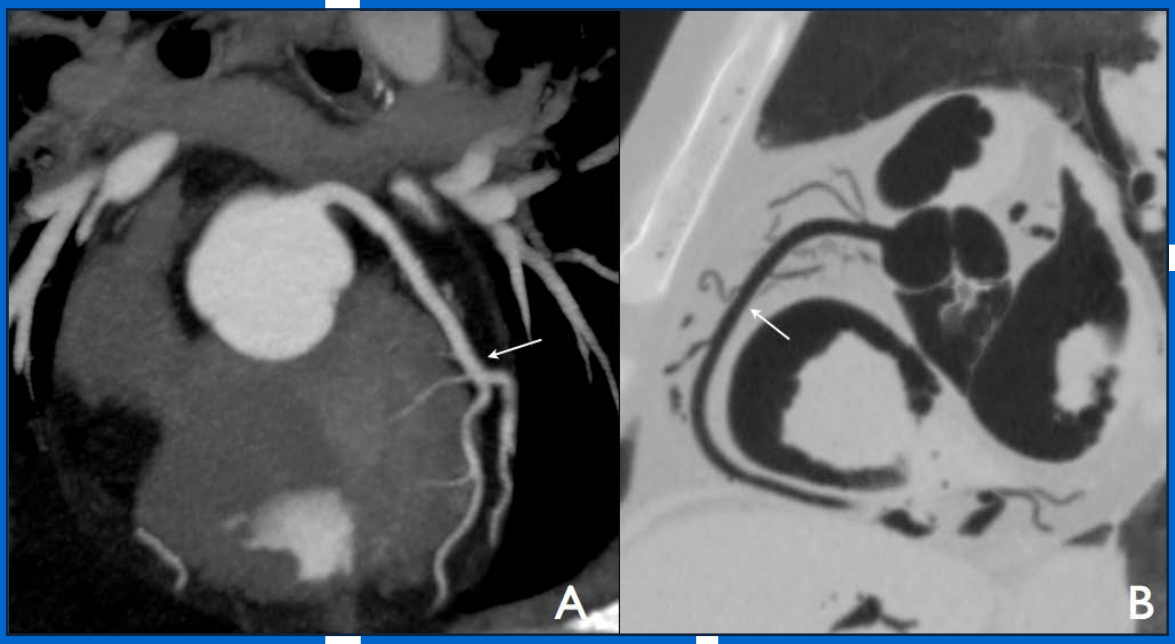
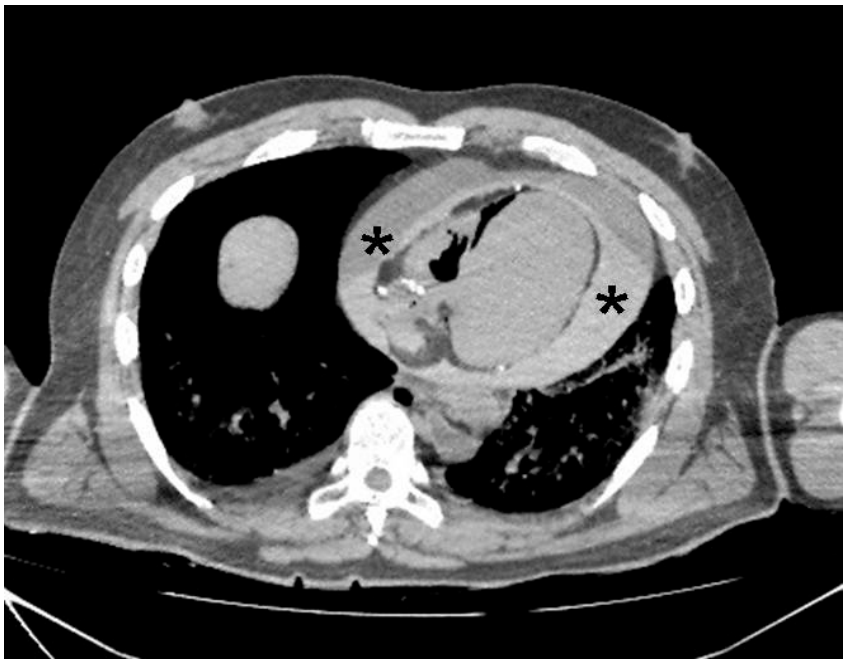
Can Cross-Sectional Imaging as an Adjunct and/or Alternative to the Invasive Autopsy be Implemented within the NHS?

Report from the NHS Implementation Sub-Group of the Department of Health Post Mortem, Forensic and Disaster Imaging Group (PMFDI). October 2012.





Axial CT image of the chest showing a fatal haemopericardium (stars)

This document contains findings, conclusions and advice offered by the NHS Implementation Sub-Group of the Department of Health Post Mortem, Forensic and Disaster Imaging Group (PMFDI) to their colleagues in the NHS. Members of the NHS Implementation Sub-Group were appointed from across the NHS for their personal experience and expertise, and not to represent any organisation or faction.

The products, manufacturers and organisations discussed in this document are described for information only and do not constitute product approval or endorsement by the NHS Implementation Sub-Group members.

The NHS Implementation Sub-Group hopes that SHA Clusters, commissioners, providers, local experts and project managers will find this advice useful.

The Group members declare no conflict of interest in the matters they have considered or the contents of this document.

First published October 2012
Published in electronic PDF format only

Chair:

Professor Guy N Rutty MBE
Chief Forensic Pathologist
East Midlands Forensic Pathology Unit
University of Leicester
Leicester

Mr Dean Jones
Senior Forensic Pathology Manager
Police Science & Forensics Unit
National Policing Improvement Agency
London

Mr James Lowell
Chair of Association of Anatomical Pathology Technology
Coldbath Square
London

Mrs Jennifer Leeming
HM Coroner for West Manchester

Dr Shona Campbell
Divisional Director
Clinical Support Division
Leicester Royal Infirmary
Leicester

Dr Jonathan Harris
Consultant Radiologist
Department of Radiology
Salford Royal Foundation Trust
Salford

Lt Col Iain Gibb
Consultant Adviser in Radiology (Army)
Fort Blockhouse
Gosport
Hants

Dr C. Rani Thind
Consultant Radiologist
St Helens and Knowsly Teaching Hospital Trust

Dr Zoe Traill
Consultant Radiologist
Radiology Department
Churchill Hospital
Oxford

Ms Claire Robinson
Advanced Practitioner Forensics
Department of Radiology
Leicester Royal Infirmary
Leicester

Ms Karen Squibb-Williams
Barrister
Strategy and Policy Directorate CPS
Headquaters
London

Mr Philip Webster
Imaging Technical Lead
Department of Health
Policy, Strategy and Finance
New King's Beam House
London

Professor Andrew Taylor
Professor of Cardiovascular Imaging
NIHR Senior Research Fellow
Head-Centre for Cardiovascular Imaging
UCL Institute of Cardiovascular Science and
Great Ormond Street Hospital for Children
London

Administrative Support:

Ms Theresa-Renée Visser
Principal Clerk
East Midlands Forensic Pathology Unit
University of Leicester
Leicester

IMAGES:

Front cover: The use of positive (A) and negative (B) contrast media to image the coronary arteries (arrows) with post mortem targeted angiography. Source: Saunders S, Morgan B, Raj V, Rutty G. The role of post mortem computed tomography in coronial autopsy practice; the Leicester experience. RAD magazine 2011; 37 (435) 19-20.

Second page: Axial CT image of the chest showing a fatal haemopericardium (stars). Source: East Midlands Forensic Pathology Unit.

Section 1: Coronal CT image of the abdomen showing an un-ruptured abdominal aortic aneurysm (arrow). Source: East Midlands Forensic Pathology Unit.

Section 2: Axial CT image of the chest showing discreet nodules in the lungs (arrows) and calcified mediastinal lymph nodes (star) in a young Indo-Pakistani female. Source: East Midlands Forensic Pathology Unit.

Section 3: 3-dimensional reconstruction of a broken neck sustained in a road traffic collision (arrow). Source: East Midlands Forensic Pathology Unit.

The NHS Implementation Sub-Group gratefully acknowledges the following individuals and Groups whose advice, information, insight and knowledge contributed to the development of this report.

UNITED KINGDOM

Mrs Caroline Browne
Head of Regulation
Human Tissue Authority
London

Dr Amanda Jeffery
Home Office Pathologist
Winscombe

Ms Alison Hewitt
Barrister
Temple Garden Chambers
London

Professor Sebastian Lucas
Histopathologist
Department of Histopathology
St Thomas' Hospital
London

Mr James Adeley
Her Majesty's Coroner
Coroners Court 2
Faraday Court
Preston

Mr Peter Bedford
HM Coroner for Berkshire

Mr John Pollard
HM Coroner for South Manchester

Mr Nigel Meadows
HM Coroner for the City of Manchester

Mr Simon Nelson
HM Coroner for North Manchester

Dr Roy Palmer
HM Coroner for South London

Mr John Leckey
Senior Coroner for Northern Ireland
Belfast
Northern Ireland

Ms Linda Cockburn
Procurator Fiscal's Office
Edinburgh

Professor Derrick Pounder
Professor of Forensic Pathology
University of Dundee
Scotland

Professor Jack Crane
Chief State Pathologist
Belfast
Northern Ireland

Mr Gordon Campbell
Pathology Provision Reviewer
Crown Office and Procurator Fiscal Office
Scotland

Mr Malcolm Rae
Buisness Manager
East Midlands Forensic Pathology Unit
Leicester

INTERNATIONAL

Professor Francesca Cittadini
Forensic Pathologist
Catholic University of Sacred Heart
Rome
Italy

Dr Chris O'Donnell
Consultant Radiologist
Victorian Institute of Forensic Medicine
Monash University
Victoria
Australia

Dr Silke Grabherr
Forensic Pathologist
Centre Universitaire Romand de Medecine Legale Lausanne
Lausanne
Switzerland

Dr Thomas Ruder
Forensic Radiologist
Department of Forensic Medicine and Imaging
University of Zurich
Zurich
Switzerland

Dr S Shiotani
Chief Radiologist
Department of Diagnostic Radiology
Tsukuba Medical Centre Hospital
Tsukuba City
Japan

Professor Morio Lino
Department of Legal Medicine
Osaka University Graduate School of Medicine
Osaka
Japan

Dr Peter Leth
Deputy Chief Forensic Pathologist
Institute of Forensic Medicine
University of Southern Denmark
Denmark

Professor Krzysztoif Wozniak
Forensic Pathologist
Department of Forensic Medicine
Jagiellonian University Medical College
Krakow
Poland

Dr Noel Woodford
Chief Forensic Pathologist
Victorian Institute of Forensic Medicine
Monash University
Victoria
Australia

ABBREVIATIONS

ACPO	Association of Chief Police Officers
A&E	Accident and Emergency (Emergency Department)
APT	Anatomical Pathology Technologist
CJS	Criminal Justice Service
CPD	Continuous Professional Development
CPS	Crown Prosecution Service
CT	Computed Tomography
DICOM	Digital Imaging and Communications in Medicine
EQA	External Quality Assurance
GMC	General Medical Council
HOSDB	Home Office Scientific Development Branch
HCPC	Health & Care Profession Council
HTA	Human Tissue Authority
IEP	Image Exchange Portal
IRR	Ionising Radiations Regulations
MDCT	Multi -Detector Computed Tomography
MDT	Multidisciplinary Team Meetings
MRI	Magnetic Resonance Imaging
NHS	National Health Service
NIHR	National Institute of Health Research
NPIA	National Police Improvement Agency
PACS	Picture Archiving and Communications System
PMPACS	Post Mortem Picture Archiving and Communications System
PMCT	Post Mortem Computed Tomography
PMCT-A	Post Mortem Computed Tomography Angiography
RCPath	Royal College of Pathologists
RCR	Royal College of Radiologists
RCOG	Royal College of Obstetricians and Gynaecologists
UK	United Kingdom
UK-DVI	United Kingdom Disaster Victim Identification Team
USA	United States of America
VIFM	Victorian Institute of Forensic Medicine
VRC	Voluntary Registration Council for Healthcare Scientists

GENERAL NOTES

The following general statements apply to this document:

- For the purpose of this document, "*his*" or "*him*" is taken to mean an individual of either gender.
- For the purpose of this document, where the text refers to the "*coroner*" this should be taken as applying to the equivalent systems for the whole of the United Kingdom unless differences are further explored within the text.
- For the purpose of this document the text relates to adult medico-legal autopsy practice only i.e. above the age of 16 years. Where fetal, neonatal, and/or paediatric practice is discussed it is referred to using the generic term '*paediatric*'.
- For the purpose of this document the words '*deceased*' and '*cadaver*' are interchangeable, referring to a deceased human being who is due for autopsy examination rather than, for example, a person who has donated their body for medical school dissection.

Contents

Preface

Establishing a pathological cause of death is more than fulfilment of a bureaucratic requirement. It has importance that is much more than the personal value and medical significance of a person's Death Certificate to their immediate family, although these should not be underestimated. Cause of death data is collated into mortality statistics, which are an important indication health status of the population. These statistics are key in healthcare planning, allocation of resources, policy development, health and injury research, and many other areas of public interest and importance. Therefore, the accurate determination and recording of the cause of death is not just desirable, it is essential.

Many countries, including a number of EU member states, do not call for pathological cause of death to be recorded. Since 1953, England and Wales have been subject to section 22 of the Births and Deaths Registration Act, which requires attending physicians to state to the best of their knowledge and belief a pathological cause of death.

Our government clearly recognises the value of accurate cause of death information. If our multi-ethnic, multi-cultural society is increasingly unwilling to accept conventional autopsy, consideration must be given to the provision of a non-invasive autopsy service that meets both the expectations of the public and provides the most reliable information possible.

Executive summary

The key recommendation from the work described in this document is that the introduction of a non-invasive alternative to the current invasive autopsy is realistic.

This concept has also been considered by The Royal Colleges of Radiology and Pathology in their document *RCR/RCPath practice guidance on medico-legal post mortem imaging in adults* (to be published in 2012). This joint collegiate document provides general guidance and current standards of practice for those involved in this area of work. The NHS Implementation Sub-Group recommends the adoption of their recommendations and a strategy for implementation of a national autopsy imaging service is discussed within this document.

To establish the new service described, there will be a requirement for capital investment and the cost of the autopsy service would increase by the addition of imaging.

There are important religious, cultural and humanitarian benefits offered by non-invasive autopsies and it is recognised that there is no longer the need to undertake invasive autopsy examinations in certain types of death. The current demand by the general public for a non-invasive autopsy service is expected to grow.

Key Recommendations:

i. An integrated, phased implementation programme for a national cross-sectional autopsy imaging service based on a regionalised service provided by 30 mortuary-based imaging centres in England.

ii. A single, integrated service involving radiology and pathology services, based on a single cost no matter what discovering the cause of death involves and supported by transparent costs for each professional group delivering the service.

iii. There should be a national costing exercise undertaken to determine the true cost of the current autopsy service for coroners within the NHS.

iv. There should be continued funding of research within the field to drive forward the medical evidence base for the service and technology development.

v. A national teaching and training programme for all professionals involved in the service should be funded and developed with sub-speciality recognition for all professions involved in the delivery of the service.

Objectives

In 2011, following increasing public interest in non-invasive imaging based autopsy, two groups of professionals were brought together to review cross sectional imaging.

The first group was formed of Members, Fellows and professional advisors to the Royal Colleges of Radiologists and Pathologists. This group has produced a document, to be published in 2012, entitled "*RCR/RCPath practice guidance on medico-legal post mortem imaging in adults*". This document deals with general guidance and current standards of practice for members of the two colleges engaged in this field of work.

The second group was formed as a sub-group of, and at the request of, the Department of Health Post Mortem, Forensic and Disaster Imaging Group and its chair Professor Erika Denton, National Clinical Director for Imaging: The "*NHS Implementation Sub-Group"*. It was comprised of practitioners with experience, both through practice and research, in the use of cross-sectional imaging in medico-legal autopsy services. Additional members were co-opted onto the sub-group from the Criminal Justice System to assist with the objectives of the group. Views were also sought from both within and outside England to address the questions that arose.

This document arises from the considerations of this second group (The NHS Implementation Sub-Group, hereon known as 'The Group') who worked between June and December 2011.

The Group's remit was as follows:

i. To provide an overview of the history of cross-sectional imaging in autopsy practice. The document is based on the Group's general knowledge of the published literature in this field and does not claim to be at the same scientific level as a systematic review, which was not able to be undertaken in the timeframe allowed for the production of this document.

ii. To consider the current NHS and world practice in this field.

iii. To consider the law related to this field of medical practice.

iv. To consider any relevant guidelines or documents in relation to implementing a national autopsy imaging service.

v. To consider the infrastructure including personnel and technology that would be required to underpin a national autopsy imaging service.

vi. To consider the cost implications of such a service with reference to the current cost of medico-legal autopsies.

vii. To provide a strategy for the possible implementation of a national autopsy imaging service.

This document presents the result of the Group's considerations. It presents the findings and recommendations in three discrete sections.

Section One:

- This section describes the basic terminology used throughout the document and defines the practitioners and their practice within the field in question. This allows the reader to understand how a new service could affect the current practice of a number of medical specialities.
- It presents a brief history of radiography in medico-legal practice to allow the reader to understand how imaging has been applied to autopsy practice. It demonstrates that as technical developments have been achieved in clinical medicine, they have been applied rapidly to autopsy practice.
- It outlines current use of cross-sectional imaging in autopsy practice both within the NHS and internationally. This allows the reader to consider where the NHS stands in terms of its use internationally.

Section Two:

- The document reviews the law and documentation of the criminal justice service to address the objectives set for the Group. There is an emphasis in this section on criminal and civil law as, although the autopsy and hence cross-sectional imaging is authorised under coronial legislation, the resulting report may end up in the criminal and civil courts. Thus, the initial actions of the coroner must not have an adverse affect on other aspects of the CJS.

Section Three:

- Having established that there is a need to consider the implementation of a new service and that there is no legal reason not to proceed, the document outlines the requirements in terms of personnel, logistics, and training that need to be achieved to establish a new service.
- Finally, the document presents a number of cost implications for the implementation of a new service.

Each chapter is presented in a similar manner:

- A short introduction.
- A highlighted text box containing an indication of the questions to be addressed.
- Text related to the questions are considered under appropriate subheadings.

- A final summary textbox, which presents the recommendations from the Group in relation to the questions considered in the chapter.

The document is supported by appropriate peer reviewed literature and references for both adult and child practice. This is not an exhaustive reference list, but rather key supportive publications.

Section One

Coronal CT image of the abdomen showing an un-ruptured abdominal aortic aneurysm (arrow)

Terminology and Practitioners

Prior to presenting the findings of the Group it is important to understand the terminology used within the document. It is also important to understand the types of autopsies currently available in England, which professional bodies/practitioners are involved in this area of practice and how the NHS' current practice differs within England and internationally. This section sets the background to the chapters that follow by outlining the following areas:

- What is meant by an '*autopsy*'?
- Which professionals are currently involved in autopsy practice in England?
- Which forms of radiography are used in autopsy practice?
- Which professionals are currently associated with radiological imaging of the dead?
- What training is available to these individuals?
- What systems of audit, EQA and standards are currently available in relation to autopsy practice and radiological imaging of the dead?
- What is the extent of research within the field of autopsy practice and cross-sectional imaging in England?

The Autopsy

The term "*autopsy*" means "*to see for oneself*" and is synonymous with the terms "*post mortem*" (and its variant spellings "*post-mortem*" and "*postmortem*"), and "*necropsy*". Rarely the term "*thanatopsy*" may be encountered. Although usually inferred to mean a detailed examination of the cadaver ("body" or "corpse") including an external examination and invasive evisceration with careful dissection of each organ, there is no definition of the true extent or precise nature of the examination to be undertaken (Burton 2010).

Currently there are two generic types of autopsy undertaken within the NHS.

i. The first and predominant type is that of the medico-legal autopsy, authorised by either a Coroner (England, Wales and Northern Ireland) or Procurator Fiscal (Scotland). The reason to undertake such an examination, no matter where one works in the world, is to assist with answering the four questions of *whom* the person was and *where, when* and by *what* means they came to their death. The emphasis of the investigation of each of these questions differs in each case - for example, in the case of a sudden death in the community where the deceased's identity, place and time of death are known it is *how* they came by their death that becomes the principal question, whereas in a mass fatality incident where the place, time and usually how

they came to their death are known, it is the identity (*who*) of the deceased that is the principal question to be answered.

ii. The second is the so-called 'hospital', 'consented' or 'permission' autopsy, which is undertaken where all four of these questions are already known but the attending clinician wishes to gain a further insight into the disease or treatment.

Thus, when considering any process that could supplement or replace the full invasive autopsy, it is critical that the four questions of *who, where, when* and *how* are answered to the same legal standard as is in force at the time, whether it is achieved by a single process or a combination of approaches.

All autopsies must be undertaken in licensed premises, licensed by the Human Tissue Authority (Human Tissue Act 2004).

This document is intended to consider autopsy practice related to medico-legal deaths only and from this point onwards will only address this matter. The use of the term "*autopsy*" from here on means "*medico-legal autopsy*". As the majority of deaths are of adults, this document is predominately concerned with adult medico-legal practice. Fetal, neonatal and paediatric deaths are addressed within the text where appropriate.

Variations of the autopsy

The examination of the dead can be sub-categorised into *non-invasive* and *invasive* approaches (Rutty 2007). All systems are currently available within the NHS although the use of full invasive autopsies predominates to date.

Non-invasive

There are only two types of systems that can be considered truly non-invasive as all other systems involve some form of break of the cadaver's skin, no matter how small. These are as follows:

View and grant	A system where one reviews the available clinical history and performs an external examination of the body. A cause of death is issued, if possible without any further procedures.
View, scan and grant	A variation of the former with the addition of cross-sectional imaging to visualise the internal organs and body cavities without an invasive procedure.

Invasive

There are several different procedures available, which all have, in addition to a review of the clinical circumstances of the death and an external examination, an invasive component. These are as follows:

Needle sampling	A needle can be inserted into the body to take a toxicology, microbiology or tissue sample for the purpose of diagnosis without the need for a full invasive examination.
Scopes	Endoscopes and laparoscopes can be used to examine the body cavities and organs without the need for a full invasive autopsy.
Evisceration	Limited (to a cavity, organ or system) or full invasive autopsy can be undertaken.

This document intends to consider the role of cross-sectional imaging either as an adjunct to or as a replacement of an invasive procedure. Therefore, from this point onwards other forms of autopsy will not be considered.

Autopsy Practitioners

In relation to who can undertake an autopsy examination, please refer to the section of this document that considers "*Law*".

There are currently a number of different approaches to autopsies within the NHS.

i. In England and Wales, the majority of autopsies are undertaken by histopathologists, within either NHS/NHS Wales premises or public mortuaries. The catchment area for practice will depend upon the coroner's jurisdictions.

ii. In England and Wales suspicious or homicide deaths are recommended to be undertaken by Home Office registered forensic pathologists. They work within Home Office defined Group Practices serving defined population areas and usually several police authority and coroner's jurisdictions. There are currently 52 consultant forensic pathologists within the UK. In England and Wales, the majority of forensic pathologists are full-time in the discipline either in private self-employed practice (majority) or employed within the universities. A few NHS histopathologists still undertake forensic practice although this trend is disappearing as these individuals retire from practice.

iii. In Scotland, the majority of autopsies are undertaken by forensic practitioners working within a small number of university-based units serving defined population areas Histopathologists assist with this work in some areas of the country.

iv. In Northern Ireland, autopsies are undertaken by forensic practitioners working within a single unit.

Internationally, medico-legal autopsies are, in general, undertaken by forensic pathologists working in units serving defined population areas. This explains why the principal journals and educational societies, as well as the source of the majority of publications in the application of

cross-sectional imaging to autopsy practice originate from within the international forensic community and not the histopathology community.

In the UK, an Anatomical Pathology Technologist (APT) (also known as a *"mortuary technician"*) assists the pathologist at the examination. They may undertake some of the dissection under the direction of the pathologist. They are responsible for the reconstruction of the body and the day-to-day running of the mortuary. They have no role in the interpretation of the findings or in the writing of the report.

Mortuaries

The mortuaries where the autopsies are undertaken may be either within NHS premises or public council run mortuaries. There is a document in production currently from the Home Office Forensic Science Regulator, which defines the standards required from the mortuary for those engaged in forensic examinations (Forensic Science Regulator in development 2011). Mass fatality examinations may be undertaken in established or temporary mortuaries. Contaminated mass fatality incident mortuary arrangements are provided by the Home Office guidance document (Home Office 2009).

Radiological Imaging

In terms of autopsy practice, there are three types of radiological imaging that can be used (see also "*Past and Present"*).

i. Plain x-rays. Traditional plain film x-rays are primarily used to image bone trauma and the presence of foreign objects within the body. Dental x-rays are used to image the teeth/jaws for identification purposes.

ii. Fluoroscopy. This modality is favoured for use in mass fatality incidents owing to its ability to image the body in real time, although, in general, cross-sectional imaging is being considered as a replacement to fluoroscopy.

iii. Cross-sectional imaging i.e. Computed Tomography and Magnetic Resonance Imaging.

In addition to these three modalities, ultrasound has limited use with cadavers owing to the effect of post mortem decomposition. The use of portable devices has been investigated in Canada, Japan and Switzerland.

In relation to the requirement for cross-sectional imaging to be undertaken in licensed premises, please see the section entitled "*Law*".

This document is intended to consider the role of cross-sectional imaging either as an adjunct to or as a replacement of an invasive procedure. Therefore, from this point onwards other forms of imaging will not be considered.

Variations of cross-sectional imaging

As with the autopsy, there are a number of variations or enhancements that can be used with cross-sectional imaging of the dead.

i. The body may be scanned prior to imaging with a surface laser scanner. This is used to generate 3 dimensional meshes of the cadaver for post imaging reconstructions and presentations. To date this technique is restricted to limited areas in England, for example, within London where the technique is used by the Metropolitan Police. Although previously (but not currently) used in Leicester, it is hoped that a similar system will be introduced to that being currently used in London in early 2012. Surface body scanning is used internationally at limited centres as part of the Virtopsy® and Virtobot® systems (Ebert 2010).

ii. The body may be subject to angiography either by use of a targeted system (Saunders 2011, Roberts 2011) or a whole body system (Gabherr 2010). To date only targeted angiography is used in England with whole body angiography being reported in use internationally, although it is anticipated that such systems will be introduced in Leicester in early 2012.

iii. Percutaneous needle biopsies may be taken during imaging (Bollinger 2010). To date this technique is not known to be in use in England but is used internationally at limited centres.

These variations have led to the use of a number of terminologies for this mode of imaging - near virtual autopsies, virtual autopsies, Virtopsy® (Thali 2002), Virtobot® (Ebert 2010), and Virtangio® (Fumedica, Switzerland (http://www.fumedica.ch; last visited February 2012)). As the last three terms refer to registered, specific systems, they are not used in this document in relation to autopsy cross-sectional imaging in the NHS.

Radiography Practitioners

Currently within the NHS, a radiographer undertakes the imaging of a cadaver with, depending on which part of the country the examination is undertaken, the images reported by a radiologist or a forensic pathologist.

Internationally either a radiographer or an APT may image the cadaver with the images reported by a radiologist or a forensic pathologist or both. This alternative system has been considered by the RCR/RCPath working Group and proposals as to how a similar system could be adopted in England are found within their document and under the section "*Workforce Training Requirements"* of this document.

In the case of PMCT angiography, a pathologist, an APT or a trained angiography technician, currently undertake the cannulation of the body and the injection of contrast medium in the NHS. Examples of where this happens within England are at Leicester usually (pathologist or angiography technician), London (APT or pathologist) and Oxford (pathologist).

