Virtopsy lends dignity to lazarus

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Abstract
Autopsy plays a significant role in Forensic pathology, which is a discipline of forensic science that deals with pathologic and physiologic changes of a body before and after death. An autopsy is an extremely specialized surgical procedure that consists of radical examination of the cadaver to work out the cause, manner of death, and to evaluate any disease or injury. The conventional autopsy procedures include examination of all body cavities and organs; but many cultures and religion do not believe in the idea of mutilating the body for the sake of autopsy. Therefore, autopsy has many emotional and ethical disadvantages. Also, with the conventional autopsy methods the 3D geometry of the body is destroyed along with an immense risk of infection to the mortuary staff and the concerned doctor. Thus, in order to ameliorate the conventional autopsy methods Michel Thali and Richard Dirnhofer developed a new method of autopsy known as "virtopsy" or "virtual autopsy", which is a scalpel free procedure of autopsy carried out using modern medical, imaging and measuring technology. A combination of many disciplines like forensic medicine, pathology, radiology, image processing, physics and biomechanics lead to the technology called "Virtopsy". It rests on certain pillars which include three dimensional surface scanning 3D/CAD, MSCT- multi slice CT and MRI and Magnetic resonance spectroscopy. Forensic odontologists play a pivotal role in human identification and with the advent of virtopsy dental identifications have become quick and accurate without damaging the head and neck region.

Keywords: Virtopsy, Identification.

Introduction
Death is an inexorable part of life and at few occasions scientific examination of bodies after death becomes imperative. With the advancement of science and technology, modern day investigations have reached at a point of savoir fare that, they are even able to establish reasons for death. The role of Forensic science in achieving this is conspicuous.

Forensic Science is an area of specialization that includes collection of data through observation and experimentation, principles and procedures for the systematic application of knowledge leading to recognition and formulation of a problem which can be used in a judicial setting. It involves 10 disciplines which include Crimanilistics, engineering science, general, jurisprudence, odontology, pathology/biology, psychiatry and behavioral science, questioned documents, toxicology and physical anthropology.[1] The main idea of identifying the dead is for personal, social, and legal purposes.[2]

Forensic pathology is a discipline of Forensic science which deals with pathologic and physiologic changes of a body before and after death wherein autopsy plays a significant role; which deals with establishing the circumstances leading to death by scientific examination.[3]

The most important forensic expertise is the medicolegal autopsy, which is also popularly called as "the expertise of expertises".[4] Autopsy is the scientific examination of bodies after death, where whole surface of the body as well as all the body cavities are explored to record the findings.[5] Autopsy derived its meaning from the Greek terminologies, *auto* meaning "self" and *opsomie*, "I will see".[6] Autopsy is a destructive procedure which is based on the subjective, manual and descriptive methods.[2]

Autopsy is a method dating from ancient times. The first in this field were the Chinese, who examined the animals' internal organs. The ancient Egyptians used this science on human beings as well.[7] In 1761, Giovanni Batista described and published nearly 700 autopsies done by him in his book. "The seats and cause of diseases investigate by anatomy". For medical and clinical purpose, Osler established autopsy as an important tool at the end of nineteenth century. From 1960 to 1970, De Bakey and his team developed many techniques for autopsy and this lead to cadaveric testing.[8]

Autopsy was crucial for medical research and education until 1960 when doctors started realizing that a progress in medicine and in understanding pathological process was a contribution of Autopsy as well.[9]

Autopsy: Do we still need it ?
The Dictionary of Legal Medicine proposed by Manif and Elias Zacharias,[10] says that the implementation of autopsy includes examination of the body, externally i.e on the surface and internally i.e body cavities, taking into consideration that the main goal to diagnose is thanatology.[11-13] The traditional internal autopsy procedure consists of body mutilating techniques; but, the major objection against autopsies are the emotional aspects of the victim's relatives.[12] Yet the need to know the cause of death and to rule out any unnatural cause as well as any criminal angle or to find the identity of the deceased individual overrules any emotional involvement. Therefore, the families and relatives of the victim often have a discordant relation with the forensic examiners.[14] Also some religious and cultural sects present serious objections for the autopsy procedure like in Judaism, the process of autopsy is strictly prohibitted.[15,16]

