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**Autopsy V. Virtopsy: A new approach for postmortem forensic examination**

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### **Autopsy V. Virtopsy: A new approach for postmortem forensic examination**

In recent years there have been new advancements across the forensic field and in the scientific world as a whole. These advancements have changed many approaches bringing new capabilities and new challenges and pushback. This report takes a specific interest in the evolution of forensic autopsy. With improvements such as magnetic resonance imaging (MRI), computed tomography scan (CT), X-Rays, and other approaches a new term and technique have been coined Virtopsy. As this new potential approach has come to light the resistance against conventional autopsy methods from some cultures and religions has grown stronger. As this controversy has made ground new attention has been directed to this new approach as a possible option for a new standard in the forensic field of postmortem investigations. The shortcomings and strengths of both Virtopsy and autopsy have been observed through many different research approaches. Of course, there are still things to improve on but, does this new technique have a chance of becoming a new standard? Does it truly measure up to the degree of qualifications for its application?

### **Literature Review**

A forensic Autopsy is an investigation of a body post-mortem with the purposes of identifying the dead, the cause of death, the time of death (also known as post-mortem interval), and the manner of death, if necessary. Under widely accepted standards, an autopsy can be conducted by primarily coroners or medical examiners in the United States. Other countries may have legal norms for who conducts an autopsy (1). An autopsy is conducted when there is legal concern warranting an investigation of unexplained, unwitnessed, sudden, suspicious, or criminal deaths. In other words, when there is a death such as homicide, suicide, or accident that would require investigation and collection of evidence (2). There are instances where an autopsy is

conducted without suspicion of criminal activity. For example, if a man were to die in his bed at night, an autopsy may be performed to determine the exact cause of death. In this instance, an autopsy is not conducted for suspicion of a crime and therefore is not considered to be a forensic autopsy. The main goal of an autopsy is to provide clarity substantiated by science around the death of a person in order to understand the manner of an unsuspecting death or the method of unnatural death.

The National Association of Medical Examiners (NAME) sets forth a multitude of standards for a forensic autopsy that lay out the responsibilities, procedures, methods, and strategies for how all autopsies must be conducted and documented. Starting with an external examination these standards require many different physical characteristics to be reported and documented through multiple approaches including photographs and written reports. Similarly, the forensic pathologist would continue the autopsy by recording various post-mortem changes including decomposition changes, livor mortis, and rigor mortis all of which are vital in determining the post-mortem interval also known as, the time since death. In specific circumstances such as sexual assault, firearm injuries, sharp force injuries, and others, there are additional documentation requirements for the Pathologist. This documentation would include but is not limited to swabs, hair combings, photographs, wound measurements, and any other suspicious observations that would warrant further investigation (2).

The next phase of an autopsy is the internal examination. An internal approach requires the examination of body cavities, internal organs, and viscera. Body cavity examination would include notes and pictures of any abnormal or unique marks, wounds, or fluids as well as evidence of surgery. Internal organ investigation would include documentation of the condition, color, and any unique markings, wounds, or injuries. The removal of any medical devices along

with organs is documented and described in order to maintain a clear and concise explanation of the procedures that took place during the autopsy. Additionally, the weights of many vital organs are required in the documentation. Examples of vital organs weighed include the lungs, brain, heart, spleen, liver, and kidneys. The documentation of the autopsy provides scientific support for determining the manner and cause of death as well as offers clear and concise notes regarding the autopsy procedure. These notes will facilitate additional pathologists, prosecutors, and defense attorneys the information necessary for a fair representation of the death in court (2).

The last components of an autopsy are radiography, specimens gathered for lab analysis, and histological examination. Radiography is the use of x-rays to attempt to detect and locate fractures, foreign bodies, or projectiles and to offer more information to assist in identifying the cause of death. Specimens that must be routinely collected and processed with accurate evidence handling include blood, urine, semen, or other fluids for potential genetic testing. Other specimens that may be collected for further investigation may include fibers, skin cells, dirt, or foreign matter that may offer insight into the manner, location, or method of death. A histological examination has the goal of investigating manifestations of illnesses that could have contributed to the cause of death. Histological examinations are microscopic investigations of various tissues to determine the body's health conditions prior to death. All of the specimens, radiology images, and histological notes provide a deeper awareness of the condition of the body and the manner of death through procedural investigation and documentation.