In the case of mobile CT used in contaminated mass fatality incidents, police officers who are members of UK-DVI have been trained to undertake some of the tasks normally performed by a radiographer during the imaging of the body. They work under the direction of a supervising radiographer.

Site of Imaging

Imaging of cadavers in England is undertaken within NHS facilities, usually at night or the weekend, unless special arrangements exist with the imaging department. In mass fatality incidents, mobile CT scanners can be deployed to either the scene of the incident or the mortuary (FiMag – Rutty 2009).

Internationally CT scanners have been placed into the medico-legal units' mortuaries. This facilitates open access cadaver imaging and can be used for both single and multiple fatality incidents. To date a scanner has not been placed into an English mortuary although in mid-2013, a privately funded venture will see a dedicated CT scanner being installed into the public mortuary in Bradford.

Image Data Storage

The process of imaging the dead, as explained later under the section '*Image Storage, Archive and Retrieval'*, is different from that of imaging the living. The image protocols are different and the data generated during the examination of any single case is of a larger volume than that for the living. A standardised national imaging protocol for autopsy cross-sectional imaging has been proposed in the joint RCR/RCPath document. Should this be accepted within the final document then this should standardise autopsy cross-sectional imaging throughout the NHS.

As this arises from medico-legal work and may be used within the CJS, it requires secure storage. There are two systems known to be in use for such data storage:

i. Local storage through removable media such as portable hard drives or images burnt to CD or DVD. This allows the images to be viewed using standalone DICOM viewing software or loaded on local image workstations.

ii. Storage on the Hospital Picture Archiving and Communications System (PACS). This provides a local data store with the ability to view the images on the dedicated radiology workstations or viewing terminals.

The FiMag system was developed jointly for the storage and distribution of cross-sectional imaging of the dead arising from a mass fatality incident. This system is available in England as a dedicated secure cadaver image repository.

Training

There are two Royal Colleges involved in training and standards for medical practitioners involved in autopsy and autopsy related radiology. In law, these doctors must obtain GMC approval in the relevant CCT (or CESR). The Colleges involved are:

- **The Royal College of Pathologists.** All NHS qualified doctors who wish to undertake autopsy practice as consultant histopathologists or forensic pathologists must attain fellowship of the RCPath with training and examination in autopsy/forensic practice as defined within the GMC approved training curriculum. To date, cross-sectional imaging is not part of the curriculum or examinations although experience in radiology is being put into the new forensic curriculum in preparation for forensic pathology being recognised as a new medical sub-speciality in a change to the Medical Act (anticipated in 2012). Within the College there is no sub-speciality group purely for autopsy related imaging, but in the current on-going 50-year review of the structure of the College, it has been proposed that a new group is brought into existence to consider all matters related to the dead and cross-sectional imaging/radiology has been suggested to be placed into that group, should it be formed.

- **The Royal College of Radiologists.** All NHS qualified doctors who wish to practice as consultant radiologists must obtain fellowship of the RCR with training and examination defined within the GMC approved training curriculum. To date there is no sub-group within the RCR for autopsy imaging and no specific training or examination for autopsy-based imaging.

The Society and College of Radiographers, Health & Care Professions Council (HCPC) and the Association of Anatomical Pathology Technologists and Voluntary Registration Council for Healthcare Scientists (VRC) provide the standards and training for these two professional Groups. The International Association of Forensic Radiographers provides training for radiographers for mass fatality imaging.

Audit and External Quality Assurance

In relation to the audit and external quality assurance of the practitioners:

- To date there is no form of audit or external quality assurance system for those currently engaged in post mortem imaging. Local arrangements may be in place in the form of multidisciplinary team (MDT) meetings where radiologists, pathologists and radiographers meet on a regular basis to discuss the CT imaging and compare it to the autopsy findings. Such MDT meetings occur within the military and at Oxford, Great Ormond Street Hospital for Children and Leicester.

- To date, the only form of audit or external quality assurance for histopathologists engaged in autopsy practice is the National Confidential Enquiries, for example,

into post-operative or maternal deaths. This does not provide individual feedback. Other than this, following their Royal College examination they will practice as lone, un-witnessed practitioners for the rest of their professional careers with no form of audit or EQA in autopsy practice (Rutty, 2006).

- Forensic pathologists are subject to a number of quality assurance schemes throughout their professional careers. Firstly, a requirement to be a member of the Home Secretary's list of forensic pathologists is that all of one's reports going to a criminal court must be reviewed and the contents agreed to be "*reasonable"* by another Home Office pathologist (so-called "*critical checking"*). Many practices extend this to include non-criminal cases as well. Secondly, they must participate in the annual Home Office audit of reports, which are assessed against the RCPath/ACPO/Home Office Code of Conduct for forensic pathologists. Thirdly, cases of homicide usually have at least one independent autopsy performed. As we move towards the start of GMC relicensing in 2012, all forensic pathologists will revalidate in forensic autopsy practice and will have to demonstrate that they are up to date in the field. As part of this, a national EQA is being developed in forensic pathology practice.

Thus, to date, outside forensic pathology practice there are no autopsy or PMCT practitioner based systems of quality assessment, audit or EQA. There are guidelines for autopsy practice provided by the RCPath, both in terms of a generic document and disease focused best practice scenarios (for example dealing with an epileptic death), but there is no assessment system to assess whether practitioners are applying these guidelines to their practice (http://www.rcpath.org/publications-media/publications/guidelines-on-autopsy-practice-best-practice-scenarios.htm; last visited December 2011).

As these are all medico-legal examinations, no matter whether they are undertaken by a histopathologist or a forensic pathologist in England, the practitioners should bear in mind the Council of Europe Group of Ministers' guidelines for conducting medico-legal autopsies, which are in force and apply to all member states (European Union, 1999). The equivalent document in England is that of the RCPath Code of Conduct that applies currently to forensic pathology practice only. Outside the UK, the EU guidelines are used as national standards for medico-legal practice. A similar document does not currently exist for autopsy cross-sectional imaging.

Payment

Medico-legal autopsy practice is a Category 2 fee service. This applies to histopathologists, forensic pathologists, and radiologists. Radiographers receive private fee payments for this service.

Histopathologists working in NHS premises and public mortuaries whilst employed on NHS contracts should undertake such work outside their contracted NHS hours of service unless local agreements exist. However, it is not unusual for this work to take place within NHS premises in NHS contracted time with the utilisation of other NHS facilities such as secretarial

support for typing of reports. Attendance at inquests to give evidence is Category 2 work and is undertaken, by the very nature of court timings, during NHS hours.

Forensic pathologists may be employed or self-employed. They undertake autopsy practice during their normal working hours, attracting Category 2 payments, which either will go to their employer or provides them with an income if self-employed. Attendance at court is part of their normal job description and thus undertaken during normal working hours.

Radiologists and radiographers may undertake cadaver cross-sectional imaging as Category 2 or fee paid work. Imaging is usually undertaken outside normal NHS clinical working hours so as not to disrupt clinical care delivery. Attendance at court would be unusual, but if required would be during NHS working hours attracting a Category 2 or private fee.

APTs are employed either within the NHS or by local Councils to run mortuaries and assist with autopsy work. They will be salaried to undertake this work. Some mortuary staff do receive additional payments from undertakers or from visiting forensic pathologists for services rendered, but their national professional body advises against this practice.

Cost of Service

The cost of the use of an NHS mortuary for body storage and autopsy examination is paid by the local Council through the coroner's service in England and Wales. In Scotland, the Procurator Fiscal office has contracts with the autopsy providers, which are all-inclusive and include mortuary and pathology services. Some coroner's jurisdictions also have such contracts.

Mortuary service costs vary throughout England and Wales as they are locally set which in recent times has led to tendering by Councils for mortuary services with NHS providers out bidding each other principally on cost. This has led to one county (Lincolnshire) having minimal county-based autopsy activities as the majority of autopsies are undertaken at mortuaries in adjacent counties.

The cost of imaging services varies depending upon location (see "*Current Use of Post Mortem Cross-sectional Imaging; practicalities, costs and perceptions-adults"*). Payment may be by:

- The local Council through the coroner's service.
- The police – for forensic suspicious death and homicide investigations.
- The general public as typified by the Manchester service.

Research

As stated above, the principal journals for publication of research related to autopsy practice and hence continuous professional development are those related to forensic, not

histopathology practice. Autopsy cross-sectional imaging papers are predominantly found within these journals or radiology journals.

Few papers are published on either autopsy or autopsy cross-sectional imaging research from England. The majority of papers arise from the forensic institutes of Europe, Japan and the USA. This is due to there being only a few true adult autopsy research centres in this field within England i.e. those of Leicester and the combined work of Oxford/Manchester. In paediatric practice, the principal research centres for autopsy cross-sectional imaging are Great Ormond Street Hospital, Sheffield, and Cambridge.

The single most important factor in the lack of research in this area in England is the lack of identifiable funding to support research. Although the Department of Health and NIHR have funded research in recent times for both adult and paediatric studies, there is currently no recurrent central government funding to support research into this area. There is no charity whose primary support is to adult research matters related to the dead, and although there are small charitable organisations who will consider research in fields where other larger organisations have no interest, the funding available is insufficient to sustain the required level of research currently required within the field. Funding is available for children through the Foundation for the Study of Infant Deaths (www.FSID.org.uk. Last visited January 2012) and Wellbeing for Women (http://www.wellbeingofwomen.org.uk/research/ last visited January 2012), but again this is insufficient to sustain the required level of research currently required within the field.

Research centres in England have failed to attract sponsorship or equipment from commercial radiology imaging companies as has occurred internationally. The reason why groups such as the Virtopsy®, Virtobot® and Virtangio® Groups have published so extensively and been able to develop their systems in this area is due to such sponsorship.

Summary

It is the Group's view in relation to the questions posed that:

- As the extent of an autopsy examination is not defined and does not imply an invasive examination, a radiological examination using cross-sectional imaging as part of a so-called 'view, scan and grant' is already available and can be used throughout the NHS.
- Although there are trained consultant pathologists, radiologists, radiographers and APTs working within the field of autopsy practice and cadaver cross-sectional imaging (both research and practice), to date there is no training programme for these professionals in cross-sectional imaging related to the dead. To take this work stream forward, standards of practice and training programmes need to be developed within each profession to deliver a trained workforce. The RCPath and RCR should lead this, in the view of the Group, with input from the Society and College of Radiographers and Association of Anatomical Pathology Technologists.

- Outside forensic pathology, there is to date no audit or EQA system for autopsy practice. Thus, to ensure standards of practice, continuous professional development and for future revalidation (or similar equivalent programmes), audit and EQA systems (as apply currently to forensic pathology) need to be developed for other professional bodies engaged in autopsy practice.

- Currently cadaver cross-sectional imaging and data storage is undertaken within NHS premises. For options for the future, please see "*Image Storage, Archive and Retrieval*".

- Currently the cost of the service and fee payment to the professionals involved arises from tenders from local Councils or Category 2 fees. For options for the future, please see "*Costing of a Pathological and Radiological Service".*

- As the programme of development, practice and implementation of autopsy cross-sectional imaging accelerates within the NHS, it is essential to underpin such development with a strong academic research strategy. Without this, the discipline will either stagnate or will not develop at the same pace as other areas of the world. It is critical to establish sustainable funding streams to fund research into the foreseeable future, in both adult and paediatric practice, as the results will in turn drive forward best practice, standards, and technical developments and define when the systems can be used as an alternative to an invasive autopsy through a published, peer reviewed evidence base.

Past and Present

This section of the document presents a concise history of the role of imaging within medico-legal autopsy practice, from the first use of plain radiography to modern cross-sectional imaging. As this document concentrates on cross-sectional imaging in adults, only the principal milestones in the use of imaging in autopsy practice are presented. Within this section, a number of questions have been addressed:

- What is the historical association between radiology and medico-legal autopsies?
- When was cross-sectional imaging first introduced into medico-legal practice?
- When was the proposition that cross-sectional imaging could replace an invasive autopsy first put forward?
- What are the major milestones in terms of the NHS' use of cross-sectional imaging in medico-legal autopsy practice?

The First Cases

Shortly after the discovery of x-rays in November 1895, the potential use of radiography as an aid to medico-legal investigation was recognised across the world.

The first criminal court case to use x-rays occurred in Montreal, Canada on Christmas Eve, 1895. George Holder was accused of shooting Tolson Cunning in the leg (Reynolds 2010). The location of the projectile could not be found by physical examination or probe. The wound healed, but remained symptomatic and so Cunning's physician requested an x-ray to be undertaken at McGill University. The image took 45 minutes exposure and showed the projectile adjacent to the lower leg bones (Brogden 1998). The image was used in court to convict George Holder of attempted murder.

The first use of radiographs in a homicide investigation is attributed to a case in 1896. Professor A Schuster of Owens College, Manchester, UK used x-rays to image gunshot injuries to Elizabeth Hartley who had been shot four times, the projectiles striking the jaw, ear and neck areas (Eckert 1984). Two x-rays were taken at her home, as she was too ill to be moved, the first taking 1 hour to complete, the second 70 minutes. A third x-ray was taken by Schuster himself, the first two having been taken by his assistants. This last film identified the location of the fourth projectile. Elizabeth Hartley died of her injuries.

Other uses of radiography related to crime investigation were also reported in 1896 in the *Journal of the American Medical Association,* including the demonstration of fractures caused by bullets and the use of x-rays to investigate suspicious packages (Brogden 1998).

Today, forensic pathologists across the world utilise radiology in a range of circumstances including:

- Identification – where a body is unidentifiable by other means;
- Firearm deaths – where location and retrieval of projectiles is of forensic importance;
- Child abuse / non accidental injury – skeletal surveys are crucial for the detection of recent and historical skeletal trauma;
- Barotrauma or suspected air embolism – such entities can be difficult to demonstrate at invasive autopsy;
- Traumatic subarachnoid haemorrhage – contrast angiography is a recognised method for examination of the integrity of the vertebral arteries;
- Other complex cases where the examination and interpretation is compromised by destruction of the body e.g. fire damage, decomposition, dismemberment, or fragmentation.

Radiology in the Courts

When one presents new technology or its application outside its recognised clinical setting to professional bodies such as lawyers and doctors, there may be initial reluctance to accept the use of such technology (see '*Law*'). Despite the success of the Montreal case, controversy about the admissibility of x-rays existed in the USA courts at that time.

The first civil trial where x-rays were accepted as evidence was in Denver in 1896, although the case had begun on June 15th, 1895. James Smith had fallen from a ladder whilst pruning a tree and sustained a hip injury. Initially, no fracture was found. However, a civil action was started and Smith was x-rayed on four occasions to try and image the injury. Finally, the outline of an impacted fracture was identified.

The arguments then arose over admissibility of the x-ray as evidence. In some jurisdictions, they were refused to be admitted as '*It is like offering the photograph of a ghost*' (Brogden 1998). However, this matter was finally settled in 1896 when Judge LeFevre decided:

"We have been presented with a photograph taken by means of a new scientific discovery. It knocks for admission at the temple of learning: What shall we do or say? Close fast the door or open wide the portals?

The photographs are offered in evidence to show the present condition of the head and neck of the femur bone, which is entirely hidden from the eye of the surgeon. Modern science has made it possible to look beneath the tissues of the human body, and has aided surgery in telling of the hidden mysteries. We believe it is our duty to be the first…in admitting in evidence

a process known and acknowledged as a determinate science. The exhibits will be admitted in evidence." (Brogden 1998).

Although the Holden case from Montreal is attributed as the first court case where x-rays were used, prior to this in England in September 1895, Miss Folliott, a burlesque and comedic actress had fallen on the steps leading to her dressing room in a Nottingham theatre. She sustained a foot injury which was subsequently "photographed" by x-ray at University College Hospital. Her left cuboid bone was displaced. The x-ray was shown in court. The theatre owners were convicted for maintaining an unsafe workplace, but Miss Folliott was also found guilty of contributory carelessness!

Thus, the use of x-rays as evidence in medico-legal cases was established within the court system and is used to this day. For a brief review of how cross-sectional imaging has been used please refer to the section entitled "*Law*".

Identification

Writing in the October issue of American X-Ray Journal, 1898 Dr Fovau d'Courmelles wrote, "Knowing the existence of a fracture in a person who has been burned or mutilated beyond recognition, we can hope to identify him by the x-ray" (Brogden 1998).

Today radiology plays an important and well-recognised role in the identification of an individual, be it their gender, age, stature or race. X-rays were famously used to examine the remains of Adolf Hitler and Josef Mengele. In both cases, radiology played a role in positively identifying their remains.

Mass Fatalities

The first use of radiology in a mass fatality incident was by the medical investigative team in the identification of the victims of the SS Noronic disaster (Singleton 1951). The ship was gutted by fire whilst tied to the pier in Toronto, Canada on the 17th September 1949. 116 of the 119 victims were ultimately identified. Singleton identified 24 of the victims by the sole use of radiology by obtaining survey x-rays of 78 of the bodies using mobile equipment in the first 48 hours after the disaster and comparing them with x-rays taken during life. In five further bodies, the comparison x-rays were sufficient to warrant a probable identification.

Today radiology is a standard technology used in mass fatality incidents for the identification of the dead. This may be in the form of dental x-rays or fluoroscopy.

Thus, the potential role of radiology in medico-legal practice was recognised within 1 month of the discovery of x-rays and has been associated with medico-legal practice for over 100 years. However, in a review of the use of cross-sectional imaging in autopsy practice Jeffery wrote:

"The post-mortem examination has been described as the ultimate surgical operation. Few surgeons would attempt a complex surgical procedure without prior sight of some form of

radiological imaging. However, the vast majority of post-mortem examinations, undertaken within the United Kingdom (UK), do not make use of this valuable investigation." (Jeffery 2010).

Ultrasound

The first person to describe its use was Akopov in Russia, 1976 (Akopov 1976). There followed a small number of papers detailing its use to image fractures, measure soft tissue thickness and even estimate a time since death (Uchigasaki 2004). It was piloted in perinatal deaths in 1989, but failed to gain widespread interest (Furness 1989). Uchigasaki suggested the use of a portable device for the examination of the dead at the scene of death or a mortuary (Uchigasaki 2004). Today, few centres outside Japan where police stations have ultrasound units available for crime scene investigations use ultrasound to investigate the dead, as it has not been shown to have advantages over other imaging modalities.

Cross-sectional Imaging

Although the application of cross-sectional imaging to the investigation of death is considered a relatively modern concept, this is not the case. CT has played a role in medico-legal investigations for over 30 years, as detailed below.

Computed tomography: the early days

The first commercially available CT scanner was invented by Godfrey Hounslow, who conceived the idea in 1967, with the first clinical scanner brought into use in October 1971 at Atkinson Morley Hospital, Wimbledon, England. The machine took 160 parallel readings through 180 angles, each 1 degree apart, with each scan taking a little over 5 minutes. The images from these scans took 2.5 hours to be processed by a large computer. Imaging was confined to the head.

In 1977, Wullenweber et al described what is thought to be the first medico-legal use of cross-sectional imaging (Wullenweber 1977). They described the CT findings of the heads of living victims with gunshot injuries. The first reported comparison between pre- and postmortem imaging was by Flodmark, who described the imaging of neonates suffering from perinatal asphyxia (Flodmark 1980). In 1983, Kranz et al described the findings of adult cadaver imaging of the head in diving related deaths (Kranz 1983).

There then followed technical developments with CT to allow for the introduction of three-dimensional, whole-body, digital image acquisition. In 1994, Donchin et al. were the first to report the use of CT imaging of the whole cadaver and propose its use as an alternative to the invasive autopsy (Donchin 1994).

Magnetic resonance imaging: the early days

Raymond Damadian created the world's first MRI machine in 1972. The first clinical use of MRI was reported in 1977. It was, however, not until 1996 that Brookes et al. reported in the Lancet

the use of MRI in association with perinatal autopsies (Brookes 1996). There followed a number of publications related to paediatric practice.

Bissett suggested that MRI could be used to investigate adult sudden deaths in 1998 (Bissett 1998). He went on to report four years' experience of the use of MRI as an alternative to an invasive autopsy for the investigation of adult deaths in 2002, reporting the first operational system of its kind (Bissett 2002). This was followed up in 2003 by Roberts et al. who presented further work using MRI (Roberts 2003). In response to this paper, Rutty and Swift put forward the concept of a new medical sub-speciality of autopsy imaging which they termed "*necroradiology*" (Rutty 2004).

Cross-sectional Imaging: the Explosion of Interest

It was not until around 2000 that the use of cross-sectional imaging, predominantly CT in deceased adults and MRI in deceased children, really advanced. This was in part owing to the establishment of a number of research programmes within the field across the world as well as exponential technological advancements within the clinical field of cross-sectional imaging and the increase in availability of scanners to autopsy practitioners.

The establishment of the Virtopsy® Group in Bern, Switzerland (now Zurich) led to a greater public awareness of the possibility of the use of CT and MRI as an adjunct or replacement to an invasive autopsy (Thali 2003). They received substantial funding to establish their research group and are the single largest group publishing in the field to date. However, their publications, like those from other centres, are predominantly case based. Currently, they are pursuing the concept of Virtobot®, a semi-automated system involving cadaver angiography, surface laser scanning, robot guided needle biopsy and cross-sectional imaging (Ebert 2010). To date, with the exception of a few centres such as the work undertaken at Oxford, Leicester and Lausanne, Switzerland, there is a lack of true, large clinical trials in this field.

In England for adults, the three principal research and practitioner groups are at Leicester, Manchester and Oxford. Leicester started CT imaging of their forensic cases in 2002. Today they image both natural and unnatural deaths for both diagnostic and research purposes and hold possibly the largest validated teaching and training image dataset in the UK. They hold an NIHR grant investigating the application of targeted angiography to natural sudden unexpected deaths and are the largest research group publishing in adult cadaver cross-sectional imaging in the UK. Manchester continue to run the service described by Bissett and, together with Oxford, have recently published the findings of a Department of Health-funded research project investigating the use of CT and MRI as an alternative to the invasive autopsy in natural death (Roberts 2011). In 2013, the first CT-based imaging system will be placed into a UK public mortuary in Bradford.

Across the world, other centres performing post mortem imaging include the USA military sponsored programmes (Levy 2006), and the CATopsy programme in Pennsylvania, USA (Hoey 2007). Despite the lack of an evidence base for the use of these systems in autopsy work, cross-sectional imaging equipment was placed into forensic institute mortuaries for

example in Germany and Denmark to facilitate cadaver imaging (Leth 2008). In Japan, where autopsy numbers are among the lowest in the world, they have explored the use of cross-sectional imaging to increase their autopsy service and were the first to describe the use of mobile CT scanners to image the dead (Hayakawa 2006).

The first use of mobile CT scanners in a mass fatality incident took place in February 2006 (Rutty 2007). Following this, Rutty's group worked with the Home Office and Department of Health to develop the UK FiMag system, a remote reporting cross-sectional imaging system for use in mass fatality incidents (Rutty 2009). Today cross-sectional imaging has an established role in mass fatality incidents across the world.

The single best example of service provision using a CT scanner within medico-legal premises is that of the Victorian Institute of Forensic Medicine in Australia. Established in the mid 2000's, today every cadaver is scanned on admission to the building resulting in over 50,000 cadaver scans to date. The law related to cadavers has been changed to allow for scanning to occur without relatives' consent or the authority of the coroner to enable the images to be used as a triage system to avoid invasive autopsy examinations (O'Donnell 2007).

Summary

It is the Group's view in relation to the history of radiology related to autopsy practices that:

- The role of radiology as an adjunct to medico-legal practice was established within a month of the discovery of x-rays and in homicide investigation shortly after this.
- Although there was some initial hesitancy by the judiciary, x-rays became accepted as admissible evidence rapidly after their introduction into medical practice.
- Over the next half century their role was established in other areas of autopsy and forensic practice including the identification of the deceased, examination of inanimate objects and use in mass fatality incidents.
- Although other forms of imaging including ultrasound and fluoroscopy have been used to variable extent and effect, it was not until the introduction of cross-sectional imaging that the possibility of the radiological non-invasive autopsy was established.
- Owing to restrictions of technology, it was not until 1994 that the concept of the use of cross-sectional imaging was proposed as an alternative to the invasive autopsy. However, it was not until the turn of the last century that there was an accompanying expansion of clinical and research use of both MRI and CT in both paediatric and adult autopsy practice.
- Today, cross-sectional imaging of the deceased occurs all over the world in both single and mass fatality incidents using CT or MRI and both in adults and children. CT scanners have been placed into mortuaries across the world with ongoing translation of clinical services to autopsy practice. However, despite all of this work and the establishment of cross-sectional imaging within autopsy practice over 30 years ago, there remains a lack of a published evidence base to support the service due to the lack of large funded clinical trials within the field.

Current use of Post Mortem Cross-Sectional Imaging: Practicalities, Costs and Perceptions

Adults

The following section of this document presents an overview of the current use of post mortem cross-sectional imaging, both within the NHS and internationally. This is based on the results of a national and international questionnaire-based survey undertaken by the Group in an attempt to gain an insight into the extent and use of cross-sectional imaging in autopsy practice as well as two recent peer-reviewed published papers considering matters related to this chapter. This section of the report has attempted to provide answers to the following questions:

i. What is the extent of use of post mortem cross-sectional imaging currently in the NHS?

ii. What is the cost of the service currently in the NHS?

iii. Who finances the service currently within the NHS?

iv. How does English practice compare to that of its international use, both in site, personnel and cost?

v. What do the professionals and public think of the proposal of non-invasive cross-sectional imaging as an alternative to the invasive autopsy?

Questionnaire

A questionnaire was developed in 2011 by the Group for the purpose of trying to gain an insight into the use of cross-sectional imaging within both England and internationally (see appendix A). During September 2011, individuals and organisations were identified by the Group members as known users or providers of post mortem cross-sectional imaging services. Those identified were written to, inviting them to participate in the survey. Both adult and paediatric users and providers were surveyed separately. Those who replied were then sent, by email, the questionnaire. Combinations of open and closed questions were used and the returns were analysed to identify trends and themes. As the number involved was small, formal statistical analysis was considered inappropriate.

The following text is a summary of the results derived from the questionnaire and provides an insight into use of autopsy cross-sectional imaging in England compared to the rest of the world. The Group recognises that it was not possible to identify every user or provider within the NHS as there is no means currently of doing this. The Group does feel however that they captured the views of the principal users, providers and research centres.

The questionnaire is regarded as a snapshot of practice rather than an all-encompassing survey. Only selected lead centres were contacted internationally, based on their known

international standing within the field and their research and publication record, to enable the Group to gain an insight into international use.

England

The majority of those surveyed in England were coroners who use/have used cross-sectional imaging in association with autopsy practice. A single histopathologist provided a reply to the questionnaire.

A total of 8 coronial jurisdictions were identified as currently using cross-sectional imaging for non-forensic autopsy work. A further 1 jurisdiction is known to use cross-sectional imaging with non-forensic autopsies, and 5 coronial jurisdictions are known to use cross-sectional imaging for forensic practice. Unless otherwise specified, the following refers to non-forensic practice only. It is understood that post mortem CT (PMCT) may have recently been introduced to the autopsy service based in Edinburgh, but no further details are known about this fledgling service.

Regional use

The areas of the country known to the Group to be currently using cross-sectional imaging in association with medico-legal autopsies can be split into four geographical areas. Within each area, the imaging modality of choice varied at the time of the survey as follows:

- London – Principally use CT (non-forensic).
- Oxford – Principally use CT (non-forensic). The military death investigations on bodies repatriated from international combat zones undertaken at Oxford use CT.
- Manchester – Principally use MRI with CT for some cases (non-forensic).
- Midlands – In the East Midlands CT is used for forensic cases, road traffic collisions and non-forensic research cases. Imaging is undertaken for the East Midlands Forensic Pathology unit at Leicester Royal Infirmary, Royal Derby, Chesterfield Royal Infirmary, Lincoln County and Peterborough Hospitals. In the West Midlands, the Group is aware of CT examinations being undertaken for forensic cases at Coventry.

