NAME Interim Meeting 2019

Nuts and Bolts of a PMCT service

Barry Daly MD

Department of Diagnostic Radiology, University of Maryland

Consultant, Office of the Chief Medical Examiner

State of Maryland

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Nuts and Bolts of a PMCT service

What kind of CT scan machine ?

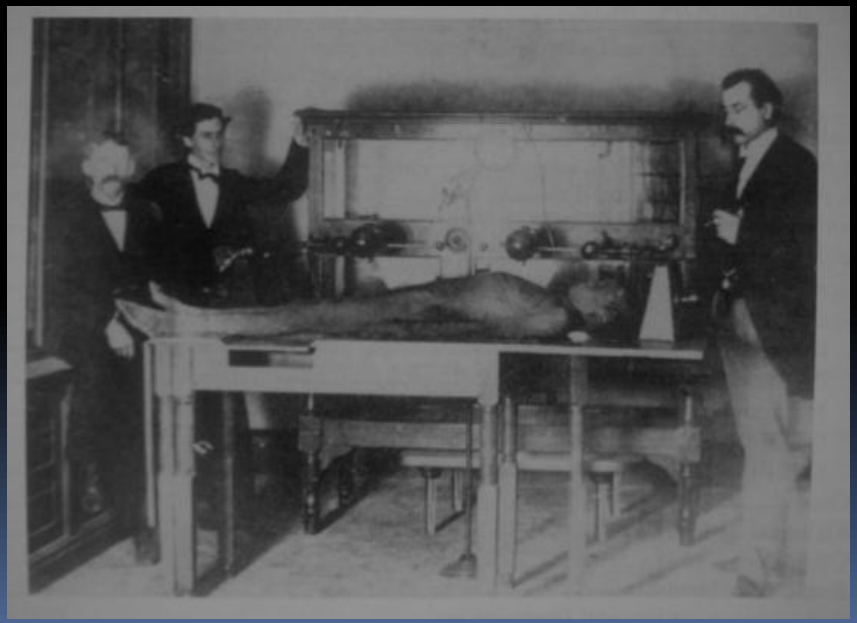
3D Workstations & PACS system ?

Interpretations by who - Radiologists or MEs?

And a (good) few other essentials…

Background

- Long history of imaging in forensic medicine
- 1898 – first forensic use of X-Ray in U.S.



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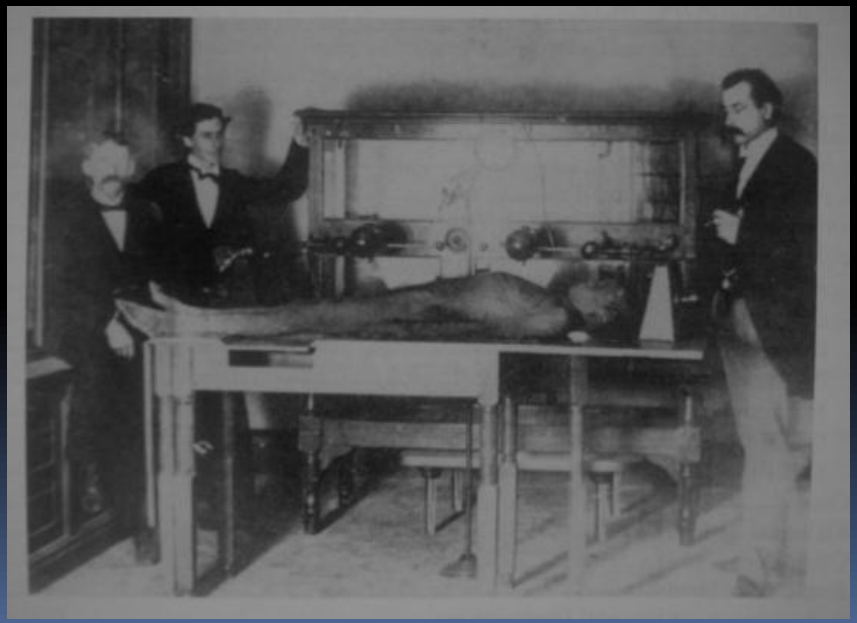


