

Review

The New Era of Forensic Autopsies: A Brief Overview of Virtual Autopsy and its Practice in The Middle East

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Abstract

Traditional autopsies have historically been crucial in determining the cause of death and ensuring the quality of care. However, in this modern technological age, many digital advances in forensic medicine were introduced, aided in the practice, and improved outcomes. The utilization of advanced imaging modalities in forensic examination in the form of a virtual autopsy is one of the advances. This article discusses the virtual autopsy's ethical aspects, strengths, limitations, and implementation, particularly focusing on the extent of its utilization in the Middle East. When discussing the ethical aspect, this review found that virtual autopsy outshines traditional methods by preserving the integrity of the deceased bodies and respecting cultural and religious beliefs through noninvasive imaging. It also discusses the strengths of this approach, such as its capability to identify unknown bodies, detect foreign objects, and examine body parts that are not usually examined in traditional autopsy. Moreover, it addresses limitations like difficulty in differentiating between antemortem and postmortem changes and the inability to obtain data gained by analyzing body samples. Additionally, it explores virtual autopsy applications in mass casualties, its role during pandemics like the coronavirus disease 2019 pandemic, and its potential to gradually replace traditional autopsy. Despite its advancements, traditional autopsy remains the gold standard in many cases. Nonetheless, it is a favorable option in the Middle East due to its adherence to the ethical principles in these countries, necessitating further implementation and awareness to maximize its potential and application in forensic medicine.

Keywords: *Forensic medicine, virtual autopsy, Middle East, traditional autopsy, medicolegal*

Introduction

Autopsy or postmortem examination has been an integral part of medical practice in determining the cause of death, establishing accurate mortality statistics, and assuring the quality of care (1,2). Autopsy means "to see for oneself" by examining the human body after death (1). The postmortem examination is divided into clinical and forensic autopsy (3). A clinical autopsy is mainly concerned with identifying the cause of death, which aids medical education and training (3). On the other hand, a forensic autopsy is carried out to identify the deceased, estimate the time of death, analyze injuries, and assess the presence of natural diseases, poisons, or medical treatments (3). Historically, the first autopsy dates back to 3000 BC in Ancient Egypt, which was performed in a religious rather than a medical context (1).

Advances in diagnostic technologies and the possible fear of legal repercussions for missed diagnoses have contributed to a worldwide decline in traditional forensic autopsies (4–6). Moreover, the fact that dissection of the dead body is a primary element of autopsies can be traumatic to the deceased's family and may not be widely accepted in some cultures (3). Therefore, noninvasive imaging modalities commonly used in daily medical practice can provide supplementary data in the context of forensic examination and may even override conventional autopsy (3).

The term 'virtopsy' was first introduced by the former head of the Institute of Forensic Medicine of the University of Bern, Switzerland, Prof. Richard Dirnhofer (7). Various imaging techniques could be employed depending on the type of tissue being tested (7). Computed tomography (CT), magnetic resonance imaging (MRI), and surface scanning techniques are used for the internal examination of the body (3).

Using X-rays for age estimation in 1986 was the first application of imaging modalities in forensic medicine which was followed by analyzing paranasal sinuses' morphology for identification in 1920 (8). The innovation of CT in 1971 prompted a true advancement in the application of imaging

techniques in forensic medicine (8). This narrative review aims to summarize the ethical aspects of forensic virtual, its strengths, limitations, and extent of implementation in the Middle East.

Ethical aspect of virtual autopsy

Virtual autopsy surpasses traditional autopsy in various aspects, including ethical matters (9). The most distinctive feature of the traditional autopsy is its invasiveness, as it is conducted by deep incision and extraction of the internal organs (9,10). In addition, it may involve mutilation or disfigurement of the dead body (9,10). This manipulation of bodily integrity is prohibited in particular cultural and religious practices, and it is also emotionally distressing for the relatives of the deceased (9,10). In addition, the nature of autopsies may raise some aggressive attitudes toward forensic physicians (9). Therefore, the virtual autopsy is considered a moral evolution since it primarily uses noninvasive imaging, such as MRI and CT scan, and minimally invasive methods, such as ultrasound-guided fine needle biopsy (9). These imaging techniques preserve the integrity of all dead bodies, respect the cultural and religious requirements, and honor the emotional needs of family members. These are the main factors driving the global rise of virtual autopsy utilization (9).

Strengths of virtual autopsy

One of the earliest applications of virtual examination in forensic medicine was through forensic odontology, specifically focusing on visualizing and reconstructing the jaw and teeth using technologies like x-rays, CT scans, and panoramic images (11). This method proved invaluable in comparing postmortem and antemortem dental data, significantly aiding in the identification of human remains, especially in cases involving mass catastrophes or severely disfigured bodies (7, 11,13). Additionally, the utilization of radiological images for age estimation, considering the sequential development of human dentition from infancy to early adulthood (mid-20s). It aids in identifying unique features that provide insights into the individual's sex and race (11,13).

