Imaging and the autopsy

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Post mortem imaging
Forensic applications

Aims to supplement (improve) the autopsy in traumatic deaths.

**Advantages:**
Identification of victim and hazards
Facilitates dissection
Provide additional information (injuries, foreign objects)
Non-destructive, therefore better access to evidence
Permanent record
Post-mortem imaging as an alternative to the autopsy

Background
- the demand for an alternative to autopsy
- emergence of the radiological autopsy

Evidence for the accuracy of post mortem imaging

Use of targeted coronary angiography

Minimally invasive autopsy service for Oxford Coroner

Recommendations for future practice
The problems

1. High autopsy rate in England & Wales (22% of all deaths in 2009), >90% performed for Coroners.

2. A large number of Coroners’ autopsies are performed to a poor standard – not meeting RCPPath guidelines, and well below acceptable “forensic” standard

NCEPOD – audit of Coroner’s autopsy reports 2006:

- one in four autopsy reports was judged as poor or unacceptable;
- in one third of mortuaries, the pathologist failed to inspect the body before the anatomical pathology technologist commenced opening it and removed the organs;
- in one in seven cases the brain was not examined;
- in one in sixteen cases, it was deemed that histology should have been taken in order to determine the cause of death;
- in nearly one in five cases, the cause of death as stated appeared questionable;
The problems

1. High autopsy rate in England & Wales (22% of all deaths in 2009), >90% performed for Coroners.
2. A large number of Coroners’ autopsies are performed to a poor standard – not meeting RCPath guidelines, and well below acceptable “forensic” standard

Future development of autopsy services aims to:
1. Reduce the number of “unnecessary” Coroners’ autopsies
2. Improve the quality of autopsies that are performed.

View & grant system used in parts of Scotland can reduce autopsy rate but does not produce an accurate cause of death – major discrepancy between V&G and CT/autopsy cause of death in 46% of cases in recent Oxford study.
The demand for an alternative to autopsy

In response to requests for Jewish and Moslem communities in the 1990s, a group of radiologists offered a post mortem MRI service for deaths reported to the Coroner.

Funded privately (~£900, by family or religious organisation) In 90% the radiologist provides a cause of death, accepted by the Coroner without autopsy

Bisset RAL et al. BMJ 2002; 324: 1423-24
BEREAVED families in Greater Manchester who object to post mortem examinations on religious grounds will be able to opt for an electronic body scan instead, the MEN can reveal. Coroners in the region are backing an initiative spearheaded in Bolton which will offer greater choice to grieving relatives. “Coroner Mrs Leeming … said the results were ‘more than 99 per cent’ accurate.”
Use of post mortem MRI in the Coronial investigation of adult deaths: is it fit for purpose?

1. Can MRI accurately diagnose the cause of death?

2. Can MRI exclude unnatural death?
Accuracy of post-mortem MRI in determining cause of death: comparison with conventional autopsy


Sudden deaths in the community, excluding violent or potentially drug-related

whole body MRI with high definition head and cardiac scans → full autopsy

MRI images reported independently by 4 radiologists, blinded to autopsy findings

A confident correct radiological cause of death was provided in only one of 10 cases (disseminated bronchial carcinoma).
DH-funded validation study of post mortem imaging

2006 Department of Health funded two trials to assess the potential value for PM imaging as an alternative to autopsy

Oxford-Manchester (adult) study -
What is the relative accuracy of CT and MRI scans in identifying the cause of death?
Can radiologists accurately identify which cases may be diagnosed using post-mortem imaging and do not therefore require full autopsy?
Can diagnostic accuracy be improved by modification of imaging protocols, such as the use of angiographic techniques?
Post-mortem imaging as an alternative to autopsy in the diagnosis of adult deaths: a validation study

Ian S D Roberts, Rachel E Benamore, Emyr W Benbow, Stephen H Lee, Jonathan N Harris, Alan Jackson, Susan Mallett, Tufail Patankar, Charles Peebles, Carl Roobottom, Zoe C Traill

Post mortem CT is more accurate than MRI in diagnosing cause of adult deaths.

There is good agreement between CT and autopsy diagnosis in those cases where the radiologists are confident in their cause of death.

