of pre-autopsy post-mortem MR (PMMR) imaging by employing a 0.15-T MR scanner. They concluded that MRI was equal to autopsy in detecting gross cranial, pulmonary and vascular pathologies and even superior to autopsy in detecting air and fluid but less sensitive for upper abdominal organs. (6)

Ten years later, Bisset and co-workers created a sensation with their claim that MRI was "a credible alternative to invasive autopsy". Pathologists objected to the lack of autopsy correlation and the credibility of clinical radiologists to correctly diagnose a cause of death. (7)

Reasons for Refusal of Post Mortem Examination

In many backward and less developed nations, post mortem is viewed as disrespectful and mutilating to the deceased. Mortuary staff are looked down upon and sometimes assaulted for conducting post mortems due to official delays, suspicion of involvement with illegal organ trade and incompatability with traditional burial rituals. In pediatric fatalities most parents refuse postmortem as a needless exercise unless the cause of death is suspect or unknown.

Compromised aesthetics also prove repulsive and provocative. The sight of corpses laid out on the tiles and exposed on the floor, inebriated and insensitive mortuary helpers surmounting the stench the stench and grotesque sights accident victims by imbibing and callousness are commonly observed. Agitated and grieving relatives throng the isolated and poorly lit perimeters, trying to expedite autopsies by offering bribes, creating nuisance and resorting to collective intimidation behaviour to exert pressure on the duty staff. Police and security staff on duty hesitate to quell aggravation due to the tragic and upsetting nature of the circumstances.

Traditional post demise rituals like bathing the corpse and chants for the departed soul are prohibited in some communities post autopsy is done and parents are prohibited from touching their dead child by their societies. (8, 9, 10, 11, 12, 13, 14)

Freezer boxes or mortuary refrigerators to store corpses awaiting autopsies are generally unavailable in most government mortuaries located in smaller cities.

Common reasons for refusing post mortem examinations are depicted in Fig 1.

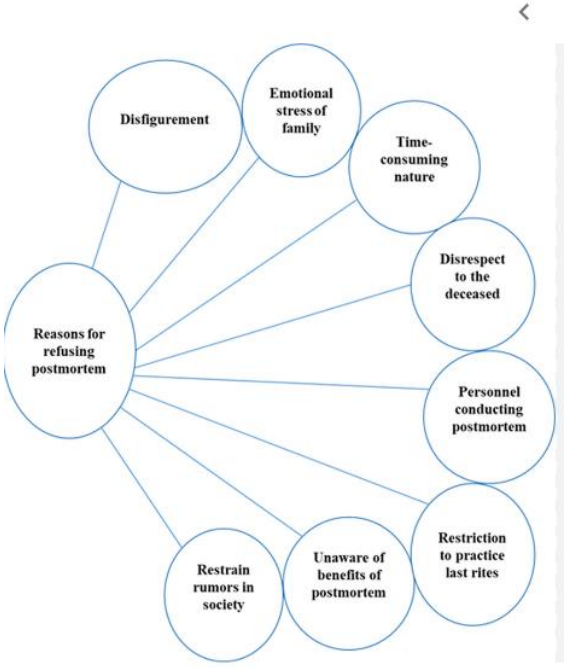

Fig 1: Reasons for Post Mortem Refusal

Obligatory indications for a post mortem are reserved for government employees who die in harness, both for compensation, insurance, provident fund pay outs and ad hoc employment of dependents. Suspected dowry deaths, homicidal and suicidal cases, disaster deaths for causal and identification purposes, deaths due to industrial accidents, fires and explosions.

