Review Article

Virtual Autopsy: An Imaging Technological Integration in Forensic Odontology

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Abstract

With the advent of new technologies being integrated into varied aspects of dental care through visual, photographic, and radiological evidences in clinical diagnostics, these aspects are yet to be involved in forensic sciences. This is despite the availability of the technological advances in today's clinical settings. This review discusses the feasibility of integration of virtual autopsy in forensic odontology practice in an Indian setting. Using high-tech radiological approaches, virtual autopsy provides an efficient and more accurate view on cases such as thanatological investigations, carbonized and putrefied body identifications, mass disaster cases, age estimation, anthropological examinations, and skin lesion analyses. In certain cases, the postmortem photographic and radiological examination becomes essential as the access to the oral cavity is hindered. These become feasible with the advent of availability of antemortem radiological digital formats stored in hospital settings, with the improved collection of data compared to the traditional techniques. However, we do not have any state and national level protocols and laboratories to augment the capabilities further. Virtual autopsy is likely to replace conventional autopsies in the future. Thus the century-old investigation system in our country can be upgraded by the utilization of this Modern Technology. This review advocates a multidisciplinary research and advocacy to develop improved tools and protocols for virtual autopsy and to stress the role of forensic odontologists in an Indian setting.

Key Words: *Anthropology, cone-beam computed tomography, forensic odontology, thanatology, virtual autopsy*

Introduction

Photography and X-rays are the most commonly adopted techniques by forensic experts or analyst since years for individual recognition or identification. Various modification techniques in the field of forensics were experimented subsequently with the invention of new strategies in the field of radiology and medicine. In 1973, computed tomography (CT) was used for the first time in forensic sciences and medicine but remained largely unused throughout the years. To overcome various challenges faced by experts, an alternative technique traditionally described by scientific articles as "Virtopsy" is introduced as an alternative or adjunct to the standard invasive procedure. This technique uses different imaging techniques which provide a complete three-dimensional (3D) view of the vital information such as position and dimensions of wound and pathological conditions in the body.[1,2]

Historical Overview

Virtopsy developed by Richard Dirnhofer, which literally means virtual autopsy, a scalpel-free procedure of autopsy subsequently developed into a multitool documentation and analysis research project, combining 3D body surface imaging methods with merged CT/magnetic resonance imaging (CT/MRI) data and 3D shape analysis. The virtual autopsy approach is applied to majority of cases of uncertain or unknown identity as a result of natural calamities, accidents, homicides, death of individual under the age of 18 years or associated civil instance, and also to recognize foreign objects such as implants and bullet fragments based on their densities.[3,4]

Modern Virtopsy Versus Conventional Autopsy

In the conventional method, the whole architecture of the body is preserved in this technique, which is not in case of conventional biopsy where all the organs are removed and examined. If the body is subjected to subsequent autopsy, it becomes a very tough job for the second autopsy surgeon to conclude with all the dislodged and dissected organs where the normal architecture is lost. Another disadvantage during autopsy procedures, include opening of all the body

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cavities and dissection and examination of all the organs can eventually cause spread of infections from a fresh dead body as well as highly putrefied body which can be avoided by this much safer procedure.[5]

In the initial period, virtopsy researchers use only CT and MRI for detection of the outcomes as adjunctive aids, but the new combined modern virtopsy method uses angiographic methods, CT scanning as such, photogrammetry or 3D surface documentation and MRI. The application of multidetector or multislice CT and MRI, high-resolution micro CT and micro MRI, magnetic resonance spectroscopy, image-guided percutaneous biopsy, postmortem (PM) angiography, PM identification, PM ventilation, noninvasive tool, and data display control such as the integration of Kinect camera or 3D printing and rapid prototyping along with conventional virtopsy found continued interest for problems specific to clinical forensic medicine.[5,6]

