Original Article

1.5 ANCC Contact Hours CE

Postmortem Computed Tomography: An Overview for Forensic Nurses Involved in Death Investigation

Sophie A. Stanley, BSc(Hons), MBChB(Hons)[1], Guy N. Rutty, MBE, MD, MBBS, FRCPath, DipRCPath(Forensic), FCSFS, FFFLM, AFHEA, DipIMC[2], and Jane E. Rutty, PhD, MSc, BSc(Hons), DPSN, RGN[3]

ABSTRACT

The traditional invasive autopsy has been considered the "gold standard" for death investigation worldwide. However, this has now been challenged by a new minimally invasive approach that utilizes cross-sectional radiological imaging to investigate the death. Globally, postmortem computed tomography is the most commonly used modality and is becoming increasingly available throughout the world. Forensic nurses working in association with coroners and medical examiners' offices, as well as mass fatality incidents, now need to update their knowledge base to understand these innovative techniques, the advantages and disadvantages to their use, and how they impact on medicolegal death investigation and the care of the deceased and bereaved. Using the example of the coroner system of England and Wales, this article provides a comparison between the traditional invasive autopsy and postmortem radiological alternatives and presents the impact postmortem radiology is now having on death investigation.

KEY WORDS:

Autopsy; coroner; death investigation; forensic nursing; forensic pathology; medical examiner; postmortem computed tomography; postmortem radiology

For the last 30 years, a slow revolution has been occurring to a medical procedure, which can trace its core processes and principals back thousands of years: the autopsy. Depending upon where one lives or dies within the world, no longer may one's death be investigated solely through the invasive surgical procedure of the autopsy. Rather, depending upon the nature of the death and the country where the death has occurred, the traditional autopsy examination may instead be enhanced or even replaced by emerging radiological examination techniques.

Forensic nurses, specifically those involved in death investigation and mass fatality incidents across the world, need to be informed of the global changes that are occurring in death investigation, as these changes may impact their own practice. Using the example of the coroner system within England and Wales, where the way death is investigated is undergoing significant change, we provide an overview of the use of cross-sectional radiology imaging for death investigation. We compare the processes associated with the traditional autopsy against postmortem imaging processes to provide an understanding of the differences between the two systems. We discuss the advantages and disadvantages of the use of the new approach so when forensic

Author Affiliations: *[1]University Hospitals of Leicester, [2]East Midlands Forensic Pathology Unit, University of Leicester, and [3]Faculty of Health and Life Sciences, De Montfort University.*

The authors declare no conflicts of interest.

Correspondence: *Jane E. Rutty, PhD, MSc, BSc(Hons), DPSN, RGN, Edith Murphy Building, Faculty of Health and Life Sciences, De Montfort University, The Gateway, Leicester, LE1 9BH, United Kingdom. E-mail: JRutty@dmu.ac.uk.*

Received October 16, 2019; Accepted for publication March 15, 2020

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site (www.journalforensicnursing.com).

DOI: 10.1097/JFN.0000000000000288

nurses are involved in decision-making processes related to death investigation, they are informed of the extent and limitations that cross-sectional imaging offers.

As with any overview, the depth to which the subject can be presented is limited. However, we hope that this article will stimulate the reader to further read around the subject to consider how this change may or may not impact their own local practice.

Autopsy Practice Is Changing

The autopsy, from the Greek word "autopsia" meaning "seeing with one's own eyes," is a surgical examination of a body after death. Existing in one form or another for several thousand years, its basic purpose is to determine *who* the person was and *where*, *when*, and *how* they died (Burton, 2010).

In England and Wales, an autopsy may take place for two reasons. First, where the cause of death is unknown or is suspected to be unnatural, a medicolegal autopsy may be authorized by a coroner. Such examinations form the commonest type of autopsy undertaken. If the cause of death is still undetermined following the autopsy or suspicious circumstances are suggested, the coroner will begin an inquest to investigate the death further. Relatives cannot refuse a medicolegal autopsy; however, they are able to have a doctor (physician) of their own choice to be present, at their own expense (The Coroners and Justice Act 2009).

Second, the clinical team caring for the patient before their death may request a so-called "hospital" or "permission" autopsy. The purpose of a hospital autopsy may be to sample tissue for research purposes or consider the efficacy of novel treatments and is therefore primarily educational or informative to the clinicians or relatives. Before a hospital autopsy can be performed, formal consent must be obtained either from the deceased prior to death or, following death, their relatives, or the individual deemed to be in legal possession of the body should no relatives exist. In the wake of the United Kingdom Bristol and Alder Hey organ retention scandals, where organs and tissues were retained at postmortem examinations without the consent or knowledge of the families, today there is a strict code of practice published by the Department of Health, which health professionals are required to follow when a hospital autopsy is requested (Department of Health, 2003; Human Tissue Act, 2004; National Health Service, 2018; Sque et al., 2008).

Conventionally, the "gold standard" for determining the cause of death has always been considered the invasive autopsy. Although the nature of the autopsy examination is not described in law, traditionally, it comprises an external and internal examination plus relevant laboratory investigations where necessary (Royal College of Pathologists, 2002). In 2017, there were 85,600 coroner's autopsies in England and Wales, which equate to the investigation of 37% of reportable deaths by autopsy (Ministry of Justice, 2017). Many of these deaths were from natural causes, with only approximately 2,000 deaths per year being investigated as so-called "forensic" investigations. It has thus been questioned as to why so many natural deaths occurring in the community are being investigated through this process and whether an alternative means, without invasive dissection, where the cause of death for natural death need only be given to the legal level of "a balance of probabilities," is possible.

