Postmortem Magnetic Resonance Imaging in Medicolegal Death Investigation

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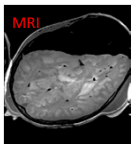
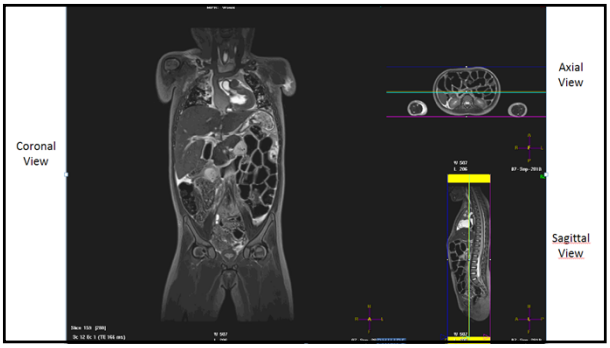
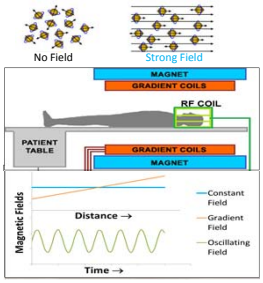
CT is really useful – why bother with MRI?

- Superior soft tissue detail
  - Complements excellent bony detail of CT or x-ray
  - Good contrast even from badly decomposed tissue
- Particularly good for imaging…
  - Fetuses and infants
  - Complex soft tissue structures (*e.g.,* brain, heart)
  - Soft tissue injury (*e.g.,* adipose, nerve)
- Not practical for every case
  - CT ~15 mins MRI ~30 mins to 2+ hours





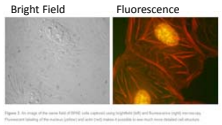
How does Magnetic Resonance Imaging work?



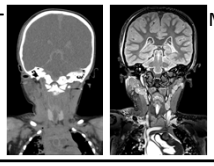
- Hydrogen nuclei (*e.g.,* in water molecules) are weak magnets
- MRI utilizes 3 **magnetic fields** to align, perturb, and spatially localize hydrogen nuclei to produce a voltage signal
- Image is *computed* from raw signal

Why is soft tissue discrimination better with MRI?

- In CT, x-rays either pass through tissue or are attenuated
  - The signal comes from the x-ray tube
  - Analogous to bright field microscopy
  - Denser tissues attenuate x-rays more
- In MRI, hydrogen nuclei absorb energy and *emit their own signal*
  - The signal comes from hydrogen in tissue
  - Analogous to fluorescence microscopy
  - Hydrogen signal depends sensitively on several properties of the local environment, **not just density**

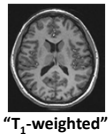


CT



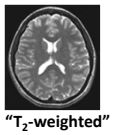
MRI

MR Contrast: Tissue Relaxation Times T_1 and T_2

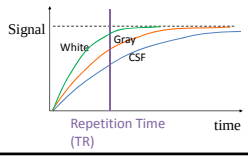


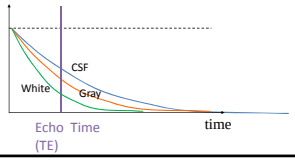
"T_1-weighted"

- Most soft tissues have around the same hydrogen density
- MR contrast depends mostly on the *time-dependence* of the hydrogen signal
- Different tissues have different relaxation times
  - T1 characterizes signal growth
  - T2 characterizes signal decay

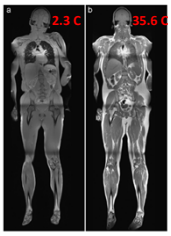


"T_2-weighted"





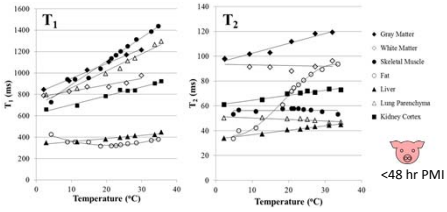
Why do PMMR Research?



From: Ruder et al. The influence of body temperature on image contrast in post mortem MRI. *Eur J Radiol.* 2012 Jun;81(6):1366-70.

