

High throughput adult cadaver axial imaging: service logistics and requirements

Guy N Rutty

Abstract

It remains unknown to date the extent of the potential role of computed tomography (CT) and magnetic resonance imaging (MRI) in autopsy practice in the United Kingdom (UK). If CT and/or MRI were accepted to have a role beyond that already been undertaken within the UK and implemented on a national high throughput scale, what impact would it have upon the National Health System (NHS) where, in the UK, the majority of mortuary facilities and practitioners work? This symposium paper explores the logistics, personnel and facilities that may be required to assist those contemplating developing such a provision of service. The discussion presented is based upon the concept that all cadavers normally subjected to invasive medico-legal (coroner's) autopsy would be imaged following receipt at an NHS hospital located mortuary. It is based on the experience of the East Midlands Forensic Pathology Unit and Imaging Department, University Hospitals of Leicester in examining cadavers using CT within the NHS where all of these problems have been encountered previously.

Keywords axial imaging; computed tomography; logistics; MRI; near virtual autopsy; post-mortem; virtual exhumation

Introduction

During the last 10 years there has been growing international interest in the use of computed tomography (CT) and magnetic resonance imaging (MRI) as an adjunct or possibly a replacement to the traditional invasive autopsy. There is a growing literature concerning the role of the so-called *near virtual autopsy* or *Virtopsy*[®] in adult autopsy practice.^{1,2} The majority of this literature is derived from forensic institutes outside the United Kingdom with the subject matter orientated towards trauma pathology. The role of CT and MRI in so-called *routine* medico-legal autopsies where the cause of death is non-suspicious and related to natural disease is controversial; as it is to a lesser extent within forensic practice.³ A number of centres in England are currently researching this area of interest.

Outside the UK the use of CT in particular has been embraced to the extent that it has become routine in some centres.^{4,5} The best international example of this is at the Victorian Institute of

Forensic Medicine (VIFM) where all bodies are scanned on admission to the Institute. This has resulted in over 25 000 examinations to date.

Although it is still unclear as to the extent of the potential role of CT and MRI in autopsy practice in the UK, one role that can be envisaged for the future is along the lines of the practice at the VIFM i.e. that all cadavers could be imaged, with CT not MRI, following death. This would allow for a permanent record of the cadaver to be maintained should an autopsy not be undertaken and the case need reviewing at some point in the future (a so called *virtual autopsy*). It would allow for an assessment of the presence of lethal pathology e.g. ruptured aortic aneurysm or pericardial tamponade, which when combined with an external examination would allow the cause of death to be certified with a *scan, view* and *grant* procedure. This would reduce the number of invasive autopsies presently undertaken in the UK and would have a positive affect on the families and faiths of the country.

However, if this system was accepted and implemented, what impact would it have upon the National Health System (NHS) where, in the UK, the majority of mortuary facilities and practitioners work? This symposium paper explores the logistics, personnel and facilities that may be required to act as a guide for those contemplating developing such a provision of service. The discussion presented is based on the concept that all cadavers normally subjected to invasive medico-legal (coroner's) autopsy would be imaged following receipt at an NHS hospital located mortuary. It does not put forward the notion of scanning *all* cadavers admitted to a mortuary as this number is significantly greater than that which are subject to autopsy examination and could, in some mortuary catchment areas, be in excess of 5000 cases per year. Should this approach be adopted, the impact on the NHS would be substantial and would probably bring most NHS based imaging units to a halt.

Process pathway

Before one can implement imaging on such a scale which, at some UK centre's, could run into over 1500 cases per year (autopsy cases, not total bodies admitted), we need to build a process pathway to consider each stage that may be involved. A simplified example pathway is presented in [Figure 1](#). From this pathway it can be discerned that there are a number of steps that need to be considered, costed and implemented prior to a robust, ethically acceptable high throughput system can be implemented. Each step has financial, personnel, equipment and training implications and must be risk assessed and have a standard operating procedure (SOP) in place to ensure that it complies with all current legislation related to the storage, handling and examination of cadavers. This can be achieved but the work involved is significant.

The process of body receipt and secure storage is common to all mortuary practice and will not be examined here. The authority to image the body or undertake an autopsy examination is also not considered in this article as this symposium focuses purely on those matters surrounding the process once the decision has been made to image the cadaver. However those operating such a system must understand the current legislation related to such matters and work within such legislation. To date, the Human Tissue Authority does not require an imaging suite to be licenced under the Human Tissue

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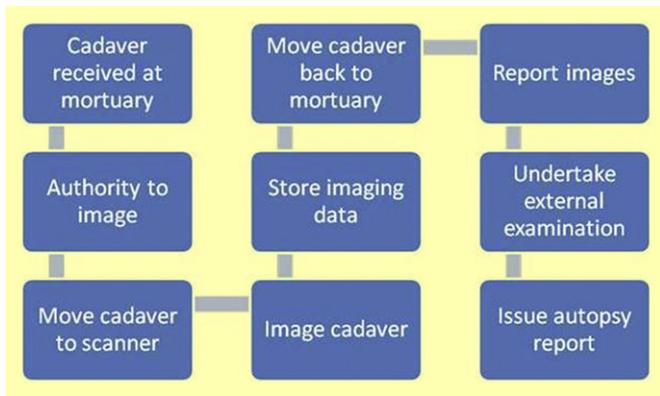


Figure 1 An example of a process pathway related to a near virtual autopsy system.