### Table 3: Major discrepancy rate between autopsy and radiology cause of death

<table>
<thead>
<tr>
<th>Category</th>
<th>CT</th>
<th>MRI</th>
<th>Consensus CT and MRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major discrepancy rate with autopsy cause of death, all cases (%)</td>
<td>32% (26–40)</td>
<td>43% (36–50)</td>
<td>30% (24–37)</td>
</tr>
<tr>
<td>Proportion of cases with definite radiological cause of death, no autopsy needed (%)</td>
<td>34% (28–41)</td>
<td>42% (35–49)</td>
<td>48% (41–56)</td>
</tr>
<tr>
<td>Major discrepancy rate with autopsy when radiologist confidence is definite (%)</td>
<td>16% (9–27)</td>
<td>21% (13–32)</td>
<td>16% (10–25)</td>
</tr>
<tr>
<td>Major discrepancy rate with autopsy when radiologist confidence is not definite (%)</td>
<td>41% (33–50)</td>
<td>59% (49–67)</td>
<td>44% (34–54)</td>
</tr>
</tbody>
</table>

Data are % (95% CI) or number (% 95% CI). Percentages are rounded to nearest whole number.
Regular meetings of the study group, correlating radiology and autopsy findings in 13 batches of 10-20 cases in each batch.

The major discrepancy rate between radiology and autopsy causes of death did not improve with increased experience of comparison between radiology and autopsy.

![Bar chart](image)

*Figure 3: Frequency of formulation errors in the general radiologist causes of death for the first six batches*
Post-mortem imaging strengths:

- Tumours and other mass lesions (e.g., internal haemorrhage)
- Fractures & pneumothorax
- Intracranial pathology
Post-mortem imaging strengths:

- Tumours and other mass lesions (eg. internal haemorrhage)
- Fractures and pneumothorax
- Intracranial pathology
Post-mortem imaging strengths:

- Tumours and other mass lesions (e.g. internal haemorrhage)
- Fractures & pneumothorax
- Intracranial pathology
Post-mortem imaging weaknesses:

<table>
<thead>
<tr>
<th>Disorder</th>
<th>Missed on imaging</th>
<th>Overattributed on imaging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coronary heart disease</td>
<td>12/86 (14%)</td>
<td>15/95 (16%)</td>
</tr>
<tr>
<td>Pulmonary embolism</td>
<td>10/10 (100%)</td>
<td>1/1 (100%)</td>
</tr>
<tr>
<td>Bronchopneumonia</td>
<td>9/28 (32%)</td>
<td>4/28 (14%)</td>
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<tr>
<td>Intestinal infarction</td>
<td>4/6 (67%)</td>
<td>1/3 (33%)</td>
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</table>

Data are n/N (%). Denominators for the left-hand column are total diagnoses of these disorders in the autopsy causes of death. Denominators in the right-hand column are the total diagnoses of these disorders in the consensus radiology causes of death.

*Table 5: Most common sources of major discrepancy between autopsy and consensus radiology cause of death*
Detection of coronary calcification

CT

MR
Demonstration of coronary artery lumen

Decomposition with intravascular gas
Two-Step Postmortem Angiography with a Modified Heart–Lung Machine: Preliminary Results

OBJECTIVE. The purpose of this study was to adapt and improve a minimally invasive two-step postmortem angiographic technique for use on human cadavers. Detailed mapping of the entire vascular system is almost impossible with conventional autopsy tools. The technique described should be valuable in the diagnosis of vascular abnormalities.

MATERIALS AND METHODS. Postmortem perfusion with an oily liquid is established with a circulation machine. An oily contrast agent is introduced as a bolus injection, and radiographic imaging is performed. In this pilot study, the upper or lower extremities of four human cadavers were perfused. In two cases, the vascular system of a lower extremity was visualized with anterograde perfusion of the arteries. In the other two cases, in which the suspected cause of death was drug intoxication, the veins of an upper extremity were visualized with retrograde perfusion of the venous system.
Whole body CT perfusion angiography
Targeted post-mortem coronary CT-angiography
Post-mortem coronary CT-angiography
Post-mortem coronary CT-angiography
Post-mortem coronary CT-angiography
First 10 cases (non-suspicious deaths in the community):

Images reported by 2 cardiac radiologists blinded to autopsy findings. Agreement between radiology and autopsy in 8/10:

4 significant coronary stenosis contributing to death

1 significant coronary stenosis not contributing to death (due to SAH)

3 no significant coronary atheroma

In two cases angiography detected coronary stenosis, not detected at autopsy; in one this resulted in a different cause of death.
Post-mortem coronary CT angiography
Targeted post-mortem computed tomography cardiac angiography: proof of concept

Sarah L. Saunders · Bruno Morgan · Vimal Raj · Claire E. Robinson · Guy N. Rutty
Comparison of targeted coronary PMCTA with 3–5 mm serial sections of the coronary arteries using macroscopic and histology.