Little change in

next 100 years

Development of Whole Body CT

- 1977 - First report of Forensic CT study
  - Ballistics in Brain
- Late 1990s - Development of Faster CT scanners
  - Interest in concept of “Virtual Autopsy” develops
- 2000s - Multi-detector scanner era
  - High resolution whole body CT becomes a reality

Development of “Virtual Autopsy”

- Late1990s - 2000s
  - Interest in concept of Virtual Autopsy develops
  - High resolution whole body postmortem CT (PMCT)
  - Focused postmortem MR (PMMR) in adults
  - Whole body postmortem MR in small children
  - Postmortem CT Angiography (PMCTA)

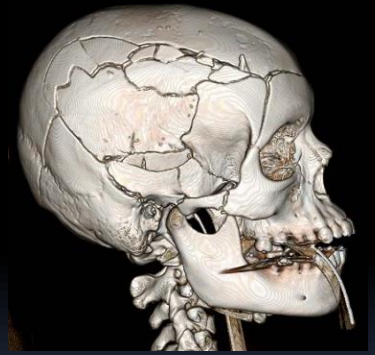
Terminology Issue:

“Virtual Autopsy” versus PMCT, PMMR, etc ?

- Concept of Virtual Autopsy may include:
  - PMCT
  - PMCTA
  - PMMR
  - Postmortem imaging-guided (CT/US) minimally invasive autopsy
  - *FOR CLARITY STICK TO SPECIFIC MODALITY*

“Virtual Autopsy”

- First developed at the University of Bern, Switzerland in 1995-2005 period
- Collaboration of Forensic Pathologists/ Medical Examiners (MEs) & Radiologists to introduce advanced imaging into routine forensic medicine practice
- CT first, PMMR and PMCTA introduced later
- **U.S. Research Initiatives limited**
  - ***Military:*** AFIP Dover AFB
  - ***Civilian:***
    - University of Maryland
    - University of New Mexico



- Now many other Centers throughout Europe, Australia, Japan, China, S. Africa ***and growing…***
- ***PMCT widely used, other techniques much less so***

International Society of Forensic Radiology & Imaging (ISFRI)

Applications of PMCT

- Blunt trauma
- Penetrating trauma
- Unidentified body
- Suspected NAI in young children
- Suspected Elder abuse
- Drowning
- Unknown cause of death
- Suicide
- Contraband
- Anthropology
- Historical Investigations
- Decomposition
- Burns

Nuts and Bolts of a PMCT service

What kind of CT scanner ?

PACS system/archive ?

Interpretations ?

And more…

What kind of CT scan machine is needed ?

- Number of Detector rows/slices (= speed)
  - 4 – 640 available
  - 16 slice adequate for most PMCT work
  - No moving body parts – scan whole body in 5 minutes
  - Generates 3,000+ images within 5-10 minutes
  - Look for CT scanner with large bore (80cm) and scan length 2m
- Single or Dual Energy (kV) ?
  - Single energy $250K+
  - Dual Energy $1M+
    - Not necessary for PMCT
- New or Used ? New not much more $$ for smaller capacity machines

16 detector row CT scanner @ Maryland OCME

80 cm bore

2 m (6 ‘ 6”) table length

What about Maintenance/Tube replacement Costs?

- Preventive Maintenance needed:
  - Maintenance contracts are not cheap (up to $100K annually)
  - X-Ray tube very expensive ($100K+), unpredictable lifespan
  - Get contract for next business day – not 24 hours for better deal
  - CT vendor usually provides, or third party operators

- Advice is available:
  - Local Hospital Radiology centers
    - Good advice on best vendor for sales and service locally
  - Regional Academic Radiology departments
  - MEs at other centers who got started in PMCT earlier
  - Independent consultants who can help set up all aspects of acquisition

What about Installation of the machine?