- *Clinical* MR image acquisition protocols are optimized for *warm, well-oxygenated* subjects
- Temperature varies post-mortem and affects relaxation of MR signal
- MR acquisition protocols can be optimized specifically for the PM setting

T_1 and T_2 : Body tissues



<48 hr PMI

- T1: increases with temp for most tissues; weak temp-dependence for liver, fat
- T2: weak temp-dependence for most tissues; but Fat T2 significantly decreases at low temp

Clinical vs. PMMR Comparison

Clinical	Post-mortem
• **Motion** is a challenge – may require gating and/or may reduce image quality	• **No motion**
• **Contrast agents** administered IV or orally	• **PM subjects require external pump** to deliver contrast – many T_1-w protocols will not be useful
• **Body temperature is constant** – tissue contrast is predictable	• **Body temperature varies** – requires optimization
• Hospital throughput, patient comfort/compliance, and need for diagnosis in emergent situations limit exam time	• Forensic case load, needs/expectations of decedents' families and law enforcement limit exam time

Other Considerations for PMMR

- Safety
  - CT or Radiography survey to screen for potentially magnetic objects – prior to MRI
    - Ferrous objects (*e.g.*, drill bits)
    - Possibly ferrous (*e.g.*, possible steel jacket)
    - Actual magnets
    - Screening not needed for fetal demise/still birth
  - MR-safe (non-magnetic) gurney is required
- MR scanning is generally more time consuming than CT

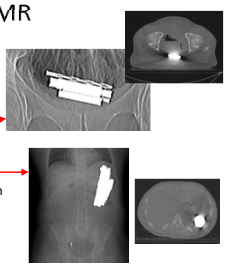
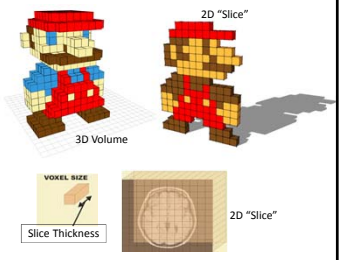


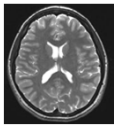
Image Data

- Voxels are volume elements
  - "Pixels" are picture elements
- The size of the voxel sets the image resolution
- Volume elements can be longer in one direction
  - 1 mm x 1 mm x 5 mm
  - Suitable for 2D display
- Volume elements can be cubes (isotropic)
  - 1 mm x 1 mm x 1 mm
  - More flexible (allows display of different planes or 3D rendering)



OMI PMMR

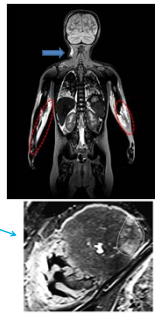
- Early application of PMMR at OMI
  - Typically use T2 weighted imaging
    - Fairly quick whole body scans ~30 minutes
    - Excellent detail of soft tissue
    - Contrast is relatively independent of temperature
- Scans typically of infants
  - Useful for brains and hearts
  - Can show soft tissue injuries
- Not for every case, and not every sequence on these select cases - multiple contrasts can lead to > 2 hrs scan



T_2-weighted Brain

PMMR is good for finding fluid

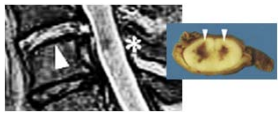
- T2-w PMMR identifies "pathological fluid accumulation"
  - Edema due to blunt force trauma (contusions of neck and forearms)
  - Focal necrosis + peri-focal edema in Myocardial Infarction*
  - Note: T2 is generally less temperature-sensitive

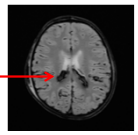


*Ruder, Thali and Hatch, *Br J Radiol* 2014:87:20130567

PMMR detection of hemorrhage

- Spinal cord injury without fracture in an adult*
- Intraventricular hemorrhage due to non-accidental trauma

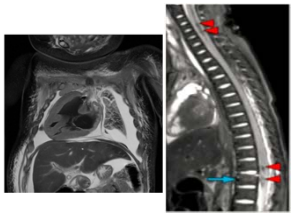




*T. Okuda, et al., A case of fatal cervical discoligamentous hyperextension injury without fracture: Correlation of postmortem imaging and autopsy findings, *Forensic Sci. Int.* (2012)

A Well-Established PMMR Application: Fetal and Infant Imaging

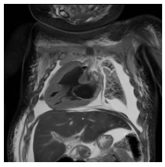
- MR well-suited for imaging complex soft tissues using small FOV
  - In utero or ex situ
- Detection of congenital anomalies, injuries
- Protocols and several systematic studies published by Thayyil, Arthurs et al. (Great Ormond Street Hospital, London)



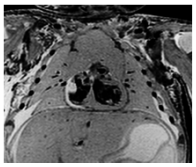
*Thayyil S, et al.; MARIAS collaborative group. Post-mortem MRI versus conventional autopsy in fetuses and children: a prospective validation study. *Lancet.* 2013 Jul 20;382(9888):223-33.