There is a general perception that the public object to the traditional invasive autopsy. However, a recent survey found that the overwhelming majority of the public do not object to such an investigation if authorized by the coroner (G. N. Rutty & Rutty, 2011). Nevertheless, these opinions, in addition to concerns over the accuracy of invasive autopsy findings, religious considerations, and the observation that postmortem computed tomography (PMCT) may be a viable alternative to the invasive autopsy, have motivated the medical profession to pursue alternatives to the invasive autopsy (J. E. Rutty, 2010; J. E. Rutty et al., 2015; The Coroner's Autopsy: Do we deserve better?, 2006). Evidence of changing practice is presented within the 2017 Coroners Statistics, which revealed that there was a 120% increase from the previous published year in the use of PMCT as an alternative to the invasive autopsy, with two thirds of coroners' areas utilizing PMCT at some point, a trend anticipated only to increase (Ministry of Justice, 2017).

Although cross-sectional imaging was first used as an adjunct to investigate the dead in 1983 (Krantz, 1983), Donchin et al. in 1994 were the first to use the terminology of "postmortem computed tomography" and proposed PMCT as not only an adjunct but a potential replacement to the invasive autopsy. They challenged the concept that the autopsy was not the "gold" standard to death investigation by showing that, in fact, PMCT could identify more findings than a traditional invasive autopsy (Donchin et al., 1994).

As a consequence of the proposal put forth by Donchin et al. (1994), the use of PMCT as both an adjunct and, more recently, a replacement for the invasive autopsy has slowly gained international acceptance. Use of the PMCT has grown rapidly over the past decade due to the significant increase in the quantity of research available to support the translation of cross-sectional radiological imaging from the living to the dead, as well as technological advancements and increased access to cross-sectional scanners by autopsy practitioners (Baglivo et al., 2013). With the foundation of the International Society of Forensic Radiology and Imaging (n.d.), practitioners within the field from across the world have come together to promote the expansion of this field of practice. Despite its relative infancy, this has resulted in postmortem radiology (PMR) being adopted globally to the extent that mortuaries across the world, including in the United Kingdom, now have dedicated scanners within them (Rutty et al., 2008). This is enabling PMR to form a

routine part of an autopsy examination (National Health Service, 2018; O'Donnell & Woodford, 2008; G. N. Rutty et al., 2008). G. N. Rutty and Morgan (2017) have predicted that PMR, most probably in the form of PMCT, will become the dominant form of death investigation within the next few years.

What Are the PMR Alternatives?

The radiological techniques used in postmortem practice are the same as those available in everyday clinical practice in the living, for example, plain film X-ray, fluoroscopy, computed tomography (CT), and magnetic resonance imaging. MicroCT, a system often encountered in geology or engineering, is an emerging technique, although currently its full potential has not been realized as few have access to it (G. N. Rutty, Brough, et al., 2013). Used as an adjunct to autopsy practice since 1896, radiology has traditionally been utilized to investigate the identity of the deceased or the cause of death in suspicious circumstances, for example, firearm, explosive, fire, and nonaccidental childhood deaths (Eckert & Garland, 1984).

Although referred to previously by terms such as the virtual autopsy, Virtopsy, digital autopsy, and so forth, the internationally agreed terminology for this field of practice, as defined by G. N. Rutty, Brogdon, et al. (2013), is PMCT and/or postmortem magnetic resonance (PMMR) imaging. Of these techniques, PMCT is the more frequently used technique both within the United Kingdom and internationally due to its availability, speed, and cost and the overall diagnostic information abilities it can provide.

The CT technology is the same as that used in living patients. A scanner rotates around the patient taking multiple X-ray images at different intervals. These images are combined using software to generate a three-dimensional reconstruction of the body. From these reconstructions, pathologists and radiologists can examine the entire external and internal structures of the body, from head to toe, to assess for natural or unnatural disease and trauma processes.

The combination of external examination with postmortem cross-sectional imaging is now challenging the "gold standard" of the invasive autopsy. Originally challenged by Donchin et al. (1994), several authors have shown that PMCT can identify more pathology that may be observed by autopsy alone and that, should all pathology be wished to be identified, the combination of PMCT and invasive autopsy should be considered as the new gold standard (Donchin et al., 1994; Grabherr et al., 2018; Jeffery et al., 2011).

First proposed in 2004 by Rutty and Swift, the expansion of postmortem cross-sectional imaging has led to the development of a subspecialty termed "necroradiology," for which specific postgraduate professional training programs, as exampled by those provided at the University of Zurich, Switzerland, and the University of Leicester, England (refer to Supplemental Digital Content 1, http://links.lww.com/JFN/A46), have been recently created to equip clinical radiologists, pathologists, radiographers, and forensic anthropologists with the skills they require to work within this emerging field of practice (O'Donnell & Woodford, 2008; G. N. Rutty & Swift, 2004; Schneider et al., 2012).

As with all new technology in medicine, although the process has been ongoing for over 30 years, PMR has undergone rigorous investigation, particularly over the past 15 years that has certified its validity as an adjunct, or now as a replacement to the traditional invasive autopsy. This research has been necessary to bring about the significant change in autopsy practice that has now occurred (Grabherr et al., 2018; Lathrop & Notle, 2016; G. N. Rutty et al., 2017; J. E. Rutty et al., 2015).

How Do the Processes Differ? The Principle of Triage

Apart from the potential lack of an invasive component to the death investigative process, the principal difference between the different approaches to death investigation is one of so-called "triage." To consider this process, we will first consider the basic steps of the traditional autopsy examination, as exampled by practice within England and Wales, followed by the steps in a PMCT examination.