The survey identified that in all cases scanned within England, static hospital-based scanners are used. The survey identified that other forms of radiology imaging outside paediatric or forensic practice are not used routinely in England in autopsy practice.

Reason for use

The principal reason for the use of the service was given as ‘religious’ in all cases. Another reason identified was to avoid unnecessary risk of infection to a pathologist in opening the body.

It is known that in the case of the military the use of PMCT has led to the redesigning of personal protective equipment and protective vehicles whilst there is ongoing active combat. This demonstrates an important health and safety role of the use of PMCT.

Cost of service

The cost of the service and the person paying for the service varies depending upon the geographical area involved:

i. In London, the cost for a CT examination was given as £250. This is paid for by the coroner's service.

ii. In Oxford, the cost for the non-military CT examination is unknown. It is subsidised by using monies left over from a Department of Health research grant to further research in this field.

iii. In Manchester, the cost for a CT examination was given as £600 with the cost for MRI ranging between £995 and £1350 depending on the number of areas of the body examined. This is paid for by the relatives of the deceased.

iv. In Leicester, the cost of a forensic CT is £350, which is paid for by the investigating police force. The cost of the road traffic investigations and non-forensic research cases are paid for from combined research funds of the EMFPU and Imaging Department, University of Leicester as part of on-going research.

v. In Derby, the cost of a forensic CT is £800, which is paid for by the investigating police force.

vi. In Chesterfield, the cost of a forensic CT is £500, which is paid for by the investigating police force.

vii. In Lincoln, no charge is made for a forensic CT examination.

viii. It is unknown whether there are any costs associated with the use of CT at Chesterfield Royal Infirmary, Peterborough or Coventry hospitals.

Personnel

The majority, but not all, cases undergoing scanning have an external examination of the body prior to examination. In London, Oxford and the East Midlands this is undertaken by a pathologist in all cases. In Manchester, the survey identified that there is a variation in practice from no external examination at all, to it being undertaken by a police officer, a radiologist or a radiologist and a pathologist.

At all sites, the imaging is performed by a radiographer. Where angiography is employed then a pathologist (Oxford, London and Leicester), a trained angiography technician (Leicester) or an APT (London) may undertake this.

In all cases, at all sites the radiology reporting is undertaken by a radiologist. From the Manchester area responses, a radiologist also produces the autopsy report, as is the cause of death. At Oxford, London and Leicester the autopsy the pathologists provide reports and cause of death.

All identified that none had undergone any specialist training to undertake reporting or interpretation of post mortem cross-sectional imaging and that there was no form of accreditation, national standards, quality assurance scheme or audit at the centres. However, the radiologists at Oxford, Manchester and Leicester, as well as the forensic pathologists at Leicester, have gained experience over time through the comparison of the post mortem cross-sectional imaging to the results of the subsequent autopsy examinations.

Perceptions

Those surveyed consider that, given the choice, the general public would prefer the use of cross-sectional imaging to an invasive autopsy. There was a mixed response to the question of who should bear the cost - i.e. whether this should be the state or the relatives. Concern was expressed about the cost and convenience of the service and whether it was as reliable in ascertaining a cause of death. There was also a mixed response to whether cross-sectional imaging should be undertaken in all cases. For example, if no autopsies were done then the practitioners' skills would be lost. Comment was made that it would be very helpful in most cases, but it must be universally available to all members of society irrespective of the religious or other requirements and irrespective of the ability to pay. Further comment was that all major mortuaries should be fitted with both MRI and CT to be used exclusively for post mortem imaging. The question of funding was raised in the responses in relation to this and the service in general.

International

Pathologists and radiologists were surveyed from six countries (Italy, Japan, Australia, Denmark, Switzerland (two areas) and Poland) at centres known to use cross-sectional imaging in autopsy practice. Some of these centres have CT or MRI or both within the mortuary complexes. Japan provided a summary document of the history and current use of autopsy cross-sectional imaging (known as Ai) for the Group's consideration.

It was identified from responders that both CT and MRI are used by practitioners, although the principal modality used is CT. It was also found that other forms of imaging, for example plain x-ray, dental x-ray and fluoroscopy are also used. Although cross-sectional imaging is used in autopsy practice, it was identified that it may be used as an adjunct, but not as a replacement to, an invasive autopsy although this was country specific. This may also reflect the differences in medico-legal autopsy practice between England and other countries (see '*Terminology and Practitioners*').

Reason for use

The reason for use was stated as family related in all but one country that identified religion to be the reason. Other reasons in the responses included the use of CT as a pre-autopsy triage tool in mass fatality incidents, avoidance of invasive techniques in infective cases and as a means of recording evidence which would otherwise be destroyed.

All practitioners responded that they had undertaken some form of training to perform the work. Some pathologists have undertaken radiology training to allow them to report the images. It was felt by the response from Italy that all forensic pathologists should undertake forensic radiology training (see '*Terminology and Practitioners*' for the reason why it is referred to here as 'forensic').

Some stated that there was some form of quality assurance scheme available at the site at which they worked. However, except for the response from one of the two Swiss responders, there was no form of national accreditation, national standards, quality assurance scheme or audit at the centres. In Japan there is an Association of Autopsy Imaging based in Tokyo.

Legislation specific to autopsy imaging

In Australia, the Victoria Coroners Act 2009 specifically mentions the use of imaging in the preliminary examination performed on all persons admitted to the Victoria Institute of Forensic Medicine (where technically possible).

Swiss legislation allows for the use of cross-sectional imaging as a means of investigating death implicitly.

Personnel

An external examination was reported by the respondents as undertaken in all cases. This is done by a pathologist. The images are reported by either a radiologist (Italy) or a pathologist (Japan, Australia, Poland and Denmark) or both (Switzerland). The autopsy report is provided by a pathologist in all cases except in Poland where MRI autopsy reports are provided by a radiologist. The cause of death, where imaging is permitted to be used, is provided by a pathologist (Japan and Australia) or both a pathologist and radiologist (Italy and Switzerland).

Cost of service

The cost for the service and the person paying for the service varied in the different countries surveyed. In some countries, there is an associated fee, but in others where scanners are within the mortuary complexes, after the initial cost of instalment, a separate fee outside the cost of the overall service is not charged.

- Italy – The cost of the service was reported as between €400 - 500 (£274 - £342).
- Japan – The cost of the service where imaging is used to decide whether an autopsy should or should not be performed was reported as $276 (£177). The

police pay the cost of this. In cases where it has already been decided to perform an autopsy, the imaging is free.

- Switzerland – The cost of the service was reported as £300 or CHF500 (£342) (site dependent).
- Poland – The cost of the service was reported as PLN1000 (£185).
- Denmark – There is no separate fee for the use of scanners which are mortuary based.
- Australia – In Victoria there is no fee for the service as there was an initial outlay for placing the scanner into the mortuary complex. The service is self-funding through the budget assigned to the Institute.

Thus, where a cost is incurred to the user this ranges from between £177 – £342 in those countries surveyed where the cost of imaging is not part of the overall service cost.

Perceptions

It was considered internationally that the cost of the service lay with the police, court, state or government. No centre expressed the view that it lay with the relatives. Reasons for it not being more widely available included concern regarding costs and lack of interest from the medical professionals. The view that medical professionals may feel threatened by the technology was expressed. Concerns were raised that CT may not provide the same quality of service as autopsy, lack of validation, and lack of radiological guidelines for interpretation. The view that dedicated scanners should be within mortuaries was again expressed.

Japan

The following section is a summary document provided to the Group from Dr S Shiotani. This summary provides an insight into how autopsy cross-sectional imaging has already been implemented on a national scale.

“The overall Japanese autopsy rate is only about 2 %, and the rate of autopsy in unusual death cases is only 11.2%, both substantially lower than in other developed countries. In contrast, the distribution ratio of CT and MRI scanners within Japan is the highest in the world. Many Japanese hospitals, including 36% of the hospitals with inpatient facilities and 89% of the large hospitals with ER facilities, conduct postmortem imaging (PMI) using clinical scanners for purpose of screening the causes of death as an alternative to autopsy or for determination of a need for autopsy on cases arriving in a state of cardiopulmonary arrest (CPA), on sudden and unexpected death cases occurring in the hospitals, on suspected medical malpractice deaths, on natural deaths due to cancer or other diseases, and at the request of the police. Throughout Japan, no less than 20,000 postmortem CT (PMCT) are performed every year. However, postmortem MRI is done in a limited number of institutions in Japan because of

much longer scanning time than for PMCT. Japanese PMI examination procedure is generally referred to as “autopsy imaging (Ai)”.

In 2007, the Japanese National Police Agency introduced PMCT to prevent mistaken inquest rulings and designated a national budget for PMCT examination costs. Of approximately 1,800 deceased cases (500 in 2007 and 1,300 in 2008) in which the police asked medical institutions to examine using PMCT, two cases were identified by PMCT findings as criminal deaths that might otherwise have been overlooked.

In 2009, the Japan Medical Association proposed that PMCT should be done on all unusual death cases brought into ERs in a state of CPA, with the expense covered under the national budget. Assuming a cost of 50,000 Yen (approx. 650 US$ or 500 Euros, supposing one yen = 77 US$ or 99 Euros) per PMI in one death case, including imaging examination and diagnosis fee, an annual cost was projected to be 7 billion Yen for 120,000 death cases in ERs.

In 2010, an association of board-certified radiologists established the “Ai Information Center” in Tokyo to overcome a shortage of radiologists capable of interpreting PMI and started to interpret PMI transferred from distant sites in Japan, thereby integrating a remote network system. Also in 2010, the Japanese Ministry of Health, Labour, and Welfare (the Ministry) made a plan to distribute CT and MRI equipment solely dedicated to PMI, with a budget of 1.3 billion Yen, to establish an Ai system nationwide. This sum was approved and allocated in the national budget for 2011. Currently, 26 of 47 Japanese prefectures have at least one Ai Center with a CT scanner dedicated to PMI and all 47 prefectures will designate at least one Ai Center in the near future. The Japan Coast Guard acquired a mobile CT unit for PMI purpose from a company which offers a rental mobile CT service.

In 2011, a committee of the Ministry investigating the practical use of PMI in death investigations submitted a report indicating the need to increase the number of radiologists capable of interpreting PMI findings and of radiological technicians capable of scanning deceased patients appropriately. The Ministry started training sessions and an official approval system for certification of doctors as PMI diagnosis specialists, and for radiological technicians as PMI technical specialists.”

Peer Reviewed Papers

There is a perception that the general public and religious faith groups find the thought of an invasive autopsy being undertaken on their relatives as distasteful. However, this may be the personal perception of the person making the comment, rather than the actual view of the public. Of the major faiths, Hinduism dislikes but does not forbid autopsies whereas Islam, Judaism and Zoroastrian faiths do not permit autopsy examination unless ordered by a coroner (Rutty (JE) 2010). Although there is an ever increasing peer reviewed literature concerning the use of cadaver cross-sectional imaging, there are to date only two such papers known to the Group specifically considering the perceptions of the users, professionals and public of such systems. No large population survey has been undertaken or published to the Group’s knowledge to date. One paper does consider matters related to consenting parents of

deceased children in relation to research autopsy related MRI (Child references; Thayyil et al 2009).

A summary of the two published papers considering perceptions is provided here.

Rutty GN, Rutty JE. Perceptions of near virtual autopsies (Rutty 2011)

This paper presented the findings of the results of a questionnaire used at two professional meetings before and after an informative talk on the current use of cross-sectional imaging in medico-legal practice. A total of 45 general public and 27 pathologists/medico-legal practitioners completed both parts of the questionnaire. The combination of closed and open questions were analysed by thematic and statistical analysis. To ensure conformability and transferability, the participants came from a range of genders, occupations, religious and geographical locations and completed the questionnaire without the opportunity to discuss the answers with other participants.

Although the outcome of this study is limited due to the sample size it provides an insight into the perceptions held by the cohorts sampled. The authors, within the tables and discussion, draw out the following observations:

i. The majority of both groups surveyed considered that it was inappropriate for the relatives of the deceased to pay the cost for a PMCT;

ii. Both groups agreed that it was appropriate that scanners used to examine the living were used to examine the dead;

iii. Common themes were identified about why there was a current interest in the use of autopsy cross-sectional imaging. The theme headings were identified as religious beliefs, public perceptions, respectfulness and family concerns as well as financial, technology related to forensic pathological investigations and health and safety;

iv. Only 7% of the public cohort indicated that they would object to an autopsy authorised by a coroner. However a larger number of the pathology cohort questioned the need for such examinations;

v. If cross-sectional imaging was available as an alternative to an invasive autopsy the general public expressed an overwhelming desire for its use whereas the pathology group showed a greater number not in favour of its use;

vi. Although the pathology group favoured an invasive investigation over cross-sectional imaging, 41% of the cohort sampled considered that they were satisfied with a "*reasonable*" cause of death, not the "*exact*" cause of death from an autopsy examination. Thus, in relation to the outcome of an invasive examination, the general public group did not appear overly concerned about the accuracy of the cause of death and the pathology group did not appear concerned that the true cause was not provided.

Jeffery AJ et al. The criminal justice system's considerations of so-called near-virtual autopsies: the East Midlands experience (Jeffery 2011).

This paper arose from a chapter of the Medical Doctorate thesis of Dr Jeffery (Jeffery 2010). The study is limited in its sample size, and is confined only to considering selected unnatural deaths that would be considered within the criminal courts.

Jeffery sought the views of members of the local regional Criminal Justice System on whether cross-sectional imaging provided the same level of information as an invasive autopsy and whether it met the end users' needs. The reports from eight selected cases that had undergone full-body PMCT and invasive autopsy examinations were modified such that the PMCT report replaced the internal examination aspects of the reports. The completed non-invasive report was compared to the original invasive autopsy report and then, by using a panel of experts consisting of a medical coroner, criminal solicitor, senior police officer, criminal barrister and criminal judge sought their views on the effect of the absent invasive component of the reports. In relation to the findings, the following are drawn from the tables and discussion from the paper:

i. Table 4 within the paper relays the results of the thematic analysis. Five themes are identified: the viability of CT as an alternative to the invasive PM, the defence, the impact on relatives, logistical considerations and use of CT imagery. The themes draw out balanced personalised perceptions related to whether the approach would reduce the need for second autopsies, whether or not the relatives would find the system more acceptable the need for specialist centres, cost and speed of service, the law and the uncertainty of the judiciary to accept the system.

ii. Jeffery concluded that PMCT is capable of providing an accurate cause of death in the majority of cases and that the absence of a histological examination did not significantly alter the outcome of the examination.

iii. There were areas of unnatural death examinations where PMCT could not compete against the current invasive procedure. Jeffery provides a balanced view of the benefits and problems arising from the use of PMCT only for each of the eight cases.

iv. In the summary Jeffery argues that before a non-invasive approach can be accepted into routine practice, it must be shown to be scientifically robust and be able to provide all relevant information that can be achieved by an invasive examination. Using a balanced argument, Jeffery also points out that an invasive autopsy may too leave questions unanswered.

v. The final conclusion is that both invasive autopsy and PMCT can add valuable information that the other cannot. Although the "*gold*" standard is always put forward as the invasive autopsy, she suggests that the "*gold*" standard should be a combination of both PMCT and invasive autopsy, but goes on to point out that this cannot be currently obtained due to limited access to facilities and cost implications.

Summary

It is the Group's view in relation to the current use, cost, and perceptions that:

- There are differences in practice between the type of cross-sectional imaging used and the personnel undertaking the service within the NHS. It is the view of the Group, to standardise the provision of service, that the recommendations of the RCR/RCPath joint working Group related to standards of practice are adopted throughout the NHS.
- There are differences in the cost of the provision of service and the person or body responsible for the payment throughout England. It is the view of the Group, to encourage implementation and the provision of service that, where possible, a single national pricing guideline for the cost of the service should be applied to the whole of the NHS.
- Based on the opinions expressed within the questionnaire and those papers published to date it is the view of the Group that it is inappropriate for the relatives of the deceased to pay for the cost of the service. The cost of the service should be payable by the principal beneficiary of the service, i.e. the coroner/Procurator Fiscal or the police (case dependent).
- The current English practice is different from that of the international centres surveyed both in costs, personnel and infrastructure. As typified by the Victorian Institute of Forensic Medicine and Demark, it is apparent what can be achieved when dedicated facilities for cross-sectional imaging are placed into mortuary facilities, or in Japan where a national approach has been adopted.
- It is apparent that the general public would wish for a radiological autopsy service over an invasive autopsy. However, there remains concern amongst the professions, both nationally and internationally that, particularly in the case of unnatural death, there is insufficient evidence to date to replace all autopsies with a non-invasive approach. There is evidence to support, in certain types of death, a radiological approach be used instead of an invasive autopsy, but not in all cases. The Group recommends that it is appropriate to invest in a roll out programme of cross-sectional imaging both as an adjunct to autopsy practice, particularly in unnatural death investigation, as well as a replacement in those areas where the evidence base supports this approach. It also recommends that funded programmes of research need to be established to build the evidence base to support which types of death cross-sectional imaging acts as an adjunct to and in which cases it can be used as a replacement.

- It is further recommended that a professional sub-group should be established to advise which types of death, arising from the evidence base, can be investigated with a non-invasive radiological approach. This group could then disseminate updated recommendations where radiology remains an adjunct and where it is appropriate to apply a non-invasive approach. This would allow the CJS to consider whether the correct approach has been applied to the correct investigation. This should reduce the need for so-called 'defence autopsies' providing not only a cost saving to the CJS but also a benefit to the relatives of the deceased.

- It is recommended that a triage system approach be adopted by the providers to enable them to advise which cases do and do not demonstrate disease processes with cross-sectional imaging that allow a cause of death to be provided. Under such an approach, all cases where an autopsy would normally have been authorised would first undergo cross-sectional imaging to establish those cases suitable for a view, scan and grant approach. This would be similar to the system employed at the VIFM, Australia.

- Based on the growing evidence within the literature it is recommended that the "gold" standard for autopsy practice should be viewed as combined PMCT and invasive autopsy. It is the recommendation of the Group that in cases of interest to the police, to achieve this standard of examination, PMCT should be undertaken in *all* cases.

Current use of Post Mortem Cross-Sectional Imaging: Practicalities, Costs and Perceptions:

Fetuses, Neonates and Children

The following section of this document presents an overview the past, present and proposed future use of cross-sectional imaging in the autopsy examination of fetuses and also subsequent neonates and children. This section of the report has attempted to provide answers to the following questions:

i. Where should post mortem cross-sectional imaging within this age group occur?

ii. Which cross-sectional imaging modality should be used in this age group?

iii. What is the background to post-mortem cross-sectional imaging in this age group?

iv. What is the evidence base for the use of post-mortem cross-sectional imaging in this age group?

v. Which professional groups should be involved in the service?

The references provided within this section and any other parts of the document that are specific for fetuses, neonates or children are found in a separate reference list. To distinguish these from those used in the remaining part of this document, the references are attributed numbers, not names and dates.

Basic Principles

Autopsy practice in fetuses, neonates and children differs from that of adults. This has been recognised recently and it is anticipated that in 2012 there with be a change in the Medical Act to recognise paediatric pathology as a new sub-speciality of medicine. Thus, autopsies within this age range are undertaken by a different cohort of medical practitioners, within a limited number of centres, which, are regionally based.

Unlike adults where the commonest modality of cross-sectional imaging in use both nationally and internationally is CT, in this age group it is MRI. Thus, a less invasive assessment in this setting should consist of post mortem MRI in conjunction with other less-invasive data, including imaging (x-rays, in particular the skeletal survey), external examination of the body, pathological assessment of the placenta, non-invasive swabs for microbiology, genetics chromosomal analysis, and other biomarkers.

Importantly, if less invasive post mortem is non-conclusive, appropriate acquisition of targeted tissue for histopathology or even conventional post mortem assessment may be appropriate.

Background to Less Invasive Post Mortem Assessment in Fetuses, Neonates and Children

For over 500 years, a post mortem examination has been used to establish cause of death. This procedure provides valuable information on pathological processes – one of the key foundations of medical education. Perinatal and neonatal post mortem examination has a particularly valuable role; this was formally recognised some 15 years ago when the Royal College of Obstetricians and Gynaecologists (RCOG) and Royal College of Pathologists recommended that a perinatal post mortem examination rate of less than 75% was unacceptable and that the ideal was 100% [1, 2]. Autopsy rates have steadily declined over the years since this document was published [2-5]. This decline has been accelerated by adverse publicity surrounding alleged organ retention without formal parental consent in the Bristol Royal Infirmary Inquiry [6] and the Royal Liverpool Children's Inquiry [7]. Neonatal post mortem examination consent rate was less than 20% in England and Wales in the most recent report of the Confidential Enquiry into Stillbirths and Deaths in Infancy (CESDI) [8].

The loss of a fetus, baby or child is devastating to parents. As well as coping with their loss, parents often want to know why their child died, and if there is an increased risk for existing children or future pregnancies. A post mortem examination may provide this information. In 14-46% of perinatal and infant post mortem examinations, additional clinically significant information is found beyond that known prior to the examination, which would affect counselling or recurrence risks [3, 4, 9, 10]. The findings may confirm or refute clinical diagnoses made during life. Many studies report significant disagreement between the pre-morbid diagnosis and post mortem examination in at least 10% of cases. This impacts both upon recurrence risks and the approach to prenatal diagnosis in future pregnancies [3, 11]. Post mortem examination thus has a valuable place in confirming or refuting pre-morbid diagnoses, making further diagnoses and identifying genetic and obstetric factors of relevance to the management of future pregnancies, allowing appropriate counselling of families who can then make informed, reproductive choices. The post mortem examination will also provide useful information for clinicians, helping them to understand the causes and effects of diseases as well as the effectiveness and complications of treatment. In addition, the post mortem examination can play a crucial role in research and so advance the progress of fetal and paediatric medicine.

Should a post mortem examination be performed, recent alterations to the post mortem examination procedure and consent process may reduce the amount of information available, especially for central nervous system abnormalities [12-14]. Until recently, the usual practice was to remove and fix the brain before dissection, a process that could take up to 3 weeks. Parents now frequently request that all organs be replaced before burial. As adequate fixation is difficult within this time, the brain has to be examined following a suboptimal period of fixation, which can make interpretation of the developing brain difficult. Delay between intrauterine death and delivery, leading to maceration of the fetus, makes brain examination more difficult for the pathologist. The RCOG guidelines state that any pregnancy terminated after 22 weeks gestation should be accompanied by feticide to ensure that the fetus is not born

alive. This procedure is usually accompanied by the administration of mifepristone (a cervical ripening drug), which has its optimum efficacy in shortening the time between induction and delivery after 48 hours [15]. This effectively means that most delivered fetuses undergoing termination of pregnancy after 22 weeks gestation will have been dead for at least 48 hours, rendering post mortem examination of the brain difficult.

In addition to the difficulties of acquiring consent to perform conventional autopsy, and sufficient time to perform optimal histological preparation, various religious communities find conventional autopsy unacceptable [1]. Provision of a less invasive, accurate and widely available method of post mortem assessment has been advocated [1] and would enable access to post mortem information for the first time for many in these communities.

Radiology in Fetuses, Neonates and Children

Though conventional radiology to assess the chest and bones has been used for some time in post mortem examination (for example, a skeletal survey is performed on all paediatric cases referred to the coroner and in all perinatal cases), MRI would be well suited as a non-invasive imaging modality for post mortem assessment. Standard imaging protocols could be performed in any hospital equipped with an MR scanner and the images sent to a centre of expertise for reporting. MRI would potentially overcome some of the weaknesses of conventional autopsy, providing a complete multisystem analysis that is non-invasive.

MRI of the excised brain [16], spine [17] and heart [18] has been successfully performed. However, although an initial feasibility study of whole-body post mortem MRI was reported in 1996 [19], its use in clinical practice has remained controversial. Several small studies of whole-body post mortem MR in fetuses have been reported [20-22]. In all fetal studies, imaging of the central nervous system (CNS) proved the most accurate, whilst body imaging, in particular imaging of the heart, proved more problematic. A recent study, focussing on the diagnosis of CNS abnormalities in fetuses and stillbirths, reported a sensitivity of 100% and specificity 92% for MR compared with conventional post mortem examination [23]. Other studies have confirmed the accuracy of CNS fetal post mortem MR [24, 25]. Imaging of the other body systems has been less well documented, though post mortem MRI of the heart has been shown to be poor [26-28].

Furthermore, MRI has grown in clinical importance in the living fetus and newborn infant [29], especially for brain anomalies. There is now extensive literature describing the normal MRI appearance of the *in-utero* fetal brain from around 17 weeks gestation [30] and the *ex-utero* preterm infant brain from around 25 weeks gestation [31].

The decline in parental consent for autopsy, and technical limitations of conventional autopsy to define some nervous system abnormalities, together with a reduction in number of skilled perinatal pathologists and morphologists, has led to a need to seek alternative less invasive methods for post mortem examination of the foetus, neonate and child. In 2001, the NHS Chief Medical Officer recommended that modern imaging methods should be evaluated [32]. Since then several reports on forensic aspects of post mortem imaging have been published,

however, these studies are limited to post mortem imaging in adults, primarily using computerised tomography (CT) and many studies were of poor quality [34].

A previously published systematic review on post mortem MRI in fetuses, newborns, children and adults demonstrates that there is insufficient evidence to recommend the use of post mortem MRI as an alternative for conventional autopsy [35]. Most comparative studies to date have been small and/or have compared single systems such as the brain and did not have adequate blinding of radiologists and pathologists due to their retrospective nature. In particular:

- None have systematically examined all the body systems in a large series of fetal, neonatal and childhood deaths.
- None of the studies have assessed the MR appearance of death-induced artefacts or the effect that death and maceration may have on the MR image.
- None have assessed the possible disadvantages or advantages of a minimally invasive post mortem examination in combination with MRI.

Thus, over a decade after the first description of post mortem MRI, we still lack the evidence for routine implementation. A large, prospective, blinded, comparative study to evaluate MRI as an alternative to conventional invasive autopsy in fetuses, newborns and children has been funded by the Department of Health. This provides an insight into the accuracy and use of less-invasive assessment in fetuses, neonates and children. However, as the study data is unpublished to date, it was not available for the Group to consider or to provide details within this document.

Questionnaire

As with the adults, the principal centres for the delivery of paediatric pathology in England were invited to participate in the questionnaire. As only two of the centres agreed to participate, owing to a lack of participants no further comments are made in relation to the outcome of the survey.

Where Should Less-Invasive Assessment be Performed?

Assessment of post mortem MRI should be performed in centres with appropriate expertise. There is much regional specialisation in paediatric radiology, paediatric cardiology and neonatal pathology. Regional centres are suggested as appropriate to undertake such imaging based on provision of existing paediatric services:

- London & South East – Great Ormond Street Hospital for Children & Evelina Children's Hospital;
- South West – Bristol & Cardiff;

- Midlands – Birmingham & Leicester;
- North West – Manchester & Liverpool; and
- North East – Sheffield & Newcastle.

In the ideal setting, bodies would be transferred to the regional neonatal centre. However, in coroner's cases, to enable parents to remain close to home, local hospitals may be able to perform the MRI, with data transfer to the regional centre.

By Whom Should Less-invasive Assessment be Performed?

Because of the specialist nature of the paediatric examination, those with skills in paediatric neuroimaging (brain and spine), congenital heart disease (heart and vessels), paediatric body imaging (chest and abdomen) and paediatric musculoskeletal system (with non-accidental injury experience) should perform assessment. This is facilitated by using regional centres where expertise is centralised.

MRI should be carried out by trained MR radiographers, who are willing to carry out this work. MRI could be performed out-of-hours, but within 24 hours of the mortuary receiving the case.

