The role of post-mortem computed tomography in coronial autopsy practice; the Leicester experience

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By Sarah Saunders,1 Bruno Morgan,2 Vimal Raj,2 Guy Rutty1
1East Midlands Forensic Pathology Unit, Leicester Royal Infirmary
2Imaging Department, University Hospitals of Leicester, Leicester Royal Infirmary

The first and last authors contributed equally to this article

Corresponding author Guy Rutty,
tel: 0116 252 3221, fax: 0116 252 3274
ing: grn3@le.ac.uk

The role of radiology within medico-legal autopsy practice is as old as the x-ray itself. Medico-legal investigations are authorised by HM coroner in England and Wales and include those undertaken for unexplained natural death (often referred to as routine coroner’s cases) and suspicious or unnatural death (referred to as forensic autopsies). Outside England and Wales it is more usual to have a single medico-legal autopsy service provided by forensic practitioners who do not apply such labels.

Imaging is considered an important and often essential adjunct to medico-legal investigations but until recently its use has generally been limited to plain film examination of suspected child abuse cases and the search for projectiles within bodies. Fluoroscopy, ex-vivo angiography and ultrasound have all been used in autopsy practice with variable success.

Despite computed axial imaging being the gold standard in clinical practice for investigating the whole body for indications such as trauma or systemic illness, traditional plain film radiography still tends to be the modality of choice among forensic practitioners. In general, forensic practitioners utilise radiology more often than non-forensic practitioners (histopathologists). However, this is rapidly changing with the current international trend towards full body multi-detector computed tomography (MDCT) prior to autopsy. Magnetic resonance imaging is of increasing interest, but this article will concentrate on the use of MDCT alone as this is the most commonly used imaging modality internationally.

Computed tomography was introduced into post-mortem practice more than 27 years ago. Due to the technology available at this time, imaging was confined to the head. Whole body post-mortem computed tomography imaging (PMCT) and the concept of so-called virtual autopsies was first reported from Israel in 1994. Since then, there has been a wealth of literature published from forensic centres across the world related to the use of PMCT with adults, children and deceased animals, for both natural and unnatural causes of death, as well as its extended use in mass fatalities and a variety of forensic science fields.

At the East Midlands Forensic Pathology Unit (EMFPU), PMCT has been the favoured imaging modality for autopsy practice since 2002. Today, whenever possible, all forensic cases, all road traffic deaths and those natural deaths referred to our unit will undergo PMCT prior to, and sometimes after, autopsy. In child death investigations plain films are still undertaken in addition to PMCT.

Our PMCT protocol takes approximately 15-20 minutes to image the whole body with reconstruction at resolutions down to 0.5mm slice thickness. This forms a pre-autopsy digital record, which can be transmitted for review by other professionals anywhere in the world. We have set up an anonymised coding system with ‘a hub and spoke’ PMCT network to involve all sites where autopsies are undertaken by unit members within the East Midlands. The centrally stored permanent record can be used for diagnostic reporting, review or audit (so-called virtual exhumation) at any time. The data can be reconstructed into 3D images for court purposes, which are deemed more acceptable to juries than autopsy photos. Although we already use printed images from the scans in court reports, we have recently introduced – for the first time to our knowledge – the use of laptop based real time Multi-Planar Reconstruction and 3D reconstructed images into court evidence.

Pre-autopsy scanning allows the pathologist to review the images and plan aspects of the autopsy procedure, for example the need to tie off the vessels to demonstrate an air embolism, or to identify the presence of potential hazards such as fragments of glass or metal. The images are formally reported by radiologists with experience in post-mortem imaging and reviewed at regular multi-disciplinary PMCT meetings. We have built up a collection of consented cases for teaching and training purposes that are validated against the subsequent autopsies.

Currently, of the four questions of the coroner’s enquiry, PMCT can be used to address ‘who’ (ie identification) and ‘how’ (ie cause of death) but cannot assist with ‘where’, and only assist to a limited extent ‘when’. We have research programmes running up to PhD level in three of these areas (http://www2.le.ac.uk/departments/emfpu). Thus, when considering the introduction of ‘near virtual’ or ‘minimally invasive’ autopsies it must be combined with other investigations, including a review of the history, thorough external examination and often laboratory investigations such as toxicology or needle biopsy histology, in an attempt to replace the need for invasive autopsy.

Most recently, in an attempt to improve diagnostic accuracy and overcome the lack of an active circulation to deliver contrast media, PMCT direct angiography has been introduced into our practice. Although this can be achieved through whole body angiography using a modified heart lung bypass machine, here at the EMFPU we have developed a protocol for targeted cardiac angiography for natural death investigation which can be used in temporary and permanent mortuaries alike. This development has taken us a significant step towards the realistic prospect of a significant reduction in invasive autopsies within the UK.

PMCT has been shown to be a useful tool for the identification of bodies, especially in a mass disaster setting. It can be used to assist the identification of gender, age, stature and race of an individual, through the use of 3D surface reconstruction to access external anatomical features (which can be entered into the Interpol post-mortem
Disaster Victim Identification form), take osteological measurements (virtual anthropology), consider epiphysis fusion and dental eruption, undertake odontological assessment and seek the presence of prostheses, implants and jewellery. Details related to clothing and the presence of natural disease (for identification purposes) can all be detailed. When combined with an external examination, it provides a powerful adjunct to the identification process.