Modern Virtopsy

Combination of the technologies of medical imaging techniques as well as other technologies are useful in identification and incorporation of bone bruises into accident reconstructions, the identification of gas, ability to identify pathology in decaying tissues, ability to extract and use information related to material composition, documentation of medical installations, and exploitation of digital data for reconstructive purposes.[7]

Virtobot System

The so-called Virtobot is a 6-axis industrial robot, that is, mounted onto an external axis along with the CT couch, so it can access the entire scannable volume. It has a changeable end effector and can, therefore, mount different tools. The system incorporates a surgical navigation system to allow for a closed loop robot control [Figure 1]. Currently, modules for automated surface scanning and minimally invasive biopsy exist.[8]

Photogrammetry and Surface Scanning

The merging method of color photogrammetric surface scan and grayscale radiological internal documentation has the advantage of being observer-independent, nonsubjective, noninvasive, digitally storable over years or decades and even transferable over the web for the second opinion.[8,9]

Computed Tomography Scanners

CT scanning is a common examination performed in clinical radiology, which provides an ample pool of antemortem (AM) studies for use in cases of unknown identification. With the increased use of medical imaging techniques in clinical medicine, an increasing number of AM datasets is available. Prominent landmarks in these scans, such as the paranasal sinuses, but also medical implants such as dental implants, bone screws and plates, pacemakers, and others can be used for comparison with PMCT datasets for identification. Using maximum intensity projections, PMCT datasets can be compared to AM 2D X-ray projections, or AM CT datasets.

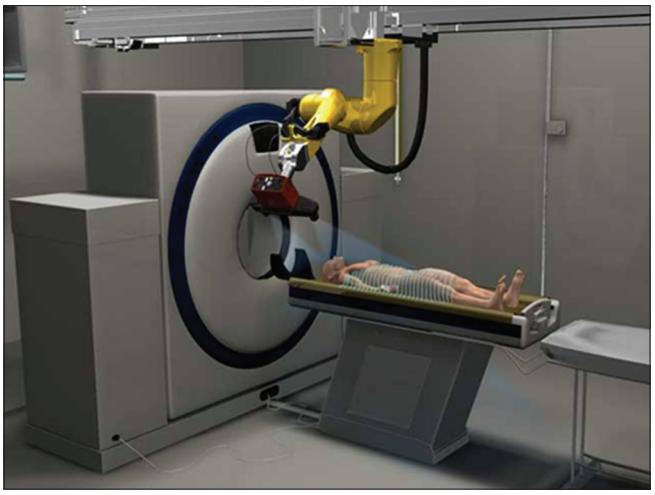

Figure 1: A representative image of the VIRTOBOT system showing computed tomography couch analyzer with scanners (Image courtesy: Int J Med Robot 2010; 6 (1): 18-27)

These techniques are reliable, even if the body has damages due to trauma or putrefaction. The advantages of these techniques are their quickness, reliability, and low costs compared to other means of identification such as DNA analysis.[9,10]

Magnetic Resonance Imaging

MRI is a powerful adjunct to CT, its ability to visualize soft-tissue organs complements the ability of CT to visualize osseous lesions. However, there are a few important differences between AM and PM MRI. The absence of motion artifacts in the PM setting allows for better depiction of anatomical details. The assessment of the cardiovascular system in living patients, involves not only the morphology but also the function of the heart – an aspect that obviously cannot be appraised in PM MRI. After the cessation of cardiac motion, gravity causes fluids to pool in the dependent parts of the body and the corpuscular elements of fluids, such as blood cells will sediment within the vascular bed. The relaxation times T1 and T2 are both temperature dependent, image contrast may change with decreasing body temperature of a decedent.[11,12]

Postmortem Computed Tomography Angiography

Using the PM angiography, the whole cardiovascular system can be visualized. If there is any injury to a vessel, there will be spillage of dye to the surrounding tissues, making it visible in the CT images.