In the current scenario, where newer infecting agents are coming in, mortuary staff as well as general public is at high risk of hazardous infection during the conventional autopsy procedure as the infectivity from the body is unknown and infection can spread from a fresh dead body as well as a highly putrefied body.[5]

Ethically, before doing a good thing, our duty is not to do anything wrong. Although, the boons of autopsy are undisputable, yet sacrificing body's integrity after death is considered as a mark of disrespect from cultural aspect. Also, conventional autopsy procedure has many shortcomings.[7]

Autopsy reports are still based on subjective and descriptive methods, despite of remarkable progress this field. Most valuable gift of technology to science is the non-invasive or minimally invasive diagnostic methods belonging to imagistic domain. The development of advanced and highly sensitive CT and MRI techniques led to the idea of using them for post-mortem investigations.[7]

Virtopsy

Based on the above mentioned objections, and in an effort to ameliorate the autopsy results, different aids in diagnosing the cause of death were developed.[17] Richard Dirnhofer, former Director of Forensic Medicine, Berne gets the credit of developing the science of Virtopsy, or "virtual autopsy", which was later continued by his successor, Michel Thali and his colleagues at the University of Berne's Institute of Forensic Medicine, Switzerland.[18]

A photograph always gives a two dimensional view of the particular object. So, during an autopsy procedure if a wound photograph is taken, it gives the position along with length and breadth of the wound but cannot exhibit the depth of the wound. Therefore, in order to determine the depth, a three dimensional view of the wound is required, thus giving an insight into the actual dimensions. Virtopsy, is a combination of the technologies of medical imaging techniques and many different technologies used in various field of science.

3-D surface scan is used to map the exterior of the body as it designs and documents the three dimensional image of the body surface area in detail. It is also used in the automobile designing.

Multi-slice Computed Tomography (MSCT)

It can detect skeletal injury, soft tissue injury, and hematologic disorders. Conventional CT devices have only one row of CT detectors, whereas, MSCT is equipped with multiple rows of CT detectors to form images of multiple sections. Using MSCT along angiography assists in the diagnosis of cardiovascular system injury.

Magnetic Resonance Imaging (MRI)

Visualizes the interior of the body for collection of all data in detail along with condition of different organs. Different parts of the body can be examined slice by slice in different planes according to the requirement.

Some other methods includes, Magnetic Resonance Imaging Spectroscopy, wherein: time lapse since death can be estimated by measuring metabolites in the brain, produced during postmortem decomposition. CT guided needle biopsy is a method by which samples for histopathological examination if required can be collected more accurately and without mutilating the body. Postmortem angiography is used to visualize the cardiovascular system.[19,20-22]

Virtopsy procedures pertaining to imagistic technologies have contributed remarkably to the reconstruction of events, thus demonstrating their utility. The angle or axis and the impact of the force can be identified in cases of victims of road traffic accidents by the use of different technologies that come under virtopsy. In cases where a murder or criminal angle is involved and the death is caused due to any firearm, reconstruction methods can ascertain the channel of the bullet along with the type of arm and ammunition used. In cases of stab wounds, depth and orientation of the lesion can be identified.[7]

In cases of identification of burned victims, direction of the fire as well as degree of tissue carbonization can be found out by Virtopsy procedures. Virtopsy is such a remarkable science that it can identify the cause of death. Knowing the horizon of virtopsy, we can simply conclude that it is a blessing to science and its benefits are indisputable. One has to see to believe the superiority of 2D, 3D reconstruction methods. Reconstruction methods assist in better understanding of the evidence and the gives a clear view into the sequence of events to even a non scientific forum like the court of law.[7]

In many critical cases a second opinion is mandatory, wherein comes a major role of virtopsy, as it can store digital images which can be easily exported to any part of the world and re examined as many times as required. Virtopsy imaging technologies have an egde over clinical imaging methods as in virtopsy there is no movement by the body and there is no limit to radiation dosage, thus, producing images of higher resolution that are free of artifacts.[23]

