Review Paper

VIRTUAL AUTOPSY: A NEW TREND IN FORENSIC INVESTIGATION

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Abstract

Introduction: The modern high-resolution imaging has been used as a well described aid in the setting of post-mortem investigations. In developed countries Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) are now being evaluated as complementary means for cause-of-death determination.

Objective: This paper explores the implication of virtual autopsy from ethical and technical point of view.

Methods: Published literature with strict inclusion and exclusion criteria were extensively reviewed through use of general and Meta search engines to elucidate the applications and implications of virtual autopsy.

Discussion: Virtual autopsy introduces a new era in autopsy examination. It utilizes the technological innovation of modern imaging system to obtain high quality 3 Dimensional images of the body in multiple plains without mutilation of the human body. 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, determining cause of death determination; decedent gender, identification in difficult forensic cases; body length and Individual decedent feature identification; identifying distinct foreign bodies – retained bullets, blades, etc.; identification of injuries and forensic reconstructions – three dimensional reconstructions, bullet tract identification; education and clinical performance improvement process; and research.

Conclusion: Due to its minimal invasive procedure, virtual autopsy is very much acceptable to the society. In USA and European countries virtual autopsy is likely to replace conventional autopsies in future. We can also utilize this modern technology to upgrade the century old investigation system in our country.

Key-words: Virtual autopsy, Conventional post mortem examination, Future aspect.

Introduction

The modern high-resolution imaging has been used as a well described aid in the setting of post-mortem investigations. In developed countries Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) are now being evaluated as complementary means for cause-of-death determination.

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Objective

This paper explores the implication of virtual autopsy from ethical and technical point of view. In this article the history of autopsy and the reasons for the gradual decrease in conventional autopsy rates over the last two decades have been briefly described. An overview on advantages and limitations of modern imaging autopsy techniques is also presented and potential future applications of modern imaging techniques in postmortem analysis are also discussed.

Materials and Methods

Published literature with strict inclusion and exclusion criteria were extensively reviewed through use of general and Meta search engines to elucidate the applications and implications of virtual autopsy. Articles containing information regarding the history of virtual autopsy, its application in different cases, and gradual development of the procedures in western countries and future aspects of this method have been taken into count for collection of data and references.

Discussion

The word "autopsy" has come from the Greek words – "Autos"- which means self and "opis" which means view or to see for one self. It is also called necropsy. ("Necros" means- dead body) or post mortem examination ("post"- means after, "mortem" means death)[1]. Autopsy is a special type of scientific examination of a dead body carried out under the law of state. A model autopsy procedure has been produced by United Nations within the context of investigation of human rights abuses called the-'Minnesota Protocol ' (The United Nations Manual on the Effective presentation and investigation of extra legal, arbitrary and summary execution). It can be used to deal with difficult, controversial or sensitive cases[2]. The first medico legal autopsy was done by Bartolomio De Varignana[3] in Italy in 1302. In this Subcontinent the first medico legal autopsy in India was performed by Dr Edward Bulkley[4] on 28th August 1693. Mainly autopsy are of three types: medico legal, pathological or clinical or hospital and anatomical[5].

In most countries, clinical autopsies are performed with permission from the family of the deceased. As a consequence of its invasiveness, permission to conduct a clinical autopsy is often not given[6-8]. In ancient Egypt and Mesopotamia postmortem dissections were frequently performed during the process of embalming. In India, autopsy and dissection were practiced by Sushruta, an early pioneer of ayurveda (the Indian art of medicine) in the sixth century B.C. In the third century B.C., Greek scholars used autopsy for the purpose of enhancing their understanding of anatomy and disease. Similar approaches re-emerged in Europe during the middle Ages and the Renaissance with the work of Vesalius and others. The first organized treatise on pathological findings at autopsy was *"The seats and causes of diseases investigated by anatomy",* published in 1761 by Giovanni Batista Morgagni when he was 79 years old. This book, describing nearly 700 autopsies performed by the author, is the foundation of modern post-mortem science. At the end of the nineteenth century, Osler established autopsy as one of the cornerstones of his approach to both medical training and clinical method [9-11]. In the first half of the twentieth century autopsy rates steadily increased. In the 1960's and 1970's, many of the advances in cardiovascular surgery developed by DeBakey and his team were pioneered using cadaveric testing. The second half of the 20th century and the beginning of 21st century saw continued decline in autopsy rates. This was largely a global phenomenon, with only a few countries where autopsy rates remained relatively constant or decreased less dramatically, including Sweden and Finland[12-13]. Over the past three decades, there has been a 40-50% drop in autopsy rates across the world[14]. In the United States, autopsy rates fell from the reported high of 41% in the 1960's to between 5% and 23% at present[15-16]. The most commonly cited factors accounting for this phenomenon include physician discomfort in requesting permission from the family, cost containment measures, risk of blood borne pathogen transmission, as well as the perceived absence of the curricular/educational value of autopsies[17-21].