- New or Refurbished space ?
  - CT Vendor will work with construction contractors
  - Vendors usually have long experience with installations
- CT room should be close to dissection rooms
- Reading room for CT interpretations ideally nearby
- Scan data may be transmitted rapidly via the internet
  - Readings may be done off site without any delay

CT Angiography 1

Allows evaluation of major vessels, coronaries, vertebrals

Recent results encouraging:

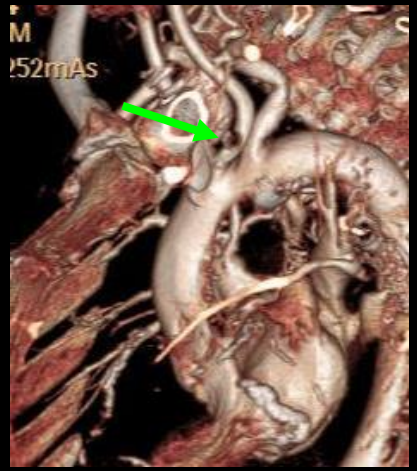
Postmortem CT/CT Angiography Compared with Autopsy:

A Forensic Multicenter Study , Grabherr et al,

(Radiology 2018)

- 500 cases (18 654 findings)
  - Autopsies identified 61% (11 433 of 18 654)
  - Postmortem CT identified 76% (14 179 of 18 654
  - Postmortem CT angiography identified 90% (16 780 of 18 654).

Potential for accurate non-invasive diagnosis in natural death, but not always cheaper



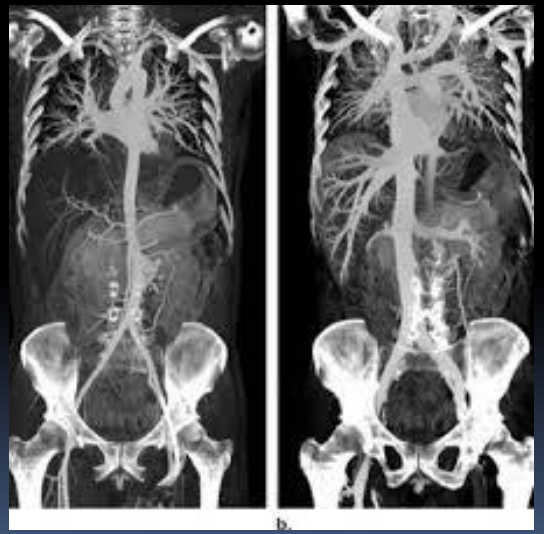
Grabherr et al, PM Coronary Angiography, 2016

CT Angiography 2

Relatively complex process

- Need pump injector to do major region or whole body
- Dedicated equipment available but expensive
- Old medical grade equipment can work
- Can work with hand injection of contrast also
  - Stand at side of machine (no scatter !)

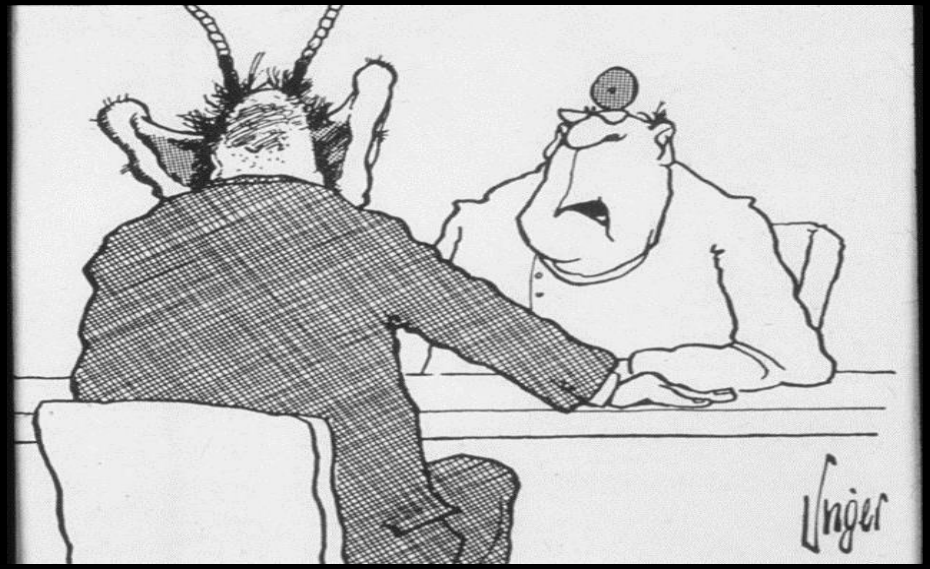
- Contrast dye
  - can use out of date contrast from hospital
  - Need to add glutaraldehyde to avoid leak into tissues
  - Barium works also - cheap
- Access from femoral arteries
- Intra or post autopsy allows easier vascular access



