VIRTOPSY: LIFTING THE VEIL

Abstract

A conventional autopsy starts with an external examination of the deceased. Incisions are made to examine and remove the internal organs, which are inspected, measured, and sampled for histopathology. Specific cases may require further sampling for cultures and biochemical estimations. In contrast, virtopsy can boast in its non-invasiveness, which can supplement or may even replace conventional autopsy. The main goals of a medicolegal autopsy are to determine the cause and manner of death, to evaluate the antemortem phenomenon of sustained injuries, and to form a reconstruction of events before death based on the findings. The technology and processes utilized in virtopsy with permanent reproducible data analyzed and stored for future reference will improve the quality of forensic investigation. Virtopsy may be superior to a conventional autopsy as it is investigator independent, objective, and noninvasive. Its future applications may include studies of morbidity and mortality in the general population and, perhaps, routine screening of bodies prior to burial.

Keywords: Virtopsy; Forensic Medicine; Autopsy; Imaging techniques; Postmortem computed tomography

Authors

Supriya Keisham
Department of Forensic Medicine & Toxicology
Regional Institute of Medical Sciences
Imphal
Manipur, India.
supriya_kei@yahoo.co.in

Soibam Neha
Department of Forensic Medicine & Toxicology
Regional Institute of Medical Sciences
Imphal
Manipur, India.

Kh. Pradipkumar
Department of Forensic Medicine & Toxicology
Regional Institute of Medical Sciences
Imphal
Manipur, India.

I. INTRODUCTION

1. **Preliminary considerations:** Forensic medicine in the past decades has seen many strides in terms of new techniques and procedures. Among these, a revolutionary one is the innovation of virtual autopsy. Thali *et al*. introduced the term “virtopsy”. Its root is in Latin, “virtus" meaning "useful, good, and efficient", "opsomei” meaning “I will see”. Thus, “virtual”, “opsomei” and “autopsy” lead to “virtopsy.” Virtopsy is a multi-disciplinary technology that combines forensic medicine and pathology, roentgenology, physics, biomechanics, and computer graphics. In virtopsy, 3D imaging techniques and 3D surface scans are used to map the external surface as well as the internal structure of the body[1].

   A conventional autopsy is an invasive approach where an external examination is first conducted to document the findings along with 2D photography. Incisions are made to examine and remove the internal organs, which are inspected, measured, and sampled for histopathology. Specific cases may require further sampling for cultures and biochemical estimations. In contrast, virtopsy can boast in its non-invasiveness, which can supplement or may even replace conventional autopsy. The main goals of a medicolegal autopsy are to determine the cause and manner of death, to evaluate the antemortem phenomenon of sustained injuries, and to form a reconstruction of events before death based on the findings. The technology and processes utilized in virtopsy produce permanent reproducible data. These can be stored and accessed easily for future reference which will improve the overall quality of forensic investigations.

2. **Scope for virtopsy:** A conventional autopsy is conducted and documented by a forensic expert in an observer-dependent manner. This subjective documentation may miss some findings which get destroyed during cremation or the integrity of the evidence is compromised, if not destroyed when the body is buried. Virtopsy provides objective non-destructive documentation where the digitally acquired data can later be consulted with subject experts to answer any new questions even after the body has been legally disposed of.

   A medicolegal autopsy is usually required in untimely deaths or deaths under suspicious circumstances. A conventional autopsy is a difficult ask for the family members who have lost a loved one in an untimely manner. Also, it may go against their religious sentiments. Virtopsy is ideal for such situations as it is non-invasive and any required tissue samplings can be conducted under minimally invasive image-guidance techniques.

   Virtopsy also has a scope in research on postmortem interval estimation, personal identification with parameters such as age, sex, dental procedures and implants, imaging in toxicology, violent asphyxia deaths, firearm deaths, burns and hypothermia, injury or organic lesions of heart and brain and other organs with emphasis on embolisms, and 3D surface pattern matching.

II. IMAGING MODALITIES AND TECHNIQUES

Imaging modalities and techniques in Virtopsy include:

- 3D surface scan using 3D photogrammetry-based optical surface scanner
- Postmortem computed tomography (PMCT) with adjuvants such as post-mortem computed tomography angiography (PMCTA), and minimally invasive tissue and liquid sampling
- Postmortem magnetic resonance imaging (PMMR) and Magnetic resonance spectroscopy (MRS)[1,2].

1. **Virtobot System:** Virtobot consists of a fixed Computed tomography system and a ceiling-mounted linear guide unit. A six-axis robotic arm with a pneumatic lifting axis at its base is mounted from this guide unit. The robotic arms have a changeable end-effector to mount different tools. [3] Newer modifications such as 3D enhanced documentation of external injuries along with their colors, etc are continuously being introduced to the existing modules for automated surface scanning and minimally invasive image-guided biopsies. The virtobot being an automated entity results in consistency and high accuracy.