While there is no doubt of the value of the scientific procedure and documentation resulting from an autopsy, there are some who feel an autopsy is too invasive and degrades the body further. Whether it is for religious or cultural reasons, there are many communities that do not approve or permit an autopsy to be performed even when there is a need for criminal

investigation. The Islamic religion as well as the cultures of many Arab countries are examples of communities who do not approve of such invasive treatment of a body following death. In Islamic beliefs, there is a requirement that bodies be buried immediately after death. The Hadith states that “the breaking of the bone of a dead person is like the breaking of the bone of the living person” (3). In other words, the followers of Islam would find the invasive cutting into a body to be disrespectful and harmful to their loved ones. There are many times when the families' wishes are not respected as the investigation of unnatural death warrants an autopsy. This is an example of when forensic science and cultural preferences collide. These universal protests against traditional autopsies have led to an extensive search for techniques that could be alternatives to an autopsy that are minimally invasive and can be conducted quickly in order to observe and respect religious requests.

One option to replace autopsy would be Virtopsy. Virtopsy is a combination of the word virtual and autopsy but this transdisciplinary approach applies the use of many technological advancements by using imaging methods in a clinical setting to facilitate the purpose of an autopsy in searching for a cause of death (4). This approach combines pathology, modern imaging, and general medical knowledge to avoid the invasiveness of traditional autopsies. Some methods applied include 3-dimensional imaging (3D), magnetic resonance imaging (MRI), multislice computed tomography, and traditional pathology. Photography is used as a reference. In this approach, 3D scanning, the 3 dimensionality is viewable on a 2-dimensional level. This projection is created with the use of multiple cameras from various angles using reference markers and true color documentation to create the 3D image. The 3D representations are used to observe and document the external portion of an autopsy and can be compared to assist in the

identification of objects or exit injuries. This is one way in which Virtopsy assists in reconstructing the course of an accident or death.

Magnetic resonance imaging (MRI) offers a multidimensional view of the muscular and skeletal nature of the body without invasive cutting. The images provide a 3-dimensional experience facilitating investigation including measurements. MRIs are most often used to investigate soft tissue injuries and organ trauma (5). MRIs apply the properties of mobile hydrogen nuclei in water fat and tissues in order to create images of internal organs. In soft tissues, there are an elevated number of hydrogen molecules. For that reason, MRIs are able to apply the relaxation and excitement of these molecules to create images of subcutaneous tissue. MRIs offer visualization of the soft tissue quickly without having to cut open the body (6). Additionally, MRIs have great applications that are easily applicable to cases involving surviving victims.

Multislice computed tomography (CT) typically applies a scanner for densities to obtain images of fractures, foreign bodies, and gas. These images facilitate a further noninvasive examination of a body post-mortem and also allows board-certified radiologists to observe even the tiniest of fractures that could have been overlooked in x-rays or traditional autopsies. Additionally, the application of detecting gases assists in identifying pneumothoraces and air embolisms throughout the body (6). These are difficult to detect through traditional means. The use of CTs offers a detailed view to facilitating investigation without an invasive traditional autopsy.

The collection of specimens during Virtopsy would typically be external collections allowing for testing and documentation without cutting open the body. Pathology continues to play a large role in Virtopsy as pathologists examine the specimens collected as well as the initial

external documented procedure. Combining the minimally invasive practices of MRI, CT and 3D imaging along with specimen collection and external examination provide a comprehensive examination without degrading the body. In this way, Virtopsy offers the Islamic community as well as others an option to investigate unnatural deaths while respecting religious and cultural values (7).

While there is tremendous confidence in a traditional autopsy, the power of new technology brings great support for Virtopsy. There have been many studies using each of these methods. As a result, the use of the Virtopsy is supported as well as the use of traditional autopsy. One study conducted by Vasiliki Chatzaraki and others focused on deaths by hanging (7). They applied the use of CTs in order to visualize the intervertebral vacuum phenomenon. The CTs also visualized the presence of bleeding. The goal of this study was to investigate the different factors that lead to complete versus incomplete hangings. They found that when there was an increased occurrence of the intervertebral vacuum phenomenon the chances of a complete hanging increased. They found that increased age and degeneration decreased the chances of a complete hanging. The findings of this study could not have been completed without the use of CT because of the ability to visualize the presence of gas between vertebrae on the CT scans. The CT also allowed the pathologists to view the impact of the bleeding on the scans to understand the severity of the hanging.

