



# **A Review on Postmortem Imaging Techniques for Finding the Cause of Death: Analysis, diagnostic precision, limitation and legal interpretation**

Aditya Verma <sup>1\*</sup>, Tanu Rajput <sup>1</sup>, Devesh Tiwari <sup>2</sup>, Dr. Preetika Chatterjee <sup>3</sup>  
1.Department of Forensic science, MATS University, Raipur (C.G.),India  
2.Department of Forensic Science Uttaranchal University, Dehradun (U.K.),India  
3.Department of Forensic Science, NFSU, Raipur Campus (C.G.),India  
aadityaverma9691@gmail.com\*

## **Abstract**

Postmortem imaging is changing the way we look at forensic investigations. Instead of relying only on traditional autopsies, modern techniques like CT scans and MRIs now give us a chance to examine the body without making a single cut. This review takes a closer look at how accurate these imaging tools are in figuring out what caused a person's death. We studied many cases, examples to understand where and when these postmortem imaging techniques will work and where they fail. In many cases, these imaging techniques can clearly show things for the cause of death (Examples - broken bones, bleeding or blocked blood vessels inside the body). These details are crucial in solving cases, but they have limitations - some infections or soft tissue injuries might not be properly analyzed through imaging techniques, which is why traditional autopsy is necessary. Postmortem imaging can be powerful when presented with expert interpretation, but it's not always accepted on its own. That is why combining imaging with traditional autopsy often gives the most solid and defensible results. In the end, while postmortem imaging is not a perfect substitute for an autopsy, it is a valuable tool—especially in situations where a full autopsy is not allowed or possible. It brings a modern, less invasive approach to forensic science and opens new possibilities for respectful and effective investigations.

**Key words:** Postmortem imaging, traditional autopsy, CT scans, MRI scans, modern technique

## 1. Introduction

Postmortem imaging, which includes CT, MRI, and other imaging methods, is the term used to describe virtual autopsy. This method improves the body's internal structural imaging while also being useful for recording research and meeting legal requirements Gascho D. (2025). Advanced forensics is constantly developing vital methods for identifying deaths and improving the effectiveness of case investigations. The methodology makes it possible to collect details and conduct a detailed analysis of internal structures (Koehler, et al.,2023).

Both clinical and forensic pathologists currently view the traditional autopsy as the "gold standard" for determining natural causes of death. Modern imaging techniques, particularly radiological cross-sectional imaging, have become a part of forensic practice's everyday routine in facilities across the globe (Grabherr, et al., 2016). Particularly radiological cross-sectional imaging—have become ingrained in daily operations (Flamm, 2007). The number of published studies in this sector has grown significantly in recent years due to the growing usage of imaging for forensic reasons and the creation of specialized research programs. Imaging is the medical advancement that has changed medical practices the most in recent decades. Currently, the use of PMI in a case's diagnostic process differs depending on the country's legal system and the kind of autopsy (forensic versus clinical) (Dedouit, 2025). Its application, however, is mostly related to the questions it is meant to address. The numbers of published studies in this field have y-sectional imaging, mainly due to parental choice, and the growing use of imaging for forensic purposes as well as the formation of specific research programs.

The use of imaging in postmortem investigations started in the early 1900s when X-rays first made their way into forensic work. After Wilhelm Roentgen discovered X-rays in 1895, experts quickly realized they could use this technology to look inside the body without making any cuts (Grabherr, et al., 2016). It was especially helpful for spotting things like bullets, broken bones, or foreign objects. But it had its limitations — it worked best on hard tissues like bones, not on soft organs.

As technology advanced, the late 20th century brought major changes. Computed Tomography (CT), which was developed in the 1970s for medical use, started being used in forensic science by the 1990s (Schulz, Stein & Pelc, 2021). This was a game-changer because CT scans could create detailed 3D images of the entire body. It helped examiners clearly see broken bones, hidden injuries, and even gas buildup inside the body, which is often important when figuring out how someone died (Villa, Olsen & Hansen, 2017).

