The Virtopsy®: Imaging Technology Transforms the Classic Autopsy

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Disclosures

• No disclosures
Autopsy – Historical Notes

• Postmortem dissections have occurred for centuries
  – Ancient Egypt, Mesopotamia → embalming, mummification
  – Ancient India, Greece → enhancing understanding of anatomy and disease
  – 1700s → re-emergence of post-mortem study

• “Modern autopsy” in medical training and clinical education
  – Popularized by Osler at end of 19th century
  – Students expected to attend and perform autopsies as part of their training
The Rise and Fall of the Autopsy

• Early in 20\textsuperscript{th} century, the medical autopsy was considered central to:
  – Clinical education
  – Medical research
  – Professional development of a physician

• 20\textsuperscript{th} century medical autopsy rates
  – Steady increase 1900s - 1960s worldwide, then gradual decline to present
  – 40-50\% drop in autopsy rate over past 30 years
Decline of the Traditional Autopsy

<table>
<thead>
<tr>
<th>Country</th>
<th>Initial autopsy rate (period)</th>
<th>Subsequent autopsy rate (period)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>21.0% (1992–93)</td>
<td>12.0% (2002–03)</td>
</tr>
<tr>
<td>France</td>
<td>15.4% (1988)</td>
<td>3.7% (1997)</td>
</tr>
<tr>
<td>Hungary</td>
<td>100% (1938–51)</td>
<td>68.9% (1990–92)</td>
</tr>
<tr>
<td>Ireland</td>
<td>30.4% (1990)</td>
<td>18.4% (1999)</td>
</tr>
<tr>
<td>Jamaica</td>
<td>65.3% (1968)</td>
<td>39.3% (1997)</td>
</tr>
<tr>
<td>Sweden</td>
<td>81.0% (1984)</td>
<td>34.0% (1993)</td>
</tr>
<tr>
<td>UK</td>
<td>42.7% (1979)</td>
<td>15.3% (2001)</td>
</tr>
<tr>
<td>USA*</td>
<td>26.7% (1967)</td>
<td>12.4% (1993)</td>
</tr>
</tbody>
</table>

Autopsy rate is expressed as a percentage of all deaths. Figures in brackets denote the years in which the data were reported. *Data summarised from a meta-analysis that included reports on all overall rates and on clinically indicated autopsy rates.5

Table 1: The worldwide decline in autopsy rates

Decline of the Traditional Autopsy

- **USA overall**
  - Early 1990s: ~19%
  - Early 2000s: ~11%

- **USA Academic Centers**
  - Early 1990s: ~36%
  - Early 2000s: ~23%

Why The Decline???

• Public attitudes
  – Emotional, cultural, religious reasons
  – Need for consent
    • Lack of education about the benefits of the autopsy
    • Not everyone is asked...

• Clinicians' attitudes
  – Consent process - tedious, laborious, not routinely trained to new physicians
  – Assumption that bereaved families are hostile to idea of autopsy
  – Advances in premortem diagnostic techniques precludes further questions about cause of death for families

Why The Decline???

• Pathologists’ attitudes
  – Low value placed on autopsy within pathology departments (training and performance)
  – Delayed, incomplete, inconsistent reports (feeds into why clinicians don’t want to work hard to get consent)
  – Perception of autopsy as unpleasant, expensive, and time-consuming to some pathologists (best done by a “junior” trainee)
  – Lack of clinician willingness/time to visit morgue and discuss case both prior to and after the autopsy (why bother if no one is going to read the report??)

• Other reasons:
  – Cost cutting measures
  – Why risk blood-born pathogen transmission (HIV, HepC, etc.)??
  – Perceived absence of the curricular/educational value of autopsies
  • Current imaging and diagnostic techniques are enough for students

How to Make the Autopsy Relevant Again

• Cross-section radiology imaging
  – Computed tomography (CT)
  – Magnetic Resonance Imaging (MRI)

• Rooted in forensics
  – First used in 1977 → CT used to describe radiographic patterns of gunshot injuries to the head
  – 1980 → comparison study of premortem CT findings and subsequent autopsy results in neonates who suffered perinatal asphyxia
  – 1990s → multiple groups started large-scale projects looking at the “Imaging Autopsy”

• Best known research project: The Virtopsy® Project
THE VIRTOPSY PROJECT

NOVEL APPROACHES IN POST MORTEM IMAGING

Stephan Bolliger, MD
Steffen Ross, MD

Centre for Forensic Imaging and Virtopsy
Institute of Forensic Medicine
University of Bern
Switzerland
The Virtopsy® Project

• Research project started in 2000 by the Institutes of Forensic Medicine and of Diagnostic Radiology of the University of Bern, Switzerland