A study from the Journal of Forensic Science explored utilizing Virtopsy for the identification of a body post-mortem (8). In this study, an unidentified woman had been found. The forensic scientists used a full body CT to examine bone lesions to determine her cause of death. The scientists were able to estimate the woman's age based on the length of her 4th rib on the sternal end as well as analyze her pubic symphyseal medial articular surface. After



comparing the CT findings to a traditional autopsy's findings, the CT was superior to the traditional autopsy in finding the cause of death because the CT was able to display dental abnormalities used for identification and signs of drowning as the cause of death. Both the traditional and virtual autopsies came to the same conclusions on the woman's age, however, the Virtopsy was able to provide more information to identify the cause of death.

A study from the University Medical Hamburg-Eppendorf explored the application of virtual autopsy through the quality control of an intensive care unit with the goal of determining the validity of a Virtopsy in comparison to a traditional autopsy (9). This study was completed in a cohort approach over a period of time. There were 285 patients involved in the study. In many instances, the patients had long-term medical issues likely resulting in their death. Only 57% of patients were subjected to virtual autopsy however there seemed to be disparities between the virtopsies and autopsies. Virtopsy often missed diagnoses such as heart attacks while traditional autopsy missed many fractures and pneumothoraces. This study shows the value of each approach, however, is not conclusive in the validity of each method. Additional investigation is needed to determine the study's goal.

A 2009 study from the Department of Radiology at Erasmus University Medical Center Rotterdam, Netherlands investigated the ability of a minimally invasive approach to autopsy in comparison to a traditional autopsy so as to confirm the validity of the Virtopsy (10). There were 30 bodies used in this study where CTs and MRIs were used to explore the cause of death. A traditional autopsy was then performed on each body and compared. 77% of the minimally invasive Virtopsy agreed in the cause of death findings with the traditional approach. The Virtopsy was determined to be very sensitive in finding brain abnormalities, air embolisms, pneumothoraxes, and calcifications.

Another study conducted in 2018 explored 25 post-mortem cases with the goal of investigating the possibilities of using cutting-edge virtopsy (11). The procedure was to complete a virtopsy prior to a traditional autopsy in an effort to compare the findings. In 65% of the cases, the cause of death identified by virtopsy matched the traditional findings. 35% the findings required the use of a traditional autopsy. Throughout the study, 2 different forensic pathologists completed the same procedures with nearly identical findings. Overall, they came to the conclusion that virtual autopsy was more beneficial for traumatic deaths than for other causes of death. In other words, deaths from hemorrhage such as a hit and runs or shooting would be easily identified through a virtopsy while a heart attack in bed would likely have required a traditional autopsy.

Autopsy and Virtopsy have their place in the world of forensic pathology. Each has proven a unique value and use. While they often result in identical findings, preferential use based on the suspected cause of death may prove necessary for ongoing success. In other words, knowing a death was likely the result of trauma would indicate the use of a virtopsy would be superior while if the conditions around a death were not traumatic this may suggest a traditional approach.

## **Discussion**

Following an in-depth review of many sources, it is my considered opinion that Virtopsy should be accepted as a new standard of practice for postmortem investigation of human corpses, or at least be the first choice unless different conditions suggest that the investigation may warrant a traditional autopsy. There are many implications to the inclusion of this method. I will discuss what will be required to fully integrate this approach as well as the financial factors of

this standard as I feel that finances will play a large role in the overall ability to move forward with the use of this approach.