Meanwhile, Magnetic Resonance Imaging (MRI) also began playing a role in forensic work. While CT was great for looking at bones and dense materials, MRI stood out for its ability to show soft tissues in great detail. It became incredibly useful for detecting injuries to the brain, finding tumours, or spotting damage to internal organs — things that a CT scan might miss (Florkow, et al., (2022). This combination of imaging methods brought a new level of precision to post-mortem examinations. Paediatric PMI is way more distinct from imaging of adult post-mortem; it needs a specific set of skills to increase its productions and clinical usage (Arthurs, et al., 2015).

## 2. Postmortem Imaging

As anticipated, PMMR is especially effective for congenital anatomical abnormalities, including brain dysfunction, renal abnormalities, and intracranial bleeding (Arthurs, et al., 2017). Skeletal dysplasia's with congenital cardiac disease. Microscopic alterations that frequently lack an imaging correlate, like kidney dysplasia's and disseminated sepsis, are particularly difficult for conventional PMMR to identify (Panda, et al., 2014). Prior to autopsy, PMMR can be especially helpful in imaging childhood deaths to determine traumatic injuries, such as internal hemorrhages and visceral or mesenteric injuries linked to blunt or piercing trauma to the body. One of the most valuable uses of PMCT (Postmortem CT) in skeletal injury assessment is for the cervical spine (Arthurs, et al., 2017). Also an effective tool in evaluation of gunshot wound in the skull (Tartaglione, et al., 2012). Regular cross-sectional imaging is excellent at revealing subtle injuries that are often missed or difficult to identify during a traditional autopsy. It provides encouragement to various centers of forensic medicine for the examining the usage of PMCT and PMMRI (Bailey, et al., 2021). PMCT, especially when combined with PMCTA (Postmortem CT Angiography), is particularly useful for evaluating sharp force injuries. It also outperforms conventional autopsies in detecting conditions like pneumothorax, pneumomediastinum, and air leaks into the soft tissues or the abdominal cavity (Datta, et al., 2025). However, PMCT does have its limits—it struggles to clearly distinguish between arterial and venous injuries. When there are multiple clustered wounds, it can be hard to interpret because the proximity makes it tough to tell them apart. When it comes to drowning cases, forensic experts often struggle because the physical signs on the body are usually vague and unreliable (Zerbini, et al., 2014). PMCT has become helpful in spotting signs of drowning. These include fluid in the sinuses (like the maxillary and sphenoid sinuses), as well as fluid in the mastoid air cells. A major indicator is fluid in the bronchial tree or trachea. Another strong

clue is sediment in the airways, which is often considered one of the most definitive signs of drowning. Other observations, such as pleural effusion (fluid in the lungs), heavy lungs, or an enlarged stomach and intestines, may also be seen (Mendes, et al., 2025). The PMCT is also considered effective in the cases of gunshot victims (Makhlouf, et al., 2013). However, these findings are not exclusive to drowning and can appear in other conditions as well. Still, postmortem imaging plays a vital role in helping doctors rule out injuries, locate foreign objects, and aid in identification. PMCT is especially valuable when dealing with charred remains. For example, it's highly effective in detecting foreign objects like bullets, which are notoriously difficult to locate in burned bodies due to the distortion caused by fire. PMCT can be used for the visualization of 3-d images of victims injury (de Bakker et al., 2019). It also helps forensic experts figure out whether blood in body cavities is from trauma (like active bleeding) or is just postmortem pooling. Additionally, bladder injuries or damage to other internal organs can be better examined with PMCT. One standout advantage of using PMCT on burned bodies is its ability to identify fractures and determine whether they were caused by trauma or heat exposure. Heat fractures in bones often appear as fine linear breaks and later develop into distinctive patterns like “flute mouthpiece” shapes (Ebert, et al., 2021). Postmortem imaging has also become a crucial tool in investigating deaths of fetuses, infants, and young children. Because of the emotional sensitivity surrounding the loss of a child, PMCT and MRI offer a respectful, non-invasive way to investigate causes of death without performing an invasive autopsy. This has become particularly important as fewer families consent to traditional autopsies’ is also useful in suspicious deaths, such as cases of hanging or strangulation (Arthurs, 2017).