Ross et al, PM Angiography, 2014

CT - Radiation Safety

CT has potential for high dose to machine operators and workers in adjacent offices

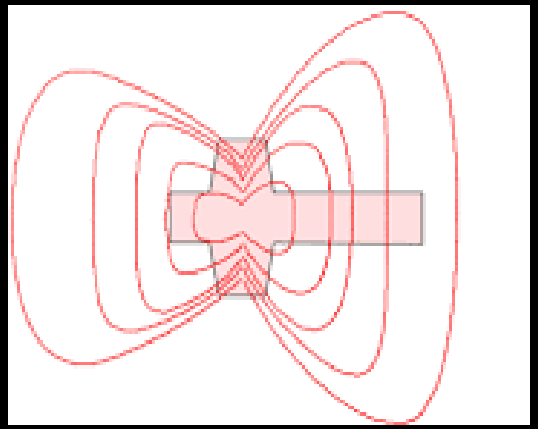


“If you remember I did mention possible side-effects”

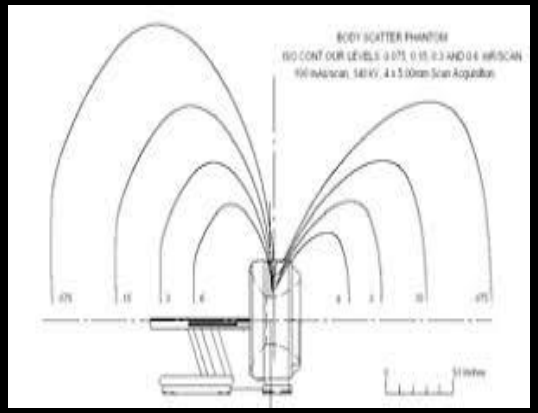
Radiation Protection for PMCT Rooms

- Protection of CT operator and workers in adjacent offices
- Shielding must protect against high energy x-rays
  - Up to 140 kVp
  - More scattered radiation than for regular x-ray machines
- May require lead/concrete shielding for walls/ceilings in the scan room
- Distance from radiation source important:
  - X-ray scatter decreases rapidly with distance from the machine
  - Large scan room means less shielding
- CT machine operator has a lead-lined console in scan room