The goal of an autopsy in a forensic investigation is to investigate a death independently but cooperatively with law enforcement to evaluate all of the circumstances connected with reported deaths to find the cause and manner of death. In a traditional autopsy, dissections are completed on all removed organs and at the discretion of the forensic pathologist additional tests can be completed to gain more insight into the conditions surrounding the death (2). With that being the typical starting point for forensic autopsy I am presenting that Virtopsy could be used as the new first line of investigation. After a death has occurred and is ruled suspicious and in need of a forensic autopsy both could first be examined through a thorough external investigation of the corpse as normal followed by a virtual “dissection” through a Virtopsy approach. The imaging, blood tests, and external observations could then assist in deciding if a traditional autopsy is warranted or if the necessary conclusions could be drawn with the information obtained. That being said the standard that has been set for interpretations and opinions in a forensic autopsy is that they review all collected lab reports, consult reports from other pathologists, investigation reports, and medical history (when relevant) to draw conclusions about the cause of death.

Virtopsy implicates an up-and-coming generation of technology including multislice spiral computer tomography (MSCT) and MR scanners from GE with spectroscopy software also known as MSCT creates three-dimensional images at high resolutions of the internal aspects of a body. MRI uses a large magnet to capture images of the internal aspects of a body in a slightly different way (12). I found support for my argument through a study completed in 2007 by a team at the Institute of Forensic Science, Center for Forensic Imaging/Virtopsy, at the University

of Berne in Switzerland. They looked at many cases and their MRI and CT results correlated with autopsy taking a closer look at the recommended indications for both using pathology as the key factor. With the number of cases that come through a year time is money and the ability to complete autopsies with accuracy and speed. A typical scan time for a CT is 1-10 minutes and when compared side to side with traditional autopsy CT was superior in spotting fractures, pathologic gas collections, and gross tissue damage. As an added benefit CT imaging is very useful and helpful when it comes to testifying in court and presenting findings to a jury. CT and MRI are also excellent in the visualization of bullet courses and the accompanied bleeding. The largest complaint that comes with CT analysis is due to the death of the patient it is not possible to use IV contrast to allow for a CT to analyze vascular problems and parenchyma.

MRI's have been found to excel in showing soft tissue injury, non-neurological organ trauma, and non-traumatic pathology in sensitivity, specificity, and accuracy. Additionally, MRI was performed at a higher level at demonstrating contusion, shearing injuries, subdural hematomas, metabolite concentrations within tissues (very useful in determining the time of death), and visceral pathology. A virtual autopsy also allows for body regions that are not traditionally dissected in a conventional autopsy such as soft tissue back spine and it is quite often found that there are typically relevant findings that go unrecognized in the inability to adequately investigate these regions. This specific article was great at discussing the shortcomings of both MRI and CT and they also offered a secondary solution, this process called micro-MR and micro-CT which includes microscopic techniques they are a noninvasive approach to obtain imaging with a higher resolution to visualize specific forensic specimens when there are more questions about the injuries after viewing MRI and CT results. This addition to virtual autopsy, applying a histopathology approach leading to a virtual histology

report really helps to bridge the gaps in the shortcomings of MRI and CT (12). An additional bonus in the use of forensic Virtopsy is that overtime if the deceased has had X-rays, MRIs, CTs, or any other types of scans they can be compared with their postmortem scans in order to assist in understanding the patient's life and how they died.

Of course, I would be remiss to not expand upon the obstacles that come with the inclusion of this approach as a new standard. As I have previously stated there are some shortcomings of the technology as well as there some diagnoses that are not possible to obtain from virtual topsy. Additionally, the benefit of a virtual autopsy is a faster process, and allowing for more cases to be processed conflicts with the current requirements of a forensic pathologist being unable to perform more than 325 autopsies a year. Another issue that stands between Virtopsy and its integration is the training that forensic pathologists receive. They can easily analyze all the results from reports after CT and MRI imaging but many of them are not certified in radiology, therefore, they will need to be an addition to the team that investigates suspicious deaths that can read and interpret CT and MRI images.

