Multimodality Imaging – Clinical Perspective

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Outline

• Challenges in diagnostic imaging technology (2009)
  – Multimodality – What, why, how?
  – Applications

• Identify trends
  – New scanners and applications
  – Low end CT scanners:
    - Point of Care CT; DentoMaxilloFacial/ENT; Portable CT

Case History

46 year old female with melanoma.
PET-CT exam for initial staging.
Multimodality, multitemporal imaging

- Payors will reimburse for a single exam from a single modality (pre-cert) at a single time – for diagnosis/staging
- Follow-up scans to evaluate disease status (e.g., restaging; response evaluation)
- Common scenario:
  - Detect lesion on CT, and characterize it with MRI. Biopsy with US.

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**Case History**

65 year old male with elevated liver function tests.

Status post sigmoidectomy for colon cancer 5 years ago.

CT exam to rule out mass or biliary tract disease.

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**Liver Mass**

CE MDCT

US
MRI of liver

Liver hemangioma

- Hepatic hemangiomas are present in about 7% of healthy people.
- Hemangiomas are four to six times more common in women than in men.
- Hemangiomas, although referred to as tumors, are not malignant and do not become cancerous.
- Hemangiomas are not unique to the liver and can occur almost anywhere in the body.
- Giant hemangiomas do occur and are susceptible to occult bleeding

Why so many modalities?

- Each has strengths and weaknesses; Synergy
- One size / type does not fit all
- Reimbursement; instrument/operator availability
- CT is most available and widely used
  - Essential technology for emergency dept.
  - CT is fast; 24/7 access
- MR is expensive, time consuming
  - Some patients are ineligible or unable to tolerate
- US is operator dependent
  - Skilled examiner is required, otherwise many errors
  - Real time; versatile; safe; widely available

Tools ~ Modalities

- Use the right tool for the job
- No single tool will suffice
- One size doesn’t fit all
- May be used separately or in combination
- Some require a skilled operator; others are simple enough for anyone to use
When is multimodality imaging used?

- **Breast** imaging: mammography, ultrasound, MRI
- **Cardiac** imaging: echo, SPECT, cardiac cath, CCTA, CMRI
- **Prostate** imaging: US, MRI, CT (for staging)
- **Brain** tumors: MRI, MRS, CT
- **Stroke**: CT (CTA and perfusion), MRI
- **Solid tumors**: CT, MRI, PET
- **Transplant**: US, MRI, CT
- **Interventional**: fluoroscopy, US, CT, MRI
- **Orthopedic**: radiography, MRI, fluoroscopy, CT
- And many others....

When is multimodality imaging NOT used?

- **Emergency**: CT
- **ICU**: radiography (sometimes head CT or portable US)
- **O.R.**: fluoroscopy (sometimes US or radiography)
- **Thyroid**: US (and sometimes SPECT)
- **Follow-up** solid tumor/surveillance: CT
- And many others....

Choice of modality and scanning protocol is difficult and complex.

- Limited knowledge of the clinical status and history
- Similar history may require very different exams:
  - Abdominal pain
    - Depends on renal function and allergy to iodinated contrast
    - Acute vs. chronic; where does it hurt?
    - WBC; fever
    - Jaundice
    - Gender and gynecologic history
  - Altered mental status
    - Prior surgery
    - Known malignancy
    - Intoxicated?
  - Search for primary tumor – occult malignancy
    - Serum biomarkers
    - Known metastases
  - Payor may deny reimbursement for repeat or additional exams.

Exceptions

- Diversity of patients; generalizations are difficult
  - Massive obesity
  - Children (including neonates and infants)
  - ICU patients – on respirator
  - Immunosuppressed; contagious (e.g., Tb)
  - Mental impairment; claustrophobia
  - Pregnancy
  - Renal failure – acute and chronic
Multitemporal imaging

- Contrast-enhanced: (within exam session)
  - Multiphase: arterial, venous, equilibrium
  - Perfusion: DCE
  - 10+ minute: excretion; redistribution

- Sequential (e.g., monthly, quarterly encounters)
  - Restaging in oncology; Baseline + followup
  - Revascularization; vessel patency
  - Measure of response to therapy
    - e.g., Imaging biomarker

Multiphase contrast-enhanced imaging

- Common in CT and MRI
- Essential for liver, pancreas, kidneys
- CT angiography typically consists of both a non-contrast and post-contrast enhanced series (same for MRA)
- Multiphase cardiac CTA:
  - Precontrast coronary calcium scan
  - Post-contrast retrospective gating

Multiphase CT

- Same slice, multiple time points
- Liver lesion after RFA
- Liver malignancy prior to RFA

Cardiac imaging – an example

- EKG and stress testing → cardiac SPECT
- Abnormal SPECT → cardiac cath & PCI or may choose coronary CTA
- Coronary calcium measurement with CT
  - Risk assessment by age and gender norms
- Valvular disease: echocardiography
- Cardiac MRI
  - Congenital anomalies, congenital heart disease
  - Myocardial viability; cardiac function

Future? – PET-CT; MRI-PET; …
Delayed CT/MRI imaging

- Redistribution phenomena
  - Gd contrast into fibrosis (Myocardial viability)
  - Cholangiocarcinoma (malignant)
  - Adrenal adenoma (benign)
  - Hemangioma (benign, but may be very large)
- Renal excretion
  - Antegrade opacification of urinary tract
  - Basis of CT urogram (akin to IVP / EXU)
Myocardial SPECT

Integration of the multislice PET scanner into a 7-T MRI apparatus.