Antemortem Versus Postmortem Imaging

Even though medical imaging techniques used in virtopsy is the same as methods used in clinical medicine, interpretation of PM image data sets has some differences. Changes common in deceased individuals can be mistaken for pathologies. This includes, but is not limited to: collections of gas due to decomposition, clotted blood, and internal lividity. MRI scans change their appearance if the body temperature is too low.

Therefore, it is advisable that PM studies be evaluated by radiologists who are experienced in PM imaging.[13,14]

Literature Review

Thali *et al*. observed that the findings of the virtopsy procedure have matched almost perfectly in side-by-side comparisons with those of the conventional autopsy procedures.[15] Peter vock showed the results of imaging techniques in case of cadaver are better, as there is no movement due to respiratory and cardiac activities as in case of the living, which may at times distort the images.[16] Bisset *et al*. in a 53 cases study using MRI showed more or less similar results in both the methods.[17]

In Dental and Craniofacial Imaging and Reconstruction

The virtual autopsy can be applied in a broad number of forensic situations, such as thanatological investigations, carbonized and putrefied body identifications, mass disaster cases, age estimation, anthropological examinations, and skin lesion analyses [Figure 2].

In cases of drowned bodies, the CT information about the volume, density, size of the lungs, and the amount of liquid observed in them is helpful in diagnosing the cause of death. Cases of firearm projectile injuries are often difficult to examine because either sometimes the bullet is not in the body, or diverted by an anatomical structure, or it can be in unknown body parts. Therefore, knowing the location of the projectile before the autopsy is performed facilitates the examination.[18]

In mass disasters, forensic odontologists could be able to chart the PM virtual data and to start the AM triage and the AM/PM comparison, while forensic pathologists are performing the conventional autopsy procedures. Dirnhofer *et al*. in his study observed for human identification purposes, the use of adapted vehicles (e.g., Oshkosh Specialty Vehicles®, Clearwater, Florida, United States of America) with imaging machines allows for PM data collection on the disaster field. The author states that mobile CT imaging could provide a high level of positive identifications. Virtual autopsies also allow documenting and saving all body evidence in its original status and provide information related to the chain of custody.[19-21]

In the odontology field, Oesterhelweg *et al*. describe a case where the victim was struck by respiratory obstruction from a foreign body (food bolus). The differentiation of the obstructive structure was performed with combined CT and MRI. In conventional autopsy examinations, the greatest difficulty is to predict the depth of the foreign body. The virtual autopsy provides this information accurate and clear. Health professionals must be aware of these complementary examinations because over 90% of these emergency cases were misdiagnosed.[22,23] Another specific odontological application for the virtual autopsy is on the comparison between AM orthopantomograms and PM reconstructed panoramic overviews of cranial CT images. This way PM dental evidence can easily be related to the AM data of the expected missing person [Figure 3].

Birngruber *et al*. reported a positive identification case based on the superimposition of PM CT reconstructed images on AM radiographies.[23] Dedouit *et al*. stressed the importance of the presence of dentists in the forensic identification team in particular to determine the age of charred bodies. In traditional medical examinations, the decomposition of the body is a limiting factor for the age assessments.[24]

Studies on restorative materials are also related on the virtual technique. Through the analysis of the restoration materials density, Jackowski *et al*. performed pioneering researches on odontology in virtual autopsy. These authors expressed in Hounsfield units, the different density of restoration materials, such as composites, temporary fillings, and ceramics, by ultra-high-resolution CT imaging. Furthermore, the author verified the course of restoration materials under high temperatures by CT images, simulating a fire mass disaster.[25] Dual-energy CT scanning is an upcoming modality with various indications and a promising application in

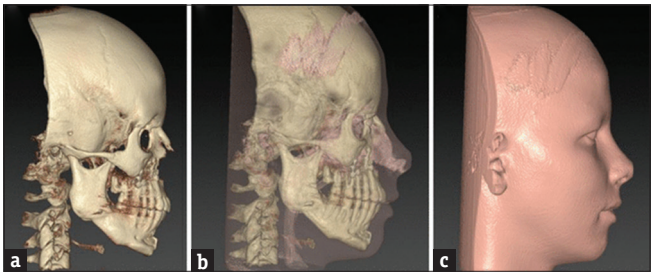

Figure 2: (a) CT image of Craniofacial structure (b) processing for Facial reconstruction (c) Facial reconstruction done