The Traditional Invasive Autopsy Procedure

Depending on the nature of the death and where in the world the death occurred, the traditional invasive autopsy may not take place on the day of the death. In England and Wales, unless the death is suspicious, a delay of several days between the death and the examination is normal. The examination, which can be undertaken by a medical practitioner or any person whom the Chief Coroner deems appropriate to undertake the examination (Section 14, Part 3 The Coroners and Justice Act 2009), comprises a series of procedures providing a full postmortem examination, although limited autopsies (e.g., focusing only on one organ system or body cavity) can also be performed on the instruction of the coroner (see Figure 1):

1. *Clinical history*. Similar to any clinical examination in the living, key to the investigation is that the pathologist should be provided with as much clinical information as possible regarding the deceased's past medical history, drug history, allergy history, history related to the circumstances of the death, and the scene of discovery prior to the commencement of the examination.
2. *External examination*. The most important part of any autopsy is the external examination. This records the identifying features of an individual; any external signs of natural disease, any historical or recent injury, and the presence and

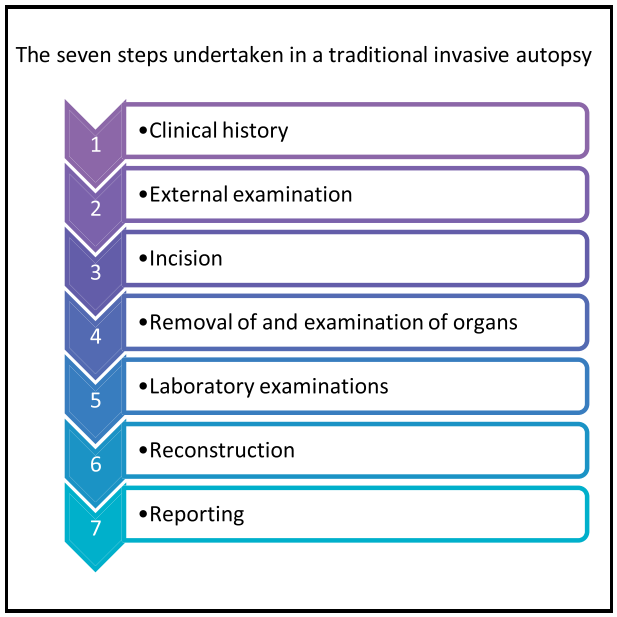

FIGURE 1. The seven steps undertaken in a traditional invasive autopsy.

consequences of medical intervention, as well as the presence of postmortem changes and the decomposition state of the corpse.

Depending upon whether the death is considered suspicious or not, evidential samples such as swabs for DNA transference or tapings for fiber transfer are collected as part of the external examination and handed to the police for further examination.

3. *Incision.* An incision is made to gain access to the internal organs. One is made to the head to gain entry to the cranial cavity and another to the body to examine the neck, chest, abdominal, and pelvic organs. These can be extended, depending upon the case to examine the face as well as the back and limbs of the deceased. The form and extent of the incisions and dissections undertaken depend upon the individual being examined.
4. *Removal and examination of organs.* All major organs are removed and weighed. The removal can follow one of the four classically described methods (Letulle, Vichow, Rokitanbsky, or Ghon) or be case specific. The weight of an organ may vary in accordance with the height, weight, and thus body mass index of the individual, as well as the presence of disease processes, for example, the weight of the heart and lungs may increase in heart failure.
5. *Laboratory examinations.* Tissue samples may be taken from some or all organs for histology as well as appropriate samples for toxicology, biochemistry, serology, genetics, microbiology, and so forth, depending upon the circumstances of the death and authority provided.
6. *Reconstruction.* Once the examination is completed, all organs are returned to the chest and abdominal cavity. The incisions are sewn closed, and the body is made presentable. Relatives often view the body, prior to funeral arrangements, once all autopsy work is complete;
7. *Reporting.* The pathologist will then report their findings to the coroner, who will decide what further action to take. If a cause of death could not be identified or the death was suspicious, an inquest is launched. For the family of the deceased, this means that the body may not be released for the funeral until all investigations and the inquest are complete, which may take several weeks. A copy of the autopsy report can be made available to the family upon request. It is usually advised that this is facilitated through their general practitioner who can assist them with understanding the content.

What Is the PMCT Process?

The procedure for PMCT differs somewhat from that of the traditional invasive autopsy. It is a triage-based approach, which works on the principal that each step proceeds to the next, but once the answers to all the questions posed in any particular death investigation are answered, the process stops (see Figure 2). Thus, the process changes to become:

1. *Clinical history.* As with the traditional invasive autopsy, as much clinical information should be gathered for consideration prior to the external examination.
2. *External examination.* As in the traditional invasive autopsy, an external examination is performed. It is essential that this is undertaken to the highest standard possible. External exhibits can be taken as required at this stage;