Once the radiological reports have been generated, these should be sent to the neonatal pathologist responsible for the case. The reports should then be interpreted with the other non-invasive data, and a decision made on whether sufficient information has been generated to either provide a diagnosis (fetuses) or a cause of death certificate (neonates and children). This should be done in collaboration with HM coroner if appropriate.

This model is comparable to that proposed for adult cross-sectional autopsy imaging (see '*Cross-sectional Autopsy Imaging Scanning Infrastructure').*

Transfer of Cases

For this age group the same body movement process could be adopted as for that proposed for adult cross-sectional autopsy imaging (see '*Cross-sectional Autopsy Imaging Scanning Infrastructure').*

Secure Data Transfer & Storage

For this age group the same image storage and archive system could be adopted as for that proposed for adult cross-sectional autopsy imaging (see '*Image Storage, Archive and Retrieval'*).

Costs

The costs for the service are described within the section entitled '*Costing a Pathological and Radiology Service'*.

Summary

It is the Group's view in relation to the fetuses, neonates and children that:

- A less invasive method of accurately assessing detailed anatomical and pathological changes in all body systems after death in fetuses, neonates and children would be of great value. Information for diagnosis and clinical audit can be obtained as well as creating a permanent electronic record of findings, whilst allaying parental concern with regard to organ retention or conventional invasive post mortems.
- Less invasive post mortem in fetuses, neonates and children should be based within the already established centres of neonatal pathology in England.
- The Group thus recommends that the following sites should be considered for this service: London (Great Ormond Street Hospital for Children & Evelina Children's Hospital), South-west England (Bristol & Cardiff), The Midlands and East (Birmingham & Leicester), North-West England (Manchester & Liverpool), and North-East England (Sheffield & Newcastle).
- Some of the skills for post mortem MRI will need to be learnt, but many are part of the normal skill set of specialist paediatric radiologists. It is important that a national training scheme be established. With 5 English centres and 4 specialists in each centre, this would require training of 20 paediatric radiologists/ cardiologists in post mortem MRI. This could possibly be achieved in a one-week course.

Disaster Victim Identification (DVI)

The following section of this document presents an overview of the types of imaging utilised in mass fatality incidents, summarising how PMCT has a significant role in such events. This section of the report has attempted to provide answers to the following questions:

i. What forms of radiography are available for use in a mass fatality incident?

ii. Does cross-sectional imaging have a role in mass fatality incidents?

iii. How is cross-sectional imaging currently used in mass fatality incidents?

Human Identification

Identifying the deceased in any scenario is primarily for the benefit of the relatives, but is also important for the legal and judicial processes triggered by the event. As touched upon elsewhere (see 'Terminology and Practitioners'), the identification of the dead is one of the primary four objectives of an autopsy examination no matter where in the world one practices. Legally we are each entitled to identity. The United Nations Universal Declaration of Human Rights Article 6 states, "*Everyone has the right to recognition everywhere as a person before the law*". The need for this identity is also paramount after the death of the individual and represents a basic human right (United Nations 1948).

The methods used for identification of the deceased must therefore be scientifically sound, reliable, and reproducible under field conditions and must be able to be implemented in a timely fashion. DNA analysis, fingerprinting and forensic odontological examination are known as 'primary identifiers' and can be used alone or in combination to identify an individual (National Policing Improvement Agency, 2009). X-ray imaging of the body is classified as a secondary identifying system and has a recognised role in body identification (Nye 1996, Harcke 2002, Viner 2006, Dawidson 2007).

Disasters

A '*disaster*' can be defined as an unexpected event causing the death or injury of people beyond that of the normal capacity of those dealing with the incident to cope with the incident. A Disaster Victim Identification (DVI) response may be initiated following major road traffic collisions, natural disasters for example earthquakes, technical accidents (fires, explosions), terrorist attacks and events occurring within the context of wars.

An '*open*' disaster is an event resulting in the death of a number of unknown individuals for example the Asian tsunami of 2004 for whom no prior data or records are available for comparison. It is difficult to obtain information about the actual number of victims following such events.

A '*closed*' disaster is an event resulting in the death of a number of individuals belonging to a fixed, identifiable group for example an aircraft crash with passenger manifest. Many events

however are mixed for example the recent M5 collision or the Australian Bush Fires 2009 where the identities of some, but not all, were known (Interpol. https://www.interpol.int/Public/DisasterVictim/Guide.asp. last visited January 2012).

Response

Following a major incident there will be overlapping phases of operation from rescue, to investigation, to recovery. The initial priority is to rescue those involved in the incident, their extrication and to save life, limb and sight while preventing further injury. These patients will be managed according to the local major incident policy. The subsequent DVI investigation should not hamper these efforts. The concurrent investigation should occur without impediment to survivor clinical care. International guidelines for DVI have been produced, and amended, by Interpol, who provide forms for the collation of all relevant ante and post mortem data (Interpol. https://www.interpol.int/Public/DisasterVictim/Default.asp. last visited January 2012).

Following the retrieval of survivors the site of disaster may then be considered a crime scene if the scenario is not a natural disaster. This will potentially further delay the recovery of bodies. The delay will vary depending on the size and location of the scenario, number of fatalities and whether there is contamination or potential contamination of the site. In a conventional scenario, the delay can be expected to be 24-72 hours. This delay will afford a sufficient window of opportunity to prepare a suitable mortuary facility to deal with the deceased.

The chosen mortuary, be it a purpose built or temporary facility, should have radiographic capability including digital radiography, fluoroscopy and CT. Those planning for such incidents must consider, and should plan for, the availability of such technology, the potential location and the integration to facilitate the efficient processing of bodies through the mortuary facility while providing maximum information for identification and evidence to the forensic pathological investigators.

Historical Use of Radiology in DVI

The conventional approach to DVI radiological assessment is three-staged (Rutty 2007). These are as follows:

i. The ‘primary survey’ is the initial triage and assessment of the body/body-bag contents. Fluoroscopy has been used for the primary survey mainly for speed of acquisition, taking as little as 10 minutes, to aid triage of the bodies. This modality provides limited detail other than basic anthropological details, location of personal artefacts, radio-opaque forensic evidence and potentially useful identifying features. Hazards for the DVI team may also be identified prior to opening of the body-bag.

ii. The ‘*secondary survey’* is the standard examination of specific structures or body parts - e.g. odontology and full body plain film series. Plain films have been used with moderate success in identifying casualties from a number of disasters since 1949 (Singleton 1951). The Oklahoma City bombing response highlights the enormity of

the task (Nye 1996). Sixty radiographers and 10 radiologists over a 10-day period were required to do full skeletal surveys, averaging 15 films, on each of the 165 deceased. This effort yielded a further 6 positive identifications where other techniques employed were inconclusive.

iii. *'Tertiary examinations'* may be undertaken in response to pathological, odontological or anthropological assessment for more thorough investigation.

The imaging process, even with digital radiography (DR) can be time consuming. Each survey required different equipment and training of the operators. Although the primary survey could be performed in 10 minutes, odontology films may take 30-60 minutes to acquire and a full skeletal examination could take 1-2 hours, requires bag opening, body movement and risks cross-contamination.

Cross-sectional Imaging in Mass Fatality Incidents

DVI techniques have been advanced by the introduction of cross-sectional imaging, specifically MDCT, to the repertoire of modalities available to the forensic pathologist. PMCT has the potential to hasten the imaging process, condense three processes into one and gain additional information.

MDCT involves a single acquisition of imaging, which can incorporate the equivalent fluoroscopic, odontological and plain film skeletal assessments into a single examination. The procedure, including positioning and scanning, the body takes approximately 15 minutes to perform. Preloaded protocols can be input into the scanner to standardise the examination. This significantly reduces the time the body is removed from cold storage and optimises the speed of scanning to prevent the x-ray tube from over-heating. The scan is performed with the bag closed. Positioning of the arms is important to ensure the whole body is within the Field of View (FOV). This may not be possible if the body has been exposed to severe heat or burning and is likely to have a pugilistic attitude. This may prevent scanning until soft tissue release is performed although this does not need to occur. In such a scenario, the use of fluoroscopy would be appropriate to perform the primary survey before the release and CT scan (O'Donnell 2010).

CT provides scout images that are near equivalent to an x-ray image, as well as axial images through the body. These can be used to produce coronal, sagittal and oblique reconstructions that assist with triangulating the position of items or projectiles. 3D reconstructions are particularly useful for assessment of bone architecture and are reliable for anthropological assessment (Sidler 2007, Robinson 2008). This avoids the need to strip bones for assessment saving considerable pathology time. Vehicular accidents often result in heavily disrupted bodies, but it can be possible to using MDCT, to correctly match a body part to the correct body (Blau 2008).

Odontological comparison with ante-mortem imaging has been a crucial investigation technique for victim identification (Fischman 1985, McKenna 1999). Following the Asian

tsunami and the Bali bombings, the Australian Society of Forensic Odontologists produced comprehensive guidelines for odontological assessment (Taylor 2008), which subsequently aided the response to the Victorian bush-fires of 2009. The odontology team found the CT data invaluable at that time. Some authors (Kirchhoff 2008) reported significant flaws with MDCT compared with conventional x-ray. It has been shown that careful assessment and use of software tools (e.g. Dentascan) improve diagnostic confidence (Rutty 2007, Blau 2008).

MDCT has further advantage over plain film in the assessment of soft tissues. This can be particularly useful for detecting visceral abnormalities or surgical changes, which could be used to identify a body and would not be detectable on plain film.

With the resultant limited use of fluoroscopy and plain film imaging there will be less need for so many team members to wear uncomfortable, heavy lead gowns for protracted periods, but the Ionising Radiation (Medical Exposure) Regulations 2000, (IR(ME)R 2000(10)) must still be followed. A Radiation Protection Supervisor or Adviser should be involved in site planning (AFR 2007).

Location of MDCT Scanner

The CT scanner can be located at or close to the scene of the incident or, outside or within the mortuary facility being used for the incident, depending upon the type and size of mortuary used. Where the numbers of fatalities are relatively small and can be managed appropriately within the mortuary facility of the local hospital or designated regional centre. Augmentation of the facility with mobile CT scanner(s) should be considered to avoid additional workload if the clinical facility has been overwhelmed with survivors. In larger events, when a temporary mortuary facility is deployed, most likely at a site distant from the major treatment facility, or where the local facilities are damaged, for instance in a natural disaster, the use of mobile CT scanners is obligated. The mobile scanners lend flexibility to the planning (Rutty 2007).

Mobile scanners are usually trailer-borne or ISO-containerised. They can be deployed outside, ideally on hard-standing, or in a large indoor space/hangar and can be powered through mains connection or independently by a generator.

Within the temporary mortuary facility, the scanner can be remote from the tables and located nearer the cold storage for ease of body movement. With regard to Health and Safety and IR(ME)R, the scanner will have predetermined policy to protect staff within the mobile and built in shielding for those outside. The scanner is unlikely to be designed to prevent radiation scatter through its roof or floor, however. Therefore if an internal location is chosen consideration for those working on floors above and below may ultimately limit the positioning of the scanner.

Archiving

Regardless of the modality of medical imaging used in the investigation, archiving of the images, reports and other salient information must be secure and monitored to ensure the stringent judicial requirements are achieved in relation to reliable evidence (Rutty 2009). A complete, closed UK disaster victim/forensic identification service, FiMag, has been produced, which not only acts as a secure archive for images and documents, but also facilitates the secure distribution of images to distant reporting radiologists, forensic odontologists and forensic anthropologists. Temporary mortuary facilities have limited resources and space, making accommodation of large numbers of personnel more difficult. With secure communications, it is possible to limit the personnel at the scene/temporary mortuary, but still have timely reporting of examinations, a capability which would be even more important in the event of a contaminated site.

Reporting

The reporting of DVI MDCT is now three staged:

i. Scout scans provide the primary survey in orthogonal planes. These images are also the equivalent of the full body plain film x-rays. The axial images, multi-planar reformats (MPRs) and 3D reconstructions provide a comprehensive assessment of the body or body parts. However, it has been shown that the basic anthropological details and gross features can be detected with the scout. MDCT can be confidently used to determine the age and sex of a body by assessing the skull development, the pelvis and growth plates (Grabherr 2009, O'Donnell 2010) and also the dental development for children (Graham 2010).

ii. More in depth assessment of the images will provide the bulk of the report including injuries sustained and location of retrievable evidence.

iii. It is then possible for the radiologists to review the studies with the pathologists in a Multi-disciplinary team (MDT) meeting before, or even during and after open post mortem examination (O'Donnell 2010). This is in essence the opportunity for the tertiary opinion or review.

The reports are recorded onto the ACPO Body Recovery form or Interpol DVI data forms and archived with the images.

Contaminated Environment

The use of MDCT combined with FiMag lends itself particularly to the investigation with a closed bag technique, image acquisition is significantly quicker and there is the potential for contemporaneous reporting. The contaminated environment creates significant logistical and safety complications for the DVI team and anything which can minimise risk is important.

DVI Team

The configuration and skill set of the DVI Imaging team will change with an increasing reliance on radiologists with forensic/post mortem experience and fewer radiographers but with more CT expertise, all working under the lead of the pathologists. Police Officers have already been trained in England to work under a lead radiographer in the operation of mobile CT scanners.

Summary

It is the Group's view in relation to the cross-sectional imaging and mass fatality incidents that:

- Radiography has an important role within a mass fatality incident.
- There is now a reasonable body of experience published in the literature, which supports the use of MDCT in the investigation and identification of disaster victims. This evidence supports that MDCT can reduce the need for three different imaging modalities into one, reduce personnel and thus cost, speed up the processes involved and provide, depending upon the question asked, more information than is currently available to investigators than other modalities.
- The Group is of the opinion that MDCT should be incorporated where possible in disaster planning in England, not only with respect to equipment procurement and positioning, but also in identifying and training appropriate staff. This applies equally to conventional and contaminated incident scenarios.
- The Group is of the opinion that the NHS is currently a lead within this field internationally. Although other countries have embraced the use of MDCT in mass fatality incident investigations, the UK may be unique in its approach with the development of the FiMag system.
- The Group embraces the use of the FiMag system along with future research and development associated with it.

Section Two

Axial CT image of the chest showing discreet nodules in the lungs (arrows) and calcified mediastinal lymph nodes (star) in a young Indo-Pakistani female

Law

The first section of this document considered the history of cross-sectional autopsy imaging, the current known NHS service, the practitioners and the international perspective. It established that post mortem cross-sectional imaging is currently not only used in England, but is used more extensively elsewhere in the world. The next section considers UK law and documentation, which may impact upon the implementation of an English national autopsy cross-sectional imaging service.

The following section of this document presents the Group's and their advisors' understanding of the law related to the use of cross-sectional imaging within the coronial, criminal and civil legal systems. Within this section, a number of questions have been addressed:

i. Is there any provision within the law that allows the use of cross-sectional imaging as an adjunct or alternative to the invasive autopsy?

ii. Is there any legislation that prohibits the use of cross-sectional imaging as an adjunct or alternative to the invasive autopsy?

iii. Could the use of cross-sectional imaging have a detrimental effect on the criminal justice system if used as an alternative to an invasive autopsy?

iv. Are there any licensing issues that arise if cross-sectional imaging is used as an alternative to an invasive autopsy?

England and Wales: the Coroners Act and Rules

The legislation in force relating to the function of the coroner is the Coroners Act 1988. It is further expanded upon within the Coroners Rules 1984 and its amendments. Within this are a number of sections which inform the Group about legislation relating to the movement of the body from the scene to the place of examination, the authority to undertake a post mortem examination, the person making said examination and the production of a report.

The coroner's power to remove a body for post mortem examination

The Group has considered where cross-sectional imaging of cadavers may be undertaken (see '*Cross-sectional Autopsy Imaging Scanning Infrastructure*'). Unless a mobile imaging unit was deployed to the scene of death or mortuary, which outside a mass fatality incident would be impractical in community deaths, then consideration must be given to any restrictions on how far away from the scene of death the imaging facility could be.

The coroner's power to remove a body for post mortem examination is limited by Section 22 of the Coroners Act 1988, the relevant part of which is as follows:

"22(1) Subject to subsection (2) below, where by the direction or at the request of a coroner, a post mortem examination of a body is to be made, the coroner may order the removal of the

body to any place which may be provided for the purpose either within his district or within an adjoining district of another coroner."

Accordingly, under the present law a coroner who wished to order a post mortem examination of a body by cross-sectional imaging would need an available facility for that purpose either within his own or an adjoining jurisdiction. This would not, of course, prevent the facility for the reporting of the images being situated more remotely (so-called '*teleradiology*').

However, it should be noted that the Coroners and Justice Act 2009, which to date is not fully in force, contains a provision in section 15 in said Act which would, if and when it was introduced into law, alter that situation. The relevant part of Section 15 reads as follows:

"15 (1) A senior coroner who-……

(b) needs to request a post mortem examination under section 14 in order to decide whether the death is one into which the coroner has a duty under section 1(1) to conduct an investigation, may order the body to be removed to any suitable place.

(2) That place may be within the coroner's area or elsewhere."

It is understood that H.M. Government is presently considering the implementation of this provision.

The coroner's power to order a post mortem radiological examination of a deceased person

The coroner's power to order a post mortem examination is described within Sections 19 and 20 of the Coroners Act 1988. Although the sections set out various powers conferred upon the coroner, that most usually employed is described in Section 19 (1b). The relevant part of the section states as follows:

"Where a Coroner is informed that the body of a person is lying within his district and there is reasonable cause to suspect that the person has died a sudden death of which the cause is unknown, the Coroner may, if he is of opinion that a post mortem examination may prove an Inquest to be unnecessary …….

(b) request any other legally qualified medical practitioner to make a post mortem examination of the body and to report the result of the examination to the Coroner in writing."

Who is eligible to undertake a post mortem examination for the coroner?

As explained earlier the term "post mortem examination" is not defined in the Coroners Act. However, Rule 6 of the Coroners Rules 1984 provides that:

"In considering what legally qualified medical practitioner shall be directed or requested by the Coroner to make a post mortem examination the Coroner shall have regard to the following considerations:

(a) The post mortem examination should be made, whenever practicable, by a Pathologist with suitable qualifications and experience and having access to laboratory facilities."

It will be noted that whilst the medical practitioner making a post mortem examination should, whenever practicable, be a pathologist there is no absolute requirement that such should be the case. If the coroner considers it not to be practicable to instruct a pathologist for good reason which arguably extends beyond the simple availability of a pathologist, then he is not obliged to do so. The only absolute requirement is that the individual conducting a post mortem examination should be a legally qualified medical practitioner. Thus, a radiologist can undertake the examination. However in a pathologist-led system for post mortem examination including radiology it would be a pathologist receiving instructions in any event, albeit that those instructions might include a direction given by the coroner to use radiology to assist in diagnosis of the deceased's cause of death.

Reports to the Coroner

The examination will require the generation of a report. Rule 10 of the Coroners Rules 1984 states:

"The person making the post mortem examination shall report to the coroner in the form set out in Schedule 2 or in a form to the like effect"

The form set out in the Schedule reflects a pathologist's post mortem examination and if, therefore, radiology were to be the source of the diagnosis of the cause of a death, consideration would need to be given to an adapted form "*to the like effect*".

Consent for a radiological examination

Although the coroner's decision in this regard must not be unreasonable, it is his decision alone as to whether a post mortem examination is required. Although clearly, a deceased person's family or personal representatives would have the right to object to the coroner's decision and to have their objections reasonably considered, their consent for the examination is not required. Likewise, their consent to radiological examination of the deceased person is not required provided that the examination is being conducted in order to discover the cause of the deceased's death.

Scotland: the Procurator Fiscal

In Scotland there is no specific legislation relating to post mortem examinations or to any ancillary diagnostic tests. The position is governed by Common Law, which permits the Procurator Fiscal to instruct a pathologist to conduct a post mortem examination and any other diagnostic test that the pathologist advises is necessary to determine the cause of someone's death. Accordingly, in a pathology-led system there would be no difficulty in law with post mortem radiological examination of a body being conducted provided that it was considered necessary in order to assist in determining an individual's cause of death. Moreover, if a pathologist having obtained the result of a radiological examination of a body was then of the opinion that an invasive examination was not required because the radiological examination had revealed an acceptable cause of death, there would be no requirement for anything further. Specifically, there would be no requirement for an invasive examination in such circumstances provided that the Procurator Fiscal was in agreement with that conclusion. The custom and practice in Scotland would mean that a Procurator Fiscal would not instruct a radiologist direct.

Ireland: a Coroner's System

The Group is not aware on the advice that they have been able to obtain that there is any legal impediment to post mortem radiology in Northern Ireland.

Risk to the Criminal Justice System

The Group have considered whether by use of a radiological examination as an adjunct or alternative to an invasive autopsy there could be any risk to the criminal justice system.

An adjunct

It would appear that where a radiological examination is conducted together with an invasive examination the extra information thus revealed could only be of assistance to the coronial, criminal and civil courts (Jeffery 2011). Thus, the Group considers that when used as an adjunct there is no apparent risk to the criminal justice system. Jeffery has suggested within a paper arising from a Medical Doctorate thesis that, due to the benefits of the examination, a PMCT examination should be undertaken in all suspicious and homicide deaths (Jeffery 2010, Jeffery 2011).

An alternative

It would be necessary to give careful consideration on a case-by-case basis to the question of whether a radiological examination alone would suffice to demonstrate an individual's cause of death, particularly in contentious criminal or civil cases. In such matters, there would be no apparent difficulty with the admissibility of radiological evidence, but there might well be potential issues as to its sufficiency if it were used alone. There is, however, to the Group's knowledge, nothing within the 'Green Book' (The Civil Court Practice 2011) or the 'White Book' (The Supreme Court Practice) which would render radiological evidence as to a cause of death

unacceptable. Nevertheless where the coroner and the pathologist were agreed that in a particular case radiology alone had sufficiently established the cause of death, there would appear to be no legal obligation in the Act or the Rules to go further.

To date, to the Group's knowledge, although PMCT images have been used in the criminal court of the UK and Europe to demonstrate injuries to the court (Rutty, 2008, Police Professional, 2011), the use of imaging alone without an invasive autopsy has not occurred in England. Thus, this is untested. It is considered that there could be a reluctance to take this step forward due to the medical, police and legal professions' hesitancy in being the first to use new technology or systems within the criminal justice system for fear of adverse repercussions. The use of PMCT only in a forensic case as a replacement to a forensic autopsy has; however, been reported from another part of Europe (Ruder, 2011).

Human Tissue Act 2004

The Human Tissue Authority (HTA) was established on 1 April 2005 under the Human Tissue Act 2004 (HT Act), which extends to England, Wales and Northern Ireland. The HTA is an Executive Non-Departmental Public Body (ENDPB) sponsored by the Department of Health, which regulates the removal, storage and use of human tissue and cells. In relation to this report, it is its regulation of the Post Mortem sector that is relevant.

As alluded to earlier in this document, it is a requirement under Section 16 of Part 2 of the HT Act that post mortem examination must take place under the authority of a licence. It follows that any mortuary where post mortem examination is conducted must be licensed for that purpose. The HTA defines post mortem examination as 'dissection and examination of a body after death, principally in order to determine the cause of death or the presence of disease processes'.

Current guidance from the HTA is that minimally invasive post mortem examinations must also take place on licensed premises (paragraph 14 of HTA Code of Practice 3). The HTA's definition of minimally invasive post mortem examinations is:

'those in which needle biopsies through the skin are taken to sample internal organs and tissues, and examinations that use an endoscope or laparoscope to provide internal access to the gastrointestinal tract and the abdominal cavity'.

With regard to non-invasive post mortems, the HTA's position is also set out in paragraph 14 of code 3, which states that:

'licensing requirements do not apply to establishments where only non-invasive PM examinations are undertaken'.

The HTA defines non-invasive post mortem examination as those in which:

'The body surface is not breached and the examination is undertaken by use of scans or ultrasound providing a three-dimensional image of the patient's internal organs and structure

(in particular the soft tissues). Non-invasive post mortems do not include the sampling of tissues for histological, microbiological, or chemical analysis.'

Aside from the licensing requirements in relation to post mortem examination, the HT Act sets out additional requirements in relation to tissue removal, the result of which is that tissue cannot be removed from the body of a deceased person on unlicensed premises (subject to certain exceptions for criminal justice purposes (see Section 39(3) of part 2)). Specifically, removal of tissue from the body of a deceased person for determining the cause of death is a licensable activity and should be undertaken in licensed premises. Where appropriate, the HTA will extend establishments' existing PM licence to take in additional areas where such removal may take place, for example in A&E departments where tissue samples sometimes need to be taken from deceased children. If an establishment is not undertaking post mortem examinations, but does have occasion to remove tissue samples from the bodies of the deceased, a licence application would need to be made to the HTA. The use of angiography with PMCT does not require a licence.

Therefore the Group is advised that currently there is no requirement for premises where radiological imaging of a body takes place to be licensed, even if imaging were used as the sole investigative system to establish a cause of death. It follows that there are no legal restrictions as to where a radiological examination of a cadaver can be undertaken. However, if alongside radiological imaging of the body targeted removal of pathological specimens also takes place, this would be subject to licensing by the HTA.

Whilst there is regulation under the terms of the Human Tissue Act 2004 concerning the retention of organs or histological samples taken from a deceased person in order to elucidate the cause of his or her death, there are no provisions in that legislation or otherwise concerning the retention of computer discs/storage device containing a record of the radiological examination of the deceased. It is therefore considered that such storage is under the authority of the coroner, just as a post mortem report would be.

Summary

It is the Group's view in relation to the questions posed that in a pathologist led system employing autopsy cross-sectional imaging:

- The use of PMCT as an adjunct or alternative to an invasive autopsy is, to the Group's knowledge, permissible under current and future legislation related to the autopsy in all parts of the UK.
- There is no legislation to the Group's knowledge that prohibits the use of PMCT as an adjunct or alternative for the investigation of the dead.
- Cross-sectional imaging has a role as an adjunct to traditional autopsy examinations in criminal cases, enhancing the information arising from the autopsy and can be used in court to demonstrate the findings. Thus, it is the view of the Group that the recommendation of Jeffery, that PMCT should be used as an adjunct in all cases of suspicious and homicide death, be adopted in England.
- Although there appears to be no legal reason not to use PMCT without invasive autopsy for the investigation of criminal cases (an external examination would still be undertaken with retrieval of appropriate exhibits), it is unknown whether cross-sectional imaging could have a detrimental effect on the criminal justice system of England if used as a substitute as this remains untested to date. It will be difficult to answer this question without carefully selected test cases being undertaken and tested within the criminal courts. Before this happens, one has to overcome the inevitable reluctance to take this step forward owing to the medical, police and legal professions hesitancy in being the first to use new technology or systems within the criminal justice system for fear of adverse repercussions. It is the view of the Group that for this to go forward a study should be commissioned to test this question.
- If PMCT is used without any other associated invasive procedure then there are no licensing issues that arise from its use. If an invasive procedure is employed to remove tissue, for example tissue guided biopsy within an imaging suite, then the suite where this is undertaken must be a licensed premises. If imaging is undertaken in premises where there is a licensed mortuary, the imaging suite can be annexed to the mortuary's license in a similar way to that already occurring in A&E departments. However, if the imaging is undertaken remote to a licensed mortuary, for example by using a mobile cross-sectional imaging unit, then the site of the imaging and additional procedures must become licensed.