AUTOPSIES IN INFECTIOUS DISEASES

Serious communicable diseases like Human immunodeficiency virus (HIV), viral hepatitis B and C, and tuberculosis infections, viral

hemorrhagic fevers, rabies, anthrax, yellow fever etc have a potential for occupational transmission. Viable HIV has been successfully isolated from the blood of non-refrigerated cadavers for at least 36 h after death and from refrigerated cadavers kept at 2 °C for at least 17 days after death. Autopsy specimens such as blood, body fluids, and fresh tissues also are a potential source of infection. The novel SARS coronavirus (SARS- CoV) pandemic had a mortality rate of 10%–15%. Complete autopsy of victims became necessary to investigate the cause, pathogenesis, and pathological changes of the syndrome.

Biosafety concerns about performing autopsies legislated biosafety level 3 (BSL 3) or 4 autopsy suites. This involved the creation of a clean area, a semicontaminated area, a contaminated area, and 2 buffer zones retrofitted with high-efficiency particulate air (HEPA) filters in the air supply and exhaust systems together with laminar plenum air flow facility. In addition, the contaminated, semicontaminated, and clean areas required approximately -50 pa, -25 pa, and -5 pa negative pressure. Working staff had to don personal protective equipment (PPE), including eye shields, N 95/FFP2 face masks, impermeable protective clothing, and 3 layers of gloves worn during autopsies. All equipment had to be decontaminated before it could exit the facility. Such elaborate facilities are beyond the means of low- and middle-income countries and, compromises were made that resulted in collateral damage and unacceptable mortality and morbidity among mortuary staff. (15, 16, 17, 18, 19, 20, 21, 22)

MINIMALLY INVASIVE AND IMAGING ASSISTED AUTOPSIES

Minimally invasive autopsy studies commenced in 2016and, the term was applied to a combination of tissue biopsies and post-mortem cultures, without any kind of imaging. This technique had an agreement and sensitivity of (almost) 60 % for ascertaining the cause of death, and also for new major findings. As the procedure was refined, it showed excellent concordance with CDA in determining CoD across different age groups, including adults, children, stillborn babies and neonates. (23, 24, 25)

The 2013 Linda-Gates sponsored ‘The Cause of Death investigation using Minimally Invasive Autopsy’ (CaDMIA study project) continued validation of the minimally invasive autopsy for the investigation of the causes of death in infants. the minimally invasive autopsy (MIA) tool can be used as a substitute for complete diagnostic autopsies (CDA) for cause of death determination (CoD) in all age groups. Preliminary results have shown that concordance between MIA and CDA is high, particularly for infectious causes of death. The CaDMIA study witnessed a high acceptance rate of MIA by next of kin of deceased individuals, keen to know causes of death of their loved ones and arrive at a finality. MIAs is now a standard tool in real life conditions in places where CDAs are unfeasible or unacceptable.

MINIMALLY INVASIVE TISSUE SAMPLING (MITS)

The MITS technique of post-mortem refers to an advanced, less invasive method for examining deceased individuals. MITS is carried out by trained pathologists and technicians. The process starts with collecting small amounts of tissue and fluid from key organs by inserting fine needles and guided by post mortem ultrasound. Advantages of endoscopy are improved visualization owing to illumination and magnification, a visual record of the procedure and, most importantly, no large incisions. These samples are then analyzed for key pathogens and infectious diseases, as well as malignant tumors. With proper counselling, MITS emerged as an acceptable alternative to less educated and sentimental communities versus CDA. The cause of death is confirmed in 67% of the patients and needle sampling correlates well with the complete autopsy in 87% cases. Postmortem needle lung and spleen cultures correlates with the complete autopsy in 85% cases. Cultures of the brain, cerebrospinal and peritoneal fluid has 100% correlation with CDA. MITS has been repeatedly validated as an alternative with a concordance rate to CDA of 90% in Mozambique and up to 97% in the Netherlands.