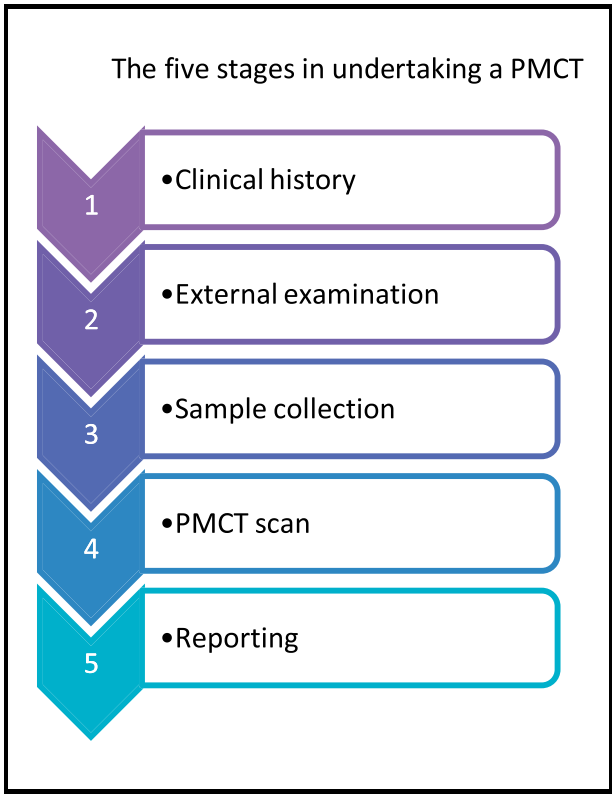

FIGURE 2. The five stages in undertaking a postmortem computed tomography.

3. *Sample collection.* As PMCT may require the use of enhanced imaging techniques, specifically the use of postmortem angiography, which, depending upon the type of angiography process undertaken, can interfere with subsequent laboratory examinations, it is advisable to retrieve samples for toxicology, microbiology, and so forth, at this stage. This requires the use of a needle insertion or small local incision to gain access to a suitable vessel. Thus, PMCT is *not* a noninvasive procedure, but rather a minimally invasive procedure as even inserting a needle into the body is considered an invasive procedure (Palmiere, Egger, et al., 2015; Palmiere, Grabherr, & Augsburger, 2015; G. N. Rutty, Smith, et al., 2013).
4. *PMCT scan.* The scan is undertaken. This could be achieved using a dedicated mortuary-based scanner, a scanner within a clinical area where access is granted for use with the dead or a truck-based scanner as exampled in mass fatality incidents. The deceased is placed on the scanner table, within a closed body bag (without the need to undress), and passes through the scanner (see Figure 3). The scan is performed by specially trained personnel, usual radiographers, although in the case of mortuary-located scanners, trained mortuary technicians may undertake the scanning.

Depending upon the circumstances of the death, certain procedures may be necessary to enhance diagnostic interpretation. As in the living radiological contrast medium may be required to be injected into the body to see the blood vessels (PMCT angiography; Grabherr et al., 2016) or it may be necessary to inflate the lungs to visualize the lung fields better by an airway tube being placed through an incision into the neck (ventilated PMCT; Robinson et al., 2014) or both. Biopsies can be taken for histology or microbiology diagnosis in the same manner as a clinical CT biopsy. It is beyond the scope of this article to expand upon these additional techniques; please refer to the recommended additional reading resources for further information (See Supplemental Digital Content 2, http//links.lww.com/JFN/A47) .

After the scanning, any tube that has been inserted is removed, and the incisions are closed. However, the sutured sites will still be visible.

FIGURE 3. A deceased patient undergoing postmortem computed tomography.

5. *Reporting.* The scan will then be interpreted. This can be by a radiologist trained in PMR interpretation or a pathologist with experience in postmortem imaging working under the governance of a radiologist.If the cause of death is apparent, then the investigation can stop at this stage and the outcome reported to the coroner. However, if the cause of death cannot be established with sufficient certainty, then the investigation will continue to a limited or full invasive autopsy, potentially with additional laboratory investigations, that is, the death is triaged through a process stopping only when all the questions to be answered are answered.

Traditional Invasive Autopsy Versus the PMR Autopsy

The PMR autopsy was developed for both sociocultural and technological reasons, meaning there are advantages to the procedure for both the public and pathologists. Having said that, there are a number of limitations to the procedure that those using the technology must be aware of.

First, a PMR procedure is neither necessarily more rapid nor cheaper but is less invasive than a traditional autopsy; for example, if religious reasons are the reason for opting for this approach. PMCT has been reported through a number of international studies to identify more pathologies and diagnostic findings than the invasive autopsy alone (Donchin, 1994; Grabherr et al., 2018; Lathrop & Notle, 2016; G. N. Rutty et al., 2017). The less invasive approach is more aligned with beliefs about protecting the body from alteration after death for certain religions such as Judaism and Islam (J. E. Rutty, 2010). Depending upon the setup of the local service, the rapidity of the procedure may expedite the examination and release of the body earlier to the relatives (Robinson et al., 2019). This enables earlier humane disposal, thus benefiting all families wishing to proceed with funeral processes, not only those that require burial or cremation within 24 hours for religious reasons, for example, Islam.

In addition, as PMCT provides a permanent detailed record of the body after death, it permits a so-called "virtual exhumation" (Saunders et al., 2011). This allows the findings, without prior disruption that would be caused by an invasive autopsy, to be revisited at any time (as long as records persist for purposes such as audit or second independent examination), thus questioning the need for a second invasive autopsy examination, which causes long delays in body release and distress to the relatives of the deceased (Chief Coroner, n.d.).