An investigation by an assistant professor in the department of forensic medicine at Jawaharlal Nehru Medical College, a College in India, discussed many of the benefits and drawbacks of forensic autopsy as well as he includes polls from medical professionals on their opinion of virtual autopsy (13). He cites many of the same barriers as have been previously stated however he additionally discusses the difficulties in the inability to directly visualize color changes, texture changes, consistency, and smell of organs and body cavities. And of course, he states the largest barrier which is the lack of judicial validity as that is still up for debate. There was a large percentage of medical professionals when asked about virtual autopsy expressed concerns about digital privacy within the use of virtual autopsy and additionally, there were

concerns again about the cost. It is also important to note that this article discusses the importance of reviewing feedback and acknowledging technical errors in order to obtain all-inclusive training for this potential innovative technology on the horizon. There are multiple other reports that had expressed similar interest in this attitude of transparency. The scientific community as a whole only thrives through the ability to converse and exchange ideas, allowing things to be under intense scrutiny in order to maintain the validity of practices.

A journal, *Seminars in Ultrasound, CT and MRI*, associated with many different radiologists and forensic pathologists from a multitude of different universities from different countries worked together to present an argument on virtual autopsy, why we should do it when it could be integrated, and how could we get there (14). A significant factor that they came to discover through their time of investigating together across disciplines was similar to the statements shared above; that *only* an intensely intertwined cooperation between both radiologists and forensic pathologists with strong backgrounds in the standardization of a reliable virtual autopsy can produce a successful virtual autopsy. It is this cross-disciplinary work that makes this approach possible. It's important that radiologists can be able to adopt a forensic or investigative approach in their techniques in order to maintain the preset standards and requirements of the forensic autopsy processes. The virtual autopsy itself has also been made a new subspecialty of radiology it is possible that starting a new one down the line forensic virtual autopsy will also have its own official subspecialty within the department of forensic pathology.

It is this noninvasive and less or nondestructive approach that overall adds a simplification to the work of a forensic autopsy (15). This process helps identify the deceased's identity, locate and demonstrate foreign bodies, and overall makes it easier to demonstrate and share in court in a way that's more accessible to the greater population.

**Conclusion**

Forensic autopsy is just a small part of an even greater department of forensic science as a whole. It integrates forensic biology, chemistry forensics, physics forensic, and many other disciplines. The forensic community has always been, and will always be a collaborative, innovative, truth-seeking, and resolution-giving community. Forensic science realizes strongly on a collaborative backbone where different forensic scientists can work together in order to analyze different components of cases and compare data and results in order to come to conclusions that are verified, reliable, and accurate. Forensic science has grown so much in the past fifteen years, and it will continue to grow from here. This innovative spirit that drives the forward-focused individuals within the forensic science community branches from an origin in which forensic scientists seek answers and ways to solve cases in new unprecedented ways. This need to find answers comes from the basis of forensic science, seeking the truth receiving specimens, objects, and corpses and making sense of what happened to give answers and assist in investigative efforts. The forensic science community seeks the truth in order to be a community that gives peace and resolution. Whether it is peace to the families who have lost a loved one or peace to communities who feel unsafe following a crime and countless others the work done by forensic scientists allows for criminal investigations to obtain all of the facts and move forward from there in order to get answers.

Based on all of these principles of forensic science, I offer virtual autopsy as a viable addition to forensic pathology investigation. A traditional autopsy undoubtedly offers many of the answers needed for an autopsy however virtual autopsy bridges this gap and simplifies this process in order to make it a more streamlined, advanced, and reliable process. It's important to

mention that the option of virtual autopsy as an alternative to traditional autopsy gives peace to community members of religious and cultural practices that are against a traditional autopsy.

As previously discussed, there are benefits and drawbacks to both forms of autopsy however there are a few specific drawbacks that I would like to discuss further I think one of the largest drawbacks is rooted in the cost that comes with a virtual autopsy. For that reason, a virtual autopsy isn't really an option in underdeveloped countries because they do not have the financial ability to add this approach to their methodology. However, in the United States and a few other countries across the world, there have already been some labs dedicated to the implementation of some of the ideals of virtual autopsy like leaning more heavily on X-rays and other imaging like that. And for that reason, I think that while the initial investment of purchasing the expensive machinery for this technology seems daunting in the long run it'll save more money and time overall. Hospital implementation of minimally invasive autopsy: A prospective cohort study of clinical performance and costs is a journal that boiled down all of the expenses that come with CT and MRI as well as a traditional autopsy (16). A traditional autopsy has a mean expense of €991(1,027.24 USD) including the use of brain biopsies period however, the mean expense of a CT is €117(121.30 USD) and an MRI is €215 (222.90 USD). This would be not considering the expense that comes from the original purchase of the equipment however you can see that the expense is much less when it's a CT and an MRI instead of a traditional autopsy.