In medical post mortems, MITS can determine underlying diseases when there is more than one pathological condition and performed faster than a conventional autopsy as it does not involve opening of the body cavities and body mutilation. The access methods are nearly inconspicuous giving an outward impression of untouched integrity of the deceased, and thereby, greater acceptability. MITS can be repeated several times when performed within a certain time interval before decomposition sets in. (26, 27, 28, 29, 30)

MINIMALLY INVASIVE AUTOPSY (MIA)

Another variation in post mortem technology is the minimally invasive autopsy (MIA). Developed by the Barcelona Institute for Global Health (ISGlobal) in 2013. (Fig 2)

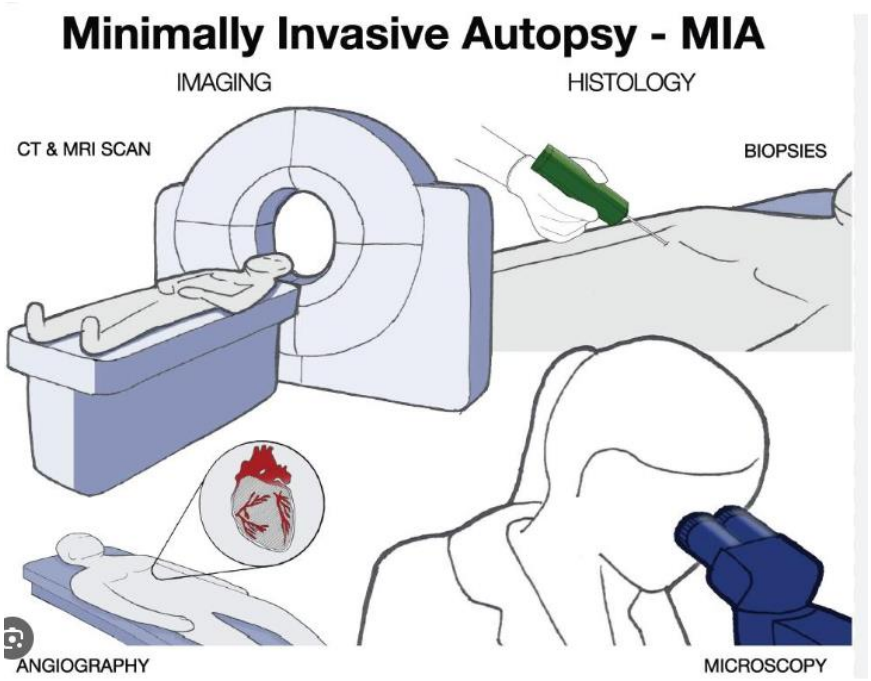

Fig 2: Components of a minimally invasive autopsy

It is a low-cost method in which needle biopsies of viscera are obtained under direct laparoscopic viewing for histopathological, thanatochemistry and immunohistopathology. (31, 32)

POST-MORTEM MRI (PMMR)

A post-mortem MRI (PMMR) is a non-invasive imaging technique where the whole body is scanned with a 1.5-Tesla MRI to provide HD- like soft tissue images that can be stored, retrieved and reviewed when needed. PMMR is a powerful tool in forensic death investigations, where detailed imaging of suspicious bone injuries can reveal otherwise undetectable findings is required, as in cases of suspected non-accidental or self-inflicted injuries. Postmortem MRI and histopathological correlation has provided important insights into the etiology and evolution of various neurologic disorders with high specificity. Both PMMR and MIA are as accurate as conventional autopsy in soft tissue and organs visualization, detection of hemorrhage and injuries despite maceration and decomposition. (Fig 3)