• Hypothesis:
  – Non-invasive imaging, cross-sectional imaging could:
    • Predict autopsy findings
    • Provide additional information not normally found in traditional forensic autopsies
  – Emphasis on forensic autopsies only
    • Unnatural and natural deaths seen by medical examiners, coroners
    • No real focus on medical autopsies
      – Some overlap with natural deaths
The Virtopsy® Project

• Virtopsy = Virtual + Autopsy
  – Virtual → from the Latin word *virtus*, which means “useful, efficient, and good”
  – Autopsy → combination of the classical Greek terms *autos* (“self”) and *opsomei* (“I will see”)
    • Autopsy means “to see with one’s own eyes”
  – Virtopsy → wanted to eliminate the subjectivity implied by *autos* – thus *virtus + opsomei = virtopsy*

• Virtopsy® term copyrighted early in the project
  – “…stands as a label and the sign of scientific quality for all the utilized technologies”
The Virtopsy® Approach
The Virtopsy® Laboratory

- Photography & 3D Optical Surface Scanning
- Dentistry & Fingerprinting
- Multi-slice CT & MRI
- Heart Lung Machine & CT Angiography
- Image-guided Dissection & Robotic Image-guided Biopsy
- Histopathology & Cytology
- Toxicology, Biochemical & Molecular Studies
The Virtobot®

• Single investigative unit to combine all implemented Virtopsy® technologies

Virtobot® – Post-mortem Angiography

Source: http://www.virtopsy.com/datastore/pictures/angiography_500x400.png
Virtobot® - 3D Optical Surface Scanner

Source: http://www.virtopsy.com/datastore/pictures/surface_scan_500x327.png
Virtobot® - Robotic Biopsy Module

Source: http://www.virtopsy.com/datastore/pictures/biopsy_500x409.png
Use of Imaging Data in Forensic Autopsies

Fracture?

Adapted from: Stephan Bolliger, MD and Steffen Ross, MD. The Virtopsy Project: Novel Approaches In Post Mortem Imaging. Presented at APIII 2008, 10/22/08.
Use of Imaging Data in Forensic Autopsies

- MSCT and MRI useful for:
  - Severe Crushing
  - Decomposition
  - Bullet Paths
  - Vascular Injuries
  - Drowning
  - Gas Embolus
  - Foreign Bodies
  - Lung & Brain
  - Trauma Documentation
  - Dissection Planning
  - Limited Autopsy

Adapted from: Stephan Bolliger, MD and Steffen Ross, MD. The Virtopsy Project: Novel Approaches In Post Mortem Imaging. Presented at APIII 2008, 10/22/08.
Post-mortem Imaging - Natural Deaths

• Natural deaths = Non-forensic deaths
  – Basically, non-accident, non-traumatic deaths where there is no suspicion of “foul play”
  – Two main types to consider (for autopsies):
    • Medical examiner / coroner deaths
    • Hospital deaths

• Post-mortem computed tomography (PMCT)
  – Limited literature available looking at utility of PMCT for natural deaths
  – Most findings to date from forensics studies and case reports
PMCT vs Clinical Imaging

• PMCT is not the same as Clinical Imaging!
  – Limitations of PMCT
    • Lack of post-mortem contrast-based imaging
      – The dead do not have very active circulatory systems
      – Can use heart-lung machines → time consuming and expensive
    • Post-mortem imaging “normal” artifacts
      – Blood sedimentation in organs
      – Gas formation during decomposition
      – Altered body temperature
  – Benefits of PMCT
    • No motion artifact
    • Potential for higher quality imaging
PMCT vs Clinical Medical Imaging

Images from: Christe, A. et. al. Clinical radiology and postmortem imaging (Virtopsy) are not the same: Specific and unspecific postmortem signs. Legal Medicine, 2010; 12:215–222
Post-mortem Imaging – Hospital Deaths

- The Virtopsy® makes sense from a forensics standpoint
  - Identification of victim / remains
  - Firearm deaths (location and retrieval of projectiles)
  - Child abuse/non-accidental injury (skeletal surveys)
  - Barotrauma or suspected air embolism
  - Traumatic subarachnoid hemorrhage
  - Other complex cases where the examination and interpretation are compromised by destruction of the body

- What about hospital deaths? What can post-mortem imaging do for the traditional medical autopsy?
Post-mortem Imaging at MGH

• Post-mortem imaging initiated at MGH in 2010
  – Radiology driven and funded
  – Collaboration with Pathology

• Main goals of project
  – Develop new radiology imaging techniques focusing on maintaining image quality while lowering radiation dose for CT scanning
  – Evaluate the use of post-mortem imaging in the medical autopsy
  – Develop new education materials for radiology training
Post-mortem Imaging Study

Radiation-Emitting Products

Radiation Safety > Radiation Dose Reduction

Initiative to Reduce Unnecessary Radiation Exposure from Medical Imaging

Like all medical procedures, computed tomography (CT), fluoroscopy, and nuclear medicine imaging exams present both benefits and risks. These types of imaging procedures have led to improvements in the diagnosis and treatment of numerous medical conditions. At the same time, these types of exams expose patients to ionizing radiation, which may elevate a person’s lifetime risk of developing cancer. As part of a balanced public health approach, the U.S. Food and Drug Administration (FDA) seeks to support the benefits of these medical imaging exams while minimizing the risks.