PET/MRI scan of a tumor in a lab mouse. The arrow points to central necrosis within the tumor.

Simultaneous PET-MRI: a new approach for functional and morphological imaging
Martin S Judenhofer, et al.
Four major manufacturers
3 major types – 16, 64, high-end

- Toshiba Aquilion 64
- GE Lightspeed VCT 64
- Siemens Sensation 64

MSCT time table – The applications of CT change as the technology advances

• As Low As Reasonable Achievable ALARA
• Whole head CT performance
• Whole thorax coverage
• Whole body coverage
• Dynamic study
• Perfusion and function

MDCT area coverage (# slices)
**Image Gently**

13 yr old Female - Scanned w/256-slice CT

- 4.8 sec scan
- 2D Anti-Scatter detector grid improves contrast resolution
- Smart Focal Spot for artifact elimination

**Clarity™ Tissue Adaptation**

- Automatically adapts to the tissue.
- Decrease noise in the soft tissue and increase the contrast in the lung.

[Image of a 13-year-old female patient scanned with a 256-slice CT machine. The MRI images show the improvements in image clarity with 2D Anti-Scatter detector grid and Smart Focal Spot.]

[Image of the Clarity™ Tissue Adaptation feature, showing how it automatically adapts to the tissue and decreases noise in the soft tissue, with an increase in contrast in the lung.]
Clarity™ CT Solution Server

- Clarity™ CT Solution Server acts as a DICOM node that receives DICOM 3.0 compliant data, then processes the data, and then forwards the optimized study to the selected destination. This destination can be any DICOM node, typically either the PACS system or a specific workstation.

Clarity™ Ultra Low Dose CT Liver

- 100% (standard dose)
- 50% (low dose)
- 50% dose (processed)
**Multirow Detector CT (MDCT) Scanner**

128 detector rows; 256 slices (iCT)

**Increased Speed, Power, Coverage**

- Higher temporal resolution
  - 0.27 sec rotation
- Increased Tube Power
  - 120 kW / 1,000 mA
  - X-Y and Z focal spot modulation
- Greater coverage per rotation
  - 8 cm
  - 256 slices

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**Nose to Toe Scan: 168 cm in 22 sec**

**Multi-phase Cardiac Imaging less than 5 sec**
Non-Gated Chest CT Scan
Excellent coronary visualization
RT=0.33sec

Large Patient Cardiac CT
BMI = 50

256-320 detector row CT scanners
Enables 4D CT angiography & Whole organ perfusion exam

64-row Helical vs. 320-row Non-Helical

40-64 channels
256 channels
320 channels

47 kg
162 cm
50 BMI
52 bpm
MRI of Cerebral Ischemia

Early DWI/MTT mismatch, lesion growth

78 yo female 3 hrs after onset of aphasia during cardiac cath.

Greg Sorensen, Massachusetts General Hospital

CT Brain Perfusion

Color-Coded Parameter Maps

Color-coded parameter maps for a selected slice

Bernhard Preim, Visualization Research Group, University of Magdeburg, Germany
**Perfusion**

**CT vs. MRI**

- T2
- DWI
- MTT

**vs. xenon CT vs. PET vs. SPECT**

**Performance**

**CTP**

**MRP**

**Non-contrast CT**

**STROKE IMAGING**

**CTP**

**MRI**

**Megan Strother, M.D., Vanderbilt University**

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**Imaging Ischemia--Vascular**

- Angiogram
  - 1950-60's (pre-CT era)
- Vascular occlusion
- Thrombolysis
- Recanalization
  - Clinical improvement

**24 hours**

**Head CT**

**No ICH**

**<1/3 MCA territory**

**<3 hours**

**IV Thrombolysis**

**Imaging Ischemia-Parenchyma**

**Megan Strother, M.D., Vanderbilt University**

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**AAPM 2008**

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Tissue Clock

Vascular Occlusion

Parenchymal changes on non-contrast CT

CBF, MTT, CBV

Wall Clock

MR vs. CT

- No radiation
- Better contrast

Diffusion = Infarct
- MR = 94% sensitive and 96% specific for infarct
- Non-contrast CT = 50% accurate for acute infarct

MR vs. CT

- MR = whole-brain coverage
- CT limited by scanner (10-40 mm max)
- Post fossa obscured on CT by beam-hardening artifact
- Speed
- Accessibility
- Spatial Resolution on CTA

-- Quantifiable
- MR relies on indirect T2* effects on tissue from gad, therefore not quantifiable

CT Scan Protocol

1st
Non-contrast Head CT

2nd
CT Perfusion

3rd
CT angiogram
CT Scanning Protocol – 320 Channel

- non-contrast head CT = 2.4 mSv
- dynamic CTA & CTP = 3.9 mSv
- neck CTA = 2.6 mSv
- post-contrast head CT = 2.4 mSv
- total dose = 11.2 mSv

Whole Head Dynamic CTA (Multiple Phases) (16 cm z-axis coverage)

- Multitemporal acquisition protocol
- Subtracted whole-brain dynamic CTA
- 3D CTA
Multimodality Imaging - Clinical Perspective

Workflow for whole brain CT perfusion exam and postprocessing...