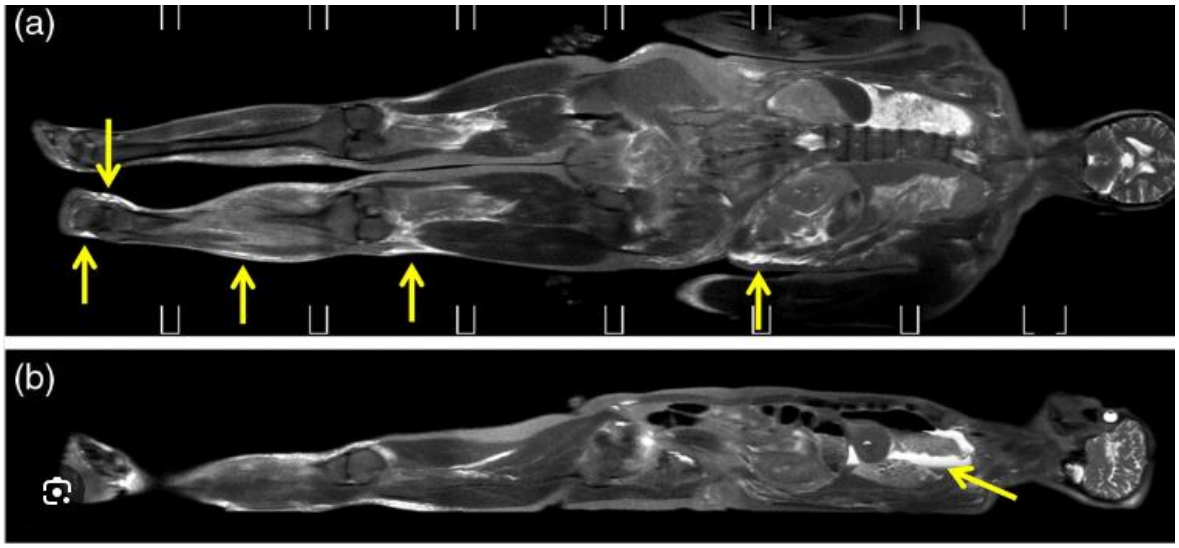

Fig 3: (a) and (b) Whole Body PMMRI

PMMR has become a total imaging matrix adjunct to, or even a replacement, for CDA as it permits reevaluation long after death. With advances in clinical radiology, 76 seamlessly integrated coil elements integrated with 32 radiofrequency channels conducts true whole-body (205-cm scan

length) imaging in a single examination in 90 minutes time for acquisitions. Blunt force injures and penetrating trauma cases are especially well documented by PMMR. Pre-autopsy cross-sectional imaging has become a standard procedure in forensic institutes worldwide and endorsed by the International Society of Forensic Radiology and Imaging (ISFRI). The significant difference between clinical MR images and PMMR images is the absence of motion artefacts on PMMR, resulting in greater anatomical detail than clinical images (33, 34).

T_2 weighted MR images are of paramount importance in post-mortem imaging as they highlight fluid accumulations, subcutaneous hematoma, bone contusion, organ laceration, internal haemorrhage, ischemic injury of the heart, brain edema, pericardial or pleural effusion and pulmonary edema. Short Tau Inversion Recovery (STIR) sequence suppresses the signal from fat, making water and abnormal fluid (like edema or inflammation) appear bright (high signal) against a dark background. During screening, they emphasize the signal from tissues with long T_2 relaxation times so that fluid accumulations show up very clearly while scrolling and termed as "forensic sentinel sign"

The PMMR protocol is initiated with a coronal whole-body STIR sequence along with a T_1 weighted and a turbo spin echo T_2 weighted sequence. After gaining a comprehensive overview covering the head, chest and abdomen, subsequent axial, sagittal or oblique images are acquired as indicated.

Thayyil et al. found better overall pooled sensitivity and specificity of post-mortem MRI in foetuses (69 % and 95 %) than in children and adults. (35)

Precise coordinates for robotic biopsy trajectories can be calculated for introducer needle insertions to minimize procedure time and costs. (36,37)

PMMR can achieve nearly 70% reduction in the number of high-risk invasive autopsies in infectious cases. (38, 39)