2. **Photogrammetry and Surface Scanning:** 3D surface scanning and documentation are given more emphasis in cases with patterned injuries. The body is prepped by cleaning any blood, water, or liquids that may act as an artifact. Small discs are placed along the body and injuries to act as reference targets. To avoid any interpersonal inaccuracies, the virtobot places these markers providing standardized and accurate results. The virtobot scans the body creating a 3D color model of the corpse taking as little as 10 seconds. Stereoscopic cameras, with a resolution of 0.02mm, capture the colored images along with a projector used to cast a mesh pattern on the body. All the data are fed to the control station computer where programmed software process the images and automatically fuses the single surface scan. [3,4,5].

3. **Post-Mortem Computer Tomography (PMCT):** A Computed tomography (CT) scanner measures the x-ray attenuation through a predefined plane of a cross-section of the body. To distinguish between different tissues, the density of different organic and inorganic materials is used. Also, a foreign body may be identified as metallic or non-metallic by comparing the individual HU (Hounsfield Units) values of different foreign bodies[3]. PMCT is excellent for the identification of foreign bodies, osseous lesions, and internal organ trauma with no external trauma markers and to distinguish putrefactive gas accumulation from the pathological gas formation with higher precision over conventional autopsy [6,7].

   PMCT also helps in the identification of a corpse by comparison with antemortem records, as it is a commonly performed investigation clinically. Prominent landmarks for comparison between antemortem and postmortem scans include the paranasal sinuses, congenital or acquired bony deformities, dental fillings, bone implants such as artificial knee or hip replacements or bone screws and plates, cardiac pacemakers and others. These techniques provide reliable, consistent results irrespective of the changes the body has undergone as a result of putrefaction or trauma. The added advantage is that these are

fast, reliable, and low in cost when compared to DNA analysis and other means of identification [8,9].

4. **Postmortem Magnetic Resonance Imaging (PMMR):** Magnetic resonance imaging (MRI) is a medical imaging technique that uses a strong magnetic field in contrast to CT which is based on x-rays. MRI is considered excellent for suspected soft tissue tumors. In virtopsy, it adds the benefit of producing excellent soft tissue contrast and supplements the CT scans. In postmortem imaging the body is motionless and any motion artifacts are eliminated and anatomical attributes accurately visualized. One of the drawbacks is that the relaxation times T1 and T2 are temperature dependent, which alters the image contrast since the body temperature keeps on decreasing after death [10,11].

   A prior CT scan is done to rule out metallic fragments or implants, and thus MRI is limited to cases with no metallic foreign bodies. Compared to CT, MRI is also more time taking and costly [3].

5. **Postmortem CT Angiography:** In the post-mortem setting, to provide a functioning circulation to distribute the contrast medium through the vascular system, a modified heart-lung machine is used to conduct a non-dynamic CT angiography. Contrast is administered through a cut-down at the level of the femoral vessels.

   - The contrast medium is injected, via a tube, into the femoral artery at a constant pressure and another tube in the femoral vein drains the overflowing blood. Imaging is performed immediately after the instillation of the contrast medium.
   - The venous system is similarly visualized with the contrast medium injected into the femoral vein and the drainage tube inserted in the femoral artery[3].

   Imaging alone can diagnose the presence of vascular injuries and any extravasation of contrast medium. Imaging can also trace the lacerated vessel/s causing intraabdominal or thoracic hemorrhages. An important advantage of CT angiography is that it can identify small vascular lesions that are difficult to visualize or get damaged before detection during a conventional autopsy. However, angiography is not suitable to assess the early cardiac muscle changes immediately after an ischemic attack which a competent observer conducting a conventional autopsy can demonstrate[3,12].

6. **Tissue/Liquid Sampling:** The imaging scans may reveal organs with pathology or special interests which can be sampled in a minimally invasive manner by CT-guided biopsies. The 6-axis robotic arm can also be programmed to collect tissue and fluid samples for toxicological and microbiological examinations[13]. This provides an added advantage as compared to a conventional autopsy where, due to its invasiveness, the quality of the sample collected is poor as it gets contaminated with other tissues or body fluids.

7. **Miscellaneous:** Magnetic resonance spectroscopy (MRS) is another technique in virtopsy that can estimate the time of death from the changes in the tissue metabolic concentrations over time after death. MR microscopy is a micro-imaging technique that is used to study soft tissue injuries like retinal hemorrhage, electrical injury to the skin, etc. Microtomography is another virtopsy technique that studies weapons and can determine

their injury patterns, which is especially helpful to determine if the weapon found at the crime scene was used to inflict injuries present on the body[1].

III. WORKFLOW OF A STANDARD AUTOPSY

Virtopsy consists of multiple techniques and the image modalities utilized are based on the individual case history. A simple workflow of a standard virtopsy is demonstrated to decide which imaging techniques are to be used to fulfill the purpose of an autopsy (Fig.1). In cases with patterned injuries, colored 3D documentation of the body surface is done. The entire body is documented with photogrammetry and surface scanning in prone and supine positions followed by a CT scan. The next modality, i.e CT angiography is performed in case of suspected vascular injuries or internal hemorrhage. Once the CT scan shows the body to be free of ferromagnetic foreign bodies such as metal fragments, an MRI scan is performed. After finishing the imaging procedures and based on the data gathered further conventional autopsy approaches can be planned.