Issues Related to Second Autopsy Examinations in Police/Criminal Investigations

It is not unusual in England that in cases of police/criminal examinations defence solicitors will make a request for an independent autopsy examination on behalf of their client to be undertaken following the first examination. This may lead to one or more (in cases where several individuals are charged with causing the death of an individual) additional autopsy examinations being undertaken on the body of the deceased. Where no one has been charged or is expected to be charged with a homicide offence within 28 days and the death remains suspicious, the coroner will normally instruct a second examination of the body. This practice has made the second examination of the body in cases of suspicious death almost the norm. The following section of the report has attempted to provide answers to the following questions:

- What is the legal basis for requests for second autopsy examinations?
- How could cross-sectional imaging interact with this practice?

Legal Basis for Second or so-called 'Defence' Post Mortem examinations

Whilst there appears to be no formal legal basis for the practice of undertaking second post mortem examinations, it is common practice for most deaths where criminal charges have or may be brought for this to occur. It provides an opportunity for a second pathologist to check on the opinion of the Home Office pathologist - i.e. a form of audit and provide evidence for the defence. There are a number of documents that make reference to this practice:

i. Whilst there appears to be no legal basis for this practice, Home Office Circular 30 of 1999 provides instruction and advice in respect of the procedure and timeliness of second post mortem examinations (Home Office 30/1990). This may be said to have given the practice of second PMs official recognition and approval.

ii. In addition, reference is made at Section 9 to the Codes of Practice and Performance Standards for Forensic Pathologists (RCPath, 2004) in respect of the Home Office pathologists' responsibilities to disclose information for the purpose of the second post mortem examination. This document is in the process of being updated and should be published in late 2012.

iii. Another document where reference is made to second autopsy examinations is a Home Office document currently being updated entitled 'Legal Issues Relating to Forensic Pathology and Tissue Retention' at Section 5 of the document (Home Office).

iv. The ACPO Murder Investigation Manual, Chapter 11 (as amended) briefly refers to second autopsy examination procedures (ACPO Murder Manual).

None of these documents would appear to impact upon either the first or second post mortem being conducted using cross-sectional imaging, either as an adjunct or as a replacement to an invasive autopsy.

Issues for Consideration

If CT scanning had been used at a post mortem examination and no intrusive examination was made of the body, then there is an issue that could arise if the second pathologist wished to conduct an intrusive PM either in part or a full examination. This would clearly be a matter for the coroner to consent to or otherwise. It is suggested that the following procedure could be adopted:

Where a first examination has been conducted by radiology alone and the defence apply for a second examination the coroner will:

i. Either provide the defence with the access to the imaging undertaken at the first examination or allow the facility for a second radiological examination.

ii. If the defence then apply for an invasive examination the coroner will:

    ii.i. Ask the defence for their reasons and any supporting evidence which might include the opinion of a radiologist and/or pathologist instructed by the defence as to why an invasive autopsy examination is now required.

    ii.ii. Consult with the Senior Investigating Police Officer and the family.

    ii.iii. Consult with the pathologist and radiologist who conducted the original examination.

iii. Grant or refuse permission.

The only remedy available to the defence at that stage if the coroner refused permission would be Judicial Review.

Summary

It is the Group's view in relation to the questions posed that:

- In reality, the use of cross-sectional imaging as a replacement of an invasive examination in the case of suspicious or homicide deaths is likely to be rare until it is accepted by the legal and pathology professions that, in the case of suspicious and homicide deaths, a non-invasive radiological approach is acceptable and would not impact upon the CJS.
- However, as an electronic record of the first autopsy would exist, which details the body prior to the autopsy examination, and this record is supplementary to the first autopsy photographs (and video if recorded), body diagrams and report, it is possible that with all this available information there would be no need for a second invasive autopsy examination. In this sense, the use of cross-sectional imaging is likely to satisfy the defence more so than current arrangements and lead to a reduction in the necessity for second autopsies.
- Until the first non-invasive, radiology only case is tested in England, the true answer to this question will remain unanswered. Prior to the first test case occurring, consultation should occur between the pathologist, radiologist, senior police officer, CPS and coroner. If all are in agreement that such a case exists then the case could proceed with imaging alone and set a precedent within the CJS.

Digital Images: Policies, Procedures and the Law

As cross-sectional imaging produces a digital image and record, the Group has considered the effects of these documents on imaging the dead. The following question has thus been considered:

- What documents currently exist in relation to the use of digital images and digital recording in criminal and civil (including family) court proceedings?

General

It is considered by the Group that there would appear to be no difference between the use of cross-sectional imaging and any other form of digital visual representation of evidence to a court. As any other exhibit produced to a court, cross-sectional imaging must satisfy the strict criteria of identification by a person, provenance of production, continuity of handling and storage. The policies and procedures relating to these processes have already been accepted by the courts, ACPO and the CPS within three main documents. Although cross-sectional imaging is not specifically mentioned within these documents, the guidance and advice does apply. There is some overlap between these publications.

ACPO (2007) practice advice on police use of digital images

This practice advice, which is found at: http://www.acpo.police.uk/documents/crime/2011/20111014%20CBA%20practice_advice_police_use_digital_images_18x01x071.pdf, covers the following areas:

- Managing Digital Images as Police Information;
- Capturing Images;
- Editing and Processing;
- Case Preparation, Disclosure and Revelation to the Crown Prosecution Service;
- Retention, Storage and Disposal of Images.

This document sets out the legal and policy framework within which digital images are managed as police information, including those relating to disclosure, human rights, data protection and freedom of information. Cross-sectional imaging is not specifically referred to within the document, but it describes the provenance and audit requirements of images passed to the police, the rules on the editing and processing of the imaging and the preparation for use in the court. Finally the document describes the decision making process for retaining and disposing of the material.

HOSDB (2007) storage, replay and disposal of digital evidential images

The document entitled “Home Office Scientific Development Branch (2007) *Storage, Replay and Disposal of Digital Evidential Images”* is available for download at

http://www.revealmedia.com/LinkClick.aspx?fileticket=N24LcvrgG_g%3D&tabid=156. This covers all aspects relating to the storage and replay of digital evidential images, including how archival needs may be estimated and communicated from imaging owners to Police Force Information Technology departments. Crucially, it allows for the storage of images on secure networks as opposed to WORM (Write Once, Read Many) media.

This is a more strategic document setting out the generic framework for the storage, replay and disposal of evidential imaging and encouraging police forces to adopt a long-term approach to managing the technology. It is concerned more with systems rather than specific guidance in relation to specific product.

ACPO/Home Office (2007) digital imaging procedure v2.0

This was originally published in 2002 and has been updated in line with the practice advice and technical documents (most notably to permit the storage of images on secure networks). It is available in hard copy and the most recent version can be found at http://www.bksv.co.uk/ServiceCalibration/Support/UKFaq/~/media/UnitedKingdom/FAQ%20Downloads/DIP_2%201_16%20Apr%2008_v2%203_%20Web.ashx

This document details the processes involved in the proper capture and handling of digital images for police applications and to define best working practices. This includes the obtaining of authority to obtain the imaging if applicable, the capture, protection and storage as well as the need to make a secure ‘master’ and working copies of the imaging.

Special Consideration

One area that has arisen in relation to the use of ‘live’ images in a court setting, for example by the use of a laptop with a suitable image viewer used to show both 2D and 3D images direct to the court, is that of the reproducibility of the reformatted images shown to a jury at trial compared with those produced at an appeal. Clearly, that which is shown in court to a jury must be capable of exact replication for any subsequent appeal or review process.

If a prepared demonstration, for example a slide set of static images or a sequence of moving images were used, then it is recommended that the version of the presentation shown to the jury is fixed on a digital device or DVD/memory device, which can be retained and secured, separate to the original recording device. In this way, the integrity of the product can be assured. However, by using such a demonstration it limits the extent to which the images can be shown to the Jury or the full potential of cross-sectional imaging for court purposes.

If a “live” demonstration was used, unless it can be captured in a manner acceptable to the criminal justice system then it would not be possible to demonstrate the exact sequence of events again. The images, however, will always remain the same and can be reviewed by any person at any time whilst they exist using the same image viewer.

If the use of cross-sectional imaging is to be used to its full potential within a court, a common system of image demonstration acceptable to the courts needs to be developed.

Summary

It is the Group's view in relation to the questions posed that:

- A number of national Home Office and ACPO guidance documents exist concerning the use of digital media within the CJS. The development of a National Image Archive as proposed elsewhere within the document (see '*Image Storage, Retrieval and Archiving'*) and the use of these images for court purposes should take into account these guidelines during the development of the proposed service.
- The use of 'live' images provides a powerful tool for court presentations. A nationally agreed protocol for their use and demonstration should be developed.

Section Three

3-dimensional reconstruction of a broken neck sustained in a road traffic collision (arrow)

Cross-Sectional Autopsy Imaging Infrastructure

The preceding two sections of this document highlight the considerations of the Group that it is appropriate to consider introducing a cross-sectional autopsy imaging service in England. From these sections, the Group does not conclude that all autopsies currently undertaken in England could be replaced by a non-invasive radiological examination; certainly not until the evidence base supports such an approach. However, the Group does agree that such a service would reduce the necessity to undertake invasive autopsies on those cases where a *reasonable* cause of death could be reached by a non-invasive approach alone for natural deaths and that there is evidence to support that in suspicious and homicide deaths there are benefits to the CJS by using cross-sectional imaging as an adjunct to the investigation in all cases. To enable those natural deaths where such an approach would be applicable to be identified, a triage system of pre-autopsy imaging is suggested.

With this in mind, the following section of the report has attempted to provide answers to the following questions:

- What are the infrastructure options available for the introduction of a cross-sectional autopsy imaging service?
- For each option, what are the advantages of the option?
- For each option, what are the disadvantages of each option?

A Cross-sectional Autopsy Service

There are two options to be considered for the introduction of an autopsy cross-sectional imaging autopsy service to the NHS. These are as follows:

i. That the service to each coroner's jurisdiction is independently negotiated by each coroner with a provider from either the public or private sector within each coroner's district with all associated costs negotiated locally.

ii. That there is a single national service provided by a single public or private health care provider with the same standard provision of service and costs to each coroner's jurisdiction.

The Group is of the opinion that, of the two options, the one that best serves the public and CJS and the one which would allow for the most efficient regulation, audit, and quality assurance and allow a national pricing strategy, workforce planning, training, research and technology replacement and update strategy would be Option 2. Option 1 would deliver a service, but would lead to the delivery of different levels of service throughout England, at different costs by a variety of providers and would be more difficult to regulate, workforce plan and connect to a national archive and reporting service.

The Group is of the opinion that Option 2 could be delivered by either the public sector or a private organisation, but that this would be best commissioned from local NHS Services where possible. As the user of the service is the CJS, the service would best be served by collaboration with the Ministry of Justice.

The Group is thus of the opinion that to enable the implementation of a cross-sectional imaging autopsy service in the NHS, this should be a single, standardised service with oversight from both the Department of Health and Ministry of Justice. Thus, from this point onwards all discussions related to costs, logistics, training and workforce are provided on the basis that this will be a national autopsy imaging service.

Imaging Modality

The document to this point has discussed two types of cross-sectional imaging that can be used with cadavers: CT and MRI. Although both can be used individually or in combination with both adults and children, considering the views of the RCR/RCPath working group, the current peer-reviewed literature and the experience of providers around the world, the Group is of the opinion that the recommendations of the RCR/RCPath group - i.e. that in the case of adults the current modality of choice is CT and for fetuses, neonates and children it should be MRI.

Thus, from this point onwards all discussions related to costs, logistics, training and workforce are provided on the basis that CT will be used for adults and MRI for children in a national service.

Cross-sectional Imaging Autopsy Workflow

The Group present a workflow model of how cross-sectional autopsy imaging could work in England. They have taken into account the current models used within the NHS and elsewhere in the world. The Group is of the opinion that the workflow model currently used at the VIFM, Australia is a good example of how such a service could work in England and, taking into account the volume of cases the VIFM deals with, and the similarities to the UK coroners' system, VIFM is comparable to England.

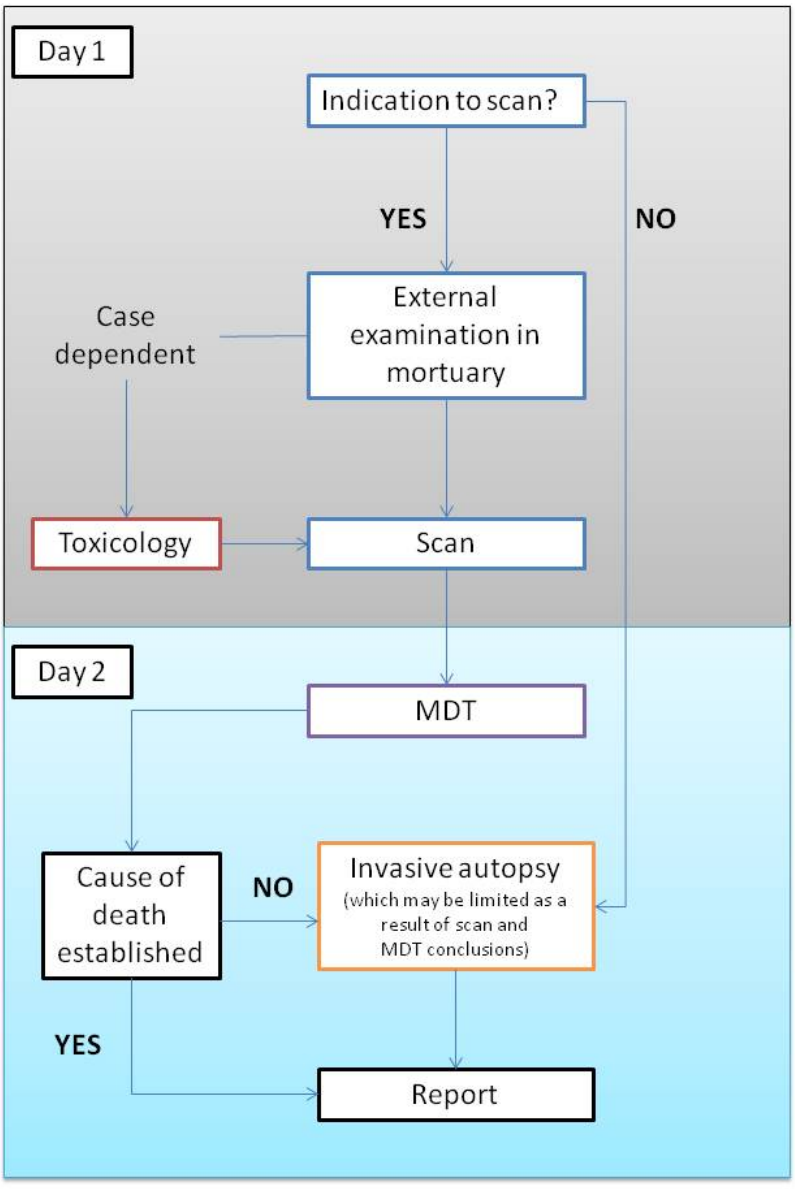
To assist the considerations of the Group, advice was taken from the VIFM, Australia. The VIFM informed the Group that they provide a cross-sectional imaging autopsy service 6 days a week with an average of 15-20 bodies admitted per day. The examination of each body is as follows:

i. An initial screening (the Group adopts the term '*triage*') is undertaken where there is a review of available documents, for example a police summary, hospital and/or general practitioner notes) with a review of the results of overnight toxicological examination, review of a PMCT scan and an external examination of the body. The results of all of this are entered onto a '*preliminary examination*' form. The time taken to undertake this is estimated at 20-30 minutes per case on average (personal communication from VIFM, Australia). The last part of the form asks whether a '*reasonable cause of death is available*' or whether an autopsy is recommended.

ii. The case is presented to the coroner with the recommendation of how to proceed. The coroner takes into account the views of the next of kin and either authorises an autopsy or proceeds without one.

Using this model, a workflow pathway that would be appropriate for the NHS can be considered as illustrated below (Figure S3.1).

Figure S3.1 Workflow model for autopsy cross-sectional imaging.



The model illustrates the need (case dependent) for additional laboratory examinations, such as toxicology to secure a cause of death without the need for an invasive autopsy. This adds a time dependent factor to the process.

The Group is of the opinion that for the national service to be established, the toxicology service utilised by the autopsy investigative team must be able to provide a diagnostic report to the pathologist within 24 hours or less from admission of the body to the mortuary. This is

achievable, but would require investment by the toxicology service providers in terms of personnel and equipment to meet this demand.

For each case, the pathologist and the radiologist should discuss the known clinical information, results of the external examination and scan, as well as any additional laboratory examination results. Having agreed the way forward, the pathologist should advise the coroner on whether an invasive autopsy is required or whether a reasonable cause of death can be issued.

Although the workflow diagram illustrates a 2 day process, with a dedicated mortuary-based scanner and dedicated workforce, in cases that have a diagnosis that can be secured on imaging alone without the need for additional laboratory investigations or an invasive autopsy, a 1 day turnaround on the case is considered achievable. If this occurred, then this would have cost saving implications to the coroners service and would allow the relatives to proceed to the registration of death and funeral arrangements at a more expedient time. This would have advantages to those religions that require early funeral arrangements for their dead.

Body Movement to the Scanner

Under current coronial legislation, the examination of the body must take place within the geographic jurisdiction of the coroner or an adjacent jurisdiction only. Thus the scanner, no matter which option is accepted, must currently be in either of these two sites. When the new coroner's legislation comes into force, this requirement is no longer in force, allowing for larger geographical movement of a body to utilise specialist facilities.

No matter which option is considered, the body will need moving to a mortuary and then to a scanner. There is a cost to this service, which is determined by local tendering for funeral director services. This cost would exist with or without a cross-sectional imaging autopsy service and varies for each coroner jurisdiction.

Once at the mortuary, there are three possible situations to be considered for body movement to a scanner, which corresponds to the three options for scanners presented below (Rutty 2010):

i. The removal of a body to a dedicated scanner situated within the mortuary itself;

ii. The removal of a body to a scanner situated adjacent to or on an external site; and

iii. The removal of a body to a scanner situated within the same hospital complex as the mortuary.

During the movement of the body, the body should remain within a sealed body bag. This protects the scanner from body fluid and tissue contamination, preserves evidence in police related cases and shields the radiographer from the body in cases scanned within existing hospital facilities, as radiographers may not be used to observing deceased bodies in various states of decomposition or trauma.

The body can be clothed or dressed in a shroud. Unclothing prior to scanning is unnecessary.

Scanner situated within a mortuary

If the scanner is situated within the mortuary itself, then the removal of the body to the scanner would not present any difficulty since this could be done by APTs in the same way, as they would remove a body from the mortuary fridges to the post mortem room. It thus presents no additional logistic or cost implications. An example plan of the space requirement for a CT scanner within a mortuary is provided in Figure 3.2.

Scanner situated on an external site

If the scanner is a mobile service situated adjacent to a mortuary facility, then portering services will be required to take the body to the scanner and move it in and out of the scanning room using the scanner lift system. This has the same portering issues as listed below. In addition to this, unless the lift is shielded from public view, the movement of the body into and out of the scanner may be observed by the general public, which could cause distress to the public and the relatives.

If the scanner is at a different geographical location to the mortuary, then the body would need to be transported to and from the mortuary by funeral directors. The funeral directors could wait until the scan is completed so that they know whether the body is to be returned to the mortuary whence it came or to go on to a funeral home.

This system involves an additional cost in carrying out the removal, which would need to be negotiated with the funeral directors. In some Coronial Jurisdictions, removal services are provided by the Coroners funding Local Authority. However, even though a fee would not be involved in such Jurisdictions, there would nevertheless still be a cost. It also adds delays in relation to the timing of the scan and takes funeral directors away from other duties.

Scanner situated within the same hospital complex

If the scanner is situated externally to the mortuary, but within the same hospital complex, then the most practical means of moving the body to the scanner would be to utilise the hospital portering services. Two porters are required for every body movement. By using already existing services, a workforce for this purpose already exists within hospitals.

However, due to the number of cases envisaged to be scanned on a daily basis (see '*Workforce Requirements*'), unless a dedicated portering service is established, which would have a cost implication to the service, the use of existing hospitals porters will take them away from other necessary duties. The porters on duty may not wish to handle the dead. Finally, within the imaging suite the porters may be required to wait with the body or assist the radiographers in manipulating the body on and off the scanner table or during procedures such as PMCT angiography, which means that they could be engaged in assisting with a body for prolonged periods of time. This could affect the portering service delivery within the hospital to other clinical services.

Where there is the necessity to move a body using a portering system, it would be most efficient to have two dedicated body movement trolleys. That way the service does not affect other body movement within the hospital and allows for one body to be moved to the scanner and another body to be prepared for movement, thus making the system more time efficient. It also provides resilience in case of mechanical failures and repairs.

An example of a dedicated movement service is currently operating at Leicester. The East Midlands Forensic Pathology Unit pays for the services of two dedicated porters to move their daily PMCT-angiography research cases from the mortuary to the CT scanner each night between 1700-1900 hours, when they have dedicated CT scanner time allocated to the unit's use. Movement is facilitated by use of two body movement trolleys.

Autopsy Scanning Infrastructure

As discussed within the sections '*Current uses of post mortem cross-sectional imaging: practicalities, costs and perceptions-adults*' there are currently three approaches throughout the world for the provision of a cross-sectional autopsy imaging service. The three options are discussed below followed by a summary of advantages and disadvantages of each. Finally, having considered each option, the Group's preferred option is provided.

In terms of the infrastructure, as opposed to the personnel (see '*Workforce Requirements*'), each option attracts generalised and specific costs. The costs that apply equally to all options include:

i. Secure data storage, retrieval and archiving (not discussed further; see '*Image Storage, Archiving and Retrieval'*).

ii. Scanning equipment:

    ii.i. Use a dedicated autopsy CT scanner;

    ii.ii. Use a 3rd party CT scanner, or

    ii.iii. Utilising existing facilities in radiology.

In relation to the three options listed above under point 2 and the information presented elsewhere within this document, the Group has considered three options for the delivery of a national cross-sectional imaging autopsy service:

- **Option 1:** Dedicated in-house mortuary sited scanning facilities (CT and/or MRI) within existing or purpose built mortuary facilities.
- **Option 2:** 3rd party supplier to provide scanning facilities adjacent or linked to mortuary.
- **Option 3:** Use existing scanning facilities within the NHS site.

There are advantages and disadvantages to each of these options in terms of capital investment, revenue costs, personnel and workflow. These are discussed for each option below.

With dedicated autopsy imaging facilities and personnel including pathologists, radiographers, APTs, and radiologists, a 24/7 service could be considered (see '*Workforce Requirements'*). Imaging could be undertaken as the body arrives at the mortuary and before initial body storage. As time delay can affect the investigation into the cause of death, as well as the result, owing to the development of a number of time-dependent imaging artefacts, imaging the cadaver as close to the time of death, which in practical terms would be on arrival at the mortuary, is preferable.

In terms of Option 1, unlike the international perspective, there are currently no NHS or public mortuaries that include a purpose built imaging facility within England. However, the Group understands that this is to change in 2013 when the public mortuary in Bradford is planning to have a dedicated CT scanner installed by a private company from Sri Lanka. Currently, the model in operation where scanning is occurring in England is Option 3. However, with this option, as clinical scanning of the living is given priority, scanning is usually confined to a limited out-of-hour's service.

If a dedicated service was to be developed with no purpose built unit, a mobile scanner sited as close to the mortuary as was possible would have to be used (see Option 2).

Option 1 – Dedicated scanner within an existing or purpose built mortuary facility

A dedicated scanner within an existing or purpose built mortuary is the ideal model for service workflow and efficiency. This is the model adopted internationally within Scandinavia, Europe, South East Asia, military and Daly in Baltimore, USA and Australia and is the model being implemented in Japan. It removes the need for transferring a body out of the mortuary as described above and facilitates fluidity of post mortem investigation with close collaboration between imaging and invasive investigation. Where invasive scanning procedures are required to be undertaken including toxicological sampling, angiography or needle biopsy sampling, these can be undertaken within appropriate facilities designed for dealing with and containing the hazards presented by a deceased body. There would be no time related restriction to accessing the scanner allowing a speedier and more efficient service. There is no conflict between the living and the dead in terms of access to scanner time.

Capital investment

This option requires physical construction within either existing facilities or new purpose built accommodation. Costs can be limited by identifying and using space within the mortuary to house the scanner and by using refurbished scanners. Lifting equipment can also be installed to facilitate scanning of bariatric cases. If the service develops towards systems proposed such as Virtangio® and Virtobot® then these can be accommodated into a dedicated mortuary based system. An example of the space required for this option is shown in Figure S3.2.

Revenue costs

This option requires a service contract and hardware renewal, for example the x-ray tube, which will affect the running cost. The options related to data storage, retrieval and archiving are discussed elsewhere and are the same for all three options considered (see '*Image Storage, Archiving and Retrieval*').

Personnel

The personnel requirements are the same for all three options and are discussed elsewhere (see '*Workforce Requirements*').

Workflow

This option provides the most efficient workflow system. There are no associated portering costs. There are no out-of-hours costs, as the entire service can operate during the proposed 15-hour day, independently of the radiology department, and infection control is optimised, as there is no scanning of living patients on the scanner.

Thus, for Option 1 the Group considers that the advantages and disadvantages are:

Advantages:

- Fluid and efficient workflow;
- Mortuary led service;
- Available 24/7;
- Limited body movement and staffing required to handle bodies;
- No additional portering staff required;
- If ceiling mounted hoist installed this may reduce staffing further;
- No possibility of causing distress to living whilst transferring the body to the scanner.

Disadvantages:

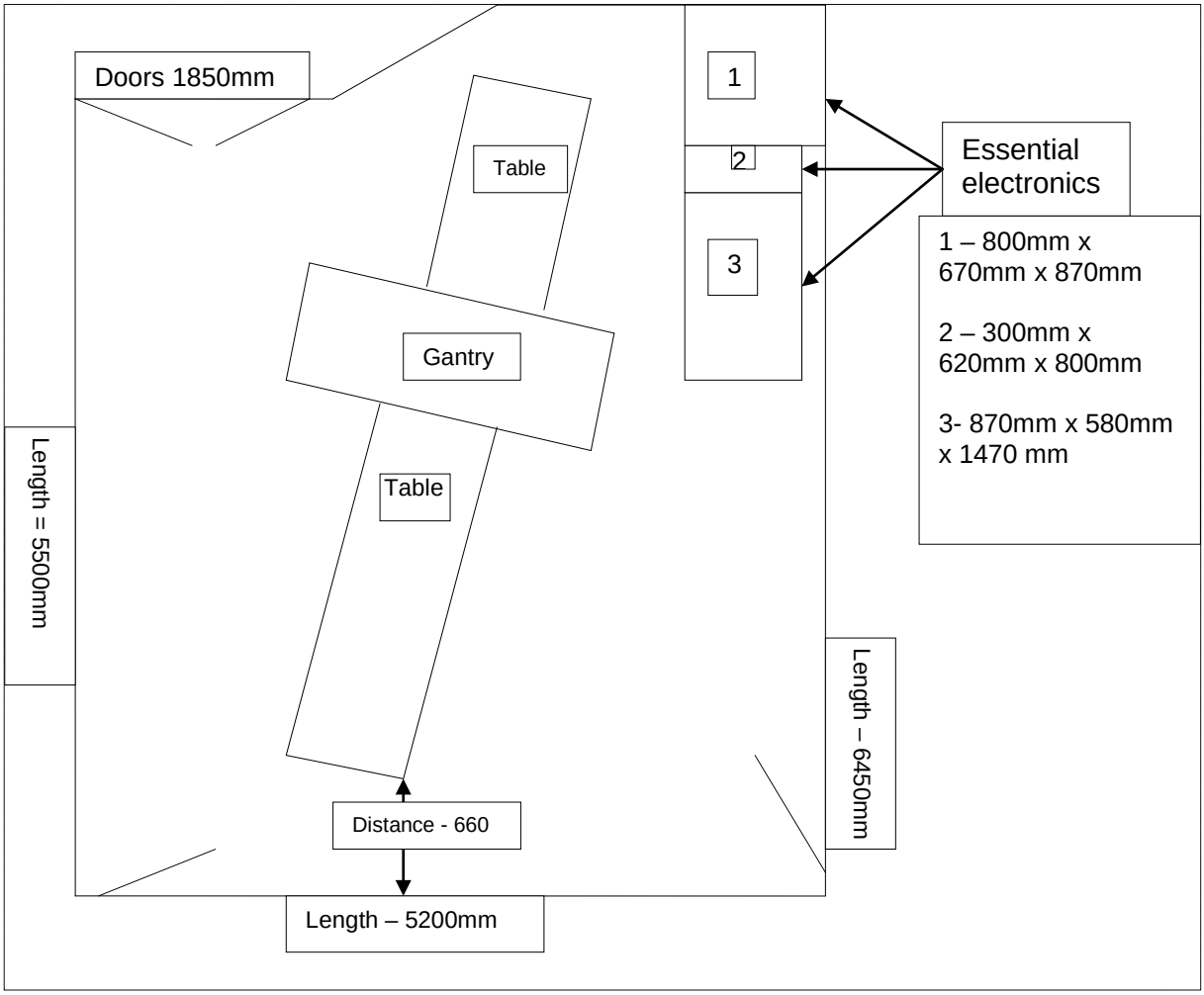
- Cost of build;
- Cost of training mortuary staff;
- Cost of IT infrastructure;
- Scanning would need to be undertaken in secondary location when the scanner is being serviced/upgraded or during unexpected downtime;
- Services need be developed with planned technology replacement. The life span of a CT scanner is a maximum of 10 years in terms of manufacturer's requirement to provide spare parts. If a service is developed with second user units, the commitment to maintain becomes vital. Where services are being upgraded, there should be continuity plans (such as availability of an interim hire scanner and location).