Research has shown that imaging can help reveal fractures and injuries in areas that are otherwise extremely challenging to examine. Another major strength is its ability to detect gas collections in the soft tissues. This can indicate infection, decomposition, or trauma. The presence of gas has long been considered an important clue in diagnosing causes of death (Hoveidaei, et al., 2025).

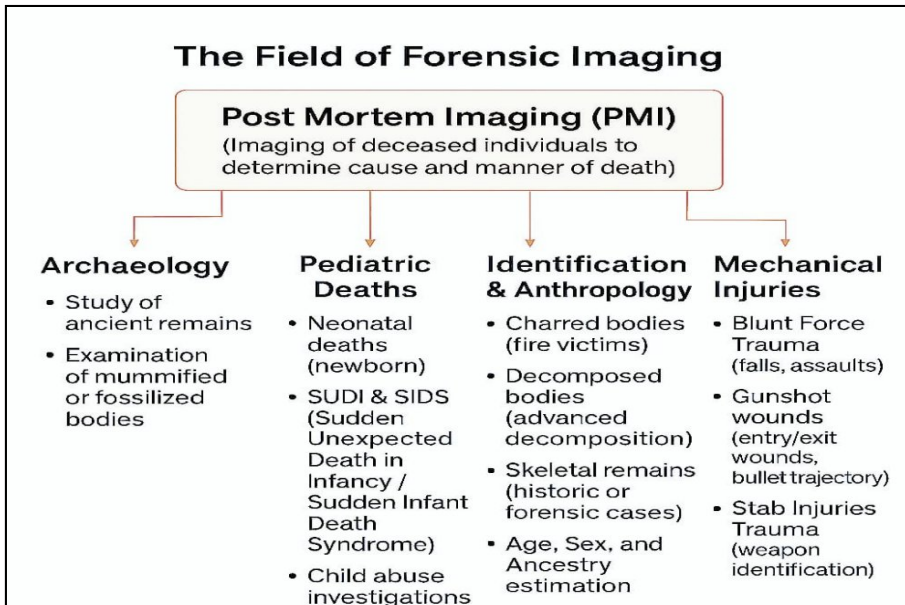


Fig .1 flow chart on fields of forensic imaging

### 3. Imaging Techniques

#### 3.1. Postmortem Computed Tomography (PMCT):

PMCT is essentially a full-body CT (Computerized Tomography) scan performed after death. It functions similarly to standard hospital CT scans. To develop detailed 3D images of everything within, the body is placed in the scanner and X-rays are taken from various angles. PMCT helps in determination of cause of death in various traumatic events (Ishida, et al., 2023). It's quite useful for identifying foreign items like bullets, gas emboli, bleeding, and shattered bones (Dedouit, et al., 2025). It's not intrusive. As a result, there is no cutting, which is quite advantageous in situations where families object to autopsies or when there is religious sensitivity. The estimation of coronary calcification before autopsy is also done in it (Weustink, et al., 2009). The results of PMCT is fundamentally in digital form as well as 3D also can be constructed again for the optimization of quality of image for distinctive types of tissue and to present different planes for viewing (Ebert, et al., 2021). Additionally, it's quick—often completed in a matter of minutes—and everything is digitally saved, allowing the scan to be reviewed at a later time if necessary. It allows detection of hemorrhagic lesions, like subarachnoid hemorrhage, cerebral hemorrhage, aortic dissection, as well as rupture of aortic aneurysms (Petridis, et al., 2017). However, it is not as good as other imaging techniques for

detection of the minor organ problem or the soft tissue damages inside the body. Gases may appear in the image generated by PMCT if the dead body is in a decomposing state which can mislead the case. Mass catastrophe victims or suspicious trauma cases are used to analyze with PMCT (Solomon, et al., 2025). However, the traditional autopsy is necessary which can provide the exact details about the body.