Five cases with 25 vessels with 124 regions assessed.

PMCTA not sensitive for detection of further stenosis distal to critical stenoses, but better than dissection for assessment of calcified segments. Complete agreement between dissection and PMCTA when the right or left coronary arteries are assessed as a whole.
# Comparison of CT angiography methods

<table>
<thead>
<tr>
<th>Whole body perfusion angiography</th>
<th>Targeted coronary angiography</th>
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<tr>
<td><strong>Equipment cost</strong></td>
<td><strong>£0</strong></td>
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<tr>
<td><strong>Consumables cost</strong> (per case)</td>
<td><strong>£6</strong></td>
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<tr>
<td><strong>Time for procedure</strong></td>
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<td><strong>1.5 – 2 hours</strong></td>
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Whole body perfusion angiography is of value in identifying the precise source of traumatic haemorrhage in forensic autopsies, but not appropriate for routine Coroner’s autopsies.

Targeted coronary angiography is equally sensitive for the detection of coronary stenosis.
Post-mortem coronary CT-angiography

Quantitative assessment of coronary stenosis: comparison of radiology vs dissection

100 vessels assessed in 25 autopsies.

CT coronary angiography followed by autopsy.

Radiologists and pathologists independently assessed stenosis in left main, left anterior descending, circumflex and right coronary arteries.

0 = No stenosis
1 = <50% stenosis
2 = 50-75% stenosis
3 = >75% stenosis
4 = complete occlusion
# Post-mortem coronary CT-angiography

Agreement between angiography and dissection  57%

Angiography detected greater stenosis than dissection  38%

Dissection detected greater stenosis than angiography  5%

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Post-mortem pulmonary CT-angiography
Post-mortem pulmonary CT-angiography
Use of imaging in a routine Coroner’s autopsy service

Pathologist reviews the medical records, circumstances of the death and discusses the death with Coroner’s office/police.

Post-mortem imaging is performed. Radiologist discusses findings with pathologist and submits a written report.

Pathologist performs a thorough external examination of the body and selects which minimally invasive techniques are appropriate.

Minimally invasive autopsy is requested.

Other investigations are performed as appropriate – aspiration of fluids for toxicology, virology, needle biopsy, etc.

Pathologist either issues a cause of death based on minimally invasive investigations or proceeds to full autopsy.
 Trial of minimally invasive autopsy service for Oxford Coroner

High risk category 3 autopsies

62 HIV/HCV-positive autopsies (mainly iv drug abusers):
All had external examination followed by aspiration of fluids for toxicology (59) and/or CT scan (24).

20/62 required invasive autopsy.

Validation of selection of cases for invasive autopsy using history, external examination and toxicology: a separate group of non-infectious post-mortems with full autopsy (n=57) were analysed. Consecutive cases with a history suggesting drug abuse. A review pathologist, provided only with clinical summary, external findings and toxicology, formulated a cause of death. This was compared with the original cause of death, based on full autopsy. The review pathologist correctly identified a drug-related death or requirement for full autopsy in 56/57 cases.

Trial of minimally invasive autopsy service for Oxford Coroner

Deaths in the community referred to Coroner:

Pathologist selects cases appropriate for minimally invasive autopsy

Full body CT + external examination → issue report & cause of death

↓ no definitive cause of death

CT coronary angiography → issue report & cause of death

↓ no definitive cause of death

Conventional autopsy

Other minimally invasive investigations performed as indicated – aspiration of fluids for toxicology and biochemistry, biopsy of tumours identified at imaging.
Trial of minimally invasive autopsy service for Oxford Coroner

120 autopsies, first 60 without angiography, 60 with angiography

Other minimally invasive investigations performed as indicated – aspiration of fluids for toxicology and biochemistry, biopsy of tumours identified at imaging.