Identification of an unknown corpse can be readily made using postmortem CT as it allows for visualization of different identifying structures, such as the frontal sinus, skeletal degenerative changes, unique calcifications, and healed fractures (7,12,123). A CT scan can also detect foreign objects in a three-dimensional (3D) manner in one examination (12). It can assess the object's location and measure its size very accurately, regardless of where it is, which facilitates its extraction tremendously (12). CT scans measure the radiopacity of foreign objects, which aids in determining their material (**Figure 1**) (12). This feature is particularly valuable in explosion victims riddled by a multitude of foreign bodies other than bomb fragments, such as glass shards and brickwork (12). Virtual autopsy can examine the whole body volume, even the parts not usually examined in traditional autopsy, e.g., the extremities, soft tissue, spine, and back, and where findings potentially relevant to the examination may be undetected (8,9).

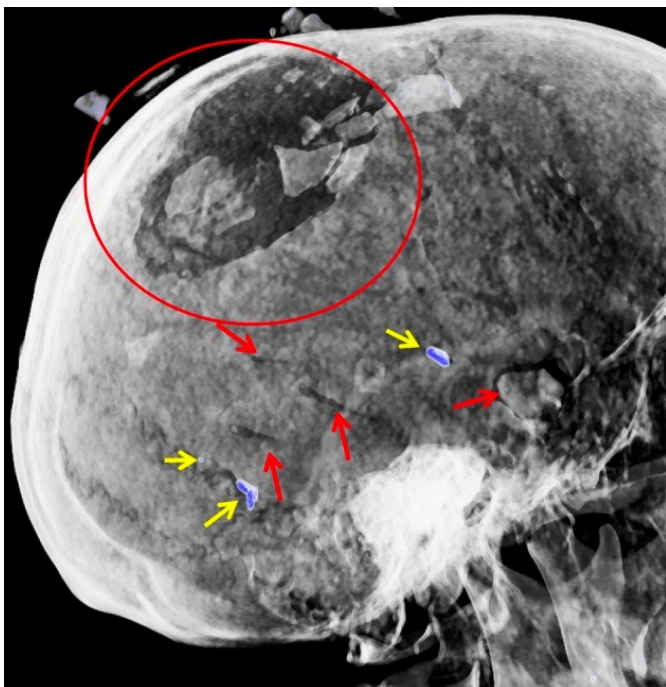


Figure 1: CT, 3D reconstruction of a skull with stab induced fractures (encircled), stab defects (red arrows), and knife tip fragments (blue colored by computer) (12).

Additionally, forensic imaging does not require physical contact or dissection of tissues to obtain findings (12–14). The lack of physical contact could assist in preserving forensic evidence, leading to a better assessment of the chronological order of

injuries using CT because, for instance, later fracture lines do not cross pre-existing ones (12). CT can reliably and easily evaluate the fracture pattern and determine which blows or gunshots occurred first (12). This can be beneficial while assessing multiple comminuted fractures of, for example, the skull after repeated blows or gunshots (12).

With CT, one can assess the fracture pattern reliably and efficiently and then, because later fracture lines do not cross pre-existing ones, determine which gunshots or blows preceded the other (12). In addition, one can also examine the facial skeleton and soft tissues in a non-destructive fashion for the next of kin to see the corpse even after the autopsy (12). Moreover, CT is far more sensitive in detecting gas in soft tissues or body cavities, such as gas embolism, pneumatosis (**Figure 2**) and decompression disease (**Figure 3**) (7,12,14). It shows the presence of gas and the amount and distribution very accurately (12).

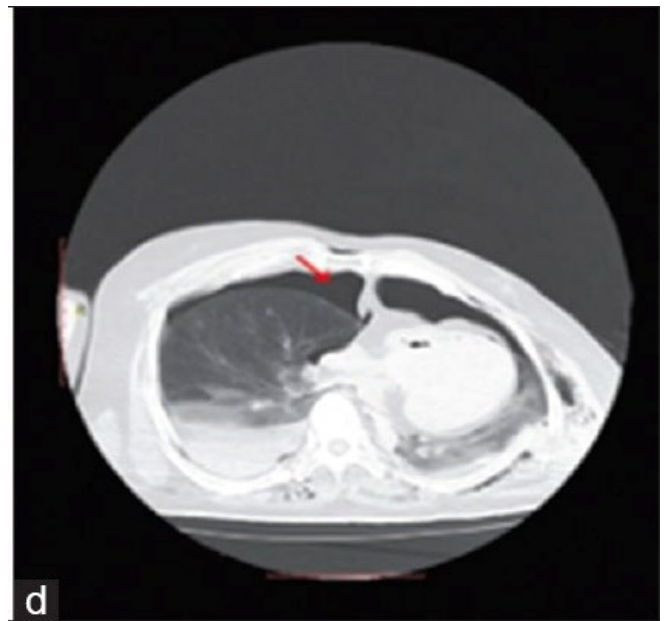


Figure 2: CT scan with thoracic cavity pneumatosis and effusion (14).