There are advantages to PMCT over the traditional autopsy for pathologists. The scanning procedure allows everything and anything to be scanned, that is, animate and inanimate. This is advantageous in cases of fragile remains, which may be significantly damaged if they are disturbed confounding investigations into the cause of death. In cases where there may be potentially harmful items in or around

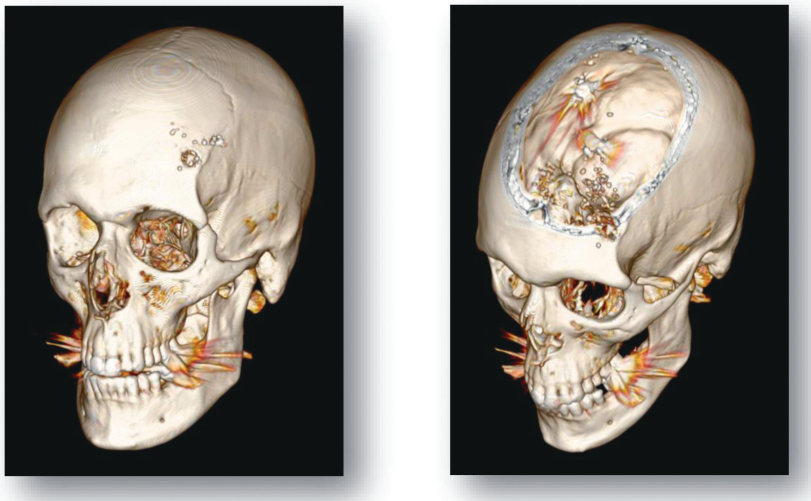

FIGURE 4. Example of postmortem computed tomography images of trauma cases: Gunshot injury to the head showing entrance wound to the left side of frontal bone with projectile path to the right side of cranial cavity.

the body, for example, bullets or sharps, prior imaging may also protect pathologists and technicians from harm. As scans do not alter the body, it is preserved for a subsequent traditional autopsy if this is required.

There are other uses of the images. For example, images produced by PMCT may be more informative and palatable for members of the public representing the jury in a court case than autopsy photographs. Three-dimensional printed computer graphical models can be produced for court presentations with key features highlighted and magnified. They can also be used for educational purposes, for example, in the teaching of anatomy within nurse education (see Figures 4 and 5; J. E. Rutty et al., 2019) as well as for identification purposes in mass fatality investigations (Biggs, 2019).

Lastly, the scanners within hospitals, used to assess living patients, can be used for postmortem investigation without any physical modifications. If purchasing a scanner for a mortuary and one cannot afford a new machine, the use of used equipment is a perfectly acceptable means of getting a service started with reduced equipment costs. Mobile CT scanners can be used for mass fatality examinations (G. N. Rutty et al., 2019). The production of standardized scanning protocols minimizes any variability between scanning locations, meaning that the procedure is not dependent on an individual specialist being present with the body. Thus, the production of transferable images allows multiple international specialists to be involved in their interpretation potentially improving the diagnostic accuracy for the cause of death (G. N. Rutty, 2018a, 2018b). The International Society of Forensic Radiology and Imaging has produced a number of positional statements on the use of PMCT for mass fatality investigation, the latest concerning the introduction and use of the new INTERPOL form for PMR for mass fatality investigation (G. N. Rutty et al., 2018).

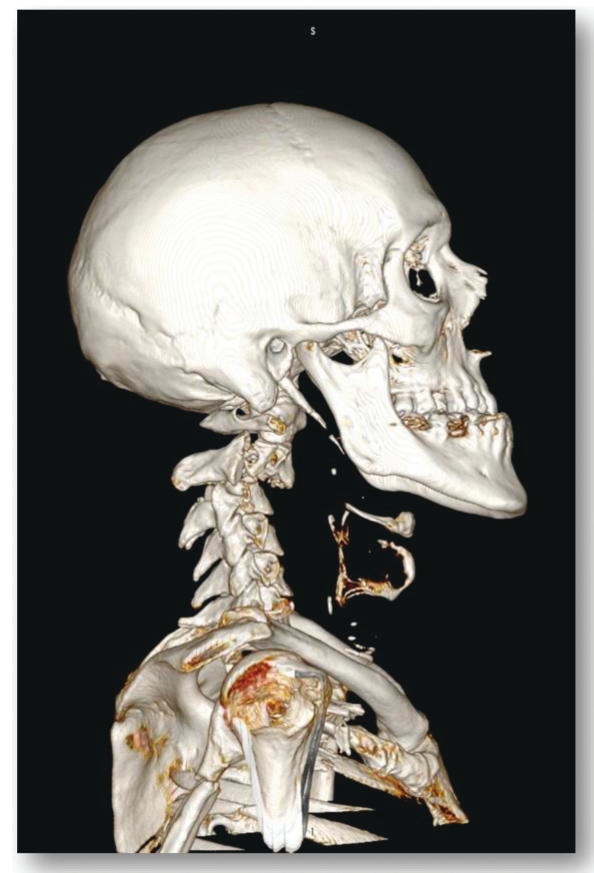

FIGURE 5. Example of a postmortem computed tomography image of trauma case: Displaced fractured neck sustained by road traffic collision.

As with all investigations in medical practice, PMCT does have limitations. Bruises, abrasions, and, depending upon their size, lacerations and incised wounds cannot be visualized with enough clarity to solely rely upon the use of PMCT to examine a body. This is why a thorough and high-quality external examination must be undertaken in all cases prior to scanning. The person reporting the images should be made aware of the findings of this examination. Contusions and penetrating injury paths may also not be visualized with sufficient confidence; hence, if the death is considered suspicious or known to have been subject to a blunt trauma or penetrating assault, PMCT becomes an adjunct to the investigation, and triage to invasive autopsy is usual. Research has shown that it is less effective for diagnosing certain conditions such as coronary artery disease when angiography is not undertaken and pulmonary thromboembolism or gastrointestinal hemorrhage with or without angiographic enhancement compared with the invasive autopsy (Roberts et al., 2012; G. N. Rutty et al., 2017). Thus, the use of PMCT angiography and ventilated PMCT is becoming standard in PMCT services to overcome the limitation posed by nonenhanced imaging.