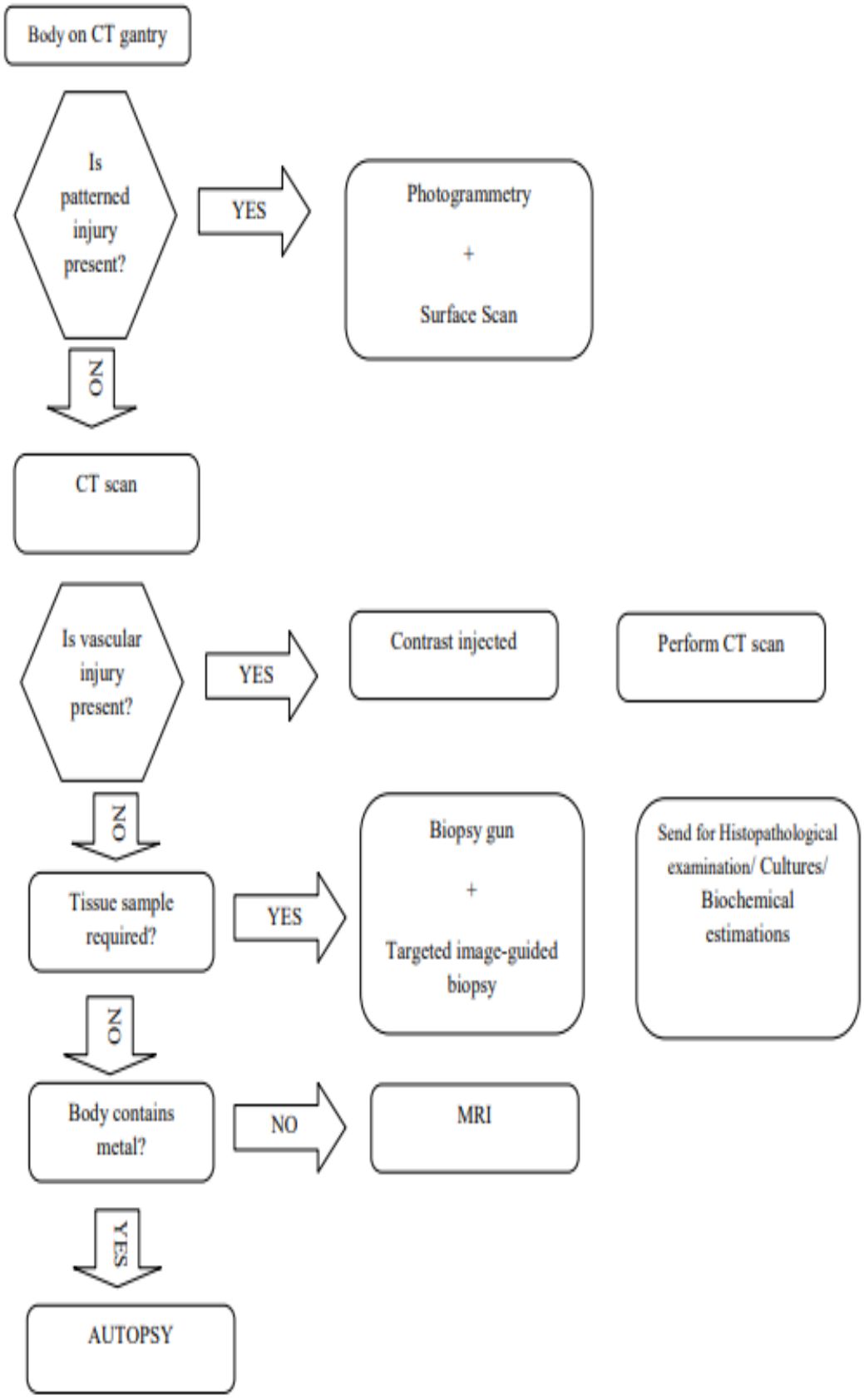

Figure 1: Workflow of a Standard Virtopsy

IV. FEASIBILITY OF VIRTUAL AUTOPSY

Virtual autopsy provides a 3D illustration of forensic cases which are easy to interpret and easily accessible. It also allows a digital re-examination of the body and even of putrefied corpse decades later thus making it a great forensic tool. 3D illustrations are reliable forensic records and also provide a better understanding of the technical aspects of the cause of death and injury in a courtroom setting. It is less time-consuming than compared to traditional autopsy. It is more acceptable as it can give better diagnoses while also respecting religious sentiments. The results provided are highly sensitive, specific, and accurate.[12] It is non-invasive and non-destructive.

With its many modifications, it is not completely without fault as there is a lack of senses like touch, feel, texture, and smell, which are great friends of any forensic pathologist[14]. Moreover, the high cost of setting up a virtopsy center makes it less feasible in underdeveloped and developing countries.

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