Radiation scatter from CT machine



Scatter distribution in room
Top view



Scatter distribution in room & through ceiling
Side view

Radiation Scatter Around CT Machine

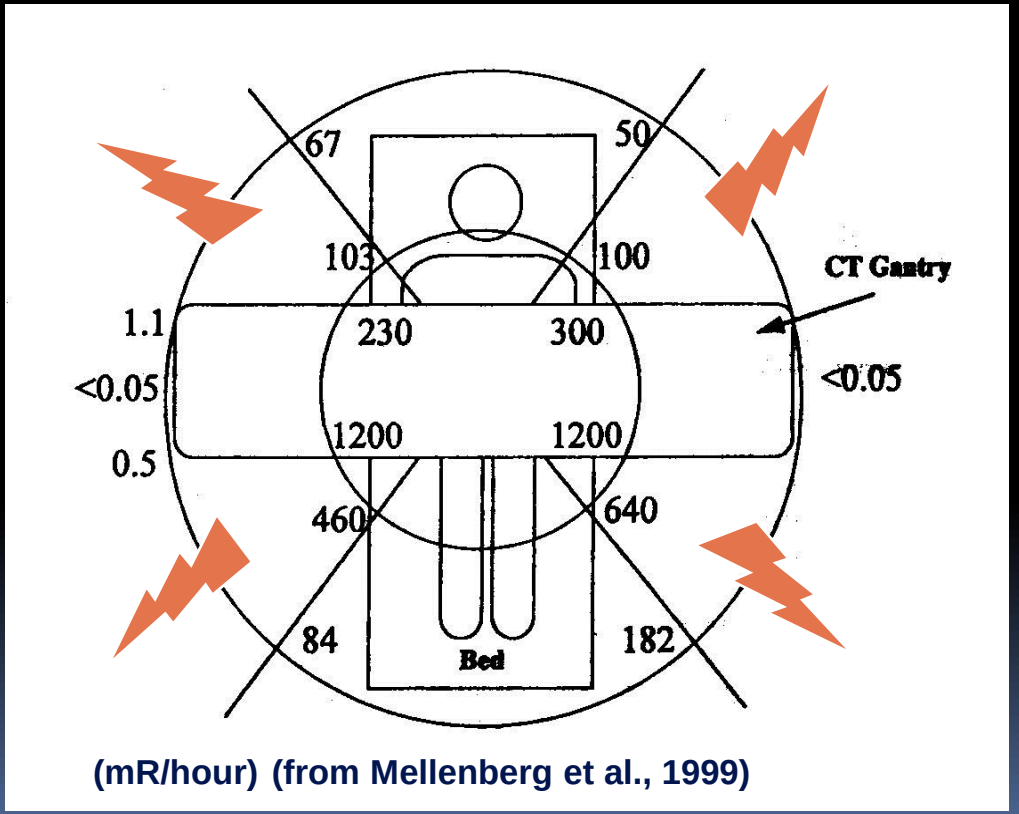
- Rotating Geometry increases scatter

Lowest doses:

1. At head end of scanner

2. With increased distance from gantry (Inverse Square Law)

3. At side of gantry



(mR/hour) (from Mellenberg et al., 1999)

Radiation Protection for PMCT

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- CT machine operator has a lead-lined console in scan room
- CT vendor will advise on construction needs

Radiation Protection for PMCT

- CT machine operator has a lead-lined console in scan room
- 1.2 mm lead
- Operator has risk of higher dose from scatter due to length of time spent at console

- Room reconstruction and radiation shielding setup can cost $50K+

PACS (“Filmless” Radiology) System

- Picture
- Archiving
- and
- Communication
- Systems

Baltimore VAMC:

Worlds first all PACS hospital

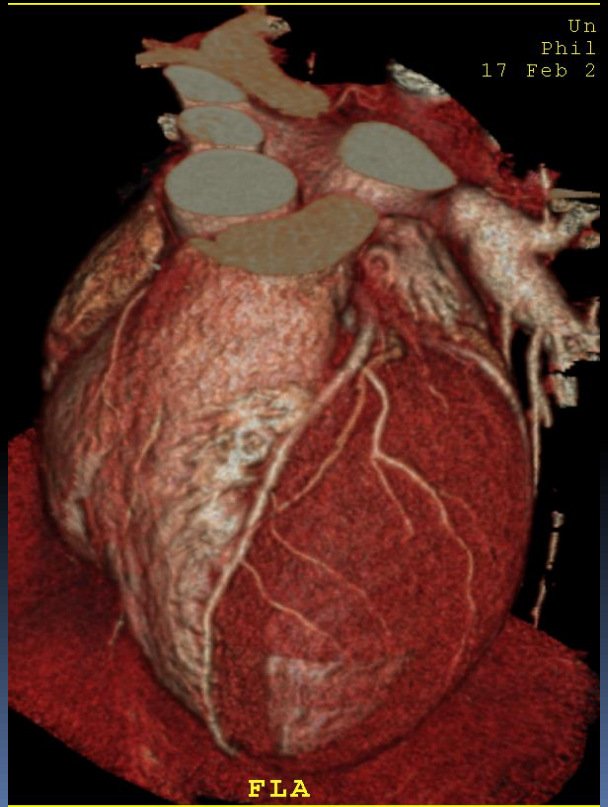
Total storage capacity in 1993 0.5 TB

PACS System

The PACS equipment must have adequate capacity and be fast enough to efficiently deal with the projected volume of studies & images