No autopsy required:
38% without angiography
70% with angiography
Trial of minimally invasive autopsy service for Oxford Coroner

Without angiography – 60 cases

<table>
<thead>
<tr>
<th>Commonest pathology in final MCCD</th>
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<tbody>
<tr>
<td>IHD</td>
<td>20</td>
<td>33%</td>
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CT diagnoses in cases where autopsy not performed:

<table>
<thead>
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<th>Ruptured aortic aneurysm/dissection</th>
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<th>35%</th>
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<td>6</td>
<td>26%</td>
</tr>
<tr>
<td>Hanging</td>
<td>3</td>
<td>13%</td>
</tr>
<tr>
<td>Haemopericardium, ruptured MI</td>
<td>2</td>
<td>9%</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>2</td>
<td>9%</td>
</tr>
<tr>
<td>IHD</td>
<td>1</td>
<td>4%</td>
</tr>
<tr>
<td>Exsanguination, incised wounds</td>
<td>1</td>
<td>4%</td>
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</table>

With angiography – 60 cases

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<td>IHD</td>
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<tr>
<td>Hanging</td>
<td>8</td>
<td>19%</td>
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<td>Ruptured aortic aneurysm/dissection</td>
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<td>7%</td>
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<td>Bronchopneumonia</td>
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<td>Subarachnoid haemorrhage</td>
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<tr>
<td>Haemorrhage from bronchial carcinoma</td>
<td>2</td>
<td>5%</td>
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<tr>
<td>Asphyxia by food bolus</td>
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<tr>
<td>Multiple injuries</td>
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# Trial of minimally invasive autopsy service for Oxford Coroner

## Without angiography – 60 cases

<table>
<thead>
<tr>
<th>Confidence in CT cause of death</th>
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<tbody>
<tr>
<td>Definite</td>
<td>23 38%</td>
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<td>8 13%</td>
</tr>
<tr>
<td>Possible</td>
<td>28 44%</td>
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## With angiography – 60 cases

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<td>Possible</td>
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<td>Unascertained</td>
<td>4 7%</td>
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CCT32
64 year-old man with documented history of angina. Sudden collapse in living room at home. Declared dead on arrival of ambulance.
CCT69
81 year-old man became very unwell in the early hours of the morning. He lost bowel control and was incontinent. Paramedics attended but he was dead on arrival to hospital. He was receiving chemotherapy for prostate cancer, he had diverticulitis which resulted in a life threatening perforation 4 years ago, hypertension and ischaemic heart disease with coronary stenting 8 years ago.
CCT17
68-year-old woman had a past medical history of osteoarthritis and longstanding back pain. She had a melanoma excised from her thigh 11 years ago. Her daughter states that she had been suffering from headaches recently but nothing else of note. She was found dead in bed in the morning by her son.
CCT5
80-year-old man with a past medical history of dementia and atrial fibrillation, was on respite care. He was found slumped in the chair and unresponsive by care home staff. An ambulance was called and he was declared deceased shortly after arrival. His family doctor had seen him 4 days previously when he was confused and “not right”. Care home staff had described him as “off his feet” for a few days. He was on Warfarin for atrial fibrillation, last recorded INR 3.3.
The future of the Coroner’s autopsy

Routine introduction of post-mortem CT

Numbers of Coroner’s autopsies would be reduced

Quality of the remaining autopsies would be improved:

Imaging findings will inform dissection. “There’s an abnormality here – what is the pathology?”

A high proportion of autopsies are of poor quality with no means of review/audit. Imaging provides a permanent record that will expose pathologists’ errors.

Use of routine CT in traumatic deaths would provide superior information to dissection about fractures and other injuries.
The future of the Coroner’s autopsy

**Practical issues:** Access to suitable imaging facilities, transfer of the bodies to the facilities, staffing the service, method of case selection (if any), storing and transferring the data, providing a radiology report within the time frame that may be useful to the Coroner, unknown % reduction in full autopsies.

**Financial issues:** Determining the cost of a service and how this will be funded (family, religious organisation, Coroner, other).

**Governance issues:** Training radiologists and pathologists, assessing their competence (diploma of post-mortem imaging?), audit of performance and continuing professional development.

http://www.rcpath.org/publications-media/publications/publications.htm#histo
http://www2.le.ac.uk/departments/emfpu/national-documents-1
Acknowledgements

UK Department of Health

PM imaging study group:
Emyr Benbow
Rachel Benamore
Zoe Traill
Stephen Lee
Jonathan Harris
Alan Jackson
Tufail Patankar
Charles Peebles
Carl Roobottom
Susan Mallett

Pathologists performing autopsies:
Raymond FT McMahon
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Lorna J McWilliam
Sanjiv Manek