**Virtopsy: Lifting the Veil**

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**ABSTRACT**

A conventional autopsy is an invasive approach where an external examination is first conducted to document any findings along with 2D photography. Then all the organs are removed, inspected, measured and sampled for histology, in order to identify pathology within the organs. If required, additional samples are collected and sent for cultures and biochemical estimations. In contrast, virtopsy can boast in its ability to be almost completely noninvasive which can supplement or may even replace conventional autopsy. In deceased persons, the main goals are to determine the cause and manner of death, to evaluate the vitality of sustained injuries, and to develop a forensic reconstruction based on the findings. The documentation and analysis of postmortem findings with techniques of virtopsy is investigator independent, objective, and noninvasive and will lead to qualitative improvements in forensic investigation. Future applications of this approach include the assessment of morbidity and mortality in the general population and, perhaps, routine screening of bodies prior to burial.

**Key words:** Virtopsy; Forensic Medicine; Autopsy; Imaging techniques; Postmortem computed tomography

1. **INTRODUCTION**
2. **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*. coined the term “virtopsy”. It is extracted from the terms “virtual” and “autopsy” where virtual is derived from the Latin word “virtus” which means “useful, good and efficient” and adding “opsomei” which means “I will see”, thus leading to the scientific canopy “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].

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1. **Scope for virtopsy**

Findings in conventional autopsy are documented in an unintentionally subjective (observer-dependent) manner, and any findings that have not been documented are destroyed irrevocably if the body is sent for 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 off.

Conventional autopsy is often rejected by family members or go against religious beliefs. Virtopsy might replace conventional autopsy and, when required, minimally invasive imaging-guided tissue sampling and angiography can be applied to address vascular questions.

Scope of virtopsy also include research with a focus on postmortem interval estimation, identification of individuals, age and sex determination, imaging in toxicology, road traffic accidents, hanging or manual strangulation, gun shots, sharp and blunt force trauma, burns and hypothermia, injury or organic lesions of heart and brain and other organs with emphasis on embolisms, and 3D surface pattern matching.

1. **IMAGING MODALITIES AND TECHNIQUES**

Virtopsy includes the following tools:

* 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 is a 6-axes industrial robot mounted on an external axis along with the computed tomography couch (CT couch). It has a changeable end-effector to mount different tools. The virtobot removes any interpersonal inaccuracies and results in consistency and high accuracy[3].

1. **Photogrammetry and Surface Scanning**

The virtobot moves over the body creating a 3D color model of the corpse taking as little as 10 seconds. Stereoscopic cameras, with a resolution of 0.02mm, are used to capture the color image along with a projector to cast a mesh pattern on the body. Small discs are placed along the body to properly align the surface scan and the interior scans for rendering the images into a single cohesive image. Computer processors use these markers to calibrate the exterior scan and match with internal imaging processes. To avoid any interpersonal inaccuracies, the virtobot places these markers on the surface of the body providing standardized and accurate results[3,4,5].

After the surface scan, the corpse which is double covered in plastic bags to prevent any contamination, is brought and laid on the sliding table of the CT, MRI, and MRS equipment simultaneously.

1. **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. The resulting dataset is a 3D volume in volume pixels (voxels). Voxels contain information about the attenuation of x-ray displayed as density which is measured in Hounsfield units (HU). 0 HU is equivalent to the density of water, –1000 HU (i.e., one thousand below zero) is equivalent to the density of air. To distinguish between different tissues, density of different organic and inorganic materials are 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 identification of foreign bodies, osseous lesions, internal organ trauma with no external trauma markers and to distinguish putrefactive gas accumulation from pathological gas formation with higher precision over conventional autopsy[6,7].

PMCT also helps in 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 costs when compared to DNA analysis and other means of identification[8,9].

1. **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. Tesla (T) is the unit of strength of magnetic field created by an MRI. Current MR units work with 1.5 T or 3 T magnets, that creates a magnetic field roughly 50,000–100,000 times more powerful than the magnetic field of the earth. MRI, in virtopsy, adds the benefit of producing greater contrast for soft tissues than CT and supplements the CT scans for neurological, cardiovascular, and musculoskeletal imaging. Since in postmortem imaging the body is motionless, any motion artifacts are eliminated allowing better visualization of all anatomical details. Since MRI is T1 and T2 weighted, one of the drawbacks is that the relaxation times T1 and T2 are temperature dependent which alters the image contrast as the temperature of the body decreases[10,11].

A prior CT is done to rule out metallic fragments or implants, and thus MRI is limited to cases with no metallic foreign bodies. Also, as compared to CT, it is more time consuming[3].

1. **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.

* Two tubes are inserted, one each in the femoral artery and femoral vein. Contrast medium is injected into the femoral artery at a constant pressure and the tube in the femoral vein drains the overflowing blood. Imaging is performed immediately after the instillation of the contrast medium.
* For visualization of the venous system, the injection and drainage tube are simply switched and the procedure and imaging are repeated[3].

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

1. **Tissue/Liquid Sampling**

CT guided biopsies can be done to collect samples in a minimally invasive manner after CT or MRI scans reveal organs of interest or specific pathology. In a similar way, tissue and fluid samples can also be collected for toxicological and microbiological examinations[13]. This provides an added advantage as compared to 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.

1. **Magnetic resonance spectroscopy (MRS)**

MRS is another technique in virtopsy which can estimate the time of death by determining the various metabolic concentrations in tissues that changes with the passage of time after death. MR microscopy is a micro imaging technique which is used to study the soft tissue injuries like retinal hemorrhage, electric injury to the skin, etc. Micro tomography is another virtopsy technique that studies weapons and can determine its injury patterns, which is especially helpful to determine if the weapon found in the crime scene was used to inflict injuries present on the body[1].

**3. WORKFLOW OF A STANDARD AUTOPSY**

Virtopsy truly is case specific and the image modalities utilized depend on the individual case history. A simple workflow of a standard virtopsy is demonstrated to decide what image modalities are required to answer the forensic questions concerning the cause of death (Fig. 3.1). In cases with patterned injuries, a colored 3D documentation of the body surface is done. Entire body is documented with photogrammetry and surface scanning in prone and supine positions. Following external documentation, a CT scan is performed. The next modality, i.e a 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 approach can be planned.

**4. FEASIBILITY OF VIRTUAL AUTOPSY**

Virtual autopsy provides 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 as 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 in nature.

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 the underdeveloped and developing countries.

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Fig 3.1: Workflow of a standard virtopsy

Body on CT couch

CT scan

YES

Photogrammetry

+

Surface Scan

+

NO

YES

Contrast injected

Perform CT scan

NO

Tissue sample required?

YES

Biopsy gun

+

Targeted image guided biopsy

Sent for Histopathological examination/ Cultures/ Biochemical estimations

NO

Body contains metal?

YES

NO

MRI

AUTOPSY

Patterned injury present?

Vascular injury present?