Figure S3.2. An example floor plan of the space requirement for a CT scanner within a mortuary facility.

All measurements are in millimetres and are width, depth and height (approximate measurements within 200mm). Sizes are for a standard 64 MDCT.

Gantry. 2250mm (w) x 1000mm (d), table; length 2800 x width 600. Coverage behind gantry; 1300 including table extension. Total length needed; 5100mm.

Control room. *Need* sufficient desk space for 2 monitors and keyboards and the CPU (440 x 750 x 700). PC for image data sorting. Space for people to view the scanning process (police/for training) and to review the imaging.



Option 2 – Third party supplier to provide scanning facilities

A mobile scanner installed adjacent to the mortuary would permit scanning with limited movement of the body away from the department. Logistics include transfer of the body within the scanner room to within the confines of the mobile unit. Service level agreements are required before contracting a third party provider. Efficiency of workflow would depend on the frequency of attendance of the mobile unit. Scan time could be offered for clinical patients whilst not being used by the mortuary.

Capital investment

For a mobile scanner to operate there is a requirement for the identification of a suitable location and construction of a hard standing to accommodate a mobile unit adjacent to the mortuary. To avoid the use of lifts, a link corridor from the mortuary to the scanner is recommended.

Revenue costs

A service contract will be required between the provider and the user.

Personnel

In addition to the described workforce, porters will be required to transfer the body to and from the scanner.

Workflow

This option provides a moderately efficient workflow, but is limited to frequency of attendance of the mobile unit. It provides an efficient option for the use of a CT scanner at a temporary mortuary facility. There should be no out-of-hours costs as the entire service can operate 9-5, independent of the radiology department.

A mobile scanner can be hired and will usually come with trained staff. The scans would be performed by trained radiographers. Such facilities tend to charge on a day rate or cost per case basis with price reducing with increasing numbers performed. It may be possible to hire only a scanner and deploy local trained staff.

Thus, for Option 2 the Group considers that the advantages and disadvantages are:

Advantages:

- Less capital investment than a dedicated scanning facility;
- Geographically adjacent to mortuary;
- All staffing costs could be part of the contract;
- Could include radiographers if required;

- Could provide replacement if scanner fails;
- Scanner can be located adjacent to the mortuary and could be moved to other centres to provide the same service;
- Scanner could accommodate living patients at predefined times by moving to another hard standing at the hospital site;
- Potential as short term option as service evolves;
- Staff are trained and maintain professional qualifications as part of the existing Imaging service;
- Additional capacity for clinical work if not all of the scanning time is used.

Disadvantages:

- Accessibility depends on contracted operational hours;
- Requires dedicated parking area and infrastructure for scanner;
- No lifting equipment for bariatric cases;
- Reliance on 3rd party personnel and equipment;
- Could be an expensive option;
- Requires a contract over a fixed period of time;
- Mobile scanner may be lower specification than departmental unit;
- Hospital or funding organisation may need to give long term commitment for the external service;
- Arrangements for continuity of service in the event of mobile unit downtime.

Option 3 - use existing scanning facilities within the NHS site

For this option, no capital investment would be required except where lifting equipment is required. Access, however, would be limited to out-of-hours, when the equipment is not currently being used for clinical cases. Considerations include: moving a body around the hospital site; undertaking minimally invasive autopsy procedures within clinical imaging areas; infection control and employing portering and radiographic personnel.

Capital investment

Considered to be minimal i.e. the possible need for lifting equipment.

Revenue costs

Costs of renewables including x-ray tube.

Personnel

As for Option 2.

Workflow

This would be limited depending on the availability of scanning equipment. Many radiology departments operate extended working days with clinical cases booked into the evenings and 7 day working. In this situation, imaging equipment would only be available during antisocial hours. This may create discontinuity in workflow and inefficiencies with portering and storage of cadavers.

Thus, for Option 3 the Group considers that the advantages and disadvantages are:

Advantages:

- No capital investment in scanning equipment;
- Trained staff in post;
- Immediate service provision;
- Potentially a bigger pool of staff to do scanning (more radiographers will be trained to use the scanner)
- Greater service resilience;
- Routine maintenance times are organised and completed during the working day, not impacting on PM scanning;
- Possible option for access to a second clinical scanner in the event of unexpected downtime on postmortem scanner;

- Costs met by radiology if funded through service level agreements with local authority or other organisations.

Disadvantages:

- Currently, without the availability of dedicated imaging, there is a need to utilise the main NHS facilities and access is limited to specific times. NHS scanners are currently used on extended days and at weekends. Most, but not all, hospitals have more than one CT scanner. Where there are two scanners, one is able to continue with emergency scanning and the second scanner could be allocated to perform cadaver imaging. In the last 10 years, there has been a three-fold increase in the number of clinical CT scans completed. This has led to extended working hours and so limiting the time available for post mortem scanning. As the number of clinical scans is expected to continue to rise and the current financial climate dictates extending the working hours further rather than providing more scanners, the free scanner time could decrease further. Therefore, using hospital scanners to provide a post mortem service may not be viable in the long term;
- This model does cause some delay after the arrival of the body as the imaging time available would probably be between 1700-0830;
- There may be additional risk through further disruption of the body and contamination;
- Additional infection control procedures are required for a combined use scanner;
- Privacy issues surrounding scanners that are housed in clinical departments centrally within the hospital;
- May require an investment of lifting apparatus;
- Limited availability due to normal activities and thus delay in performing the scans;
- Body movement may have inherent delays if mortuary is not located near the imaging department;
- Need dedicated porters for mortuary cases.

Structured Development Options

Whilst Option 1 is the preferred and ideal environment, it is not a pragmatic solution for all currently operating mortuaries in a nationwide service in times of fiscal prudence. Thus, a limited number of centres, based on regional workload figures, are considered a more reasonable option (see '*Workforce requirements'*).

The dedicated facility (Option 1) can be a solution for the hub of a "hub and spoke" network, with the third party supplier (Option 2) as a second best alternative.

Incorporating scanning in Imaging Departments (Option 3) could be the "spoke" component for peripheral centres. As the service evolves and consolidates, the "spokes" may establish themselves as further "hubs" and be considered for Option 1.

Summary

It is the Group's view in relation to the questions posed that:

- It would be possible to operate in England a workflow model based on that currently in operation at the VIFM, Australia. This, depending upon the need for additional laboratory investigations such as toxicology, and assuming that the providers of such services can provide reports within the specified timeframe, could lead to a cross-sectional imaging autopsy service with a body turnaround time of 2 days or less. This is comparable, if not shorter than, current autopsy practice. This would have benefits to the coroner's service as well as to the relatives of the deceased.
- To enable this workflow model to be achieved, there are three options for locating scanners. Each of these has logistic, personnel and monetary advantages and disadvantages.
- Of the three systems considered, the Group is of the opinion that the most efficient option would be that of dedicated scanners within pre-existing or purpose built mortuary facilities.
- The costs associated with the capital investment for Option 1 could be reduced by having less scanning facilities than current mortuary facilities. A reduced number of sites could be supplemented in a hub and spoke system by use of Option 2 or 3. Option 1 would be more efficient for the delivery of a dedicated autopsy service in terms of workforce planning, governance, audit, research and training as well as the costs of running the service and future proofing.

Image Storage, Archive and Retrieval

In the following section of the report, the Group has attempted to address the following questions, both in terms of the infrastructure that would be required for cross-sectional imaging autopsy and the associated costs for the options identified. The questions that were considered are as follows:

- How much data is generated during post mortem cross-sectional imaging?
- How could such data be stored?
- How could such data be archived?
- How could such data be retrieved?
- What are the cost implications for any option identified for questions 1-4?

Data Storage

Currently there are different approaches to the protocols used, the volume of data acquired, and the techniques applied, for example the use of different approaches to post mortem angiography, at those centres undertaking cross–sectional post mortem imaging within England. The presence of findings resulting from post mortem change may confuse the unwary or untrained during interpretation (Christe 2010, Rutty 2010). Despite these differences, the principles of data storage, archiving and retrieval are the same as for clinical practice.

The Group is of the opinion that a single national standardised PMCT protocol is adopted such as the one given within the RCR/RCPath joint working Group's report.

PMCT can, depending upon the protocol used, generate in the order of 4000 DICOM images for a whole cadaver image series. This volume can increase to approximately 9000 images if additional imaging in the form of whole body or targeted angiography is used. Thus, compared to clinical imaging, PMCT may generate large data files.

In addition to the volumetric data, this information is associated with clinical and technical report information, which all needs to be stored in a secure data archive. This process must meet the standards and guidelines presented in the section entitled '*Digital Images; Policies, procedures and the Law*' of this document.

Currently, there are two models of image storage utilised:

i. Local storage through removable media such as portable hard drives or images burnt to CD or DVD. This allows the images to be viewed using standalone DICOM viewing software or loaded onto local image workstations.

ii. Storage on the hospital Picture Archiving and Communications System (PACS). This provides a local data store with the ability to view images on dedicated radiology workstations or viewing terminals.

Thus, for the implementation of a new, clinical service there must be an integrated dynamic data storage system to replace the use of removable storage media. The system must accommodate large volumetric data sequences, allow easy access to users, which may include remote reporting, and yet provide assurances to the CJS of its robustness and security. It must have a robust chain of custody mechanism built into the system.

To establish such a service, the Group is of the opinion that there are three options available for consideration:

- **Option 1** - Use of local PACS and image transfer system for secure data sharing, for example within an NHS hospital.
- **Option 2** - Use a dedicated mortuary based PACS and secure data transfer system as used, for example, at the VIFM, Australia.
- **Option 3** - Create a dedicated specialist infrastructure through expansion of the existing Home Office secure image storage infrastructure to provide an integrated archiving retrieval and viewing system utilising the existing Image Exchange Portal (IEP).

All three options are acceptable to the Group. However, Option 1 may place a burden upon hospital PACS systems that will need to accommodate permanent storage of large data sets generated by the service for use by the CJS. Option 2, as detailed below, is the most expensive of the three options and adds another image repository to, for example, a hospital where others already exist. Option 3 allows for the development of a central, national resource with centralised security access, validated controls on all cases and for the development of a national research and training resource.

Image Data Workflow

It is considered by the Group that, as this is a new clinical service, although existing data storage and archiving systems could be used, or a dedicated PACS system could be acquired for a mortuary based scanner, owing to issues related to scan image data volume, security of the system and the option for remote reporting, it would be preferable to develop a new dedicated National Post Mortem Picture Archiving and Communications System (PM-PACS), i.e. Option 3 above. This would be based on the Home Office secure image storage infrastructure, which already exists.

Protocols and networking

The system would work as follows:

i. Post mortem cross-sectional imaging would occur at a local site using the RCR/RCPath protocol to standardise PMCT imaging throughout the whole of the NHS. Thus, the volume of data for each case imaged at any site can be predicted (from an expected volume range) and thus the national requirement for data storage and archiving can be predicted based on geographic population data and trends for NHS deaths per year. This would allow for models to be generated predicting future use and costs.

ii. Imaging could be undertaken as either a Hub or Spoke as part of the national network. An example of how such a system could work if extrapolated onto a national scale is that of the Hub and Spoke imaging, storage, archiving, retrieval, reporting and dissemination to defence commissioned pathologists used within the East Midlands in relation to forensic cases examined by the East Midlands Forensic Pathology Unit. This has provided a workable regional solution for multi-site forensic case imaging.

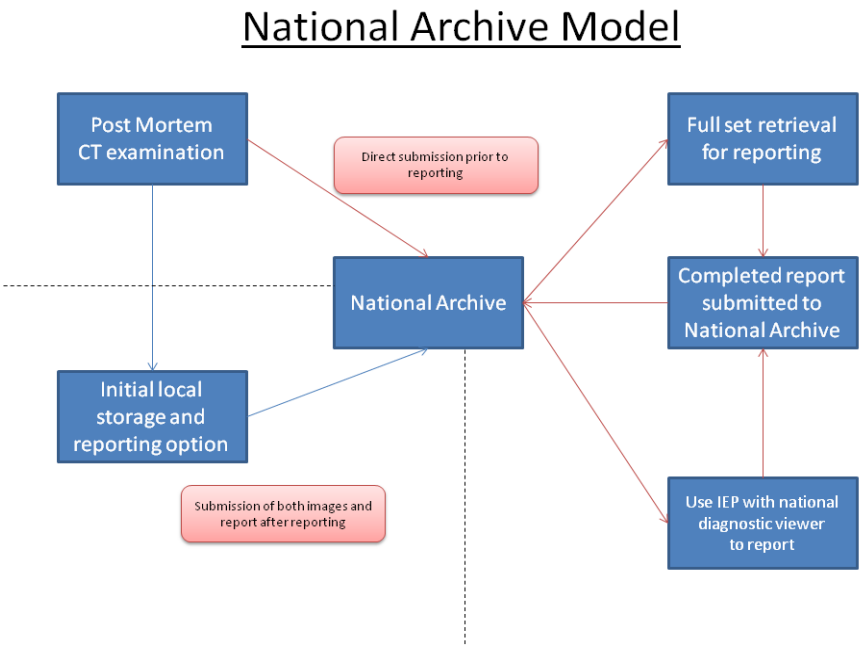
Reporting

There are two options for accessing the images for reporting which could be implemented to meet local preference, hospital infrastructure and clinical practice as illustrated in Figure S3.3:

i. Data could be held locally for an initial period to allow reporting on local workstations if required, with long term archiving in the central data store.

ii. All data is transferred immediately to a central archive and reported using a full capability diagnostic viewer.

Figure S3.3. The proposed model for cross-sectional autopsy imaging image acquisition, storage, archiving and reporting.



Suitably qualified individuals locally could then undertake the reporting, regionally, nationally or internationally. As PMCT utilises 3D reconstruction of large data sets, the use of an integrated IEP viewer operating remotely can cause problems for two reasons:

i. If the N3 Network cannot be accessed and the local network connection is not very fast (beyond the scope of most hospital and domestic broadband systems), reporting is frustrating owing to delayed reconstructions, skipping of images and time lag on image modifications.

ii. Radiologists have to work on image analysis software they are familiar with.

Thus, the Group's preferred option would be a period of storage on the local system for reporting purposes prior to submission to the National Archive for archiving. The option to send straight to the National Archive is also acceptable although; through the experience of exercising the FiMag system, the Group has been advised that a system enabling downloading of suitably coded, anonymised images (the full DICOM set) be used for reporting purposes with this option. Although the full download would take time, once on the local server, reporting would be more efficient. It would also allow the use of any standard analysis package that the radiologist was used to reporting with.

National archive

Authorised medical professionals via the high security internet gateway could access the images and report from the National Archive. Access to any single case within the archive by non-medical personnel would be possible, similar to the access the police currently have to clinical data held with a PACs, but only if the correct authority for access is demonstrated. A

suitable data request and release system for non-medical personnel would be required to be established.

This system would provide a national dedicated resource for post mortem imaging which would be kept separate from clinical images.

By using a National Archive, this allows for a national resource to build up a national, consented, validated teaching and research archive.

Costs

As three different options are available for data storage, there are three cost options to be considered based on images being archived for 15 years (Rule 56 Coroners Rules 1984). Those from homicide cases may require longer storage periods, as in accordance with the Criminal Procedures and Investigations Act 1996, and the circumstances of each particular case.

The costs as estimated in December 2011 are as follows:

- **Option 1** - If image storage and archiving is undertaken locally, the existing NHS hospitals where scanning is undertaken bear the costs of data storage and maintenance of the system. The costs could be passed onto the users of the system. **The cost of this would be dependent upon the local PACs contracts and existing infrastructure.** For example, a 95TbSAN costs approximately £500,000 with long-term storage costs of approximately £300,000 plus support costs.
- **Option 2** - Following the example of the VIFM, Australia, a dedicated local PACs system could be installed, for example, in association with a mortuary-based scanner. The provider of the facility where scanning is undertaken would bear the costs of data storage and maintenance of the system. The costs could be passed onto the users of the system. **The cost of this is estimated as follows based on a dedicated PACs system sized for 2000 cases per year:**
    - £150K per site Capital
    - £20K annual cost for system
    - £25K cost for storage
- **Option 3** - A Post Mortem PACs is provided as a national service. The cost of a National Archiving system using IEP with diagnostic viewer and secure central archive is estimated at:
    - £45K annual cost for system and viewer licences
    - £25K cost of storage

Thus, the outline costing for a National Image Archive service over 30 sites (see '*Workforce Requirements'*) would be for each option:

i. Local PACs access (dependent on local Trust contracts) £2.1 million

ii. Local dedicated PACS Infrastructure £4.5 million

iii. IEP System licences £1.35 million

The revenue costs of storage are £25K. Should children be imaged using MRI, the image storage costs would be comparable and the same National Archive could be used. The system is applicable to mass fatality incidents (FiMag).

Thus, considering the estimated costs, the Group is of the opinion that best cost option would be a central National Archive.

Summary

It is the Group's view in relation to the questions posed that:

- The principles of data storage, archiving and retrieval are the same for clinical and post mortem cross-sectional imaging. The protocols used, the volume of data acquiring, the interrelation and security issues are, however, different.
- There are three choices in relation to how data can be stored, archived and retrieved. The choices are those of a local or national based system. Each has different requirements both in equipment, outlay and running costs.
- The Group believes that the preferred option should be a National Archive. This would allow a central standardised secure resource for the whole of the NHS to be developed with the added benefit of becoming a national teaching and research resource. If a local option is pursued, the diagnostic work would be achieved, but at greater cost and an integrated national teaching and research resource would be more difficult to establish.
- As the system is for use by health care professionals (providers) for the CJS (users), this would require an initial investment followed by running, maintenance and future development costs. If a local system were pursued, the cost of the system would need to be placed onto the users, which would raise the cost of the service.
- A National Archive would allow the option for both local workstation reporting and the use of an IEP based system. Owing to the volume of images involved in reporting, a local workstation option is preferred but both can be accommodated. The National Archive approach would allow for local, regional, national or international reporting by authorised medical personnel.
- Owing to the nature of cross-sectional imaging both options are applicable to both children and adults. The costs are comparable for both age groups. A national system would accommodate both age groups in a single national archive. It would also allow the use of the system for mass fatality incidents (FiMag).

Workforce Requirements

In the following section of the report, the Group has attempted to address the following questions in terms of the workforce that would be required for cross-sectional autopsy imaging and the location from where the service could be delivered. The questions that were considered are as follows:

- In relation to the workforce, what problems exist to the introduction of a national cross-sectional imaging service?
- What are the workforce requirements necessary to implement a cross-sectional imaging autopsy-based service to the NHS?
- What would be the workload for the workforce?
- How could the workforce deliver the service?
- What time period would be required to develop a national service?

Workforce Problems

As discussed within the section '*Terminology and Practitioners"*, England currently has a number of established different medico-legal autopsy services operating. Although discussed previously these can be summarised as follows:

i. In Scotland and Northern Ireland, the service is almost entirely provided by full time medico-legal autopsy practitioners, working within employed service from a limited number of centres.

ii. South Wales, until recently, had a single service under the governance of an employed Home Office forensic pathology group practice service working from a single site.

iii. Cases in England are examined by either NHS histopathologists or practitioners from one of the 7 Home Office forensic pathology group practices, the majority of which are self-employed, depending on the nature of the case.

When considering the international delivery of medico-legal autopsy services, points 1 and 2 above are the nearest systems to their international colleagues.

Radiographers and APTs already exist within the NHS and are trained in their respective roles.

Currently few radiologists in England have any experience of this diagnostic service.

Thus, the introduction of a cross-sectional autopsy imaging service poses a number of workforce problems, which are in turn dependent on where in England one works. These are as follows:

i. The only problem envisaged for radiographers and APTs is that of training related to new job roles within the service. This is not considered to be a significant hurdle. It is considered that both of these groups may embrace the opportunity to extend their professional job roles.

ii. There will be an initial shortfall of radiologists in the workforce to undertake the diagnostic reporting. This can be addressed by workforce planning and training.

iii. The most significant hurdle to the introduction of the service will come from the pathologists in England. Whilst England retains a two-tier autopsy service with few dedicated autopsy practitioners, there may remain problems in the implementation of a national cross-sectional autopsy imaging service.

The Group outlines below its considerations of the workforce requirements to establish a cross-sectional imaging autopsy service within the health service of England.

Workforce Requirements

As discussed within the section '*Cross-sectional Imaging Autopsy Infrastructure'* there are a number of options around how scanning could be delivered within a National Health Service model. What is apparent is that a dedicated mortuary based autopsy scanner would deliver the best solution to the service as exemplified by the VIFM, Australia.

Considering the number of examinations that may have to be undertaken at any one single scanning site, it is calculated that a single scanner operated for 15 hours per day dedicated for post mortem imaging could scan in excess of 30 cadavers per day. Although this is in excess of the normal number of cadavers where autopsies are authorised by and undertaken for a coroner at one site on any given day, this number could support the concept of centralisation of autopsy services at a number of dedicated sites within geographical areas. This would

- allow for the employment of a dedicated workforce,
- investment in a dedicated infrastructure, both in terms of scanners and mortuary facilities,
- make it easier to apply new technology and methodology as it is developed throughout the world,
- provide a network of training and research centres, allow for the use of a National Image Archiving System at the costs proposed (see '*Image storage, Archiving and Retrieval'*),

- allow for the development of a national quality assurance scheme related to the service.

This model would be applicable to adults and children. The model would follow current considerations for the future delivery of paediatric and forensic pathology services to police forces of England.

Personnel

A single scanner operated for 15 hours per day dedicated for post mortem imaging could scan in excess of 30 cadavers. To deliver a dedicated service where there is a dedicated presence of the CT scanner for 15-hour days Monday to Friday would require a minimum of:

- Anatomical Pathology Technologists 2
- Radiographers 2
- Radiologists 2
- Pathologists 2

The exact number of personnel at any one site would be dependent upon the workload. Workforce numbers must also take into account provision of service during periods of annual leave, predictable training days, special leave such as maternity leave and unpredictable sickness leave.

This workforce would deliver about 150 examinations per week. An out-of-hours service for unpredictable predominately police cases would be required as on-call and remunerated accordingly. However, by having a dedicated scanner service, as opposed to the current system where police cases are examined on NHS scanners out-of-hours owing to conflict between the needs of the living and those investigating crime related to the dead, it should be possible to provide a scanning service to the police within normal working hours. This would be more efficient to police investigations in terms of the European Working Time Directive and police custody times. Avoiding both scanning and autopsy examinations during the night would provide a potential cost saving in terms of overtime payments within the police services.

Operating the scanner

Currently, cross-sectional imaging of the living and the dead is undertaken by radiographers. In a national cross-sectional autopsy imaging service this could continue. However, an alternative to having radiographers potentially work within a mortuary environment would be to have the scanning undertaken by APTs. This model is used internationally.

The Group considers that APTs could be trained to operate CT scanners and operate them, for autopsy purposes, under the governance of a local lead autopsy radiographer. The APTs or other appropriately trained technical assistants could also undertake cadaver based procedures such as PMCT angiography or needle biopsies.

In the case of fetuses, neonates and children it is recommended that MRI trained radiographers perform the imaging (see '*Current Use of Post Mortem Imaging; Practicalities, Costs and Perceptions – Fetuses, Neonates and Children'*).

Pathologists

It is proposed that at each scanning centre there would be required a minimum of 2 pathologists. There are two options to be considered:

i. That these are full time autopsy pathologists.

ii. That they come from the current workforce.

The Group is of the opinion that either system would work although a full time dedicated autopsy workforce is preferred.

If a regional, centralised service is accepted to be the best way to implement the service, then at those sites where examinations are to be undertaken the pathologists involved could have a conflict between the delivery of the autopsy service and diagnostic reporting of histopathology for clinical services. The pathologists will be required to undertake reviews of the clinical notes and undertake external examinations, review the results of a toxicological examination when undertaken and discuss the results of the radiological imaging (or report the images themselves under the governance of a radiologist) before discussing the case with the coroner and writing a report. An autopsy may still be required on a number of cases. For this to be undertaken in the most timely, efficient manner with appropriate quality assurance, training, CPD and revalidation, a dedicated workforce is recommended.

It is anticipated that such a proposal will meet resistance from some quarters of the pathology world, as this would be a fundamental change in how the medico-legal autopsy services are delivered in England.

The Group believes that it is not the remit of this document to promote one sub-specialty over another, although it suggests that those undertaking this work should be appropriately trained to deal with the full spectrum of death that will present within a centralised rationalised service; be subject to relevant CPD, audit and EQA; and undertake revalidation within this field of work.

Radiologists

Based on the workload figures discussed above, the resulting 30 examinations per day would require 30 hours of diagnostic reporting. Following the recommendations of the RCR/RCPath working group report, the diagnostic reporting would fall to a radiologist or another suitable qualified individual, for example a cross-sectional autopsy pathologist, working under the governance of a radiologist.

The Group suggests that the recommendations within the RCR/RCPath work group document of who reports the images are adopted.

If radiologists alone, owing to the potential workload involved, undertook the image reporting this would require dedicated radiologists at each centre to undertake the work. If the international model was adopted then radiologists and pathologists could share this workload, under the governance of a radiologist.

The reporting of the images could be undertaken either at the site of imaging or by utilising a hub and spoke approach with a regional service, at a central image-reporting centre. The centralised model would make use of the National Image Archiving System as proposed in the section '*Image storage, Archiving and Retrieval'.*

Towards a Centralised Regional Cross-sectional Imaging Autopsy Service

The section entitled '*Scanning Infrastructure for Cross-sectional Imaging Autopsy'* outlines the options available for the implementation of a cross-sectional autopsy imaging service. From this, owing to the cost of the CT scanner, its installation and ancillary costs (lead lining, ceiling hoist etc), it would not be feasible to expect a CT scanner in every mortuary in England. In addition, the potential workload would not utilise a scanner in every mortuary to its maximum. This could lead to a conflict as, if it is not located in the mortuary, the scanner could be used for clinical scans and these may take priority over the deceased.

Staffing so many scanners, whether by radiographers or APTs, would be difficult to manage and may necessitate employing more staff. Training the number of staff needed to operate so many scanners would be costly and take time.

