



An Analysis of the Effectiveness of X-Ray as a Supporting Tool in the Autopsy Process: a Literature Review

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Abstract

This study aims to analyze the effectiveness of using X-ray technology as a supporting tool in the forensic autopsy process. The method used is qualitative with a literature study approach that includes various scientific sources such as journals, books, and medical documents. The results showed that X-ray plays an important role in modern autopsy, especially as a non-invasive method to detect foreign bodies, fractures, and internal trauma that are not visible to the naked eye. In addition, technological developments such as postmortem CT (PMCT) and virtual autopsy (virtopsy) utilizing X-ray have also further expanded the application of imaging in the autopsy process, providing a three-dimensional view of the body without the need to perform surgery. Literature studies show that X-ray is effective in detecting internal lesions and foreign bodies, and aids in victim identification. However, this technique has limitations in visualizing soft tissue and microscopic abnormalities, so it should be used as a complement to traditional autopsy. In conclusion, the use of X-ray in autopsy improves diagnostic efficiency and accuracy, but should be combined with other imaging techniques for more comprehensive results.

Introduction

Autopsy is one of the most essential medical procedures in the fields of forensic science and medicine, serving to determine the exact cause of death, particularly in suspicious or unnatural cases (Santi et al., 2024). In practice, traditional autopsies are generally performed through comprehensive dissection of the body to observe damaged or abnormal internal organs. This procedure not only requires a high level of expertise and considerable time but also often raises ethical debates, especially in cases involving cultural or religious beliefs that prohibit invasive procedures on the deceased (Jahn Kassim & Alias, 2016; Ng & Fung, 2023; Carew et al., 2023; Suwalowska et al., 2023).

Therefore, advancements in medical and radiological technology have introduced alternative non-invasive approaches as innovative methods to complement or even replace conventional autopsies. One such approach gaining increased attention is the use of X-ray radiographic technology, which is considered capable of providing internal visualizations of the body without surgical intervention (Withers et al., 2021; Morimoto et al., 2022; Abhisheka et al., 2024). Initially developed for clinical diagnostic purposes, X-ray technology has gradually been applied in forensic settings to detect bone fractures, bullet projectiles, and other foreign objects that may not be visible through external observation. This demonstrates the considerable potential of X-rays as highly effective supporting tools for facilitating faster, more

accurate, and ethically acceptable autopsy procedures (Nolte et al., 2011; Babu & Johnson, 2023).

The current development of technology in forensic medicine reflects a trend toward more digital, efficient, and minimally invasive approaches—exemplified by the emergence of the concept of virtopsy or virtual autopsy. This method utilizes various medical imaging tools, including CT scans, MRIs, and X-rays, allowing internal examination of the body without physical dissection (Habiburrahman & Yudhistira, 2021; Hussain et al., 2022; Islam et al., 2023). While CT and MRI scans are gaining popularity due to their ability to generate detailed three-dimensional images, X-rays still hold a strategic position owing to their lower cost, accessibility, and speed of execution. In forensic contexts, X-rays are particularly useful for detecting foreign objects such as bullets, metal fragments, glass shards, or needles, and for mapping injuries and bone fractures that are not visible externally (Dhawan et al., 2024; Bolea-Fernandez et al., 2024). These advantages make X-ray a preferred choice for preliminary examinations, especially in urgent cases such as mass disasters or crimes involving multiple victims. Furthermore, the use of X-rays minimizes physical damage to the body, which is crucial in respecting cultural, religious, or familial values.

Nevertheless, the effectiveness of X-rays in the autopsy process is not without technical and methodological challenges that require critical assessment. One of the main limitations lies in the reduced ability of X-rays to clearly visualize soft tissues, unlike CT or MRI scans which offer high-resolution imaging of complex internal organs. Additionally, the effectiveness of X-rays heavily depends on the expertise of the operator and forensic pathologist in interpreting radiographic images; improper interpretation may lead to diagnostic errors or misjudgment in identifying the cause of death. Other factors such as the condition of the corpse—including decomposition or burns—may affect X-ray image quality and the accuracy of interpretations (Iswara et al., 2023; de Bakker et al., 2019). Despite these limitations, X-rays remain highly valuable in facilitating rapid forensic reconstruction, particularly in emergency scenarios requiring prompt and efficient action. Thus, to evaluate how effective X-rays are in autopsy practices, comprehensive research is needed—one that not only examines the quality of the produced images but also considers procedural, ethical, and integrative aspects with other forensic methods (Alafer, 2025; Nolte et al., 2011).