Left: Dextrocardia and structural anomalies of heart
Right: *Cervical and lumbar spinal cord injuries (non-accidental trauma)

Scanning Method Makes a Difference

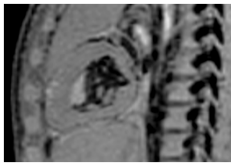


Individual 2D scans of long and short Axes, 4 chamber views –
time consuming, no MPR



3D Isotropic view – 0.7 x 0.7 x 0.7 mm resolution on a heart that is 3.2 cm across
~30 to 40 min scan with MPR option

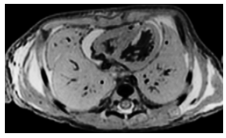
MPR – Multiplanar reformatting



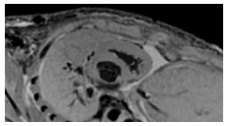
Sagittal view

Multiple views from a single 3D volume image

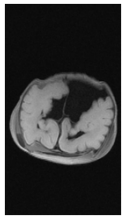
Axial view



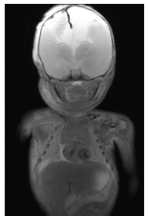
Oblique view



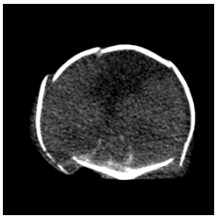
Brain Cysts



MRI - FLAIR



T2 weighted

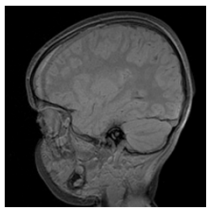


CT – brain window

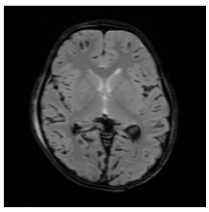
Multiple contrasts

- Multiple contrasts are possible with PMMR
  - Discuss with neuroradiologist about desired sequences
- Useful for brain imaging
  - Not just T2, but T1, FLAIR, hemo sequences
- These are often temperature dependent and resolution can be affected if not accounted for.
- Examples: ->

2 year old suspected child abuse

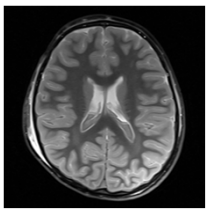


FLASH – T1



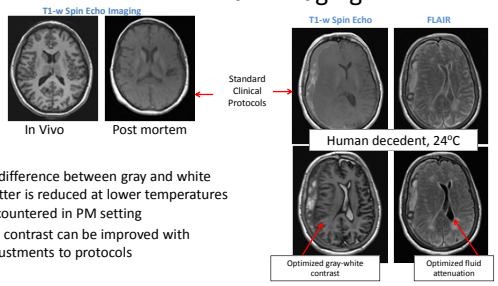
Hemo sequence

Contrasts continued



Ax-destir (FOV 180)

PMMR Brain Imaging



- T1 difference between gray and white matter is reduced at lower temperatures encountered in PM setting
- PM contrast can be improved with adjustments to protocols

Interpretation

- OMI pathologists are trained for CT and have limited experience with MRI – primarily T2 weighted images
- The scans are performed:
  - Permanent record of detailed information for interpretation
  - Contact radiology
    - This typically involves a specialist that can interpret these special images
    - Different than CT – your local radiologist may need to contact his/her neuroradiology colleague

Take Home Points

- 3D imaging is useful in the ME context
- MRI enables superior soft tissue discrimination, relative to CT, due to fundamental differences in signal generation
- PMMR is particularly good for examining complex soft tissue anatomy, detecting pathological fluid accumulations and hemorrhage, and imaging fetuses and infants
- PMMR requires additional optimization, due to the greater variability of subject temperature in the PM setting

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