### 3.2. *Postmortem Magnetic Resonance Imaging (PMMRI):*

Postmortem MRI or PMMRI works mainly like regular MRI scans but it is used to examine people after the death. Instead of using X-rays it relies on magnetic fields and radio waves to produce highly and accurate detailed images of soft tissues like the brain, heart, and other organs (Addison, et al., 2014). In this process the body is placed inside the MRI machine and the scan takes place it takes time to generate the image of the body. PMMRI is especially useful for spotting conditions that might not show up on a CT scan such as brain bleeding early signs of stroke or subtle damage to the heart. It is particularly valuable when examining infants or children where even small internal changes can be crucial (Tedyanto, et al., 2022). On the other hand, the scans take longer cost more and not every forensic lab has the equipment. Plus, if the body is badly decomposed the images may not be very clear due to distortions and decomposition.

Still when it is available PMMRI is one of the best non-invasive ways to investigate how someone died especially when the focus is on soft tissue problems

### 3.3. *Postmortem Computed tomography Angiography (PMCTA):*

PMCTA is an advanced addition of conventional computed tomography applied in the field of forensic investigations for the imaging of the body after the death. This technique involves the radiological analysis of the detailed visualization of both the arterial and the venous structures inside the body. The process effectively reconstructs a comprehensive and extensive map of the circulatory system providing an understanding that are often missed or not analyzed through standard postmortem CT (La Russa, et al., 2019). PMCTA indicates a higher accuracy for identification of skeletal and vascular lesions (Grabherr, et al., 2014). The diagnostic use of PMCTA is particularly significant in the cases involving suspected vascular pathologies in forensics. PMCTA plays a crucial role in identifying the conditions such as ruptured arteries, coronary artery occlusions or internal hemorrhages, traumatic vascular injuries and undetected aneurysms in dead body (Wan, et al., 2024). Additionally, it has proven valuable in revealing

surgical complications that might be overlooked in conventional imaging modalities which makes this technique more reliable. One of the primary advantages of PMCTA is its ability to provide the detailed vascular assessment without the necessitating of a full invasive autopsy. This non-invasive approach is especially beneficial when the traditional autopsy is declined due to religious, cultural, or personal reasons (Heinemann, et al.,2017). Despite its clear benefits the technique is not without limitations. The procedure of using PMCTA requires specialized equipment sophisticated perfusion devices and personnel trained in both the field radiological imaging and postmortem vascular injection techniques. Furthermore, improper administration of the contrast agent can lead to suboptimal visualization potentially compromising diagnostic accuracy which can cause misleading in the analysis. The availability of PMCTA remains limited to well-equipped forensic centers restricting its widespread application (ASMIRT 2022).

#### 3.4. *Postmortem MR Angiography (PMMRA):*

PMMRA working is very much similar like PMCTA but instead of using a CT scanner, it is based on MRI to look at the blood vessels. A special contrast dye mainly gadolinium is used which is injected into the body's vascular system allowing the MRI to capture highly detailed and accurate images of both the vessels and the surrounding soft tissues in the dead body (Jacobellis, et al., 2024). This method is majorly useful where the doctors suspect heart problems or diseases affecting the blood vessels. Since MRI is excellent at showing soft tissue, it gives a clear view not just of the vessels but also of organs like the heart and brain etc. It is particularly helpful in cases of sudden cardiac death or when examining blood flow issues in the brain (Michaud, et al., 2019). However, it takes longer than CT costs a lot more and is not widely available most forensic labs don't have the right equipment or trained staff to do it regularly it needed a trained technicians and staff for the use of this imaging techniques. Plus, like other MRI scans the quality can suffer if the body has started decomposing which can affect the final analysis.