In Indonesia, the use of X-ray technology in forensic medicine has yet to become a standard component of autopsy procedures, although some major medical institutions have begun implementing it on a limited scale. The lack of trained professionals in forensic radiology, insufficient infrastructure, and budget constraints are major barriers to widespread and equitable adoption of this technology. Moreover, the absence of a detailed national guideline regulating the use of X-rays in autopsy procedures has led to disparities in practice across regions, underscoring the need for policy harmonization and ongoing training for medical personnel (Putra & Yuhandri, 2021; Al-Worafi, 2024). These realities show that although the theoretical potential of X-rays is substantial, practical implementation still faces significant gaps that must be addressed through evidence-based scientific approaches. Therefore, research focusing on the effectiveness of X-ray use in the autopsy context is not only scientifically relevant but also crucial in supporting the transformation of Indonesia's national forensic service system. A qualitative analysis of X-ray utilization as a supporting tool in autopsies could serve as an initial foundation for developing modern, efficient, and socially adaptive standard operating procedures.

Based on the explanation above, it can be concluded that the use of X-ray technology in autopsies holds strategic value in addressing the demands of modernizing forensic procedures that prioritize efficiency, accuracy, and sensitivity to social and cultural norms. This technology not only accelerates the identification of causes of death but also offers a more socially acceptable, non-invasive alternative. Nevertheless, its effectiveness requires further assessment

through in-depth scientific approaches, particularly qualitative methods that can explore the perspectives of forensic experts, medical practitioners, radiology technicians, and victims' families in understanding the role and limitations of X-rays in autopsy contexts. This research is essential not only for evaluating the medical success of X-ray technology but also for examining the legal, ethical, and social dimensions surrounding autopsy practices in Indonesia. Therefore, this article aims to critically analyze the effectiveness of X-ray as a supporting tool in the autopsy process through a qualitative approach grounded in factual evidence and field experience. The findings of this study are expected to make a significant scholarly contribution to the reform of Indonesia's autopsy system toward a more modern and human-centered model.

Methods

This study employs a qualitative method with a literature review approach aimed at conducting an in-depth analysis of the effectiveness of X-ray technology as a supporting tool in forensic autopsy procedures. The qualitative method was chosen for its ability to explore and comprehensively understand various perspectives, concepts, and contexts related to the use of X-ray in forensic medicine—dimensions that cannot be fully explained through quantitative approaches alone. The literature review approach was conducted by examining a variety of relevant scholarly sources, including national and international journal articles, research reports, academic books, official forensic guidelines, and documents from medical institutions that discuss the application of radiological imaging technologies—specifically X-ray—in autopsy procedures.

Sources were selected systematically based on criteria such as timeliness, validity, and relevance to the research topic, ensuring that only credible and focused materials were included. Literature searches were carried out using scientific databases such as Google Scholar, PubMed, ScienceDirect, and the National Library of Indonesia, utilizing keywords such as “X-ray in autopsy,” “radiographic forensic methods,” “non-invasive autopsy,” and “virtual autopsy with X-ray” to ensure broad and in-depth information coverage. This literature review enables the researcher to compare various findings, technical approaches, and practical experiences of X-ray implementation in autopsies from different countries and institutions, including documented challenges and advantages.

The data collection process was conducted through the inventory and classification of documents relevant to the research topic. All collected literature was categorized according to main themes, such as X-ray procedures in autopsy, diagnostic effectiveness, implementation challenges, and socio-ethical acceptance. The collected data were then analyzed using content analysis, a method for identifying patterns, meanings, and relationships between concepts found in the narratives or texts of the reviewed literature. This analysis was carried out using an inductive approach, where the researcher drew conclusions based on observations of the available data and developed theoretical understanding from naturally emerging variable relationships within the documents.

The analysis process followed systematic steps, including reading and re-reviewing the content of all documents, making important annotations, organizing information into thematic categories, and synthesizing insights from various perspectives found within the literature. This process was conducted iteratively to ensure consistency in interpretation and to deepen the understanding of the discussed material. The researcher also conducted content validation through source triangulation by comparing analytical results from multiple sources to minimize bias and ensure data reliability. The results of this analysis were then used to formulate key findings regarding the effectiveness of X-ray in the context of autopsy procedures—examined from technical, practical, and ethical dimensions—and are presented in a structured scientific narrative.