Through the Initiative to Reduce Unnecessary Radiation Exposure from Medical Imaging, FDA is advocating the universal adoption of two principles of radiation protection: appropriate justification for ordering each procedure, and careful optimization of the radiation dose used during each procedure. Each patient should get the right imaging exam, at the right time, with the right radiation dose.

In support of this goal, FDA will use our regulatory authority and also collaborate with others in the Federal government and the healthcare professional community to:

1. Promote safe use of medical imaging devices;
2. Support informed clinical decision making; and
3. Increase patient awareness.

By coordinating these efforts, we can optimize patient exposure to radiation from certain types of medical imaging exams, and thereby reduce related risks while maximizing the benefits of these studies.

MGH Post-mortem Imaging Methods

• Recently deceased patients are scanned in MGH Radiology CT scanners
  – Same clinical scanners that are used for living patients
• Average 15-30 minutes total scanning time
  – Each human body is scanned seven times, once at standard CT dose and the remainder at multiple levels of low radiation dose
    • Average 1-2 minutes per CT scan
• Body is kept as found in morgue (in body bag, under sheets, etc.)
  – Arms are crossed and placed above the chest to aid in imaging and to reduce artifact before scanning
• Scans are only performed on bodies to be autopsied if:
  – Attending pathologist agrees
  – CT scans will not interfere with performance of autopsy
Post-mortem CT at MGH
Whole Body Scanning
PMCT – Whole Body Scanning
PMCT – Whole Body Scanning
Autopsy Correlation
Autopsy Correlation
PMCT – Whole Body Scanning
Autopsy Correlation
Autopsy Correlation
## Minimizing Radiation Dose

### Table 1. Radiation Doses from Various Types of Medical Imaging Procedures

<table>
<thead>
<tr>
<th>Type of Procedure</th>
<th>Average Adult Effective Dose (mSv)</th>
<th>Estimated Dose Equivalent (No. of Chest X-rays)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dental X-ray</td>
<td>0.005-0.01&lt;sup&gt;6a&lt;/sup&gt;</td>
<td>0.25-0.5</td>
</tr>
<tr>
<td>Chest X-ray</td>
<td>0.02</td>
<td>1</td>
</tr>
<tr>
<td>Mammography</td>
<td>0.4</td>
<td>20</td>
</tr>
<tr>
<td>CT</td>
<td>2-16&lt;sup&gt;6b&lt;/sup&gt;</td>
<td>100-800</td>
</tr>
<tr>
<td>Nuclear Medicine</td>
<td>0.2-41&lt;sup&gt;6c&lt;/sup&gt;</td>
<td>10-2050</td>
</tr>
<tr>
<td>Interventional Fluoroscopy</td>
<td>5-70&lt;sup&gt;6d&lt;/sup&gt;</td>
<td>250-3500</td>
</tr>
</tbody>
</table>

Minimizing Radiation Dose

- 8.2 mSv
- 20.2 mGy
- 4.1 mSv
- 10.1 mGy
- 2.0 mSv
- 5.0 mGy
- 1.0 mSv
- 2.7 mGy
- 0.5 mSv
- 1.4 mGy
- Autopsy
Minimizing Radiation Dose

| 8.2 mSv | 20.2 mGy | 5 mSv | 12.3 mGy | 2.4 mSv | 5.8 mGy |
PMCT – The Radiology Perspective

• Efforts to date
  – 75 PMCT scans have been performed
  – All raw data from scans are kept
    • Image post-processing performed:
      – To determine if image quality can be enhanced
      – For manipulation of images for radiopathologic correlation
    • Web portal being developed for radiologist and technician training on low dose radiology imaging with radiopathologic correlation
PMCT- The Radiology Perspective

• Barriers to PMCT
  – Slow access to the recently deceased
    • Workflow and communication issues between Death Office, Radiology, and Pathology
    • Need for Attending Pathologist review of case prior to scan
  – CT scanner access limited by clinical radiology services (busiest 8AM to 5PM)
    • Clinical scans have immediate top priority
  – Lack of pathologist buy-in
    • Not all autopsy pathologists give access for PMCT
Radiopathologic Correlation