One report from Australia demonstrated a sharp drop in autopsies from nearly 40% in the year 2000 to just over 10% in 2001 which was attributed to a significant increase in autopsy refusals[22]. The Virtopsy, or "virtual autopsy" was developed by Richard Dirnhofer, former Director of Forensic Medicine, Berne, which was then continued by his successor, Michel Thali and his colleagues at the University of Berne's Institute of Forensic Medicine, Switzerland. During autopsy the 3-D geometry of human body is destroyed but using the cross-section imaging technique, it is possible to document the same findings in a noninvasive way. A multi-slice computed tomography (MSCT) and magnetic resonance imaging (MRI) –visualize the interior of the body for collection of all the data in details in regards to condition of different organs. Specific software (e.g. Tera Recon Aquarius NET®, Foster City, California, United States of America) allowed for 3D reconstructions of the computed tomography images from the observed structures. Another part of the documentation concerns the body surface recording, performed by forensic photogrammetric and 3D optical scanning. One can examine the part of the body slice by slice in different planes according to the requirement of the situation. Apart from these, using the magnetic resonance imaging spectroscopy, time since death can also be estimated by measuring metabolites in the brain, emerging during postmortem decomposition. The samples for histopathological examination if required can be collected more precisely using CT guided needle biopsy. Postmortem angiography is used to visualise the cardiovascular system[23-26].

In 1980, Flodmark et al performed a comparison study of premortem computed tomographic findings and subsequent autopsy results in neonates who suffered perinatal asphyxia[27]. Kalender et al followed in 1990 by developing acquisition and processing of three-dimensional digital radiographic imaging data[28]. The 1990's saw the inception of large-scale research programs dedicated to imaging autopsy. The most prominent of those programs is the Virtopsy Project at the University of Bern, Switzerland. Other programs include those headed by Donchin et al[29], military-sponsored programs in the USA[30], and the CATopsy program at St Luke's Hospital in Bethlehem, Pennsylvania, USA. R A L Bisset et al[31] studied 53 cases at Manchester, UK in the year 1997, using MRI where the findings were confirmed by conventional autopsy. According to their study, the findings were more or less similar in both the methods. In their study, they could detect cardiac ischemia, pneumonic consolidations, pleural effusion or pulmonary oedema etc apart from the other cases. In Japan, postmortem computed tomography (PMCT) is widely applied for three major roles –screening the cause of death, screening candidates for autopsy, and for guidance and/or supplemental information for autopsy.

In a study conducted in Japan, questionnaire sheets were distributed, regarding the use of PMCT, to 183 major medical establishments having Emergency Rooms. Of these, 67% responded and it was found that 89% of the respondents used PMCT. This high rate was likely because the number of CTs in Japan was greater than 10,000 units, constituting more than one-third of those world wide[32]. Since 2005, United States Army Forces Institute of Pathology has scanned and analyzed about 800 bodies killed in war zones in order to determine cause of death and examine the injuries[33-35]. This information will eventually be used to improve head and body armor and to improve combat casualty care. 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, determining cause of death and decedent gender, identification in difficult forensic cases, body length and Individual decedent feature identification; identifying distinct foreign bodies – retained bullets, blades, etc.; identification of injuries and forensic reconstructions – three dimensional reconstructions, bullet tract identification; education and clinical performance improvement process; and research – from medical to historical (i.e., mummies, etc)[36].