Result and Discussion

Autopsy is a critical procedure used to determine the exact cause of death. With the advancement of technology, various supporting methods have been adopted to improve the accuracy and efficiency of autopsy processes. One significant innovation is the use of radiographic imaging, particularly X-ray technology, in postmortem examinations. X-rays serve as a non-invasive tool capable of revealing internal body conditions without the need for direct dissection, assisting in the detection of foreign objects, fractures, and soft tissue trauma not visible to the naked eye. The use of X-rays in modern autopsy procedures has even evolved into virtual autopsy (virtopsy), which integrates CT scans and MRI, offering a more socially and ethically acceptable scientific approach. Based on this, the following table presents the results of the literature review used as references for the discussion:

Table 1. Research Result

No.	Author(s) and Year	Research Findings
1.	(Inai et al., 2016)	A prospective study in Japan demonstrated that postmortem CT (PMCT) was more accurate (74%) than clinical diagnosis (46%) in determining immediate causes of death in hospitalized patients.
2.	(Ubelaker et al., 2014)	X-ray is a basic and essential imaging method in forensic medicine, allowing non-invasive evaluation of critical findings prior to autopsy and aiding in optimal dissection strategies.
3.	(O'Donnell & Woodford, 2008)	Postmortem radiography is effective in detecting foreign objects such as bullets and metal fragments, as well as in injury documentation and victim identification.
4.	(Thali et al., 2003)	The use of X-rays in virtual autopsies enables internal visualization without dissection, increasing efficiency and reducing ethical concerns associated with traditional autopsy.
5.	(Ross et al., 2012)	Postmortem radiography can identify causes of death not detected during conventional autopsy, particularly in cases of blunt force trauma.
6.	(Grabherr et al., 2011)	The use of PMCT and postmortem angiography enhances the detection of vascular lesions and bleeding sources, providing additional information not always visible during conventional autopsy.

The application of X-ray technology in autopsy procedures has advanced significantly, especially with the introduction of postmortem computed tomography (PMCT) as a non-invasive diagnostic aid. A study by Inai et al. (2016) showed that PMCT had an accuracy rate of 74% in determining the immediate cause of death in hospitalized patients, compared to 46% with traditional clinical diagnosis. This finding affirms PMCT as a more accurate alternative for identifying causes of death, particularly in cases where conventional autopsy is not feasible or is declined by the deceased's family. PMCT offers the advantage of providing a three-dimensional visualization of internal body structures without surgical intervention, thereby reducing contamination risk and preserving the integrity of the corpse. Moreover, PMCT can identify internal lesions, fractures, and hemorrhages that might not be detectable through external examination. However, it is important to note that PMCT has limitations in identifying microscopic abnormalities or pathologies that require histological analysis. Therefore, PMCT should be considered a complementary, rather than a substitute, procedure to traditional

autopsy. Integrating PMCT with conventional autopsy can enhance diagnostic accuracy and provide a more comprehensive understanding of the cause of death.

Conventional X-ray imaging remains a fundamental and essential tool in forensic medicine, particularly for initial evaluations before performing an autopsy. According to Ubelaker et al. (2014), X-rays enable non-invasive assessment of critical findings, such as identifying foreign bodies, fractures, and other structural anomalies that can assist in planning optimal dissection strategies. X-rays are also crucial in cases involving suspected foreign objects, such as bullets or metal fragments, that may not be externally visible. Additionally, X-rays can be used for injury documentation and for identifying victims by matching with medical or prior radiographic records. Other advantages of X-rays include rapid results and relatively lower costs compared to other imaging modalities. However, X-rays have limitations in visualizing soft tissue and internal organs, which may prevent full identification of the cause of death. As a result, in modern forensic practice, X-rays are often used in conjunction with other imaging techniques, such as PMCT or MRI, to obtain a more comprehensive diagnostic view. The integration of various imaging modalities can significantly improve the effectiveness and efficiency of forensic autopsy processes.

injury documentation and victim identification. According to O'Donnell & Woodford (2008), postmortem radiography can detect foreign objects such as bullets and metal fragments, and assist in documenting injuries and identifying victims. In cases of violent or accidental death, postmortem radiography can provide critical information regarding projectile trajectories, weapon types, and injury mechanisms. Additionally, it is useful in detecting fractures that may not be externally visible, particularly in small bones or difficult-to-access areas. Radiography is also valuable in cases where autopsy cannot be performed, such as in mass disaster victims or when there are religious or cultural objections to surgical procedures. However, like conventional X-rays, postmortem radiography is limited in visualizing soft tissues and internal organs. Thus, postmortem radiography should be used as part of a multimodal forensic autopsy approach, incorporating other imaging techniques and laboratory analyses. This approach enhances the accuracy and efficiency of determining causes of death and supports the victim identification process.