Virtual autopsy can also be used adjuvant to external inspection with 3D photogrammetry-based optical scanning, and external findings can be documented in an objective, 3D, and readily reproducible manner (7,12–14). Furthermore, imaging data from the virtual autopsy can be preserved for a long time and can also be retrieved long after the burial or cremation of a corpse (7,12–15).

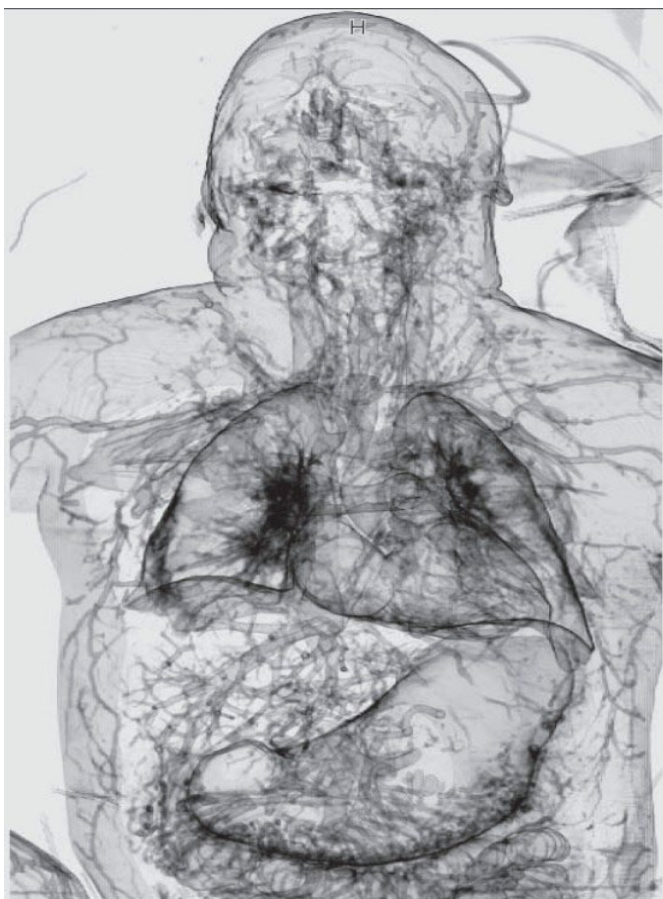


Figure 3: displays a 3D CT reconstruction depicting gas in vascular beds as a result of decompression disease due to a scuba diving accident (12).

CT is a very rapid examination technique where a significant number of corpses can be scanned quickly, which is especially useful in mass catastrophes (12,13). Virtual forensic examination can be utilized in medicolegal aspects in both living and deceased subjects (12). For instance, evidence of manual strangulation, such as deeper injury of soft tissues in the neck, may be missed upon gross examination but can be readily seen on MRI objectively and reproducibly (12).

Forensic imaging can be presented in court to provide clear and understandable findings necessary for the medical layperson to understand and judge correctly (12). Virtual autopsy can help give clean, bloodless images easier to understand than photographs of a dissected body with which only a physician will be familiar or comfortable (7,15).

Limitation of virtual autopsy

Even though virtual autopsy gains some perks by its noninvasive technique and whole-body coverage, it is yet to be applied in all forensic institutions for several reasons. With the absence of invasion, there are limitations in documenting data that are usually gained by analyzing body samples for histopathological, microbiological, or toxicological findings (8). For instance, malignant tumors are challenging to analyze by virtual autopsy; thus, medical autopsy remains the gold standard in oncological and hematological cases (16). Moreover, obtaining data by imaging will cause difficulty in differentiating between antemortem and postmortem changes, especially color changes and minor tissue injuries (17). In addition, CT scanners are not commonly found in forensic medicine facilities, which means an added difficulty in transporting the cadaver to a possibly distant location that contains suitable equipment, i.e., the radiology department. Moreover, virtual autopsy requires prior preparation of the setting with qualified personnel to avoid false positive results (16). The cost of forensic imaging is approximately about 30024 per case (16).

Applications of virtual autopsy in the Middle East

The Middle East consists primarily of countries following Islamic laws set by the Prophet Mohammad (Peace be upon him) (18). The prophet instated the Islamic judicial system (Shari'ah) which dates back to around 1400 years (18). Shari'ah law's evidential requirements ranked by importance are confessions, testimonies by ordinary witnesses, the expert witness testimony. False oaths constitute imprisonment and severe punishment by the Shari'ah law (18). Therefore, in some legal cases with clear evidential material, prosecutors may believe that a traditional autopsy is not necessary and deem external examination sufficient if it produces clear findings of the cause of death (18). In such cases, if further investigation is needed or confirmation of the finding is requested, a virtual autopsy can be utilized as a fast non-invasive method of forensic autopsy to add to the external examination findings (18).