Thus, the Group is of the opinion that it would be best to consider a number of dedicated, regional centres for autopsy cross-sectional imaging. This concept further supports the proposal of a dedicated, autopsy service to support the regional centres as invasive autopsies will still be required to be undertaken on a reduced number of cases at the centres when imaging does not identify the cause of death.

In the long-term, as mortuaries require refurbishment, the Group would suggest that rather than refurbish established premises, which can be costly, it may be more cost effective to build purpose built mortuaries with imaging facilities. Such facilities could be built on a structural scale to provide resilience for mass fatality incidents thus moving away from the concept of temporary mortuaries.

Number of centres

During 2010, 101,943 coroner's autopsies were undertaken in England and Wales; 95,402 in England and 6,541 in Wales (Coroners Statistics, 2010). Based on the population distribution for England and the number of examinations requested it is felt that 30 regional-based centres would provide the backbone of a national infrastructure for cross-sectional autopsy imaging and, where necessary, autopsy examinations. The number of centres per region based on coroners autopsies request data in England could be:

Number of Autopsies		**Region**	**Proposed Centres**
5,869	6%	NORTH EAST	3
15,637	16%	NORTH WEST	4
9,274	10%	YORKSHIRE AND THE HUMBER	3
7,111	7%	EAST MIDLANDS	3
9,066	10%	WEST MIDLANDS	3
10,496	11%	EAST OF ENGLAND	4
10,860	11%	LONDON	3
16,381	17%	SOUTH EAST	4
10,708	11%	SOUTH WEST	3
Total			
95,402			**30**

Implementation Plan

To enable the establishment of a national cross-sectional post mortem imaging autopsy service based on the workforce recommendations above and the concept of regionalised, centralised centres, the following plan is proposed:

The immediate plan

It is important to identify the sites within each region where the majority of autopsy services are currently provided and the number of trained staff available. Consideration can then be given, based on the concept of 30 sites each performing approximately 30 scans per day with an on-call service available, where the most appropriate location for these centres are within each geographical region. Each site would be providing the service for the local and neighbouring coroners and hospitals catchment areas.

Once the number of current trained workforce has been established additional staffing needs based on the workforce requirement model outlined above can be worked out and built into for future workforce planning.

The long-term plan

The long-term plan should be to have dedicated mortuary cross-sectional imaging facilities with a dedicated trained workforce. As each mortuary reaches a point in its working life where it requires significant refurbishment, a new purpose built mortuary with imaging facilities should be built. This will require:

2-year plan

- Agreed funding to provide 30 scanners including maintenance contracts into existing mortuaries;
- A pre-determined location of the 30 centres and where the scanners will be sited within these;
- Agreed funding for organising and providing training for pathologists, radiologists, radiographers and APTs;
- An established core team to organise and provide training;
- Preliminary planned building work (roof supports for hoist, lead lining, floor);
- Plans in place to fit the scanner and have confirmed start date;
- A preliminary training programme for APTs to start when the scanner goes in;
- An established list of CT core trainers (radiographers).

As discussed within the section '*Current Use of Post Mortem Imaging; Practicalities, Costs and Perceptions – Adults'* there are a number of sites in England which are already providing either clinical or research or both services within this field. To initiate the implementation of this work stream those centres already working within this area of practice in England could be targeted to initiate the development of the service and the establishment of the National Image Archiving System They could provide the framework of a national training and research network which in turn would build the evidence base for service development.

5-year plan

- Have 50% of the scanners in place and the staff trained to operate them and report the scans;
- The scanners to be operating at least at 75% capacity;
- Have the remaining 50% of scanners planned to be installed in the next 5 years;
- Have the training in place for the remaining staff.

10-year plan: Ideal long-term solution

- All 30 CT scanners would be located in mortuary complexes and all staff fully trained. The scanners should be operating at 100% capacity;
- The scanners would be staffed 0700-2200 Monday to Friday and on-call by a combination of APTs and radiographers;
- A workforce of full-time, employed pathologists and radiologists to support the service;
- As each mortuary requires refurbishment it is replaced by a purpose built mortuary, capable of providing the full range of non-suspicious and suspicious death investigation, a medical examiners service, imaging and mass fatality service.

Summary

It is the Group's view in relation to the questions posed that:

- To establish a national cross-sectional imaging autopsy service, the Group is of the opinion that approximately 30 regional centres should be identified for the establishment and delivery of the service in England. The remaining parts of England where dedicated autopsy services already exist will translate into this model.
- At each centre, there should be a dedicated mortuary-based CT scanner.
- Associated with each centre there should be a dedicated workforce to deliver 15-hour days of scanning, Monday to Friday with on-call availability for unpredictable work if and when it arises.
- The workforce will require training and changes to current job roles and the delivery of the service. This is anticipated to be welcomed by some professions and met with resistance from others.
- It would be possible to establish the backbone of the services within 2 years of implementation and have a fully functional service within 10 years or less. This would be facilitated by targeting the development of the system initially on those centres within England with a pedigree in autopsy cross-sectional imaging, which would form the backbone of the development of the National Image Archiving System and research and training programmes.

Workforce Training Requirements

In the following section of the report, the Group has attempted to address the following questions in terms of the workforce training requirements for a national cross-sectional autopsy imaging service. The questions that were considered are as follows:

- What training is currently available in England for an autopsy cross-sectional imaging autopsy service?
- What training requirements are necessary to implement an autopsy cross-sectional imaging autopsy service?
- How could training be delivered?

Current Training Programmes

As highlighted within the section entitled '*Terminology and Practitioners'* there are currently **no** training programmes in the areas specific to PMCT or MRI for those engaged in the provision of a national cross-sectional imaging of the dead within England, either within the Royal Colleges, university or private sectors.

The International Association of Forensic Radiographers provides training programmes for radiographers engaged in mass fatality incidents. This is related to the imaging of the dead in such circumstances and not the diagnostic reporting of the images.

Although those international centres that assisted with the questionnaire for the section entitled '*Current Use of Post Mortem Imaging; Practicalities, Costs and Perceptions – Adults'* did indicate that they had undergone some form of training within this area of practice, to the Group's knowledge there is no internationally recognised standard for training within this field of practice.

The only course known to the Group to give practitioners experience within this field of practice is that of the Virtopsy® Basic and Advanced Teaching Courses (http://www.virtopsy.com. Last visited December 2011). These are considered by the Group as introductory courses to the concept of post mortem imaging and are not adequate for the training of an English workforce to supply a diagnostic service.

Within the RCR/RCPath joint working Group's document is the recommendation for training within this field of practice. The Group endorses this proposal.

Training

A centrally devised and funded training programme would facilitate early implementation of a national service and provide oversight governance of the training delivered. Central funding to facilitate the training and allow staff to be released for dedicated training periods would allow early implementation of the service. Training would be further facilitated by the early

establishment of a number of training centres already experienced in the field of cross-sectional imaging related to the dead. This would be further facilitated by the prioritisation of the placement of dedicated mortuary based scanners at these centres. This approach would underpin the development of the National Image Archiving System, which would allow for teaching on a validated consented image archive and research within the field.

Training should follow a standard curriculum devised from current practice and include recommended generic protocols and techniques to facilitate common imaging irrespective of equipment manufacturer. Co-ordination of the training and scanning standards needs to be maintained by a core team derived from practitioners within the field i.e. radiologists, radiographers and pathologists.

Protected training time should be allocated within job plans. Those working within the field should undertake CPD activities relevant to this field of practice including meeting attendance and journal reading.

Radiographers and APT core training requirements

Radiographic training would ideally be provided to the lead autopsy/forensic radiographers nationally to cascade that to their local autopsy cross-sectional imaging teams, which may be comprised of radiographers or APTs or both. This would include the use of nationally agreed imaging protocols and the use of supplementary invasive procedures such as PMCT angiography or needle biopsy techniques.

Radiographers

The level of training required by either radiographers or APTs will depend upon their previous experience within the field of autopsy cross-sectional imaging. Thus:

CT trained radiographers with autopsy/forensic experience.

It is considered that a minimum 1 day training course is required on ‘How to scan the dead’, learn the national protocols and appreciate the differences between antemortem and post mortem imaging, along with the common post mortem artefacts that may be encountered. This could be achieved at a training centre with practical experience of supervised PMCT scanning of 5 cases (could be simulated). Following this training remote support can be provided for example by phone or the development of an internet based training and update package.

CT trained radiographer with no autopsy/forensic experience

In addition to the above training requirements, training would be provided in the legal and ethical issues surrounding PMCT imaging. This would need to be a minimum of a half-day course.

Non-CT trained radiographers

A local training programme should be instigated to train the staff how to operate the scanner. The training could involve:

- Scanning parameters – such as high kV and mA, rotation time, field of view (FOV), pitch factor and helical pitch, Standard Deviation, reconstruction thicknesses and windows.
- Scanning protocols – how to scan and experience from current scanning sites.

Once this initial training had been undertaken, trainees would proceed to follow the training of those without autopsy experience.

Thus, it would be possible to provide training to qualified radiographers to undertake cross-sectional imaging of the dead with approximately 2 days dedicated training. This would be best achieved at a number of national training sites experienced in the scanning of the dead all working to a national curriculum. Once trained, CPD and update programmes should be devised. Future radiographers could have this training incorporated into their undergraduate curriculum.

Anatomical pathology technologists

It is proposed that the most efficient model for the delivery of a national autopsy cross-sectional imaging autopsy service would be to have dedicated CT scanners within a number of existing or purpose built mortuary facilities (see '*Cross-sectional Imaging Autopsy Infrastructure*'). By implementing this model, scanning can be undertaken within mortuary facilities by the APTs under the governance of a lead autopsy radiographer. APTs currently have no training within this field and thus would require the following training:

- Mandatory Ionising Radiations Regulations (IRR) training plus reading and discussing local rules and radiation protection (The Ionising Radiations Regulations 1999);
- 1 week spent observing/completing clinical scanning including quality assurance procedures and daily and weekly calibration;
- 1 day learning about the differences between antemortem and post mortem imaging along with the common post mortem artefacts that may be encountered;
- 1 day theory of CT scanners, scanning parameters and protocols;
- 2 weeks supervised post mortem scanning.

Thus, the APTs require a longer training period but this could be completed within less than three weeks. Future APTs could have this training incorporated into their professional certificate or diploma training.

Radiologists

Radiologists will already be competent in cross-sectional imaging, but there are differences in reporting PMCT, for example in the interpretation of road traffic collision injuries points of primary, secondary, tertiary and quaternary impacts, bumper heights, seatbelt marks, ejection pathology, etc., or in the interpretation of post mortem changes and artefacts. Additional radiological training would be provided through sharing practice from existing specialists in radiology and pathology, through formal training and attachment supported by a national validated case archive using the National Image Archiving System. Attendance at the proposed national training centres to gain access and experience to PMCT image report would be required. Future radiologists could have core training incorporated into their professional training curriculum.

Pathologists

There are two possible training requirements for pathologists depending on the involvement in the reporting of autopsy CT images:

No diagnostic image reporting role

If a pathologist undertook no diagnostic reporting of images then, apart from the necessity to have up to date IRR training, no further training beyond that of their professional autopsy training would be required. Future autopsy pathologists could have cross-sectional imaging training incorporated into their professional training curriculum.

Diagnostic image reporting role

If a pathologist undertook diagnostic image reporting under the governance of a radiologist then this should be to a level to enable them to report clinical CT images.

The Group is of the opinion that the training required for pathologists to undertake independent diagnostic cross-sectional PMCT image reporting should be determined by the RCR.

Summary

It is the Group's view in relation to the questions posed that:

- The Group endorses the proposal of the RCR/RCPath Group for the need to establish a national curriculum and delivery programme for those engaged in cross-sectional imaging of the dead.
- The delivery of such training in the initial stages of implementation would be facilitated by using a number of sites already engaged in post mortem imaging. It would be further facilitated if these sites were prioritised for the provision of CT scanners within existing mortuary facilities. This would help populate the proposed National Image Archiving System with consented validated training and research cases.
- Training of radiographers, APTs, radiologists and pathologists for the new service will depend upon the profession and prior experience within the field. Some training will take longer than others because of crossing boundaries of current professions practice.
- The future workforce could have the training incorporated into their professional training curriculums, delivered at a number of national training centres or, if implemented, at the limited sites of autopsy cross-sectional imaging autopsy.

Costing of a Pathology and Radiology Service

In the following section of the report, the Group has attempted to address the following questions in terms of the costs that would be required for the establishment and running of a national cross-sectional autopsy imaging service. The questions that were considered are as follows:

- What is the current cost of undertaking a medico-legal autopsy?
- What is the estimated cost of undertaking post mortem cross-sectional imaging?
- What is the estimated cost of a cross-sectional imaging based medico-legal autopsy service?
- Would a cross-sectional imaging autopsy service be less, more or comparable in costs to the current system?

Costing of Pathology and Radiology Cross-sectional Autopsy Services

There are a number of service costs currently applicable to medico-legal autopsies. These can be broken down into two basic groups:

i. Professional fees;

ii. Costs incurred by organisations providing the autopsy infrastructure.

The current system with professional fees for coronial cases paid only to pathologists for non-suspicious deaths is anomalous if an inclusive cost for examination to be recovered by the host organisation is to be implemented.

Professional fees

England and Wales

In the case of professional fees, as the service currently applies to pathology invasive autopsy services only, then the only fees that need to be taken into account are those payable to the pathologist undertaking the examination. There are three different fee levels that apply to medico-legal autopsy work, depending upon the nature of the work and the individual undertaking the investigation. These are all nationally determined and thus should be applicable to all pathologists in England and Wales. The exact fees paid are

i. The so-called ‘routine’ medico-legal fee **£96.80**

ii. The so-called ‘special examination’ fee **£279.90**

iii. The fee for police Home Office investigations **£2,460.00**

Fees 1 and 2 are payable to the pathologist by the coroner. They do not include laboratory investigations. A histology examination can add for example up to **£286.50** to this cost to the coroner.

Fee 3 is payable to the pathologist or, in the case of employed services, the employer of the pathologist, by the police. This figure was derived by the Home Office following a national review of forensic pathology services. The fee is split into a payment to the pathologist and a payment to support secretarial support and secure storage of case material. It is based on the notion that a full-time self-employed Home Office pathologist undertaking 60 Home Office police cases per year can earn an equivalent salary to a year seven NHS employed consultant with additional discretionary award. The secretarial support fee is calculated on the basis of 0.5 WTE secretarial salary per consultant. The fee does not include laboratory investigations but the work extends beyond that of the autopsy examination as outlined within the ACPO approved Memorandum of Understanding, which all Home Office pathologists must have with the police force(s) to whom they provide services.

None of fees 1-3 include court attendance fees which are nationally set by, for example, the Legal Services Commission and are based on periods of time of attendance. In the case of attending a coroner's court, the fee ranges from **£88.50 – 248.00**. In the case of attending Crown Court, the fee is recommended to be of the order of **£250.00** per half-day attendance.

Thus, the total professional fee for a 'routine' autopsy with histological examination and minimal time period attendance at a coroner's inquest is **£471.80**.

Scotland

Scotland has a national medico-legal service with salaried pathologists. The contract costs are paid from a central fund with professional fees incorporated into the cost. Thus, there is no distinction between autopsy types in terms of costs as in England and Wales. The central cost for each autopsy is approximately £1000, which includes mortuary costs, laboratory histology investigations and court attendance. The contracts for the autopsy service are currently under review.

Northern Ireland

Northern Ireland has a state medico-legal service with salaried pathologists. The service costs are paid from a central fund with the cost of the professional fees incorporated into the service fee. Thus, there is no distinction between autopsy types in terms of costs as in England and Wales. The central cost for each autopsy is approximately £1500 to £2000. This fee includes the undertaking of an autopsy examination, the preparation of the report, histology laboratory examinations and attendance at court.

From this point onwards, the Group's considerations apply to non-suspicious autopsy work for England and Wales only. It is not the remit of the Group to consider or suggest alterations to the current fees and contracts of those working within the devolved nations. As the fees paid for Home Office forensic pathology cases are based on provision of service beyond the undertaking of an invasive autopsy, the Group do not further discuss these costs as this is a matter for the Home Office Pathology Delivery Board (PDB) which oversees the provision of forensic pathology in England and Wales. The Group are also of the opinion that the current professional fee paid to radiographers for work undertaken for forensic cases should stand owing to the nature of the work involved.

From this point onwards, example costs are provided within the text of the document. Where costs are known, for example the professional fees as stated above, these reflect accurate costings. Where costs are unknown, for the reasons explained within the text, attempts have been made to provide reasonable estimated costs to give examples of potential cost differences between current and proposed services. The Group recommends that a national costing exercise is undertaken by the Department of Health, as has recently occurred in Scotland in relation to the ongoing review of medico-legal contract provision, to determine the true cost of the current autopsy service undertaken for the coroners within the NHS to ensure that, should this proposal not be implemented, the true costs of the current service are recovered by the providers of the service.

All costs provided from this point onwards have been rounded up to the nearest whole figure unless specified.

National Cross-Sectional Imaging Autopsy Professional Fee Options

It is the opinion of the Group that there are two funding options available to England and Wales in relation to the professional fee for a national cross-sectional autopsy imaging service:

- Option 1 – A fee based structure based on the current structure
- Option 2 – An inclusive organisational service cost similar to the devolved Nations

For Option 1 in England and Wales, professional fees would apply as they currently do to a cross-sectional imaging service. However, unless suitably trained pathologists emerge, as for example in other areas of the world (see '*Current Use of Post Mortem Cross-sectional Imaging; Practicalities, Costs and Perceptions Adults*') a radiologist professional fee would need to be determined and incorporated into the costing as the radiologist will play an integral part of the diagnostic and reporting process.

As an internal examination is no longer undertaken in a cross-sectional imaging autopsy service using a non-invasive approach, it could be considered that the pathology costs are adjusted to take into account the time taken for an external examination, consideration of the radiological findings and production of the report only without the time required for an internal examination. Using the information provided by the VIFM, Australia, the majority of this work may be achieved in 20-30 minutes.

Option 1: a fee based approach

Assuming a system similar to that of Australia is adopted in England, it is not unreasonable to base the costing of such a system in terms of units of 30-minute time frames. Although funding is currently different for pathologist fees and the costs included in the radiology tariff, a common approach to costing has been taken by the Group to identify the base costs of either option. Based on this and on standard NHS consultant salary scales at the midpoint of consultant grade, professional fees related to 'routine' cases could be considered as follows:

- A medical professional fee per consultant for those involved in a view, scan and grant system based on 60 minutes of work could be of the order of **£76**, allowing for 20-30 minutes triage and then 30 minutes for the production of a report. The fee should be set nationally and reviewed annually in line with inflation, changes in national medical salaries and changes in medical practice. This is less than the current national 'routine' autopsy fee.

- When an autopsy is required, there is additional work required by the pathologist in the case, i.e. an invasive examination on top of the examination undertaken in point 1. Based on a minimal time period of 30 minutes to undertake the additional internal examination, the fee, based on a total of 1.5 hours of work, could be of the order of **£114.**

- A reporting fee is payable to the radiologist. Assuming a period of up to 1 hour to report each case, this could be of the order of **£76.** The fee should be set nationally and reviewed annually in line with inflation, changes in national medical salaries and changes in medical practice.

- A fee would be payable to the radiographers undertaking the imaging. Based on Agenda for Change, at a mid-band 6 salary based on a minimal time period of 30 minutes to undertake the imaging, the fee could be of the order of **£11** per case.

- A fee should be payable for secretarial support to the pathologist for the preparation of the reports. Assuming the report can be typed in a maximum of 30 minutes and that support is provided on basis of 0.5 WTE secretarial support per consultant with a midpoint Grade 3 Agenda for Change salary, the fee could be **£6** per case.

Thus, unless a suitably qualified pathologist undertook the review of the CT scans themselves, and the APTs undertook the imaging, both of which occur internationally, then the introduction of a cross-sectional autopsy imaging service based on the payment of professional and Category 2 type fees will inevitably be more expensive than the current fee structure. Thus, to start with, the new service will be more expensive to the coroners than the current service.

Using the figures above, the minimum professional fees could be of the order of £169 per case. This does not include laboratory or court related fees, which would be in addition to this figure. The so-called 'special' examination fee would need to be adjusted upwards to take into account the increased professional costs.

Service fees would be set locally as they are now and thus would vary throughout England and Wales. These would be in addition to the professional fees and would be for each coroner's jurisdiction to negotiate.

Option 2: an inclusive cost recovery approach

For Option 2, where the examination is part of an NHS based service, the approach could be on the basis of a revised simplified funding process to allow NHS organisations to incorporate this activity by employed autopsy practitioners and fully recover the costs of the procedure. The cost should be set nationally and reviewed annually in line with inflation, changes in national medical salaries and changes in medical practice. The fee structure and application for both pathology and radiology will need to be considered in future Ministry of Justice guidance.

Using this approach, based on the experience of the devolved nations, Australia and Denmark, it is possible to incorporate the professional fees into the service costs, to recover these costs and to employ full-time autopsy practitioners.

Underlying service costs

In addition to the professional fees incurred for the service, there are underlying costs for the running of the service. These are more difficult to assess as they are currently agreed locally between the user and service providers. Currently there is no national fee structure for such costs. Thus, they vary between each coronial district depending upon the charges made by each NHS or public mortuary service.

The Group required this information to try and compare the cost of the current invasive autopsy system versus a cross-sectional autopsy imaging service to assess whether or not there would be a cost saving or a cost increase to the coroners. Thus, it has been necessary to investigate these costs to the best of the Group's ability.

The potential costs for pathology services were determined by the development of a standard costing model for autopsy costs based on the input from 4 English pathology departments who agreed to share their local costings with the Group. The results were then validated across reference sites. The costing model was developed based on a bottom up costing methodology for fixed and variable costs.

Costing the current invasive autopsy

The cost model used by the Group to estimate the cost of an invasive autopsy service, within the NHS, without cross-sectional imaging included:

- Direct costs
  - Body booked in
  - Communication for decision to Post Mortem
  - Body preparation
  - Consumables
  - Professional enquiries
  - General administration
  - Secretarial support
  - Postage/stationery
- Indirect costs
  - Formal identification
  - Viewing
  - Fridge maintenance /cleaning
  - Human Tissue Authority Licence
  - Pathology department management cost
- Proportional central costs
  - Capital charges/hospital overhead
  - On call payments
  - Body storage costs
  - Body washing
  - Total overhead costs

The cost of the service for a non-complex so-called 'routine' invasive autopsy examination without a pathology professional fee was calculated as **£296**.

Thus, using this estimated service cost, and adding the cost of the current, 'routine' pathology professional fee (£97), then the total current service cost, excluding laboratory investigations and courts fees is estimated to be of the order of **£393** per case.

Cross-sectional imaging costs

The national costing exercise identifies an inclusive cost to hospitals for CT examinations. This structure could be extended to fully recover the costs of a cross-sectional imaging autopsy service. There are inevitable additional costs to the service for the use of the cross-sectional modality, both direct costs and indirect cost including, for example, portering and radiographers' and radiologists' time when part of agreed job plans.

The costing approach taken by the Group was to develop an NHS based service with all costs included as part of the hospital infrastructure. None of the professional groups receive

separate professional fees, similar to the current autopsy service for the devolved nations, as the imaging is viewed as part of NHS service provision.

Costing the cross-sectional imaging autopsy service

For the model used, the imaging costs included standard components based on the reference costing methodology for the direct access tariff as well as the service costs outlined above for the mortuary aspects of the service. The additional radiology costs are:

- Direct costs
  - Scanning time
  - Reporting time
  - Data archiving
- Indirect costs
  - Equipment maintenance
  - Department management cost
- Proportional central costs
  - Capital charges/hospital overhead
  - On call payments
  - Total overhead costs

The cost of the imaging aspects of the service for a non-complex cross-sectional imaging autopsy examination without professional fees was calculated as **£181** per case.

Thus, using this estimated service cost and adding the costs of the professional fees estimated above (£169) and the autopsy related service charges, which still need to be applied in a cross-sectional imaging autopsy service (£296) then, excluding laboratory investigations and courts fees, the estimated cost of the service is of the order of **£646** per case.

The cost of a non-complex non-invasive MRI examination (based on three body areas) on the model applied was calculated in the order of **£800** per case.

The costing model is sensitive to capture increases in direct and indirect costs should the pathologist or radiologist time component require increasing on a case or overall service basis. Image archive and storage costs would be additional based on the storage method chosen.

Illustration of the Cost Difference

Based on the coroners' total workload figures for England, 2010 of 95,402 cases and assuming *all* cases are amenable to a non-invasive approach, which in reality will not be the case, the following are estimated:

- The total estimated cost of the current invasive autopsy service, without laboratory and court fees, using the estimated figure of £393 for England approximates to **£37.5 million**.
- The total estimated cost of 100% cases being undertaken as the proposed cross-sectional imaging autopsy service, without laboratory and court fees, using the estimated figure of £646 is **£62 million.** In practice, the actual percentage of cases will be determined following evaluation of the current research studies.

Thus, as stated and factoring in autopsy services, imaging services and more personnel, it is an inevitably more expensive service to run.

Should a decision be taken to train the pathologists to report the images, as occurs internationally, under the governance of a radiologist, a reporting fee for the radiologist can be removed from the fee costs. This also applies to the radiographer's fee as APTs could be trained to undertake the imaging within a mortuary where they are already employed to work and are costed into the general service fee. The professional fees could be reduced by **£87** per case.

Using a revised professional fees cost of **£82** and excluding laboratory investigations and court fees, the estimated cost of the service is of the order of **£560** per case.

Thus, using this revised figure, the total estimated cost of the proposed cross-sectional imaging autopsy service, without laboratory and court fees, is now estimated at **£53 million**.

Although this remains more expensive than the current estimated cost this should be balanced against the religious, cultural and humanitarian benefit to those members of the general public who do not want their relatives to undergo invasive autopsy examinations. As the service is provided within the NHS, it becomes amenable to audit, EQA, and regulation. There would also be potential administrative cost savings to the coroner's service if this new service accelerated investigation of death.

Development of a National Service

To implement the proposed cross-sectional imaging autopsy service there are a number of options in relation to where the imaging is undertaken (see '*Cross-sectional Imaging Infrastructure*'). If England follows the lead set by international autopsy providers, then the ideal option would be to place dedicated CT scanners into mortuaries across the NHS.

To develop a national network of imaging centres, 30 centralised units should be developed in England undertaking scanning, reporting and limited or full autopsy where indicated. To achieve this, a *minimal* budget of **£500K** per site (based on implementation of a refurbished 16 Slice CT scanner) would be required. More modern, preferably dual beam scanners would be preferable and although they would have an increased cost, they are now available second hand. Thus, a *minimal* national infrastructural capital investment of **£15 million** would see the establishment of a national cross-sectional imaging framework. The final costs would be determined by the building configuration and choice of equipment manufacturer.

As suggested in the section entitled '*Workforce Requirements',* the backbone of the service could be accelerated by targeting a number of sites across England for initial service development. This would also provide the establishment of a training and research centre network that would drive forward technical development and workforce recruitment and training. Although the money to underpin the service should be agreed at the initiation stage, the costs of the establishment of the service could be staggered over the time frame suggested in the section '*Workforce Requirements'*. Thus, for an initial capital funding of **£3.5 million**, up to **7 sites** across the whole of England could be funded and established within 2 years of initiation.

Once established, the costs discussed would pay for the running costs of the service at each site including maintenance costs and professional fees. Court fees and laboratory examinations would be in addition to this unless England and Wales followed the example of the devolved nations by adopting an all-inclusive service of contract.

Equipment Replacement Programme

The Group is of the opinion that there should be a managed equipment service for future sustainability of the infrastructure.