Virtopsy not only caters to scientific benefits but also qualms of the society, thus giving a sense of relief to the victim's relatives. By virtue of Virtopsy, the integrity of human body can be maintained even after death; which is the moral right of each individual and a mark of respect for all by the advancement of science and technology.[7]

Forensic medicine, radiology, pathology, image technology, physics and biomechanics along with many other scientific disciplines combines to form a technology known as Virtopsy.[24]

Virtopsy Techniques

Virtopsy includes detailed digital documentation along with various scans and minimal invasive technologically guided techniques which assist in collection of samples for histopathology, microbiology and toxicology.[25]

CT – computed Tomography for 3D Imaging

X-rays, CT scans and other radiographic procedures have the same modus operandi to get image of different body parts. The principle being attenuation of body tissues as the x rays are passed through it and then the image is formed on the detectors placed behind the body.[25]

GOM – high-resolution Surface Scanner

This is a unique technology which can produce the actual 3D colour of the body surface along with the advantages of being highly stable, accurate, user friendly, flexible, and mobile. GOM can also reproduce accurate 3D surface colour for severely damaged bodies of all sizes. Bern University of Forensic Medicine use GOM TRITOP/ATOS for keeping the records of body surface, tools and vehicles.[25]

Angiography
In cases where individual body organs or body regions needs to be analyzed along with vascular injury leakages a post mortem heart lung machine is used.[26]

Contamination free Sampling
Guided sampling methods are used for easy sampling of body fluids and body tissues for toxicology, microbiology and histopathology examinations. Recently, use of robotic technology is being utilized as it decreases examination time and is presumed to be more accurate.[25]

Ultrasound Technology
Utilization of this technology in post mortem helps in gauging different organs for any damage, pathology, injury and abnormality.[27]

Animations in Forensic Pathology
It is a known fact that visual effect has a deeper and relatable impact on human brain. Thus, animations or dynamic illustrations of any crime or crime scene gives a detailed and an understandable evidence to the jury members to convey an otherwise complex medical evidence, immensely helping forensic pathologists. It is a computer based science which a comparison is drawn between crime and biological evidence or as the case may be.[28]

Photography
From times immemorial, photographs have been a part of our extra-curricular activity, but the pioneer of dry plate photography for prison record is Maddox, an English physician (1854). Later on, in 1864 the first lawyer to use photographs as an evidence for crime scene and criminal identification was Odelbrecht, Thereafter, Paul Jesrich, a forensic chemist in 1898, identified and compared two bullets in the court of law using photographs and was accepted as an evidence.[29] Photography, scaling, note taking and videography are four main tasks of documentations. Nowadays, it has become mandatory to take detailed photographs as the first step towards investigation of any crime.[30]

Virtopsy: Benefits[3,31]
1. Non invasive imaging technology.
2. Can be digitally stored and can be exported to all parts of world for a review of opinion, thus allowing a reexamination of evidences in cases of retrial or de novo evidentiary hearings, whereas we don't have such liberty with conventional autopsy methods.
3. Religious sentiments are not hurt as it proves to be a more ethical and a better accepted science by victim's relatives.
4. Body is not mutilated so no hazard of infection to the mortuary staff from bofy fluids.
5. Less time consuming and body can be handed over to the relatives of last rites as soon as the scanning is done.
6. Facility of 3D illustration and reconstruction providing a detailed insight into the crime and crime scene thus, aiding the forensic experts, lawyers and the judges along with provision of documentation.
7. Non-destructive, minimally-invasive Virtopsy has an edge over conventional autopsy in cases of massively destroyed bodies e.g. hit by train or burnt bodies.
8. In traditional autopsy procedures examination of body areas like pelvis or neck is difficult but can be scanned thoroughly using virtopsy.

Virtopsy: Downside[5]
1. Insufficient data base for comparative study.
2. All the pathological conditions cannot be to distinguished.
3. Cannot give the infection status.
4. Antemortem or the postmortem wounds are difficult to differentiate.
5. Postmortem artifacts are difficult to appreciate.
6. Difficult to appreciate the colour changes.
7. Fear of missing small injuries.