Thali et al[37] have shown that virtual autopsy in gunshot wound victims is useful to localize the bullet in three dimensions, document the bullet path, visualize fracture patterns associated with gunshot wounds, and evaluate internal organ injury prior to autopsy. In 1977, Wullenweber et al reported one of the earliest forensic applications of computed tomography to describe radiographic patterns of gunshot injuries to the head[38]. In mass disaster cases Dirnhofer et al[39] describe for human identification purposes the use of adapted vehicles (e.g. Oshkosh Specialty Vehicles®, Clearwater, Florida, United States of America) with imaging machines allowing for PM data collection on the disaster field. The author states that mobile CT imaging could provide a high level of positive identifications. In the odontology field Oesterhelweg et al[40] described a case where the victim was struck by respiratory obstruction from a foreign body (food bolus). Birngruber et al[41-42] reported a positive identification case based on the superimposition of post-mortem CT reconstructed images on ante-mortem radiographies. Dedouit et al[43] stressed the importance of the presence of dentists in the forensic identification team in particular to determine the age of charred bodies. Other studies[44-47] also relates the role the forensic odontologist on age estimations.

In one study over 40% of postmortem CT studies revealed clinically significant findings that were not identified on traditional autopsy. IA offers excellent accuracy, including very close estimation of solid organ weights[48]. Imaging autopsies provide visualization of soft tissue patterns in cases of severe putrefaction. Aghayev et al described the use of both MSCT and MRI to document herniation of cerebellar tonsils prior to traditional autopsy in patients with blunt head injuries[49]. The same group also advocated postmortem imaging as a good forensic visualization tool for documentation and examination of traumatic injuries and other pathologic findings in a broad range of scenarios[50]. Oyake et al conducted an IA study to help determine the etiology of sudden death due to non-traumatic causes in infants and children. Imaging autopsies in that study were able to point to the cause of death in 14 of 15 decedents when radiographic information was combined with premortem clinical and laboratory data[51]. In 2007, Levy et al published a series of postmortem CT examinations of military air mishap victims. In that study, pockets of ectopic air in various anatomic areas were found in 24% of victims. They also noted that detection of solid organ injury and superficial traumas were significantly worse on CT than on a traditional autopsy, corroborating the complementary character of IA studies[52]. In hanging cases the CT images of the injuries of the neck obtained by CT scan clearly showed the ligature mark, the hemorrhagic suffusion in the soft tissue (thickening of derma) and in the muscles (sternocleidomastoid) of the neck. Furthermore, CT 3-dimensional reconstruction showed brain edema, fracture of the left posterior horn of the hyoid bone, and a grade 1 retrolisthesis of C5 on C6. In drowned bodies the CT information about the volume, density, size of the lungs and the amount of liquid observed in them is helping in diagnosing the cause of death[53].

The data is stored in digital format, so can be transmitted to any part of the world and easily transferred to courtrooms and because they offer a less gruesome alternative to traditional autopsy photographs, less time consuming and body can be released immediately after the scanning, better acceptance for the relatives of the diseased and also by the religious customs as incisions are not used. The disadvantages of this procedure includes: insufficient data base of comparative study of virtopsy and conventional autopsy. It is not possible to distinguish all the pathological conditions with this technique, cannot give the infection status, difficult to differentiate antemortem or the postmortem wounds, difficult to appreciate the postmortem artifacts, difficult to appreciate the colour changes, small tissue injury may be missed and in our scenario, it is not possible to provide these types of investigations to all the living persons.

Conclusion

Virtual autopsy introduces a new era in autopsy examination. It utilizes the technological innovation of modern imaging system to obtain high quality 3Dimensional images of the body in multiple places without mutilation of the human body. It also incorporates other minimally invasive techniques such as image guided biopsy, MR spectroscopy, postmortem angiography etc. followed by data analysis to give a postmortem diagnosis. Due to its minimal invasive procedure, it is very much acceptable to the society. In USA and European countries virtual autopsy is likely to replace conventional autopsies in future. We can also utilize this modern technology to upgrade the century old investigation system in our country.

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