Summary

It is the Group's view in relation to the questions posed that:

- The Group is of the opinion that there are two costing options for a cross-sectional imaging autopsy service. The first is based on the current service structure with separate professional and service related fees, the former set nationally and the latter set locally. The second option is an all-inclusive single cost service run by a single service provider.
- To stop the current situation of each coroner's service having to locally negotiate service contracts, and to allow national costing tariffs to be applied, the Group recommends that for non-suspicious deaths a single cost recovery based charge is introduced, similar to that of the devolved nations, with the service activity being undertaken as part of the NHS.
- The Group recognises that to initiate a new service there will be a requirement for capital investment. It recognises that the service cost will be more expensive than the current invasive autopsy service. However, in time, the opportunity exists for the professional fee costs to drop. There are added benefits of faster turnaround times for death investigation, enhanced use of technology for the CJS, introduction of audit, EQA and regulation to the service and the humanitarian benefits to the general public with the avoidance, where applicable, of invasive autopsies.
- The Group is of the opinion that fees applicable for forensic cases should be retained for all professional groups until such times that there is a substantive change to the delivery of the service with the introduction of non-invasive suspicious death and homicide investigations.

References – Adult

ACPO. Defence and second autopsy examinations. In, ACPO Murder Manual.

Akopov VI, Lozovskii BV, Kuryshev AN. The possibility of using ultrasonic diagnosis in forensic medicine. Sud Med Ekspert 1976; 19: 16-18.

Association of Forensic Radiographers. Mass fatality mortuaries: Radiography facilities and requirements. 2007. IAFR website - Information for Emergency Planners – last visited 10/01/12.

Bisset, R. Magnetic resonance imaging may be alternative to necropsy. BMJ, 1998. 317: 1450.

Bisset RA, Thomas NB, Turnbull IW, Lee S. Postmortem examinations using magnetic resonance imaging: four year review of a working service. BMJ. 2002; 324: 1423-4.

Blau S, Robertson S, Johnstone M. Disaster victim identification: new applications for postmortem computed tomography. J Forensic Sci. 2008; 53: 956-61.

Bolliger SA, Filograna L, Spendlove D, Thali MJ, Dirnhofer S, Ross S. Postmortem Imaging-Guided Biopsy as an Adjuvant to Minimally Invasive Autopsy With CT and Postmortem Angiography: A Feasibility Study. American Journal of Roentgenology 2010; 195: 1051-1056.

Brogdon, B.G. and J.E. Lichtenstein, Forensic radiology in historical perspective. In; *Forensic Radiology*, Brogdon B.(Ed). 1998, CRC Press, Boca Raton FL. 15-34.

Brookes JA, Hall-Craggs MA, Sams VR, Lees WR. Non-invasive perinatal necropsy by magnetic resonance imaging. Lancet. 1996; 348: 1139-41.

Burton J.L. The history of the autopsy. In, The Hospital Autopsy. A manual of fundamental autopsy practice. Eds, J.L.Burton and G.N.Rutty. Hodder Arnold, London, 2010, pages 1-10.

Christe A, Flach P, Ross S, Spendlove D, Bolliger S, Vock P, Thali MJ. Clinical radiology and postmortem imaging (Virtopsy) are not the same: Specific and unspecific postmortem signs. Leg Med (Tokyo). 2010; 12:215-22.

Codes of Practice and Performance Standards for Forensic Pathologists. Royal College of Pathologists, 2004.

Coroners Act 1988, HMSO.

Coroners and Justice Act 2009, HMSO.

Coroners Rules 1984, HMSO.

Coroners Statistics 2010 England and Wales. Ministry of Justice Statistics bulletin. Ministry of Justice.

Council of Europe Group of Ministers. Recommendation No R(99)3. Of the Group of Ministers to Member States on the Harmonisation of Medico-Legal autopsy Rules. 1999.

Criminal Procedures and Investigations Act 1996, HMSO.

The Safe Handling of Contaminated Fatalities. Guidance Document. Home Office June 2009.

Dawidson I. Identification of the Swedish tsunami victims in Thailand. Forensic Sci Int. 2007; 169: S47-48.

Department of Health. Ionising Radiation (Medical Exposure) Regulations IS 1999/3232. Norwich: 2000. Stationery Office.

Donchin Y et al. Utility of post-mortem computed tomography in trauma victims. J Trauma 1994; 37: 552-555.

Ebert LC, Ptacek W, Naether S, Fürst M, Ross S, Buck U, Weber S, Thali M. Virtobot--a multi-functional robotic system for 3D surface scanning and automatic post mortem biopsy. Int J Med Robot. 2010; 6: 18-27.

Eckert WG, Garland N. The history of the forensic applications in radiology. Am J Forensic Med Pathol 1984; 5: 53-56.

Fischman SL. The use of medical and dental radiographs in identification. Int Dent J. 1985;3: 301-6.

Flodmark O et al. Correlation between computed tomography and autopsy in premature and full-term neonates that have suffered perinatal asphyxia. Radiology 1980; 137: 93-103.

Forensic Science Regulator. Codes of Practice and Conduct. Draft standards for facilities employed for “forensic” post-mortem investigations (England, Wales and Northern Ireland). Home Office 2011.

Furness ME, Weckert RC, Parker SA, Knowles S. Ultrasound in the perinatal necropsy. J Med genet 1989; 26: 368-372.

Grabherr S, Cooper C, Ulrich-Bochsler S, Uldin T, Ross S, Oesterhelweg L, Bolliger S, Christe A, Schnyder P, Mangin P, Thali MJ. Estimation of sex and age of "virtual skeletons"--a feasibility study. Eur Radiol. 2009; 19: 419-29.

Grabherr S, Doenz F, Steger B, Dirnhofer R, Dominguez A, Sollberger B et al (2010) Multi-phase post-mortem CT angiography: development of a standardized protocol. Int J Leg Med. 2011; 125: 791-802.

Graham JP, O'Donnell CJ, Craig PJ, Walker GL, Hill AJ, Cirillo GN, Clark RM, Gledhill SR, Schneider-Kolsky ME. The application of computerized tomography (CT) to the dental ageing of children and adolescents. Forensic Sci Int.2010;195:58-62.

Harcke HT, Bifano JA, Koeller KK. Forensic radiology: response to the Pentagon attack on September 11, 2001. Radiology. 2002; 223:7-8.

Hayakawa, M. et al. Does imaging technology overcome problems of conventional postmortem examination? A trial of computed tomography imaging for postmortem examination. Int J Leg Med2006; 120: 24-6.

Hoey, B.A. et al., Postmortem computed tomography, "CATopsy", predicts cause of death in trauma patients. J Trauma, 2007. 63(5): p. 979-85; discussion 985-6.

Home Office Circular No. 30/1990. Post mortem examinations and the early release of bodies, HMSO.

Home Office. Legal Issues Relating to Forensic Pathology and Tissue Retention. Update in preparation 2011.

Human Tissue Act 2004, HMSO.

Jeffery A. The evaluation of computed tomography for its use in forensic pathological investigations. MD Thesis. University of Leicester. 2010.

Jeffery A. The Role of Computed Tomography in Adult Post-mortem Examinations: an Overview. Diagnostic Histopathology 2010; 16: 546-551.

Jeffery A, Raj V, Morgan B, West K, Rutty GN .The criminal justice system's considerations of so-called near-virtual autopsies: the East Midlands experience. J Clin Pathol. 2011; 64: 711-7.

Kirchhoff S, Fischer F, Lindemaier G, Herzog P, Kirchhoff C, Becker C, Bark J, Reiser MF, Eisenmenger W. Is post-mortem CT of the dentition adequate for correct forensic identification? Comparison of dental computed tomography and visual dental record. Int J Legal Med. 2008; 122: 471-9.

Kranz P, Holtas S. Postmortem computed tomography in a diving fatality. J Comput Assist Tomogr. 1983; 7:132-134.

Leth PM. The use of CT Scanning in Forensic Autopsy. Forensic Sci Med Pathol 2007; 3: 65-69.

Levy AD et al. Virtual autopsy: preliminary experience in high-velocity gunshot wound victims. Radiology 2006; 240: 522-528.

McKenna CJ. Radiography in forensic dental identification--a review. J Forensic Odontostomatol. 1999; 17: 47-53.

National Police Improvement Agency Body Identification. Briefing Guide to Assist in Body Identification. 2009.

Nye PJ, Tytle TL, Jarman RN, Eaton BG. The role of radiology in the Oklahoma City bombing. Radiology. 1996; 200: 541-3.

O' Donnell C, Rotman A, Collett S, Woodford N. Current status of routine post-mortem CT in Melbourne, Australia. Forensic Sci Med Pathol. 2007; 3: 226-232.

O'Donnell C, Iino M, Mansharan K, Leditscke J, Woodford N. Contribution of postmortem multidetector CT scanning to identification of the deceased in a mass disaster: Experience gained from the 2009 Victorian bushfires. Forensic Sci Int. 2011; 205: 15-28.

Police Professional. Legal precedence with first use of 3D imaging from PMCT. 2011; 263 (July 2011): 25.

RCR/RCPath. RCR/RCPath practice guidance on medico-legal post mortem imaging in adults. 2011. In progress.

Reynolds A. Forensic radiography: an overview. Radiological Technology 2010; 81: 361-379.

Roberts IS, Benbow EW, Bisset R, Jenkins JP, Lee SH, Reid H, Jackson A. Accuracy of magnetic resonance imaging in determining cause of sudden death in adults: comparison with conventional autopsy. Histopathology. 2003; 42:424-30.

Roberts ISD, Benamore RE, Peebles C, Roobottom C, Traill ZC. Diagnosis of coronary artery disease using a minimally invasive autopsy: evaluation of a novel method of post-mortem coronary CT angiography. Clin Radiol. 2011; 66:645–50.

Roberts IS et al. Post-mortem imaging as an alternative to autopsy in the diagnosis of adult deaths: a validation study. Lancet. 2012; 379: 136-42.

Robinson C, Eisma R, Morgan B, Jeffery A, Graham EA, Black S, Rutty GN. Anthropological measurement of lower limb and foot bones using multi-detector computed tomography. J Forensic Sci. 2008; 53:1289-95.

Ruder TD, Hatch GM, Thali MJ, Fischer N. One small scan for radiology, one giant leap for forensic medicine - Post-mortem imaging replaces forensic autopsy in a case of traumatic aortic laceration. Leg Med (Tokyo). 2011; 13: 41-3.

Rutty GN, Swift B. Accuracy of magnetic resonance imaging in determining cause of sudden death in adults: comparison with conventional autopsy. Histopathology. 2004; 44:187-9.

Rutty GN. Who audits and autopsy? Forensic Sci Med Pathol 2006; 2: 71-72.

Rutty GN. Are autopsies necessary? The role of computed tomography as a possible alternative to invasive autopsies. Rechtsmedizine 2007; 17: 21-28.

Rutty G.N, Robinson C.E, BouHaidar R, Jeffery A.J, Morgan B. The Role of Mobile Computed Tomography in Mass Fatality Incidents. J Forensic Sci. 2007; 52: 1343-1349.

Rutty GN, Morgan B, O'Donnell C, Leth PM, Thali M. Forensic institutes across the world place CT or MRI scanners or both into their mortuaries. J Trauma. 2008; 65: 493-4.

Rutty GN, Robinson C, Morgan B, Black S, Adams C, Webster P. Fimag: the United Kingdom disaster victim/forensic identification imaging system. J Forensic Sci. 2009; 54: 1438-42.

Rutty GN, Rutty JE. Perceptions of near virtual autopsies. J Forensic Leg Med 2011; 18: 306-309.

Rutty JE. Religeous attitudes to death and post-mortem examinations. In: Burton JL, Rutty GN, editors. The Hospital Autopsy. A manual of fundamental autopsy practice. 3rd edition. London: Hodder Arnold, 2010, pages 39-58.

Rutty GN. High throughput adult cadaver axial imaging: service logistics and requirements. Diagnostic Histopathology 2010; 16: 573-577.

Saunders SL, Morgan B, Raj V, Robinson CE, Rutty GN. Targeted post-mortem computed tomography cardiac angiography: proof of concept. Int J Legal Med. 2011; 125: 609-16.

Saunders S, Morgan B, Raj V, Rutty G. The role of post-mortem computed tomography in coronial autopsy practice; the Leicester experience. RAD magazine 2011; 37 (435): 19-20.

Sidler M, Jackowski C, Dirnhofer R, Vock P, Thali M. Use of multislice computed tomography in disaster victim identification--advantages and limitations. Forensic Sci Int. 2007; 169: 118-28.

Singleton AC. Roentgenological identification of victims of "Noronic" disaster. Am J Roentgenol. & Rad. Therapy 1951; 66: 375-384.

Taylor J. A brief history of forensic odontology and disaster victim identification practices in Australia. J Forensic Odontostomatol 2009; 27: 64-74.

The Civil Court Practice 2011. Butterworths, 2011.

The Supreme Court Practice. Sweet and Maxwell, 2011.

Thali MJ, Yen K, Schweitzer W, Vock P, Boesch C, Ozdoba C, Schroth G, Ith M, Sonnenschein M, Doernhoefer T, Scheurer E, Plattner T, Dirnhofer R. Virtopsy, a new imaging horizon in forensic pathology: virtual autopsy by postmortem multislice computed tomography (MSCT) and magnetic resonance imaging (MRI)--a feasibility study. J Forensic Sci. 2003; 48: 386-403.

The Ionising Radiations Regulations 1999, HMSO.

Uchigasaki S et al. Application of compact ultrasound imaging device to post-mortem diagnosis. Forensic Sci Int 2004; 140: 33-41.

United Nations. 3-5United Nations (General Assembly) (1948) Resolution 217 a (III) Universal Declaration of Human Rights.

Viner MD, Rock C, Hunt N, Martin AW, and MacKinnon G. Forensic radiography, response to the London suicide bombings on 7th July 2005, Proceedings of The American of Forensic Sciences 58th Scientific meeting, Seattle, WA. p.176, 2006.

Wullenweber R, Schenider V, Grumme T. A computer-tomographical examination of cranial bullet wounds. Z Rechtsmed 1977; 80: 227-246.

References – Children

1. Parker A. Less invasive autopsy: the place of magnetic resonance imaging. Department of Health. February, 2004.
2. Joint working Party of the Royal College of Obstetricians and Gynaecologists and Royal College of Pathologists. Report on fetal and perinatal pathology. London: RCOG, 1988.
3. Cartlidge PHT, Dawson AT, Stewart JH, Vujanic GM. Value and quality of perinatal and infant post mortem examinations: Cohort analysis of 400 consecutive deaths. *BMJ* 1995; 3:155-158.
4. Brodlie M, Laing IA, Keeling JW, McKenzie KJ. Ten years of neonatal autopsies in tertiary referral centre: Retrospective study. *BMJ* 2002; 324:761-763.
5. O'Grady G. Death of the teaching autopsy. *BMJ* 2003; 327: 802-804.
6. Kennedy I. Learning from Bristol. Bristol Royal Infirmary Inquiry. 2001. London HMSO (Kennedy Report. http://www.bristol-inquiry.org.uk/final_report/rpt_print.htm).
7. Redfern M. The royal Liverpool Children's Hospital Inquiry.2000. London HMSO (http://www.rlcinquiry.org.uk).
8. Confidential Enquiry into Maternal and Child Health (CEMACH) Perinatal Mortality 2007: United Kingdom CEMACH: London, 2009.
9. Shen-Schwarz S, Neish C, Hill LM. Antenatal ultrasound for fetal anomalies: importance of perinatal autopsy. *PediatrPathol* 1989; 9:1-9.
10. Thornton CM, O'Hara MD. A regional audit of perinatal and infant autopsies in Northern Ireland. *Br J ObstetGynaecol* 1988; 105:18-23.
11. Clayton-Smith J, Farndon PA, McKeown C, Donnai D. Examination of fetuses after induced abortion for fetal abnormality. *BMJ* 1990: 300; 295-7.
12. Joint Royal Colleges Working Group, London: Royal College of Paediatrics and Child Health. Fetal, perinatal and paediatric pathology: a critical future. RCPCH, 2002.
13. Families and post mortems; a code of practice. Department of Health, 2003 (Families and post mortems: a code of practice, forms and information leaflets http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_4006800). London, England: the Stationery Office, Department of Health, 2001.
14. Ros PR, Li KC, Vo P, Baer H, Staab EV. Preautopsy magnetic resonance imaging: initial experience. *MagnReson Imaging* 1990; 8:303-308.
15. Tang OS, Thong KJ, Baird DT. Second trimester medical abortion with mifepristone and gemeprost: a review of 956 cases. *Contraception* 2001; 64:29-32.
16. De Groot CJA, Bergers E, Kamphorst W, Ravid R, Polman CH, Barkhof F, van der Valk P. Post mortem MRI-guided sampling of multiple sclerosis brain lesions: Increased yield of active demyelinating and (p) reactive lesions. *Brain* 2001; 124:1635-1645.
17. Lycklama à Nijeholt GJ, Bergers E, Kamphorst W, Bot J, Nicolay K, Castelijns JA, van Waesberghe JHTM, Ravid R, Polman CH, Barkhof F. Post mortem high-resolution MRI of the spinal cord in multiple sclerosis: A correlative study with conventional MRI, histopathology and clinical phenotype. *Brain* 2001; 124:154-166.
18. Meyer-Wittkopf M, Cook A, McLennan A, Summers P, Sharland GK, Maxwell DJ. Evaluation of three dimensional ultrasonography and magnetic resonance imaging in the assessment of congenital heart anomalies in fetal cardiac specimens. *Ultrasound ObstetGynecol* 1996; 8:303-308.
19. Brookes JAS, Hall-Craggs MA, Sams VR, Lees WR. Non-invasive necropsy by magnetic resonance imaging. *Lancet* 1996; 348:1139-1141.

20. Woodward PJ, Sohaey R, Harris DP, Jackson GM, Klatt EC, Alexander AL, Kennedy A. Postmortem fetal MR imaging: Comparison with findings at autopsy.*AJR* 1997; 168:41-46.
21. Huisman TAGM, Wisser, Stallmach T, Krestin GP, Huch R, Kubik-Huch RA. MRautopsy in fetuses. *Fetal DiagnTher* 2002; 17:58-64.
22. Alderliesten M E, Peringa J, van der Hulst V P M, Blaauwgeers H L G, van Lith J M M. Perinatal mortality: clinical value of post mortem magnetic resonance imaging compared with autopsy in routine obstetric practice.*British Journal of Obstetrics and Gynaecology* 2003; 110; 378-382.
23. Griffiths PD, Variend D, Evans M, Jones A, Wilkinson ID, Paley MNJ, Whitby E. Postmortem MR imaging of the fetal and stillborn central nervous system. *AJNR Am J Neuroradiol* 2003; 24: 22-27.
24. Gerards FA, Stoutenbeek P, Gooskens RH, Beek FJ, Groenendaal F. Diagnostic value of prenatal MRI in fetus with intracranial anomalies diagnosed by ultrasonography. *Ned TijdschrGeneeskd* 2001;145:179-84.
25. Guo WY, Chang CY, Ho DM, Wong TT, Sheu MH, Cheng HC, Chen SJ, Hung JH. A comparative MR and pathological study on fetal CNS disorders.*Childs NervSyst* 2001; 17:512-8.
26. Deng J, Brookes JA, Gardener JE, Rodeck CH, Lees WR. Three-dimensional magnetic resonance imaging of the post mortem fetal heart.*Fetal DiagnTher* 1996; 11:417-421.
27. Earls JP, Ho VB, Foo TK, Castillo E, Flamm SD. Cardiac MRI: Recent progress and continued challenges. *J MagnReson Imaging* 2002, 16: 111-127.
28. Razavi RS, Hill DL, Muthurangu V, Miquel ME, Taylor AM, Kozerke S, Baker EJ. Three-dimensional magnetic resonance imaging of congenital cardiac anomalies. *Cardiol Young* 2003; 13: 461-465.
29. Robertson NJ, Wyatt JS. The NMR revolution in brain imaging: impact on neonatal intensive care. *Arch Dis Child* 2004; 89:F193-F197.
30. Sevely A, Manelfe C. Magnetic resonance imaging of the fetal brain. In: Rutherford MA and Bydder GM eds. *Magnetic resonance Imaging of the Neonatal Brain.* WB Saunders 2001.
31. Counsell SJ, Rutherford MA, Cowan FM, Edwards AD. Magnetic resonance imaging of preterm brain injury. *Arch Dis Child* 2003; 88:F269-F274.
32. The Chief Medical Officer. The removal, retention and use of human organs and tissues from post mortem examination (http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_4064942).
33. Scholing M, Saltzherr TP, Fung Kon Jin PH, Ponsen KJ, Reitsma JB, Lameris JS, Goslings JC. The value of post mortem computed tomography as an alternative for autopsy in trauma victims: a systematic review. EurRadiol. 2009; 19(10): 2333-2341.
34. Thayyil S, Robertson NJ, Scales A, Weber MA, Jacques TS, Sebire NJ, Taylor AM;MaRIAS (Magnetic Resonance Imaging Autopsy Study) Collaborative Group. Prospective parental consent for autopsy research following sudden unexpected childhood deaths: a successful model. Arch Dis Child. 2009;94(5):354-8.
35. Thayyil S, Chandrasekaran M, Chitty LS, Wade A, Skordis-Worrall J, Bennett-Britton I, Cohen M, Withby E, Sebire NJ, Robertson NJ, Taylor AM. Diagnostic accuracy of post mortem magnetic resonance imaging in fetuses, children and adults: a systematic review. Eur J Radiol. 2010;75(1):e142-8.

APPENDIX A

Questionnaire used in association with the following Section 1 of this document.

Department of Health
Computed Tomography/Magnetic Resonance Implementation Group
Experience Data Collection Sheet

The Department of Health is currently considering matters related to the consideration of the use of axial imaging (Computed Tomography (CT) and Magnetic Resonance Imaging (MRI)) as an adjunct or alternative to the invasive autopsy. As part of this process the implementation Group, Chaired by Professor Guy Rutty, Chief Forensic Pathologist, East Midlands Forensic Pathology Unit, is trying to establish a snapshot of the current extent of use of CT/MRI associated with all forms of autopsy practice within the United Kingdom as well as within the international arena.

In an attempt to capture this data we would request that you complete this questionnaire, as fully and truthfully as you are able to. We realise that we request from you information that concerns the identification of individuals and sites as well financial details. We would ask that you consider providing this information to us as without it we cannot establish accurate background knowledge in the area.

To ensure that this data is treated sensitively and confidentially, your sheets should be returned to Ms Theresa Visser at trv3@le.ac.uk NOT Professor Rutty so that the data can be collated into a spreadsheet prior to the sheets being destroyed. You should sign the consent form to allow the data within the spreadsheet to be viewed by the members of the Group ONLY for the Terms of Reference of the group ONLY. The data will be summarised using descriptive statistics (i.e. no identifying data will be included) for the purpose of writing a final report of the Department of Health but not passed onto any other party who may have business or commercial intentions.

Please complete and return the questionnaire by **Wednesday 21st December 2011**.

We thank you for your participation. If you have any concerns please contact us for advice or clarification via trv3@le.ac.uk.

Professor Guy Rutty
Chair of Implementation Group
East Midlands Forensic Pathology Unit

Consent

I have read and understood the introductory page to this datasheet. I consent for the information that I return in this data sheet to be used for the purposes as specified.

Name _____

Signed_____

Date _____

Email address:

Please print off this sheet and sign it. Then please send it along with the completed form to trv3@le.ac.uk.

1. Participant details

Please provide these basic details. Please allocate yourself an 'anonymisation code' comprising of between 6 – 8 letters and numbers. Please put this code onto all subsequent sheets.

Name	
Work address	
Email address	
Occupation	Pathologist Radiologist Coroner Other (specify)
Self allocated anonymous code	

2. Experience

This section is designed to gauge your experience with the use of CT/MRI in autopsy practice. Please give as much information as you can in each section. The boxes will expand to accommodate an unlimited amount of text.

2.1. Do you use either CT or MRI or both with autopsy practice?

Yes No (Please circle yes or no)

Please indicate if it is CT or MRI or both and if known any details of the Equipment used e.g. 64 Toshiba MDCT

2.2. Assuming the answer to 2.1 is *Yes*, is this with adults or children or both?

2.3 Do you use other forms of radiological examinations in your autopsy/identification practice? **Yes**

No

If *yes* please provide examples of the technology you use and when you use it.

2.4 Please describe the circumstances when you would use CT/MRI as an *adjunct* (assistance) in an autopsy examination.

2.5. Please describe the circumstances when you would use CT/MRI as a replacement to an autopsy examination.

3. Professional and Legal Matters

This section is designed to gauge your knowledge of professional and legal issues that could affect the use of CT/MRI in autopsy practice. Please give as much information as you can in each section. The boxes will expand to accommodate an unlimited amount of text.

3.1 Have you undergone any formal training concerning the use, interpretation or reporting of CT/MRI images related to autopsy practice.

Yes **No**

If *yes* please provide a brief description of your experience.

3.2. Are you aware of any form of accreditation, audit, internal or external quality assurance, local or national standard operating procedures for the use of radiology in autopsy/identification practice?

Yes **No**

If *yes* please provide a brief description of any of these systems or any other such systems you think relevant to this question.

3.2. Are you aware of any legislation that prohibits or allows the use of radiology as an adjunct or a replacement to autopsy/identification practice?

Yes **No**

If *yes* please describe.

3.3. Please add any other comments you wish to add in relation to your experience with this section of the data sheet. Please feel free to draw to our attention any website or publication which you feel assists you in completing this section of the sheet.

4. Logistic and Personnel

This section is designed to inform us as to the logistics that are used in your service, personnel that assist you and cost of the service. Please give as much information as you can in each section. The boxes will expand to accommodate an unlimited amount of text.

4.1 Please inform us of the cost of the service for CT/MRI related examinations in relation to autopsy practice. If it is a single cost to encompass scanning, reporting and personnel please indicate this. If it is broken down into a differential structure please inform us of each cost breakdown.

4.2 Do you use a fixed or mobile service provider?

Fixed Mobile

4.3 Please inform us of the provider of your CT/MRI service. Please provide the address and the contact details of the manager as we may wish to contact them to engage them in this survey.

4.4 Is an external examination of the body undertaken in every case?

Yes No

If *yes* what is the professional background of the individual performing this examination e.g. radiologist, radiographer, pathologist, APT?

4.5 Who reports the images?

Radiologist….Pathologist….Both?

4.6 Who takes responsibility for the production of the autopsy report where CT/MRI imaging forms part of the autopsy process?

Radiologist….Pathologist….Both?

4.7 If CT/MRI is used as a replacement for an autopsy, who takes responsibility for providing the cause of death?

Radiologist….Pathologist….Both?

4.8. Please provide the contact details of the radiologist/pathologist undertaking this work for you as we may wish to contact them to seek their assistance with this data collection.

5. General Comments

5.1 If given the choice, do you think the general public would prefer the use of CT/MRI as an alternative to an invasive autopsy? Please comment.

5.2 If CT/MRI was available as an alternative to an invasive autopsy, who do you think should bear the cost of the examination? Please comment.

5.3. What do you think are the reasons why CT/MRI may not be more widely used currently as an alternative to an invasive autopsy? Please comment.

5.4. If CT/MRI was considered to provide sufficient information to provide a cause of death without an invasive autopsy and the public wished its use but it was more expensive than an autopsy, would you use it? If not, why not?

5.5. What facilities, staff, training, information or support do you think are necessary to be provided for the more widespread use of CT/MRI in autopsy practice? Please comment.

5.6 If the resources were available do you think a CT/MRI should occur in all deaths you deal with and if so why?

5.7 Please provide any further comments that you wish to make, from your experience, as to the potential use of CT/MRI in autopsy practice.

We thank you again for your participation.