Advantages of PMMR

a) PMMR displays anatomical details and relationships well into the process of decomposition
b) MRI autopsy has a 95% accuracy and similar sensitivity in the evaluation of subarachnoid hematoma, 85% accuracy and 82% sensitivity for subdural hematoma and 85% accuracy and 67% sensitivity for epidural hematoma. False-negative findings are reported in intracranial hemorrhage with a blood layer less than 3 mm thick and postmortem MRI showed false-positive findings in subdural and epidural hematomas
c) Ligature marks, subcutaneous hemorrhage, perifocal hematoma surrounding fractured laryngeal structures, and congested lymph nodes are pathognomonic in strangulation. Whole-body MRI also finds application the forensic examination of living assault victims, to classify soft-tissue lesions that cannot be detected through external forensic inspection e.g. surviving strangulation victims.
d) Hemothorax is detected with a 88% sensitivity and 86% specificity of 86% while pneumothorax is diagnosed with 100% sensitivity and 73% specificity. Lung parenchymal trauma like contusions and lacerations are detected with 100% sensitivity and 68 to 83% accuracy if putrefaction has set in.
e) Myocardial ruptures are clearly evident on PMMR and detected with 75% sensitivity and 97% specificity. Pericardial hemorrhage and tamponade seen as postmortem sedimentation effect of the corpuscular particles in the pericardial sac is also well visualized.
f) Pneumomediastinum, secondary to tracheobronchial laceration can be detected with 100% sensitivity and 85% specificity.
g) The sensitivity of MRI for grades II–VI hepatic lesions is 80% with specificity of 100%. MRI has low sensitivity of 50% for the detection of splenic lacerations. For pancreatic injury, postmortem MRI has a sensitivity of 60% and specificity of 79%. MRI depicts renal trauma 66% sensitivity and 100% accuracy and detects peritoneal and retroperitoneal hemorrhages with sensitivities of 80% and 100% respectively.
h) Postmortem collapse of major vessel lumen due to exsanguination, hampers precise localization of the vessel wall lesions but perivascular and intramural hematomas provide indirect evidence of such incidences.
i) Spinal column fractures are observed with 86% sensitivity and 96% specificity. These are often overlooked at conventional autopsy. For rib fractures the rates are 71%; sensitivity and 84% specificity. Fractures of the upper extremities are poorly displayed on MR images with a 40% sensitivity owing to the limited FOV of the MRI unit fractures of the lower extremities are detected with 100% sensitivity. These are also frequently undetected at autopsy.
j) The overall sensitivity of MRI for the identification of subcutaneous hematomas is 91% with specificity of 68%. The highest sensitivity (95%; specificity, 95%) is observed for galeal hematoma while the lowest sensitivity (79%; specificity, 54%) is observed for hematomas of the extremities. False

positive MRI findings seen in decomposed bodies with anasarca.

k) PMMR can provide crucial information for forensic accident reconstruction, help to make the autopsy procedure less destructive to the corpse, and direct the dissection to reveal undetected pathologic findings and second opinion autopsy.

l) In sudden cardiac death ischaemia-induced oedema can be viewed on PMMR. Within 3 hour of the event. Combined ischaemia/reperfusion injury results in more extensive oedema (with both intracellular and interstitial fluid accumulation) than ischaemic injury without vascular reperfusion. If oedema is not present, but PMMR features one or several small hypointense myocardial lesions, early ischaemic injury can be interpreted. whole-body PMMR angiography can assess the coronary arteries.

m) If death occurs before signs of ischemia are visible in the myocardium, the assessment of the coronary arteries is of paramount importance. Whole-body PMMR angiography is an option for this. Fat-saturated T_1 weighted images offer good image contrast, but this is susceptible to position-dependent sedimentation of contrast medium, which degrades the image quality. Presence of calcified coronary artery plaques and left ventricular hypertrophy can also point towards cardiac disease and sudden cardiac death.

n) The gastrointestinal tract remains somewhat of a blind spot on PMMR. In our personal experience, detection of gastrointestinal pathologies is hindered by both intraluminal and intramural post-mortem gas formation and the inability to introduce intraluminal contrast. Non-contrast PMMR reveals better soft-tissue detail than non-contrast PMCT, and MR is therefore considered to be more useful than CT to assess the abdominal organs. High soft-tissue contrast and the ability of MR to visualize soft-tissue pathology are also the principal reason why PMMR is the modality of choice in post-mortem neonatal and paediatric imaging.

