Neuroradiology 2.0: Informatics Opportunities for the 21st Century

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Why Neuro?

- Volume is high
- Proportion of neuro exams is increasing
- Large morbidity and mortality of brain disorders
  - Depression
  - Psychiatric
  - Stroke
  - Neurodegenerative

Neuroimaging makes up over 50% of all MRI studies.

Source: 2006 IMV MRI Market summary report, courtesy Lisbeth Geerts, Philips Medical Systems
Why Neuro?

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Source: The Imaging Market Guide 2005
Arlington Medical Resources, Inc.
Why Neuro?

• Mature technology
• Almost entirely tomographic
• Multimodal imaging is the norm
  – CT: pre, post, perfusion imaging, angiography
  – MR: semi-infinite
    • Commonly T1, T2, T2*, diffusion, post contrast
• Allows voxel segmentation
Common Questions in Neuro

• Bigger versus smaller (50% of the job?)
  – Tumors, strokes, ventricles, etc.
  – Currently ±10% due to slice selection issues with 2D imaging
    • 10% change in a 1 cm tumor = 10 million new cells
    • We would like to see smaller changes and be more reliable.
    • Change therapies faster

• What is it?
  – Unknown brain masses
  – Poorly characterized white matter lesions
    • “UBO’s”
  – Ring-enhancing lesions

• Treatment effect (good) versus disease progression (bad)
  – Radiation necrosis versus tumor recurrence

• Dead or alive?
  – Imaging the penumbra in stroke.
  – Time sensitive
  – Predicting outcome
    – Voxels
    – Patient function
Where is the new stroke?
Where is the new stroke?
Where is the new stroke?
Bigger versus Smaller

- **Auto-alignment of 2D slices**
  - Based on prior images
  - Must be on the same scanner

- **Template-based approach**
  - Consistent slice planes based on standard anatomic template using the localizer scout images
  - Will be faster for radiologists to read!

- **3D isotropic voxels**
  - Allows reformatting in arbitrary planes
  - 3D IR-SPGR T1, 3D CUBE FLAIR & T2, ASL
  - Problem: 3D scans are long, and motion is a problem
    - Motion correction methods in the pipeline.
Bigger versus Smaller

• Once we have perfectly aligned images, how do we read them?
  – Traditional = side-by-side monitors
  – Future = toggle-mode
    • The human eye is built to see differences
  – “Blink radiology”

• Goal
  – Faster readout
  – More confidence in the bigger vs. smaller question
    • Would like to get to 1% sensitivity
    • Still 1 million cells
What is it?

- So you’ve got a brain lesion...
- Differential diagnosis relies on trained radiologist integrating information from different sequences
  - Common descriptions
    - T1 low, isointense, high, heterogeneous
    - Enhancement pattern: none, uniform, ring, heterogeneous
    - Multiple, single
    - Location: random, gray-white junction, extra-axial, white matter, etc.
Example: Ring-enhancing brain mass

- MAGIC DR
  - Metastasis
  - Abscess
  - GBM
  - Infarct
  - Contusion (hemorrhage)
  - Demyelinating
  - Radiation
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- Gold standards?
  - Biopsy
    - Sampling error problem
    - Stereotactic biopsy and correlation with images
  - Expert diagnosis (based on clinical features, progression, response to treatment)

ADEM
Radionecrosis
Metastasis
GBM
Abscess
Diagnosis: Cerebral Abscess

Why?

Dark T2 rim
More enhancement laterally
Low CBV
Diffusion positive (pus)
Another ring enhancing lesion

Diagnosis: Glioblastoma Multiforme

Features: Nodular enhancement, high CBF, high CBV
Treatment (Good) vs. Disease Progression (Bad)

• Radiation necrosis vs. tumor recurrence
• Use keywords like
  – Mass effect
  – Enhancement pattern (feathery vs. solid/nodular)
  – Perfusion imaging (CBF, CBV changes)
  – MR Spectroscopy
  – Stability
• Problems
  – Not always biopsed, often a mixture...
  – PET can act as quasi-gold standard (FDG uptake)
56 yo woman, left parietal glioblastoma
1 yr later, s/p resection, chemo, XRT

New enhancement, mass effect - worrisome for tumor recurrence
1 yr later, s/p resection, chemo, XRT

Radiation necrosis
Dead or Alive? the Penumbra Model of Stroke

- Classical definition\(^1\)
  - Lost electrical activity (EEG silent)
  - Retained function of Na-K pumps
  - Still viable with reperfusion

- “Preventable infarction”\(^2\)
  - Type A: Tissue that is dead at the time of imaging
  - Type B: Tissue that is destined to die in the absence of treatment.
  - Type C: Tissue that will survive regardless of therapy

Goal of neuroimaging is to distinguish these 3 types of tissue.

Generalized linear models

- Multimodal MR data
- Acute scan compared with final scan
- Probability of infarct is estimated.

from Wu et al., Stroke 2001
72 yo woman, 60 min acute loss of consciousness

tPA given due to short presenting time
72 yo woman, 60 min acute loss of consciousness

1 day later, large infarct, edema, herniation
46 yo woman, awoke with right-sided symptoms
82 year-old woman, last seen normal 1 hr ago, now mute & with R hemiparesis, NIH Stroke Scale 22

Carotid terminus occlusion, minimal to no parenchymal low attenuation

MRI 1.5 hrs later

MTT

CBV

Tmax

DWI
82 year-old woman, last seen normal 1 hr ago, now mute & with R hemiparesis, NIH Stroke Scale 22

PWI lesion for $t_{\text{max}} > 6.0\text{s} = 89.9\text{ ccm}$

$\text{DWI lesion (SD > 2.20)} = 9.3\text{ ccm, mismatch ratio: 9.7}$

$\text{DWI lesion (ADC < 615)} = 3.4\text{ ccm, mismatch ratio: 26.4}$

RAPID post-processing, Bammer/Straka
Initial

Clot removed using MERCI @ 4 hrs
NIHSS 22 to 3

3 days later,
NIHSS 0
Potential Directions

• Template based 3D isotropic image sets
  – Speed up radiologists
  – More confidence in bigger/smaller questions
  – Reduce delays in changing/intensifying treatment

• Unknown brain mass
  – Select criteria, use biopsy or expert opinion as gold standard
  – Stability/change an important factor

• Treatments vs. disease
  – Consider radiation necrosis/tumor progression as a model

• Preventable infarction
  – Imaging or clinical outcome can act as gold standard
  – Atlas-based templates relating region to function.