Another significant issue that was discussed earlier in this report was the idea that IV injections of contrast fluid for CT are not easily administered to a deceased person. However, A comparative study of vascular injection fluids in fresh-frozen and embalmed human cadaver forearms, published in the Journal of Anatomy, discussing the injection of fluids for vascular



infusion in cadavers spoke of alternatives that could assist in the eventual use of contrast fluid for CT in postmortem investigation (17). This article only focused on the arterial system of the forearm however more research is needed to focus on vascular injection of different organ systems like the lymphatic or venous systems. It's not a perfect science yet and there is still a lot more research to go before this addition to virtual autopsy could be made however you can still use a traditional basic CT without contrast and get wonderful images showing findings that you can't easily see a conventional autopsy. Countless more doors will be opened following the research and discovery of a CT contrast fluid that can be used in postmortem investigations.

The next shortcoming, I would like to talk about isn't really a shortcoming it's more just an obstacle. In the accepted recommendations and regulations by the National Association of medical examiners, it has been stated that no more than 325 autopsies can be completed by any one forensic pathologist in a single calendar year (2). However, I think that further review will need to be done on this specific limitation because if a virtual autopsy was allowed to be integrated a lot of the work that comes with a traditional autopsy would be eliminated and therefore there would be less burnout and fewer mistakes. Once this limit has been extended the use of virtual autopsy can assist in the processing of forensic autopsies. The ability to process forensic autopsies quicker is just the tip of the iceberg. It's also important to note that once a virtual autopsy is integrated into the standard methods of forensic autopsy the records of these specific CT and MRI images and any other imaging used will be easily accessible and viewable to future or outside medical examiners. This is one limitation of a conventional autopsy, once an autopsy has been completed the body is, typically, then released back to the family. The virtual autopsy images and tests obtained won't change and are easily shareable across the forensic community forever.

**Recommendations**

My proposed recommendation for the forensic autopsy community moving forward is the integration of virtual autopsy into the new standardized methods. My recommendation for the procedure is as follows. I would recommend that the forensic pathologists first complete an external examination followed by a virtual autopsy through a partnership with a forensic radiologist or certified radiologist followed by any necessary further biopsies and pathology reports. All of this would be as noninvasive as possible. Then just as in a traditional autopsy the forensic pathologist would review all of the investigative reports medical records laboratory results and images and use their own discretion to identify if the cause and manner of death were found to the necessary requirements of a forensic pathologist. If it is found that the information collected is not sufficient to give adequate evidence and conclude the manner and cause of death it is my recommendation that they would then proceed with a conventional traditional autopsy if needed. In this step, I believe it's vital that the radiologist and forensic pathologist work closely not only together but with other consulting forensic pathologists and radiologists in order to make this decision as collectively as possible. At this point, the largest obstacle still in the way is admissibility in court so it is my recommendation that the forensic science community sits down with legal personnel in order to assist in furthering the admissibility and approval of a virtual autopsy in court. Once this admissibility is received it is now time to share all of this information with the investigating officers and eventually testify. At this time not only would the data found in the virtual autopsy would be discussed but also some of these images would be used to explain to a jury what happened, how it happened, and why someone died. I think this is one of the strongest aspects of the argument in favor of virtual autopsy. At the end of the day as a forensic pathologist, you will be called to testify. When you testify you have to be able to relay your

information as well as you can to a jury that is full of the general population. Not all of them will have medical knowledge or forensic knowledge and for that reason, the ability to show images that will have limited blood or disturbing features in order to assist in explaining what happened will help the jury get a better idea of what happened and assist them in coming to conclusions.

The forensic community as a whole, as previously stated is a community that strives to always have the newest, best and most accurate approaches to investigating a crime. A virtual autopsy is just that and the integration of a virtual autopsy into the standardized normal methods of a forensic autopsy is a valid choice moving forward. After receiving the appropriate approvals at the legal level and furthering research into all of the many ways these approaches can be helpful in forensic autopsy the possibilities are endless.

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