- An adult whole body PMCT typically generates 3,000-5,000 images
- Using high resolution thin slices with image generation in multiplanar transverse, frontal, and lateral planes and volume rendered or MIP 3Ds

Cardiac CT Angio for evaluation of chest pain - 16 row CT generates 3D from >2000 0.75mm slices



Functions of PACS System

- For 3D image generation
  - May have independent 3D software or built into PACS
- For image display and interpretation
  - For both onsite and web-based CT study readings
  - Typically scans can be viewed on many PCs at same time on a local area network within office/department and/or on internet
- For image data storage
  - Long term digital image storage and backup (preferably offsite) necessary
  - Data may be stored for many years based on local regulations

PACS - Web or Local Area Network based

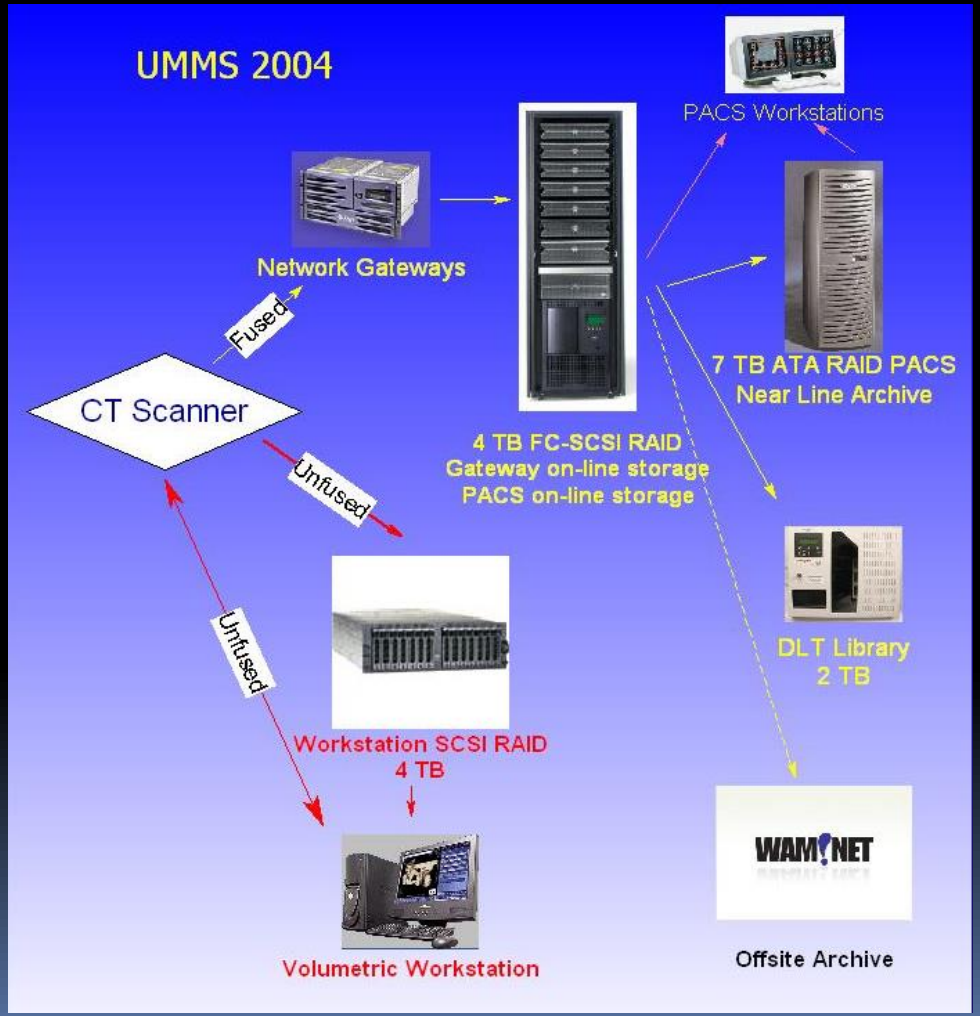
By facilitating synchronous access to multiple separate users on a Web or LAN basis, PACS allows for remote interpretation and consultation on PMCT studies

Some vendors of CT machines also manufacture PACS equipment, and may offer discounted costs for the joint purchase of both these major pieces of equipment.