Clinical radiology is of course subject to interpretation errors, and thus, if PMCT is used as a replacement, for example, of natural death, one can argue that the diagnosis provided could be wrong. This would be unacceptable within a homicide forensic investigation, which is why, to date, PMCT remains an adjunct to such investigations. However, as it would be exceptional for all deaths within any given country to undergo autopsy examination, there will be an inevitable cause of death error rate within those deaths not subject to such investigation (McGivern, 2017). It also assumes that the diagnosis given at invasive autopsy is correct, which, in the case of England and Wales, occurs in a system without witness or audit of diagnosis, where the cause of death need only to be "on a balance of probabilities." As PMCT services are amenable to audit at any time, they are recommended to be subject to such, and where causes of death are given, it should be based on obvious gross pathological abnormalities, for example, ruptured abdominal aortic aneurysm with corresponding appropriate clinical history. If such gross pathology is either not present or the pathology identified does not fit with the clinical presentation (so-called "dying with not dying of" scenario) then the triage system continues along its pathway.

PMCT is also a compromise in terms of whether to use PMCT or PMMR. In an ideal situation and in the mortuaries of the future, both should be available to the investigator. PMMR has advantages over PMCT in terms of the detail that can be seen with regard to soft tissues (e.g., bruises) and organs such as the heart where myocardial infarction can be visualized earlier than at autopsy (Persson, 2018). However, cost, availability, and the specialist nature of the examination currently prohibits widespread use. Overall, PMCT provides detailed images of all tissues of the body of sufficient detail to allow equivalent diagnosis to autopsy in up to 92% of natural death and 100% in certain types, but not all types of trauma deaths (Grabherr et al., 2018; Lathrop & Notle, 2016; G. N. Rutty et al., 2017; Vanhaebost et al., 2017). Refer to Supplemental Digital Content 2, http://links.lww.com/JFN/A47.

The Impact of PMR on Forensic Nursing Practice

The acceptance of PMR to enhance or replace the traditional invasive autopsy impacts forensic nurses practicing in death investigative services all over the world. Said nurses may encounter processes and technologies they are unfamiliar with or relatives may make enquiries into the availability of PMCT for the investigation of their loved one's death having read about or heard about the developments through sources such as social media. Forensic nurses need to be aware of the emerging developments so that they can consider the role, if any, within their own local practice and be able to explain this to the relatives of the deceased. Those involved in the provision of death investigation services and mortuary planning should be aware of the global changes in autopsy practice to future proof their services and facilities.

Conclusions

The evolution of new techniques within health care enables the provision of better, potentially quicker, and more reliable services for patients and their relatives. Death investigation is no different. Traditionally, the "true" cause of death could only be determined by a traditional invasive autopsy. This traditional invasive surgical procedure comprises external and internal examination, supplemented with laboratory investigations, followed by reconstruction of the body. However, technological advances in conjunction with sociological change have driven the advent of a new less invasive alternative: PMCT (Ampanozi et al., 2020).

PMR involves a new triage approach to death investigation. It starts with an external examination of the body followed by a scan, most commonly PMCT and tissue sampling for laboratory analysis if necessary. This new approach has been validated over the past 15 years so that it can now be offered in certain centers not only as an adjunct but as an alternative to the traditional invasive autopsy. All forensic nurses working in death investigative services should therefore have an understanding of this alternative and its potential advantages and disadvantages in order to provide the best standard of care and support to the deceased, next of kin, and family.

References

Ampanozi, G., Halbheer, D., Ebert, L. C., Thali, M. J., & Held, U. (2020). Postmortem imaging findings and cause of death

determination compared with autopsy: A systematic review of diagnostic test accuracy and meta-analysis. *International Journal of Legal Medicine*, *134*(1), 321–337.

Baglivo, M., Winklhofer, S., Hatch, G. M., Ampanozi, G., Thali, M. J., & Ruder, T. D. (2013). The rise of forensic and post-mortem radiology: Analysis of the literature between the year 2000 and 2011. *Journal of Forensic Radiology and Imaging*, *1*, 3–9.

Biggs, M., & Marsden, P. (2019). Dental identification using 3D printed teeth following a mass fatality incident. *Journal of Forensic Radiology and Imaging*, *18*, 1–3.

Burton, J. C. (2010). The history of the autopsy. In J. L. Burton, & G. Rutty (Eds.), *The hospital autopsy: A manual of fundamental autopsy practice* (3rd ed., pp. 1–10). Hodder Arnold.

Chief Coroner. (n.d.) *Guidance No. 32. Post-mortem examinations including second post-mortem examinations*. https://www.coronersociety.org.uk/_img/pics/pdf_1569321731-72.pdf

Department of Health. (2003). *Families and postmortems: A code of practice, forms and information leaflets*. Author.

Donchin, Y., Rivkind, A. L., Bar-Ziv, J., Hiss, J., Almog, J., & Drescher, M. (1994). Utility of postmortem computed tomography in trauma victims. *The Journal of Trauma*, *37*(4), 552–555.

Eckert, W. G., & Garland, N. (1984). The history of the forensic applications in radiology. *American Journal of Forensic Medicine and Pathology*, *5*(1), 53–56.