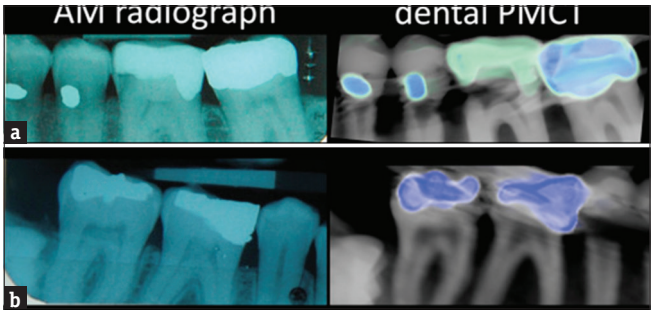

Figure 3: (a and b) both images are comparing between dental antemortem radiograph and dental postmortem CT

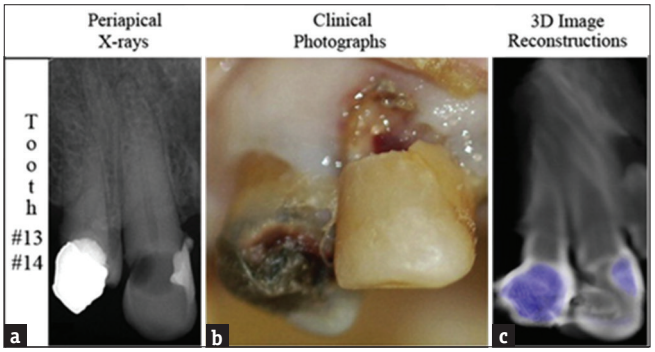

Figure 4: (a) dental restorative materials on peri apical X-ray, (b) dental restorative materials on clinical photographs (c)dental restorative materials on 3D image reconstructions

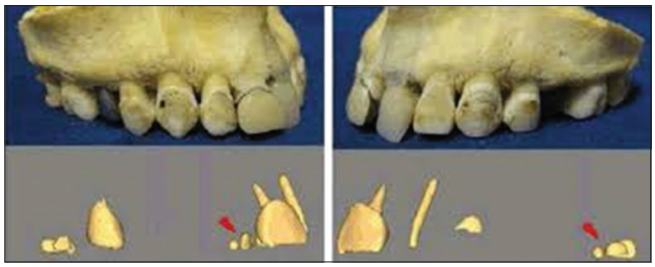

Figure 5: Image showing dental identification using dental cone-beam computed tomography (Image courtesy: https://doi: 10.4172/2161-1122.1000332)

forensic imaging. The use of the dual energy allows among others color encoding of dissimilar body materials for an ultra-high scan resolution. Such scanning procedure might reveal the possibility to distinguish between composite and ceramic dental restorations[26,27] [Figures 4 and 5].

Disadvantages

Although the technique has good reliability, there is a little of forensic importance that virtual autopsy cannot detect. It is not possible to distinguish all the pathological conditions, infectious status, AM or PM wounds. It is also difficult to appreciate the PM artifacts, color changes, and sometimes small tissue injury. No literature supporting the use of specific color resolutions for image analysis in full-body CTs could be retrieved.[20,27,28]

Conclusion

Postmortem CT has been widely used for screening the cause of death, candidates for autopsy, and guidance and/or supplemental information for autopsy. Although there are differences in the AM radiological findings and PM findings, this field needs further study intensively. Dental PM full-body CT charting has to be considered as a treasured and supplementary tool in the human dental identification technique. Nevertheless, it is a new development in the field of investigations of death and its acceptability in the court of law is yet to be proved.

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Conflicts of interest

There are no conflicts of interest.

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