o) PMMR to highlight bone marrow oedema on STIR sequences is superior to PMCT in forensic case reconstruction of skeletal injury as it can make a distinction between antemortem and post-mortem fractures based on the presence or the absence of bone marrow oedema. Fractures of the upper extremities can be missed because of the limited field of view. However, hematomas in the overlying subcutaneous fat can be viewed with 100% sensitivity for further detailed study.(40,41)

Confounding Factors

A. Immediately after circulatory arrest, position-dependent fluid sedimentation develops that results in a distinctive fluid–fluid level on T_2 weighted PMMR images in the lungs Post-mortem clots show up as a hypointense layer, which can confound underlying pulmonary pathology.

B. T_1 and T_2 relaxation times are temperature-dependent and result in low contrast between fat tissue and muscle tissue on T_2 weighted images, and enhanced contrast between fat tissue and fluids increases in low temperatures of cadavers. Below 20 °C, the contrast between fat tissue and muscle tissue disappears and T_2 weighted images resemble short tau inversion–recovery (STIR) images. T_1 weighted images, display an overall low image contrast. Below 10 °C, the image contrast deteriorates further and affects the detection of pathology or injury.

C. Artefacts can arise from intrahepatic gas can be detected following cardiopulmonary resuscitation, air embolism, penetrating liver injury or putrefaction.

D. Ferromagnetic objects can also create artefacts. A whole-body PMCT scan prior to PMMR may be indicated to screen for metallic objects like debris from motor vehicle accidents, shrapnel from explosion, jewellery, projectiles and prosthetic joints is advisable. Ballistic projectiles are generally non ferromagnetic as they are composed of lead or brass.

E. Vascular lesions, skull base and undislocated rib fractures, are not well visualized with MRI

F. Detection of pulmonary embolism is very challenging. The differentiation between post-mortem clot and true pulmonary embolism proves to be a difficult task. In cases where circumstantial evidence is suggestive of pulmonary embolism, it is certainly wise to acquire axial images of the lower extremities to screen for evidence of deep venous thrombosis.

CONCLUSIONS

PMMR is a powerful diagnostic tool with a wide scope in forensic and medical autopsies based on institutional protocols, availability of experts, financial resources and individual case circumstances.

PMMR offers excellent anatomical detail of the brain, heart, subcutaneous fat tissue and abdominal organs and bony skeleton. The procedure is able to detect ischaemic injury at an earlier stage than traditional autopsy and routine histology. It also renders opening of the skull for formal brain autopsy unnecessary.

PMMR coronal whole-body images provide a comprehensive overview and STIR images screen for pathological fluid accumulation (“forensic

sentinel sign") that can be targeted to abbreviate scan time.

By providing robust data on the causes of stillbirth, s-MITS can play a crucial role in informing public health strategies aimed at reducing stillbirth rates globally. The findings also highlight the importance of placental and lung pathology in postmortem evaluations of stillbirths, which should remain central to MITS protocols. MIA being significantly more acceptable across a range of ethnic and religious groups than traditional autopsy makes discussing autopsy options easier with parents. PMMR is acceptable to 99% of the parents involved, including the 33% of parents who did not consent to conventional autopsy, and religious groups for whom conventional autopsy was not acceptable.

Interdisciplinary collaborations between radiologists and forensic pathologists will make MIA an acceptable alternative to CDA in selected cases for achieving the best possible diagnostic accuracy and better overall health care quality control.

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How to cite this article: Dr. Chandrsasekhar Krishnamurti, NEWER DEVELOPMENTS IN AUTOPSY EXAMINATION, Asian J. Med. Res. Health Sci., 2026; 4 (1):-195-202.
Source of Support: Nil, Conflicts of Interest: None declared.