Grabherr, S., Grimm, J. M., & Heinemann, A. (2016). Atlas of Postmortem Angiography. Springer, London. https://doi:10.1007/978-3-319-28537-5

Grabherr, S., Heinemann, A., Vogel, H., Rutty, G., Morgan, B., Wozniak, K., Dedouit, F., Fischer, F., Lochner, S., Wittig, H., Guglielmi, G., Eplinius, F., Michaud, K., Palmiere, C., Chevallier, C., Mangin, P., & Grimm, J. M. (2018). Postmortem CT angiography compared with autopsy: A forensic multicenter study. *Radiology*, *288*(1), 270–276.

Human Tissue Act. (2004). http://www.legislation.gov.uk/ukpga/2004/30/contents

International Society of Forensic Radiology and Imaging. (n.d.). *About us*. http://www.isfri.org/

Jeffery, A., Raj, V., Morgan, B., West, K., & Rutty, G. N. (2011). The criminal justice system's considerations of so-called near-virtual autopsies: the East Midlands experience. *Journal of Clinical Pathology*, *64*(8), 711–717.

Krantz, P., & Holtas, S. (1983). Postmortem computed tomography in a diving fatality. *Journal of Computer Assisted Tomography*, *7*(1), 132–134.

Lathrop, S. L., & Nolte, K. B.. 2016 *Utility of postmortem X-ray computed tomography (CT) in supplanting or supplementing medicolegal autopsies*. https://www.ncjrs.gov/pdffiles1/nij/grants/249949.pdf

McGivern, L., Shulman, L., Carney, J. K., Shapiro, S., & Bundock, E. (2017). Death certification errors and the effect on mortality statistics. *Public Health Reports*, *132*(6), 669–675.

Ministry of Justice. (2017). *National statistics: Coroners statistics 2017*. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/706052/coroners-statistics-bulletin-2017.pdf

National Health Service. (2018). *Post mortem*. https://www.nhs.uk/conditions/post-mortem/

O'Donnell, C., & Woodford, N. (2008). Post-mortem radiology—A new sub-speciality? *Clinical Radiology*, *63*(11), 1189–1194.

Palmiere, C., Egger, C., Grabherr, S., Jaton-Ogay, K., & Greub, G. (2015). Postmortem angiography using femoral cannulation and postmortem microbiology. *International Journal of Legal Medicine*, *129*(4), 861–867.

Palmiere, C., Grabherr, S., & Augsburger, M. (2015). Postmortem computed tomography angiography, contrast medium administration and toxicological analyses in urine. *Legal Medicine (Tokyo, Japan)*, *17*(3), 157–162.

Persson, A., Baeckmann, J., Berge, J., Jackowski, C., Warntjes, M., & Zech, W. D. (2018). Temperature-corrected postmortem 3-T MR quantification of histopathological early acute and chronic myocardial infarction: A feasibility study. *International Journal of Legal Medicine*, *132*(2), 541–549.

Roberts, I. S. D., Benamore, R. E., Benbow, E. W., Lee, S. H., Harris, J. N., Jackson, A., Mallett, S., Patankar, T., Peebles, C., Roobottom, C., & Traill, Z. C. (2012). Post-mortem imaging as an alternative to autopsy in the diagnosis of adult deaths: A validation study. *Lancet*, *379*(9811), 136–142.

Robinson, C., Biggs, M. J., Amoroso, J., Pakkal, M., Morgan, B., & Rutty, G. N. (2014). Post-mortem computed tomography ventilation; simulating breath holding. *International Journal of Legal Medicine*, *128*, 139–146.

Robinson, C., Deshpande, A., Richards, C., Rutty, G., Mason, C., & Morgan, B. (2019). Post-mortem computed tomography in adult non-suspicious death investigation—Evaluation of an NHS based service. *BJR Open*, *1*(1).

Royal College of Pathologists. (2002). *Guidelines on autopsy practice: report of a working group of the Royal College of Pathologists*. Author.

Rutty, G. N. (2018a). *Grenfell Tower disaster remote radiology reporting from facilitated DVI process*. Presented at the International Society of Forensic Radiology and Imaging Conference, Melbourne, Australia, 10–12 May. http://www.isfri2018.com/program.php

Rutty, G. N. (2018b). Post mortem radiology for natural and forensic death investigation MSc, PGDip, PGCert. https://le.ac.uk/courses/post-mortem-radiology-for-natural-and-forensic-death-investigation-msc

Rutty, G. N., Alminyah, A., Apostol, M., Boel, L. W. T., Brough, A., Bouwer, H., O'Donnell, C., Fujimoto, H., Iino, M., Kroll, J., Lee, C. T., Levey, D. S., Makino, Y., Oesterhelweg, L., Ong, B., Ranson, D., Robinson, C., Singh, M. K. C., Villa, C., … Wozniak, K. (2018). Positional statement: Radiology disaster victim identification reporting forms. *Journal of Forensic Radiology and Imaging*, *15*, 4–7.

Rutty, G. N., Biggs, M. J. P., Brough, A., Morgan, B., Webster, P., Heathcote, A., Dolan, J., & Robinson, C. (2019). Remote postmortem radiology reporting in disaster victim identification: experience gained in the 2017 Grenfell Tower disaster. *International Journal of Legal Medicine*, *134*(2), 637–643. 10.1007/s00414-019-02109-x

Rutty, G. N., Brogdon, G., Dedouit, F., Grabherr, S., Hatch, G. M., Jackowski, C., Leth, P., Persson, A., Ruder, T. D., Shiotani, S., Takahashi, N., Thali, M. J., Woźniak, K., Yen, K., & Morgan, B. (2013). Terminology used in publications for post-mortem cross-sectional imaging. *International Journal of Legal Medicine*, *127*, 465–466.