In the Middle East, the potential utilization of virtual autopsy can offer a more convenient tool for forensic examination, facilitating the acquisition of relevant information (19). Numerous aspects such as religion and culture, limit forensic pathologists from reaching an appropriate conclusion (19). However, with the help of virtual autopsy, evisceration is dramatically reduced in a variety of cases (19). As mentioned previously, religious beliefs play a role in the practice of forensic medicine (18). For instance, Muslims have the religious belief that immediate burial of the body provides comfort to the deceased (18). Therefore, delaying the burial for an autopsy without a strong indication is opposed (18).

Worldwide, the traditional autopsy remains the standard, and the virtopsy is considered as an alternative, especially in countries with cultural and religious boundaries, such as Saudi Arabia (20). The first virtual autopsy in the Middle East was conducted at King Khaled University Hospital and the radiologic findings were consistent with an autosomal recessive polycystic kidney disease (ARPKD), that was supported by conventional autopsy (20). It was done in 2014 by Aljerian et al. to diagnose the cause of death in a stillbirth female (21). Hence, the use of virtual autopsy would be very productive and acceptable in Saudi Arabia (20).

Despite the long history of traditional forensic medicine in Egypt that dates to ancient times, the application of virtual autopsy is still limited in Middle Eastern countries (16). Advanced imaging techniques are a cornerstone in the application of virtual autopsy; hence the possible scarcity of such modalities in most countries in the Middle East may hinder its utilization (22).

In Egypt, the conduction of virtual autopsy faces many barriers and obstacles (23). There is no legal foundation or framework to validate the use of a virtual autopsy in criminal investigation (23). In addition, virtual autopsy applications need specific indications and guidelines (23). Moreover, there are financial obstacles due to the high expenses of the tools that require regular maintenance (23).

One of the crucial applications of virtual autopsies in the field of forensics is their significant role in gathering postmortem data during mass casualties (24). An example of the utilization of this application was reported in Kuwait in the case of the tragic incident of 212 females and children during a wedding ceremony (24). In these disasters, recognition of dead bodies is the major concern to be addressed, and CT has a great value in mass casualties to rapidly and efficiently identify the victims (24). In this study, a small number of cases were investigated, and the results showed that CT scanning takes approximately 5–10 minutes (24).

Virtual autopsy in modern days

In the next few years, traditional autopsies will remain the standard (25). However, as knowledge and acceptance increase, a traditional autopsy can be gradually replaced by a noninvasive virtual autopsy (25). Postmortem virtual autopsy has the potential to gain wide acceptance among public and professional circles, making it possible to maintain high levels of quality control in forensic examination (25).

Virtual autopsy can easily be conducted in large numbers within a reasonable time frame to handle catastrophic events such as tsunamis and earthquakes (12). Visualization tools will enhance the quality and efficiency of the virtual autopsy procedures and help to deliver general information about the deceased individual, including height, weight, sex, major injuries, foreign bodies, and probable causes of death (26).

During COVID-19, the possibility of infection spreading to those performing traditional autopsies, such as doctors and technicians, necessitated an alternate autopsy method to reduce the risk of contamination by the spillage of infected body fluid (10). Furthermore, an autopsy may be required in cases where the infectious status of the deceased is unknown, placing the staff at higher risk of infection, especially during a pandemic (9,10). Since traditional autopsy was deemed unsafe during a public health crisis, virtual autopsy usage increased dramatically and was strongly recommended due to the absence of any autopsy-

related infectious hazards (10). Even before COVID-19, virtual autopsy has been suggested in the forensic examination of cases with other infectious diseases, including hepatitis and acquired immune deficiency syndrome (AIDS) (10). Therefore, virtual autopsy enables healthcare workers to perform an autopsy safely and effectively regardless of the infectious status of the dead body (9,10).

Conclusion

Virtual autopsy is a valuable tool in forensic medicine. Utilizing minimally invasive modalities is more socially accepted than a traditional autopsy. As many promising prospects, these modalities contribute to advancing forensic medicine, virtual autopsy has some limitations, and traditional autopsy remains the gold standard in many cases. Virtual autopsy modalities are still underutilized in the Middle East. Virtual autopsy conforms to the ethical principles in Middle East countries; therefore, further implementation would be positively regarded.

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Conflict of interest

There is no conflict of interest.

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Data availability

Data that support the findings of this study are embedded within the manuscript.

Author contribution

All authors contributed to conceptualizing, data drafting, collection, and final writing of the manuscript.

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