#### 3.5. *3-D Surface Scanning (3DSS)*

3D surface scanning (3DSS) has become a valuable tool in forensic science, particularly in countries like Switzerland where it's used by legal medicine institutes and police departments. It's commonly applied in reconstructing traffic accidents, analyzing injuries, and comparing bite marks to a suspect's dental profile (Villa, et al., (2023). 3dss The technology relies on fringe light scanners, which use a projector and two cameras to cast and record patterns of light

across an object's surface. As the light moves, it creates fringe distortions that the cameras capture (Feng, et al., 2023). These distortions are then processed by a computer using triangulation to generate a detailed 3D point cloud of the object's surface. High-end scanners can capture up to 16 million data points in a single scan, and multiple scans from various angles are often combined to create a complete, high-resolution 3D model (Zhang, 2025).

While mobile hand-held scanners offer flexibility for on-site investigations, stationary scanners typically provide superior resolution—some achieving precision as fine as 0.017 mm. These 3D models can be overlaid to compare injuries with potential weapons or other objects, and can also be integrated with CT or MRI data for comprehensive forensic reconstructions (Carew, et al., 2021). The technique is praised for being non-invasive and capable of producing highly detailed models relatively quickly—scanning an entire body can take as little as 15 minutes. However, 3DSS wasn't originally designed for forensic use, which introduces some challenges. For instance, the scanners are optimized for smooth surfaces, making it difficult to accurately capture textures like human skin or reflective and dark materials. Additionally, the process is sensitive to movement and lighting changes, limiting its effectiveness outdoors. The quality of the results also heavily depends on the operator's expertise.

Despite these limitations, 3DSS has proven its worth in legal contexts and is increasingly influencing forensic investigations. As the technology continues to evolve, it's expected to play an even more significant role in the future of forensic science.

Types of Death	Analysis in Post mortem imaging
Blunt force trauma	identifying the fractures and internal bleedings.
Gun shot wound	visualization of the wounds of entrance and exit, direction of the bullet
Drowning	identification of the presence of liquid
Sudden infant death	detect the injuries of the trauma, also can reveal the suffocation faced by the body

Stabbing	reveal the angles of the stabbing and connecting with the suspected weapon
Bone fractures	reveal the internal fractures present in the body

Table 1. Types of death and their analysis in postmortem imaging.

#### 4. Understanding AI, Machine Learning, and Neural Networks

Artificial Intelligence (AI) is a branch of computer science focused on replicating human-like intelligence to solve complex tasks. Early examples include chess-playing programs and handwriting recognition systems. While traditional AI relied heavily on rule-based algorithms, a more dynamic subset—machine learning (ML)—emerged to allow systems to learn from data rather than follow fixed instructions (Aldoseri, et al., 2023). A common ML application is spam detection, where algorithms analyze patterns in flagged emails to filter future messages.

Deep learning (DL), a specialized form of ML, uses artificial neural networks (ANNs) to process data. These networks are inspired by the structure and function of biological neurons. Each artificial neuron receives multiple inputs, applies weights, and produces an output based on a threshold. This concept dates back to 1943, when McCulloch and Pitts introduced a model of logical units mimicking brain activity, later expanded by Frank Rosenblatt with the perceptron model (Taye, 2023). ANNs are structured in layers—input, hidden, and output. Each node in a layer connects to nodes in the previous layer, forming a topology. Learning occurs through backpropagation, where the network adjusts weights to minimize error between predicted and actual outputs. This process uses gradient descent and a cost function to guide optimization. The final output is often normalized using a softmax function, which converts raw scores into probabilities (Montesinos et al., 2022).

As data complexity increased, especially in image analysis, traditional ANNs became computationally intensive. For example, a 512×512 pixel image would require over 260,000 input nodes. To address this, convolutional neural networks (CNNs) were developed in the late 1980s, initially for digit recognition. CNNs reduce image complexity by applying filters that extract local features, followed by pooling operations that downsample the image. ReLU activation functions further refine the data by eliminating negative values. These steps are repeated across multiple layers, producing feature maps that feed into the neural network for classification (Krichen, 2023).