Rutty, G. N., Brough, A., Biggs, M. J., Robinson, C., Lawes, S. D., & Hainsworth, S. V. (2013). The role of micro-computed tomography in forensic investigations. *Forensic Science International*, *225*, 60–66.

Rutty, G. N., & Morgan, B. (2017). Autopsy on autopilot. *The Pathologist*, *32*, 12–13.

Rutty, G. N., Morgan, B., O'Donnell, C., Leth, P. M., & Thali, M. (2008). Forensic institutes across the world place CT or MRI scanners or both into their mortuaries. *The Journal of Trauma*, *65*(2), 493–494.

Rutty, G. N., Morgan, B., Robinson, C., Raj, V., Pakkal, M., Amoroso, J., Visser, T., Saunders, S., Biggs, M., Hollingbury, F., McGregor,

A., West, K., Richards, C., Brown, L., Harrison, R., & Hew, R. (2017). Diagnostic accuracy of post-mortem CT with targeted coronary angiography versus autopsy for coroner-requested post-mortem investigations: A prospective, masked, comparison study. *Lancet*, *390*(10090), 145–154.

Rutty, G. N., & Rutty, J. E. (2011). Perceptions of near virtual autopsies. *Journal of Forensic and Legal Medicine*, *18*(7), 306–309.

Rutty, G. N., Smith, P., Visser, T., Barber, J., Amorosa, J., & Morgan, B. (2013). The effect on toxicology, biochemistry and immunology investigations by the use of targeted post-mortem computed tomography angiography. *Forensic Science International*, *225*(1–3), 42–47.

Rutty, G. N., & Swift, B. (2004). Accuracy of magnetic resonance imaging in determining cause of sudden death in adults: Comparison with conventional autopsy. *Histopathology*, *44*(2), 187–189.

Rutty, J. E. (2010). Religious attitudes to death and post-mortem examinations. In J. L. Burton, & G. Rutty (Eds.), *The hospital autopsy: A manual of fundamental autopsy practice* (3rd ed., pp. 39–59). Hodder Arnold.

Rutty, J. E., Biggs, M., Dowsett, D., Kitchener, A., Coltman, N., & Rutty, G. (2019). Post mortem computed tomography: An innovative tool for teaching anatomy within pre-registration nursing curricula. *Nurse Education Today*, *76*, 154–164.

Rutty, J. E., Morgan, B., & Rutty, G. N. (2015). Managing transformational change: Implementing cross-sectional imaging into death investigation services in the United Kingdom. *Journal of Forensic Radiology and Imaging*, *3*(1), 57–60.

Saunders, S., Morgan, B., Raj, V., & Rutty, G. N. (2011). The role of post-mortem computed tomography in coronial autopsy practice; the Leicester experience. *RAD Magazine*, *37*, 19–20.

Schneider, B., Chevallier, C., Dominguez, A., Bruguier, C., Elandoy, C., Mangin, P., & Grabherr, S. (2012). The forensic radiographer: A new member in the medicolegal team. *American Journal of Forensic Medicine and Pathology*, *33*, 30–36.

Sque, M., Long, T., Payne, S., Roche, W. R., & Speck, P. (2008). The UK postmortem organ retention crisis: A qualitative study of its impact on parents. *Journal of the Royal Society of Medicine*, *101*(2), 71–77.

The Coroner's Autopsy: Do we deserve better? (2006). https://www.ncepod.org.uk/2006ca.html

The Coroners and Justice Act. (2009). http://www.legislation.gov.uk/ukpga/2009/25/contents

Vanhaebost, J., Ducrot, K., de Froidmont, S., Scarpelli, M. P., Egger, C., Baumann, P., Schmit, G., Grabherr, S., & Palmiere, C. (2017). Diagnosis of myocardial ischemia combining multiphase post-mortem CT-angiography, histology, and post-mortem biochemistry. *La Radiologia Medica*, *122*(2), 95–105.

Instructions:

- Read the article. The test for this CE activity can only be taken online at http://nursing.ceconnection.com. Tests can no longer be mailed or faxed.
- You will need to create (its free!) and login to your personal CE Planner account before taking online tests. Your planner will keep track of all your Lippincott Professional Development online CE activities for you.
- There is only one correct answer for each question. A passing score for this test is 13 correct answers. If you pass, you can print your certificate of earned contact hours and access the answer key. If you fail, you have the option of taking the test again at no additional cost.
- For questions, contact Lippincott Professional Development: 1-800-787-8985.

Registration Deadline: June 3, 2022

Disclosure Statement:
The authors and planners have disclosed no potential conflicts of interest, financial or otherwise.

Provider Accreditation:
Lippincott Professional Development, will award 1.5 contact hours for this continuing nursing education activity.

Lippincott Professional Development is accredited as a provider of continuing nursing education by the American Nurses Credentialing Center's Commission on Accreditation.

This activity is also provider approved by the California Board of Registered Nursing, Provider Number CEP 11749 for 1.5 contact hours. Lippincott Professional Development is also an approved provider of continuing nursing education by the District of Columbia, Georgia, and Florida, CE Broker #50-1223.

Payment and Discounts:

- The registration fee for IAFN members is $12.50; for nonmembers, $17.95.
- IAFN members — To obtain the discounted fee online, members can take the test by logging into the secure "Members Only" area of www.iafn.org to get the discount code. Use the code when payment is requested when taking the CE test at http://nursing.ceconnection.com.

For 11 more continuing education articles related to Forensic Nursing topics, go NursingCenter.com/CE.