There is a substantial, predominately case report-related, body of literature demonstrating the role of PMCT related to the cause of death. Blunt and sharp force trauma related deaths, hangings, foreign body upper airway obstruction, ligature and manual strangulation, drug mules, haemorrhage from ruptured internal organs, as well as from the effects of penetrating projectiles, are all reported. Complex fractures of the skull vault and facial bones not normally detectable on routine autopsy without extensive dissection are well demonstrated on CT, as well as vehicle control injuries (those injuries sustained by the person in control of the vehicle at the time of the incident) or pedestrian impact injuries, which reduces the amount of dissection needed at autopsy. Imaging of weapons, for example knives, chisels and saws, still in situ reduces the risk of injury to the pathologist at subsequent autopsy. Impact direction, wound track depths, angles of penetration, injuries caused to organs and even an estimation of the force used can all be opined from PMCT. The EMFPU has experience of all the above cases along, with the most common forms of natural death encountered in medico-legal autopsy practice.

One of the major considerations if PMCT is to be adopted is who is going to report the scans. Clinical radiologists with limited exposure to PMCT imaging and, even with experience of forensic interpretation of plain radiographs, are at risk of misinterpreting findings if they apply the rules of clinical radiological analysis. There are differences between clinical and post-mortem scans, such as the effects of lividity, the sedimentation of blood elements, intravascular clot formation and the alteration in the shape of organs due to lack of a circulation. Bodies in rigor mortis, severely charred or in the advanced stages of decomposition are often not in optimal scanning positions. Cases with decomposition and putrefaction are particularly problematic. Post-mortem formation occurs early causing significant artefacts and the untrained radiologist can make incorrect diagnoses if this is not fully understood or appreciated. The assessment of the continuity of air within the coronary circulation can be used to assess patency. Finally, there are a number of processes that are not seen in the living, such as heat haematomas, post-mortem fractures in burnt bodies and the facial distortion seen with advancing decomposition that radiologists may be unfamiliar with.

The main barrier to the widespread implementation of PMCT within the UK will be cost. Installing scanners in mortuaries is the ideal, but could prove prohibitively expensive to a cash-strapped NHS. With the demand for hospital scanners to image the living at a maximum, will there be any space on the lists for the dead? One way round this problem is to scan bodies at night. This is our practice at PMCT within the UK will be cost. Installing scanners in radiologists may be unfamiliar with.

Due to the nature of forensic cases and the burden of proof required for court proceedings, the use of PMCT in forensic practice currently remains an adjunct, not a replacement, although this may change in the future. However, it is foreseen by some that PMCT will replace the need to undertake invasive autopsies in the majority of routine ‘non-suspicious’ cases referred to the coroner. There is no doubt that in the future the so-called View, PMCT scan, and grant +/- toxicology protocol will become the norm for such cases. Thus, it is predicted that when a body arrives at the mortuary, a full external examination is undertaken by a pathologist with toxicology samples taken if indicated. The body will then undergo PMCT with angiography. The PMCT report along with the history, external examination and toxicology results are then reviewed. If a cause of death can be given on the basis of balance of probability (the level of burden of proof for coroners, civil and family court cases) then a death certificate will be issued. If there is any doubt or the radiologist/pathologist in unable to give a cause of death then an autopsy will be carried out.

Such a system could see a significant reduction in the number of routine coronial autopsies, especially where there is objection by the family to autopsy. This system is currently being used in limited centres across England and the number of sites is anticipated to increase. The work at the EMFPU concerning the role of angiography in this process continues to progress towards this goal but there are a lot of questions still to be answered in relation to this system, which is why at Leicester such work remains at a research, not diagnostic stage. Significant, funded research is still needed in this area and groups from around the world are working towards proving the validity and limitations of the near virtual autopsy. The EMFPU are associated with a number of international centres that are beginning to consider working together towards a common goal. This is certainly a topic which is going to gain momentum in the future, with a paradigm shift in autopsy practice over the next ten years towards PMCT. The inclusion of PMCT to autopsy, with or without angiography, will likely become the gold standard for forensic autopsy practice all over the world. The EMFPU is at the cutting edge of developments in the use of PMCT for both natural and unnatural death in the UK.

References
FIGURE 1
3D reconstruction images of a fracture dislocation of a neck from a road traffic incident.

FIGURE 2
Multi-planar reconstruction showing positive contrast (A) in the left anterior descending coronary artery and air as a negative contrast (B) in the right coronary artery using targeted coronary artery angiography.

FIGURE 3
Haemopericardium (star) in a person with calcified atheroma of the coronary arteries. This is an example of so-called lethal pathology which, if identified on a pre-autopsy CT scan, raises the question as to the need for an invasive autopsy.

FIGURE 4
3D reconstruction of a fracture to the hyoid bone from a suicide by hanging.

FIGURE 5
Malignant mesothelioma of the right pleural cavity with mid-line shift to the left of the central thoracic structures. Although such an image could have a role in so-called scan, view and grant autopsies, there are other medico-legal issues related to the mesothelioma which currently would require the case to proceed to autopsy examination.
FIGURE 6
3D reconstruction of a fracture of the second cervical vertebrae. Such an injury would be technically difficult to observe and record at autopsy examination.

FIGURE 7
3D reconstruction of skull, facial and mandible fractures received in a road traffic incident. Such an image is more acceptable to a jury rather than an autopsy photograph assuming that a photograph could be produced without the need for extreme autopsy dissection.