Such systems must be coupled with 3D image generation software including a broad set of advanced tools for the generation of multi-planar images of the body.

The cost of a web based mini-PACS with remote access suitable for most PMCT systems users (5 users at a time) is in the US$250,000 range.

Storage Architecture



3D Image Generation

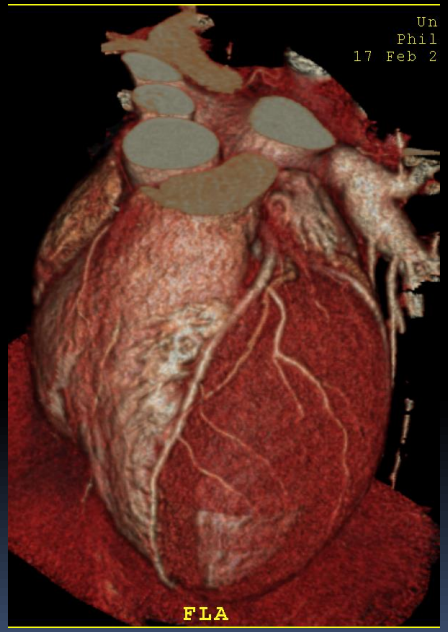
May have Independent 3D workstation or software built into PACS

3D may be used to show complex anatomy/provide overview

Can make the main findings stand out – more easily seen by the untrained eye

BUT - Can mask important details

3Ds are based on original thin section axial image set – always need to review thin section images first to ensure important details are not overlooked



Who will do the scanning ?

- Operation of a medical CT scan machine is typically performed by a CT technologist
  - cost of such a service especially on a 24/7 basis is considerable
- Training of mortuary technologists to generate PMCT scans now in use
  - Mortuary technologists often on duty 24/7
  - Have training in radiation safety
  - Can perform technically satisfactory PMCT scans using a very limited number of standard protocols
  - Should be supervised by an experienced CT technologist who provides both training and QA
  - Use will be dictated by local statutory radiation, occupational health and safety, and other legal requirements
  - In some jurisdictions, only credentialed CT technologists are allowed to operate a CT scan machine
- In other countries, Radiologists and MEs may run the CT scanner !

Who will interpret the PMCT studies ?

Experience to date varies by country/jurisdiction:

- Option 1: Medical Examiners
- Option 2: Radiologists
- Option 3: Mixture of 1 & 2

Where forensic medicine is funded on a national basis, Radiologists are more involved

- Local Hospital Radiology centers
- Regional Academic Radiology departments

Where funding is limited, Medical Examiners may read their own studies

- Ideally will have access to Radiology consultation

PMCT Interpretations – Needs in USA

- Establishment of a cohort of trained forensic radiologists and/or forensic pathologists who can interpret PMCT scans on a daily basis

- One logical approach suggests the establishment of regional forensic imaging centers based in major academic radiology (or forensic pathology) departments throughout the USA

- Medical Examiner's Offices equipped with CT scanners would transmit PMCT studies through secure intranet pathways to their regional interpretation center and receive timely, high-quality interpretations by expert readers

- Many night-time clinical CT studies at U.S. medical centers are already transmitting to day-time Australian reporting centers for this purpose. Economics of scale could allow dedicated regional forensic imaging centers to be financially self-sufficient.

Conclusions - “Nuts & Bolts” of a PMCT Service

- What kind of CT scan machine to purchase?
- Installation of CT scan machine and Radiation protection
- Maintenance and equipment service and contracts
- 3D Workstations & PACS “Filmless Radiology” systems
- Who will do the scanning ?
- Interpretations by who - Radiologists or MEs?

- Costs of CT machine, Installation, PACS, Maintenance ~ $750,000+

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- Costs of CT machine, Installation, PACS, Maintenance ~ $750,000+
- Who is going to pay for this ??

THANK YOU!