• Current model:
  – Radiologist perform a preliminary read on PMCT at the time of and immediately after scanning
  – Subspecialty radiologists brought in as needed
  – Pathologist have access to the PMCT report
    • Perform medical autopsy per usual departmental protocols
    • Gross images, PAD, and final reports made available to radiology
  – Final pathology reports and PMCT radiology reports compared
    • Discrepancies in findings noted – research ongoing
PMCT – The Pathology Perspective

• First impressions
  – Slow adoption by pathologists
  – Mixed views by residents and attending pathologists
    • Some are very engaged in reviewing the PMCT results
    • Some completely ignore that PMCT was done
  – Pathologists can include PMCT findings in final autopsy report
    • PMCT images and radiology report not a part of patient medical record at this time

• Autopsy conference
Autopsy Conference at MGH

Weekly Autopsy Case Conference
Tuesday August 30, 2011
A Woman with Abdominal and Flank Pain

Presenting:
Autopsy Pathology:
Fei Dong, M.D.

Clinical Pathology
Alexandra Kovach, M.D.

Radiology:
Keith Quencer, M.D.

Putschar Conference Room
Warren Basement
12:30 - 1:00 pm
PMCT at MGH – Initial Pathology Projects

• Radiopathologic correlation with comparison of PMCT to Medical Autopsy
  – Replacement versus augmentation of the traditional autopsy

• Redesign of the medical autopsy to better suit radiology imaging
  – Use of PMCT for directed autopsies
  – Is there value in doing cross-sectional (axial) cutting of organs for correlation with PMCT?
Extending the “Virtopsy®” Paradigm to Surgical Pathology

• Collaborative efforts are not limited only to autopsy!

• Micro-CT Imaging
  – “Table-top” imaging device capable for potential use with surgical pathology
Micro-CT Imaging at MGH - Rationale

• Initial pilot study:
  – 1-in-3 breast cancer operations are later found to be margin-positive → require re-excision!
  – Could we find a way to let the surgeon know, at the time of surgery, whether the cancer has been completely excised?

Slide courtesy of Dr. James Michaelson, MGH
Micro-CT Project at MGH

• Micro-CT Imaging
  – Very high resolution radiology imaging device
  – Developed initially for small animal visualization and industrial uses
  – Little use in a medical context to date

• Currently testing three machines at MGH
  – Nikon XT H 225 Micro-CT
    • In collaboration with Drs. Neil Gershenfel & Kenneth Cheung, Center for Bits and Atoms, MIT
  – GE eXplore CT 120 MicroCT animal Micro CT
    • In collaboration with Dr Scott Malstrom in the Koch institute, MIT
  – SkyScan 1173 high-resolution micro-CT

Slide courtesy of Dr. James Michaelson, MGH
Many Collaborators Involved!!

Surgery
Barbara Smith, MD, PhD
Juliette Buckley, MD
Leopoldo Fernandez, MD
Suzanne Brooks Coopey, MD
Jennifer Rusby MD

Pathology
Elena Brachtel, MD
Frederick Koerner, MD
James Michaelson, PhD
Yakuko Yagi, PhD
John Gilbertson, MD

Breast Imaging
Elizabeth Rafferty, MD
Daniel Kopans, MD
Richard Moore

MIT
Scott Malstrom, PhD
Neil Gershenfeld, PhD
Kenneth Cheung, PhD

Slide courtesy of Dr. James Michaelson, MGH
Micro-CT Instruments

GE eXplore CT 120 MicroCT

Skyscan 1173 Micro CT

Nikon XT H 225 Micro-CT

XT H Series
Micro CT – Future Steps

• Clinical Trials
  – Measure the impact of this technology on reducing additional operations
  – Measure the impact of this technology on survival

• Determine the utility of this technology in other areas of surgical oncology (prime opportunities: brain, colon, prostate)

• Adapt the technology to ready it for real-time surgical and pathology use

• Communicate the benefits of this technology
Conclusions

• Medical autopsies rates are declining worldwide
• Cross-sectional radiology imaging has the potential to transform the traditional medical autopsy
  – PMCT-directed autopsies
  – Collaboration between multiple specialties
  – Direct quantitation of autopsy findings (effusion fluid volumes, extent of metastatic disease, etc.)
  – Radiology training for pathology residents (implications for surgical pathology)
Thank You

• MGH Radiology
  – Dr. Mannu Kalra
  – Dr. Sarabjeet Singh

• MGH Pathology
  – Dr. John Gilbertson
  – Dr. Jeffrey Stone
  – Dr. Eugene Mark
  – Dr. Abner Loiussaint