CNNs have revolutionized image processing by enabling efficient and scalable analysis, making them essential in fields like medical imaging, autonomous vehicles, and forensic radiology (Mienye, et al., 2025).

Postmortem computed tomography (PMCT) has become a vital tool in forensic investigations, offering detailed insights into skeletal injuries, soft tissue damage, and foreign bodies (Fornasari, 2025). Studies like those by Ampanozi et al. have shown that PMCT is highly reliable for detecting fractures, while PMCT angiography enhances soft tissue contrast, making it particularly effective for identifying hemorrhages. Unlike clinical radiology, which focuses on diagnosing conditions for treatment, postmortem radiology aims to determine the cause and manner of death (Dobay, et al., 2020). It typically involves full-body scans at high resolution, generating over 10,000 images per case. This extensive data volume places a heavy burden on forensic pathologists, especially given the global shortage of trained experts.

To address this challenge, researchers are turning to artificial intelligence—specifically deep learning. Unlike traditional image processing, which requires manual feature selection and tuning, deep learning models can automatically learn patterns from data, making them more adaptable to the variability in postmortem scans. These techniques have already shown promise in clinical radiology and are now being explored for forensic applications such as organ segmentation, injury detection, and foreign body identification (Loh, et al., 2021). Efforts to integrate deep learning into forensic workflows are gaining momentum, with international organizations like the International Society of Forensic Radiology and Imaging and the Netherlands Forensic Institute identifying it as a key research priority. As the field evolves, AI-driven tools could significantly reduce analysis time, improve diagnostic accuracy, and make postmortem imaging more accessible and cost-effective (Obuchowicz, et al., 2025).

#### **4.1 Enhancing Functionality**

One of the developments is in the integration of artificial intelligence (AI) and machine learning into forensic imaging. These technologies are used to designed and support forensic experts by analyzing large volumes of imaging data quickly and accurately (Dunsin, et al., 2024). AI can help to distinguish between the natural postmortem changes such as decomposition gases or fluid shifts inside the body and actual pathological findings like internal bleeding, fractures, or organ damage through imaging techniques. This not only reduces human error but also speeds up the diagnostic process which is particularly valuable in complex cases or mass disasters and provide information about the cause of death (Ishida, et al., 2023).

## 4.2 Efficiency

A significant emerging trend is the development of portable imaging systems. Traditional imaging equipment is large and typically located in hospitals or specialized forensic centers where the body is taken for the analysis (Alafer, 2025). Portable CT and MRI units are design to bring imaging capabilities directly to remote locations, crime scenes, or disaster areas due to which it is easier and take less time for the analysis. This advancement has the potential capability to revolutionize how quickly and efficiently forensic examinations are conducted especially in situations where time, analysis and access are limited (Khalid, et al., 2025).

## 5. Discussion

The foremost radiological imaging fashion employed in forensic drug is conventional radiography. This system involves directly exposing the body to X-rays, and the structures that are exposed to the ray are also projected into a radiographic image. The benefits of radiography are its ease of use, speed, and cost- effectiveness. In forensics these radiological tools are utilized for the purpose of virtual anthropology as well. (Dedouit, et al., 2025). Radiography is constantly used for bodies of unclear identity, invigorated corpses, and extremely spoiled, burned, or else damaged bodies. Along with other completing tests, conventional radiography can also yield precious information for determining the age of both living and departed individualities.

Recent advances in medical image segmentation have laid the groundwork for applying deep learning to postmortem computed tomography (PMCT). Traditional segmentation techniques—such as multi-atlas, patch-based, and probabilistic atlas methods—have been used to analyze abdominal organs (Xu, et al., 2024). However, newer approaches like fully convolutional networks (FCNs), particularly the U-Net architecture and its extensions, have shown significant promise in clinical radiology for segmenting complex anatomical structures (Asadpour, & Xie, 2025).