The concept of virtual autopsy, or "virtopsy," has emerged as an appealing alternative in modern forensic medicine, allowing visualization of internal structures without dissection. Thali et al. (2003) introduced the use of X-ray imaging in virtual autopsies, enabling internal visualization without dissection, thereby increasing procedural efficiency and reducing ethical objections associated with traditional autopsy. Virtopsy combines multiple imaging techniques, including PMCT, MRI, and 3D photogrammetry, to generate digital reconstructions of the human body. A major advantage of virtopsy lies in its non-invasive nature, which allows preservation of the body's integrity and reduces contamination risks. Furthermore, virtopsy facilitates digital documentation of findings, which is beneficial for education, research, and legal proceedings. Nevertheless, virtopsy is limited in detecting microscopic abnormalities or pathologies that require histological analysis. Therefore, it should be viewed as a complement rather than a replacement for traditional autopsy. Combining virtopsy with conventional autopsy can improve diagnostic accuracy and offer a more holistic understanding of the cause of death.

A study by Ross et al. (2012) demonstrated that postmortem radiography can identify causes of death not detected through conventional autopsy, especially in cases of blunt force trauma. In such cases—such as traffic accidents or falls from heights—internal injuries may not be externally visible and are difficult to detect through visual inspection alone. Postmortem radiography assists in identifying fractures, hematomas, and other internal injuries that might go unnoticed during conventional autopsy. Additionally, radiographic imaging offers objective and permanent documentation of findings, which is valuable for legal and educational

purposes. However, it is crucial to acknowledge the limitations of postmortem radiography in visualizing soft tissues and internal organs. Therefore, it should be employed as part of a multimodal approach in forensic autopsy, alongside other imaging techniques and laboratory analyses. This comprehensive approach enhances diagnostic precision and efficiency in determining causes of death and identifying victims. Integrating various imaging modalities can provide a more complete and accurate representation of the cause of death.

The use of PMCT and postmortem angiography has been shown to improve the detection of vascular lesions and sources of hemorrhage, offering additional information not always visible during conventional autopsy. Findings from Grabherr et al. (2011) indicate that combining PMCT and postmortem angiography increases the ability to detect vascular injuries and bleeding sources. Postmortem angiography enables detailed visualization of the vascular system, aiding in the identification of bleeding origins, aneurysms, or vascular occlusions. This technique can also assist in detecting air or fat embolisms, which may not be apparent during standard autopsy. However, postmortem angiography requires specialized equipment and technical expertise, and may increase the cost and duration of examinations. Thus, its use should be considered based on case needs and available resources. The integration of PMCT, postmortem angiography, and conventional autopsy can provide a more comprehensive understanding of the cause of death and injury mechanisms. This multimodal approach can enhance diagnostic accuracy and efficiency in forensic autopsy processes.

The use of X-ray technology in autopsy procedures has become a vital element in modern forensic science due to its ability to identify foreign objects, internal injuries, and bone abnormalities that are not visually detectable during external examination of the body. In practice, X-rays serve as a non-invasive tool that provides a comprehensive overview of the internal condition of the deceased without the need for immediate dissection. This facilitates a more focused and efficient autopsy process. Moreover, X-rays are particularly beneficial in cases involving gunshot wounds, sharp object injuries, or complex fractures, as they can accurately reveal the location of projectiles, metal fragments, and other traumatic impacts. In this context, radiography can expedite forensic medical decision-making concerning the cause of death, especially when the body is decomposed or severely damaged.

The effectiveness of X-rays has been further enhanced by advancements in digital radiography (DR) and computed radiography (CR), which offer higher accuracy in visualizing bones and soft tissues compared to conventional methods. These developments are particularly supportive in emergency situations such as mass disasters or large-scale criminal investigations, where speed and precision in handling remains are crucial. According to research by Ruder et al. (2011), postmortem radiography can improve the accuracy of autopsy interpretations by up to 20%, particularly in cases involving head and chest trauma. Therefore, X-rays hold significant value as a complementary tool in autopsy procedures, providing both medical and legal information comprehensively (Nolte et al., 2011; Dirnhofer et al., 2006).