Act 2006 for cadaveric imaging despite the fact that the process could be viewed as an autopsy and can be used for the purpose of determining a cause of death.

Imaging examination site

Prior to addressing the process pathway one has to consider where the imaging suite is in relation to the mortuary. Although the body process pathway will share many common steps and resources, the choice of model will be important for those planning the service. To date there are three models that can be considered to facilitate the service.

1. That the mortuary has either a CT or MRI or both within the mortuary itself. This purpose built approach is seen for example within Europe, Scandinavia and Australia. To date no such facility exists in the UK.
2. That the CT or MRI or both within the NHS hospital where the mortuary is located is utilized. This is the present model adopted within the UK.
3. That a mobile CT or MRI or both (would require two separate vehicles) is utilized. This approach has been used in Japan and is the system available for mass fatality associated work at either the scene or temporary mortuary within the UK.^{6–8}

Each of these approaches has pros and cons. If all autopsies are undertaken by full time medico-legal practitioners within dedicated legal medicine facilities then option one is the best approach as the use of the scanner can have a wider function in both animate and inanimate examinations. However in England the placement of a CT scanner into a mortuary may not be financially viable and may be under utilized. Thus option 2 may be the preferred option. Mobile CT, although excellent for short term deployment within temporary mortuaries, is an expensive method for day to day routine scanning and brings with it other problems for example the placement of the scanner, power supply and data storage.

This becomes more complicated if both CT and MRI imaging are undertaken as the two imaging modalities may be located at two different sites within the hospital. To keep this article simple I will restrict the discussion from this point onwards to the use of CT only, the imaging modality used at Leicester.

I have heard concerns voiced related to the use of CT scanners for cadavers, specifically that the operation of the machines should

be prioritized to the living. This is discussed below related to operational timings. The images are part of the pathologist's clinical decision making processes and are as important to them as to a clinician treating a living person. Clinical scanning involves a wide range of urgency, from immediate to routine scanning. Imaging departments in acute hospitals are used to prioritizing such cases and scanning of the living and the dead can operate together, as explained below, without impacting upon the treatment of the living.

Operational hours of service

Leading on from the initial decision of *where* the imaging suite is located is the consideration of *when* imaging is to be undertaken. There are two options available to the user.

1. If the scanner is within the mortuary or a mobile scanner is been utilized then this allows for a dedicated imaging suit for cadaver use only. The scanner can operate 24 h per day with dedicated mortuary based staff and resources. Thus there is no restriction on when the imaging can be undertaken in relation to the arrival of the body to the mortuary. Scanning can thus occur prior to initial body storage.
2. If the scanner is within an NHS imaging department where it will be used during normal NHS working hours then access to imaging will be limited to specific time frames as live patients will be given priority for imaging. There will be an impact on the NHS in relation to staffing and resources although there are advantages for example in relation to maintenance, and running costs. Scanning takes place after initial body storage.

NHS imaging departments often have scanners that are used heavily during standard working hours but are then used solely for emergency work between 1800 and 0700 h allowing time for extra cases to be performed. At Leicester Royal Infirmary two scanners work side by side in the emergency department, with one scanner operational 24/7 and the other in reserve outside standard hours. This gives a window of time when option 2 can successfully operate. However waiting for access to an NHS scanner can cause delays in autopsy practice for example, if one wished to image a homicide gunshot victim who arrives at the mortuary at 0900 h access may not be available until after 1800 h. Such time delay can affect the investigation into the death and have an affect on the police, for example custody and charge times for those arrested in relation to the death. In the case of near virtual autopsy practice this delay slows down the decision making process as to whether an invasive autopsy is required to be undertaken on the body which affects funeral arrangements for certain faiths. Also a number of time dependent imaging artefacts develop after death, and thus the longer the time between death and imaging the more artefacts will be present on the images. To be able to image the cadaver as soon after death is the preferred option.

Body movement

The body must be moved to the scanner. If the scanner is within a mortuary then mortuary staff can undertake this procedure. If a mobile scanner or NHS scanner is used then the body must be concealed within an appropriate trolley to allow movement to the scanner. The use of mortuary staff for this task may be inappropriate especially if, as is likely, scanning is undertaken outside normal working hours. Hospital porters can be utilized for this task who

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