Whole Brain Perfusion (16 cm z-coverage)

Whole Brain Perfusion

Axial Views

Coronal Views

3D View (Interactive)

Spectral and Dual Energy CT

Simple Analogy

Traditional CT

Spectral CT

Limited Spectral CT

Dual Energy CT

Yesterday & Today

Future

Future

Today
Dual-energy Material Separation

Dual-energy Material Separation

Spectral vs. Dual Energy CT
Techniques That are Possible on Commercial Systems

Spectral vs. Dual Energy CT
Techniques That are Available on Research Systems

Dual Source

Dual K Switch

Dual Spin

Not Spectral CT

Dual-layer (“Double Decker”) Detector*

Photon Counting*

*Works-in-Progress: Pending commercial availability and regulatory clearance
Dual-Layer CT (Orion-N)

X-Rays

Photons

100%

SCINT1

Low Energy Raw data

E1 image

-50%

SCINT2

High Energy Raw data

E2 image

-50%

Double-Decker Diode

Weighted combined Raw data

CT image

Spectral CT

How does spectral CT fit into today’s standard of care?

“new clinical features, such as spectral imaging, may still be works in progress through 2010 and longer”

- Lung perfusion
- Cardiac perfusion
- Bone removal

Dual Energy CT

Conventional CT

• No medical guidelines include spectral CT
• No reimbursement for spectral CT
• No large studies have been published for spectral CT
• Alternative approaches exist for proposed spectral CT clinical applications
• Rapidly changing technology

CONE BEAM CT

DentoMaxilloFacial-CT

NEWTON 3G 3D ACCUTOMO

i-CAT

CB MERCURY
Advantages in Dental Imaging

- Lower dose than helical CT
- Compact design
- Superior images to Panoramic
- Low cost
- Low heat load

Dose:
Panoramic: 6-20 µSv
CBCT: 20-70 µSv
Conventional CT: 314 µSv

CBCT vs. Panoramic

Shortcomings

- Metal artifacts?
- Worse low contrast detectability
- Long scan times – motion artifacts
- Slightly inferior quality to conventional CT

Periodontal ligament spaces easily recognizable in the dental CT but not satisfactory in the CBCT
Low X-Ray Radiation Dose

Sinus CT with a full-body scanner
- Adult: 1.0-2.0 mSv
- Child: 1.0-2.0 mSv

Sinus CT with the MiniCAT™ low-dose scanner
- Adult: 0.13 mSv (7-15x lower radiation dose)
- Child: 0.07 mSv (14-28x lower radiation dose)

Another Clinical Example....

Patient
500lb 38 year old African American male

Symptoms
Aphasia and right sided hemiparesis.

Issues
Unable to scan a patient over 450lbs. Patient went 5 days without a CT scan.

Imaging
Large MCA infarct with mass effect & midline shift.

This is the same pt scanned within 24 hours using the Ceretom portable scanner and then a GE stationary scanner...

Which do you prefer?
Cerebrovascular Evaluation

CT Perfusion (CTP)
- axial, 1 cm slice, 1 slice/second
- acquisition time is user defined (30-40 seconds)
- reconstruction on the scanner in real time

Direct Coronal Facial CT
4 months apart, same Pt, same dose, same recon settings

Enterprising Visualization & Analysis
8/3/2009
Use of multimodality and multitemporal data

- Post-processing software tools
  - Visualization: MPR and 3D
  - Fusion: usually limited to image pairs
  - Perfusion: based on assumed compartmental model, not standardized
  - Most interpretations are subjective
- Enterprise integration with PACS
  - Access to images and advanced analysis tools remotely
  - Subspecialized experts apply unique tools for planning, implant specification, response measurement

Medical Imaging Workstations

Thick Client – expensive, with substantial local processing capability
Thin Client – small, portable Accessible throughout enterprise

Thin Client Solutions

Why
- Time is a physician’s most precious asset
  - “Every 15-seconds matters”

What
- Images
- 3D Viewing
- All Key Applications

Where
- Scanner
- Workstation
- PACS
- Virtual Private Network
- Department
- Hospital
- Imaging Center
- Home

Enterprise Visualization

Should we offer advanced visualization services across the enterprise using a client-server system?
**Conclusion**

- Multimodality (and multitemporal) imaging is widely used
- Tailoring systems to solve specific diagnostic imaging problems is complex
- Workflow includes post-processing on imaging workstations, distributed across the clinical enterprise
- New scanners and technologies are emerging – wide area CT, dual energy, cone beam OMF scanners, portable CT, PET/MRI

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