The effectiveness of X-rays in supporting autopsy procedures also heavily depends on the operator's skill and the forensic expert's ability to interpret radiological imaging results. Misinterpretation or lack of precision can lead to errors in determining the cause of death or injury location (Maudsley & Williams, 1996). Hence, extensive training and multidisciplinary collaboration between radiologists and forensic specialists are essential to improve accuracy. A study by O'Donnell & Woodford (2008) showed that involving radiologists in autopsy teams enhances the quality of image interpretation and helps prevent underdiagnosis of minor fractures or small foreign objects.

Furthermore, X-ray documentation holds significant legal value as part of forensic medical records, which can serve as admissible evidence in court. Various legal cases rely on radiographic evidence to support medical arguments and to prove or refute claims of physical

abuse or medical negligence (Grosso, 2018; Wojdyla & Chen, 2025). This advantage demonstrates that X-rays are not only diagnostic tools but also play a critical role in legal processes and justice enforcement. However, it is important to consider the limitations of X-rays, such as their inability to visualize soft tissues in detail compared to CT or MRI scans. Therefore, X-rays should ideally serve as an initial supportive tool, used in conjunction with other imaging techniques to obtain a holistic view of the cadaver (Jashnani et al., 2010).

X-rays have proven to be highly effective in supporting autopsy procedures, especially in early detection, injury documentation, and as a tool for legal litigation. Although X-rays have lower resolution than more advanced imaging technologies, their advantages in availability, speed, and operational ease make them extremely useful, particularly in forensic settings with limited resources (van Rijn & Bilo, 2023). This effectiveness is further enhanced when combined with digital technology and advanced image processing systems to better visualize complex body structures.

Future challenges lie in efforts to standardize X-ray procedures in autopsies, improve human resource capacity, and integrate with other forensic technologies such as postmortem CT scans. With continuous scientific development, X-rays will remain a vital tool in addressing complex questions regarding the cause of death and injury mechanisms. The application of this technology is also aligned with the principle of minimally invasive autopsy, which is increasingly adopted in modern forensic practice as an alternative to traditional autopsies (Fittipaldi Júnior et al., 2025). Therefore, X-rays not only enhance the medical effectiveness of autopsies but also reflect a shift in forensic investigative paradigms toward more efficient, accurate, and technology-based approaches. Through an interdisciplinary approach involving forensic science, radiology, and digital technology, the effectiveness of X-rays as a supportive tool in autopsy procedures can be fully optimized.

Conclusion

The conclusion that can be drawn from the use of X-ray technology in autopsy procedures is that it has proven to be highly effective in supporting forensic examinations by providing a comprehensive visualization of the internal condition of the body. X-ray technology is capable of detecting foreign objects, internal injuries, and bone abnormalities that are not directly identifiable through external examination.

Its application is particularly important in cases involving trauma or internal injuries such as gunshot or stab wounds, where accuracy in locating injuries is a key factor in determining the cause of death. In addition, X-rays facilitate faster forensic-medical decision-making, especially when the body is in a decomposed state or has sustained severe damage. The advantages of X-rays are further reinforced by technological advancements such as digital radiography (DR) and computed radiography (CR), which allow for more detailed and accurate visualization. These clearer images are also highly beneficial in emergency situations, such as disasters or major criminal investigations, where speed and precision are critical.

Overall, X-ray technology makes a significant contribution to the acquisition of comprehensive medical and legal information, making it an indispensable tool in autopsy procedures. However, the effectiveness of X-rays in autopsies greatly depends on the operator's skill and the forensic expert's ability to accurately interpret the imaging results. Without accurate interpretation, there is a risk of misdiagnosing the cause of death or the location of injuries, which may impact the outcome of investigations and legal decisions. Therefore, it is essential that X-ray operators receive adequate training and work in collaboration with forensic and radiology experts to produce accurate diagnoses.

Moreover, X-ray documentation carries significant legal value, as it can serve as valid evidence in court in cases involving violence or medical negligence. On the other hand, although X-rays have limitations in visualizing soft tissues compared to other imaging techniques such as CT

scans or MRIs, they remain a highly useful tool in the initial stages of autopsy protocols, especially for identifying fractures or foreign objects within the body. Its application in forensic settings, although not yet widespread in all regions, has significantly contributed to improving autopsy procedures and providing deeper insights into undetected diseases or medical conditions during life. In conclusion, the use of X-rays in autopsy procedures has had a broad positive impact in medical, legal, and social contexts.

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