Applications of Virtopsy
Forensic situations, such as thanatological investigations; burned and decomposed body identifications; mass disaster cases; age estimation; anthropological examinations and skin lesion analyses can be done through Virtual Autopsy. In cases where drowning is the cause of death, CT scans can give away the data of the volume, density, size of the lungs along with the amount of liquid present in the lung.[32]

In cases of bullet injury at times the bullet is not present in the body or changes its direction due to any obstruction caused by any anatomical structure, thus, making the investigation a difficult one. Here virtopsy assist in finding the projectile of the bullet along with reconstruction of crime scene through animation and 3D reconstruction methods.[33]

In mass disaster cases Dirnhofer et al. described, 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. It is accepted that mobile CT imaging could provide a high level of positive identifications.[33]

Application of Virtopsy in Forensic Odontology
Forensic science deals with the identification of the dead using numerous techniques. Forensic odontology plays a major role in human identification and age estimation by using methods like rugoscopy, bite marks, palatal rugae examination, photographs, lip prints, etc.[34] For identification purposes, forensic science rests on the pillar of preservation of soft-tissue of the body and dwindles where the body is burnt, decomposed, mutilated or destroyed. Luckily, in human body, teeth and facial bones can withstand decompositional as well as destructional forces even under extreme forces and temperature variations. Radiographs are able to capture the distinct and variable features of hard tissues like bone and teeth, thus making imaging techniques an invaluable tool in forensic sciences. Radiographic identification has been in use from times immemorial as it is efficient, easy to use, can be done in ante mortem and post mortem cases and is economical than DNA technology.[35] Therefore, expert knowledge and apt application of radiological techniques has a valuable role in forensic identification and solving medico-legal

cases thus making forensic odontologist an indispensible part of the forensic team.[36,37]

In case of burned and decomposed body, any dental remains, such as restorations, teeth present, missing teeth and prosthesis, play a vital role in identifying the body. Teeth (max. 1000°C) and dental restorations (acryclic 540°C, gold and amalgam 870°C, porcelain 1100°C) are resistant to destruction by fire and, therefore, useful in identification. In dental identification there is a comparison of ante mortem and post mortem radiographs and the data is analyzed based on the facts like presence of teeth. Missing teeth, crown size, pathology present, restorations etc. Therefore, digital records should be maintained for all the citizens of the country for fast and easy identification in cases of mass disaster.[4,36]

Oesterhelweg et al. described a case where the victim died due to respiratory obstruction from a foreign body (food bolus), where virtual autopsy proved to be a boon in solving the case.[39]

Virtibot: Recent Advancement in Virtopsy

Recent advances in the field of medicine are growing leaps and bounds contributing inordinately in various fields of science. Nanotechnology can be defined as the technology that allows control, manipulation, study and manufacture of structures and devices in the nanometer size range.[40]

Virtibot is a Robotic technology that carries out Virtopsies. They are multifunctional robotic system that serves to perform 3D surface scanning and automatic post mortem image guided biopsies. Emerging as a latest technology, the virtibot is a link between forensic science, diagnostic imaging, computer science, automatic technology, telematics and biomechanics. Thus improving the outcome of forensic investigations and better understanding of medical evidence by the law.[41]

Conclusion

Virtopsy is emerging as a indispendible tool for forensic investigations owing to the progress in imagistic domain thus changing the face of conventional autopsy.

Its main benefits scientifically are related to less time consumption and improved data collection. The facility of visualizing and analyzing the 3-D anatomical structures thoroughly, in real time, without mutilating the body is an important achievement along with a possibility of obtaining a second and third opinion for future reference.

Scientifically, role of virtopsy is indisputable along with an immense psychological and cultural advantage on people of certain communities who believe that body and soul are inseparable and thus forbid autopsy.

The age old methods are the launching pads from which we jump into the world of new technology. In forensic science, virtopsy is still developing and getting space along with conventional procedures like Autopsy.

Being costly and highly technique sensitive, it requires well trained experts to perform such procedures but quickly gives valuable information. Both Virtopsy and Autopsy have certain limitations; to overcome these, combination of both can provide highly sensitive and specific results.

"Dead speaks" is an old saying, not in vain, but in order to unearth the truth both Virtual and Conventional Autopsies should go hand in hand.

Conflict of Interest: None.

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