Some researchers have proposed hybrid methods, such as registering organs by their center of gravity followed by voxel-level classification using convolutional neural networks (CNNs). These techniques are especially effective for organs with high anatomical variability (Fu, et al., 2021). Despite these developments, automated segmentation of 3D PMCT data remains largely unexplored. If implemented, it could support forensic tasks like estimating organ weight, identifying anomalies (e.g., hemorrhagic effusion), and guiding procedures such as CT-assisted needle placement (Mai, et al., 2023).

Beyond segmentation, deep learning has also been applied to age estimation using facial recognition. Early work by Kwon and Lobo (1999) used geometric ratios, while more recent studies have employed support vector machines and deep learning to extract features from facial landmarks (Abhulimen, & Ogunti, 2021). In forensic contexts, PMCT is invaluable for identifying victims in mass disasters and estimating biological profiles—including sex, age, ethnicity, and stature—based on skeletal and dental features (de Boer, et al., 2018).

PMCT also aids in estimating time of death by detecting postmortem changes like gas formation, which complements traditional indicators such as lividity and body temperature (Andrews, 2016; Solomon, et al., 2025). For trauma analysis, deep learning has proven effective in detecting fractures in clinical radiographs. For example, Kim and MacKinnon (2018) used a pre-trained Inception v3 model to identify wrist fractures. In head CT scans, deep learning can reveal not only injuries like hemorrhages and tumors but also reconstruct the sequence and direction of gunshot wounds.

Studies by Chilamkurthy et al. (2018) and Arbabshirani et al. (2018) have demonstrated the use of natural language processing and CNNs to detect intracranial hemorrhages in clinical CT data. However, machine learning applications for gunshot wound analysis in PMCT remain unexplored.

## **6. Conclusion**

Postmortem imaging technologies like PMCT and PMMRI is a precious instrument in identification of the reason of demise. In comparison to conventional autopsy, the PMCT is more accurate in detecting the cause of death (Roberts, et al., 2012). In forensics postmortem imaging is majorly utilized in the cases relating to trauma. This technology has enabled overcoming the traditional autopsies and its cons. PMCT can provide the particulars of the result for future verification during postmortem and help the expert to concentrate on the structure in need. PMCT, PMCTA, and biopsies together provide the most accurate analysis of cause of death. There are many studies which involves the advantages of the traditional autopsy but it hasn't affected the decreasing rate of the autopsies. Hence, new methodologies and approaches requires examination proper analysis to overcome this reducing percentile.

But every technique has its own cons, similarly the PMCT cannot determine the toxicological and biochemical sources. Whereas in the cases of death due asphyxia imaging cannot help efficiently. Depending on anyone of the either method is not a good idea as well, both imaging and traditional autopsy are complementary of each other so, in the forensic cases should both

of methodologies should be applied by the experts in order to get the appropriate outcomes. Despite of the fact that there are lot of advantages of postmortem imaging in forensic medicine some of the part of world is still untouched this advanced technology. As a result, there as cases which are not efficiently solved and justice isn't provided.

## 7. Future recommendations

Postmortem imaging has become an important support to traditional autopsy practice, but its role in forensic investigations can be strengthened further. One of the key future needs is the **standardization of imaging protocols and reporting methods**, which would allow results to be compared more reliably across institutions and legal systems. Clear guidelines would also improve confidence in the interpretation of findings and their acceptance in court. Additionally, AI-based tools have the potential to assist experts by quickly identifying fractures, hemorrhages, and other significant findings, while also helping to distinguish normal postmortem changes from true pathology. This could reduce workload and improve consistency, particularly in complex or high-volume cases. For this to be effective, large and well-annotated postmortem imaging datasets will be essential. Focus should also be given on **combining imaging with minimally invasive techniques**, such as image-guided biopsies and postmortem angiography. This approach may help address current limitations in detecting infections, metabolic disorders, and toxicological causes of death, while maintaining a less invasive examination process. Improving access to **portable and affordable imaging systems**, along with structured training for forensic professionals and greater legal awareness, will be crucial. Together, these steps can help establish postmortem imaging as a reliable, respectful, and widely accepted component of modern forensic practice.

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