Multimodality Breast Imaging Systems

Tomo/Ultrasound/Optics, Ultrasound/Other

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Outline

• Combinable modalities with screening potential
  – Auto 3D Ultras.   - 2/3D x-ray   - Optical   - MRI
• The two geometries, dependent and compressed
  – Breast Tomo/Ultras./Optical or photoacoustic
  – MRI/x-ray CT/Ultras./Diffuse Optical
• Colocated and image based registration
• Contrast agents; in screening?
• Other ultras. modes

#1 Ultrasound

• No longer mainly solid/cyst ~ all Dx studies include US
• Automated ultras. – extensive evaluations of screening for breast cancer
• Ultras. is sensitive to cancers not well detected by mammography, particularly in dense breasts
• US screening sees many apparent abnormalities, increasing callbacks. US misses many cancers detected/diagnosed by their microcalcs.
• Colocated ultrasound and BT, MRI or possibly x-CT should essentially eliminate this barrier.
The future of the world (breast screening) is divided into two (or 3) geometries

- Distant 3rd is supine for US and optical, but not compatible for collocating with dependent or compressed breast
- 1st is the conventional mammographic geom.
  - Breast Tomo/Ultras./Optical or photoacoustic
- 2nd is dependent breast in air or water
  - MRI/x-ray CT/Ultras./Optical/Microwave

Breast Tomosynthesis (BT)

- X-ray in mammographic geometry is now dominant for good reasons
  - Calcification, fat, H2O/protein contrast
  - Mean of max thickness 5.5 cm
  - High res., low dose
- No reason x-ray shouldn’t be in 3D, with compression till MR improves in several aspects
  - 1 to 2x the equivalent mammography dose
- FDA approval of breast tomosynthesis (BT) delayed because of poor resolution/noise in 2 dimensions for early application and pubs.
US Screening - ↑ Mammo Sensitivity, ↓ Specificity

- Particularly in dense breasts
- ACRIN 666, Kolb papers, international experience

- Not enough skilled practitioners to perform US screening in the US and pretty expensive
- Map of same tissues in x-ray & US a problem
- Goal of supine & prone automated US systems

Manually Guided Supine 3D

- ~Most positive AUS clin trials reports
- From Sonocine Website

Colocation Reader Study Display GUI showing Corresponding VOI's in DBT & AUS

SonoVu - Standalone by U-Systems, Inc. (Siemens)
New human study of the combined system BT & BT + AUS, of 52 going to Bx

- Preliminary results of human study of the combined system:
- AUS did not aid substantially in diagnosis of these masses chosen by mammo and US to go to biopsy, while BT did.
- I.e., BT improved over mammo plus hand-performed US, whereas adding AUS to BT increased sensitivity slightly and decreased specificity.
- If simple cyst cases had been included at an ~ typical 22% of diagnostic US exams, and AUS identified them, then the PPV of BT alone or of clinical mammo & US would be 24 or 25%, respectively, vs. 30% for BT & AUS.
- Readers opined strongly that adding US to BT would in a screening situation would allow them to make fewer referrals for further imaging studies.
- CAs - 13, benign – 39. 5 readers.

Misdiagnosis by two of four r’drs on BT as Benign, corrected by US

RALM view of a carcinoma (black arrow)

Improvements

- Coverage
  - Cowling
  - Mesh paddle
  - Dual Sided imaging
- Other Image Quality Improvements
  - …
Phantom 2 design

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<th>Tissue-Mimicking Material</th>
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<th>Relative Echogenicity (dB)</th>
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Relevant physical properties of materials in high SOS-contrast phantom. EL Madsen and G Frank designed with us and constructed.

US Images from Top, Bottom, Fused

Figure 5: Cancer-like double cones and cysts imaged from both sides [(a) and (b)] and roughly fused (c). Subcutaneous fat layers cropped.

Diffuse Optical or Photoacoustic

- Diffuse optical imaging and photoacoustic tomography (PAT) are sensitive to vascular anomalies including small vessels with flow too slow for Doppler US.
- PAT offers higher resolution, but optical penetration limitations.
- The penetration looks promising for PAT imaging from both sides of the compressed breast.
- Spectroscopic PAT, S-PAT can distinguish oxy- and deoxyhemoglobin.
- Coregistered BT, US and optical imaging might well provide similar screening effectiveness as the combination of current mammography, ultrasound and contrast MRI examinations.

Three-modality Imaging of Breast Cancer

Combine three promising medical imaging modalities for breast cancer detection and diagnostic: 3D x-ray, advanced ultrasound (US), and photoacoustic tomography (PAT).
Combined US and NIR systems and a handheld probe with a centrally located US linear array and NIR source-detector fibers distributed at the periphery of the probe.


(a) US image of a suspicious tubular-like lesion (arrow) located at 12-o’clock position in the right breast in 71-year-old woman.

(b) tHb map showed an isolated, well-defined mass with high tHb of maximum of 97.8 µmol/L and average of 65.7 µmol/L at the corresponding location of section 3.

MRI/x-ray CT/Ultras./Optical/Microwave

Other Ultrasound Modes

- Additions possible to the considerably orthogonal information provided by BT, pulse echo US and S-PAT
- Scatterer size and density
- Elasticity, strain or shear wave velocity
- Transmission ultrasound imaging - attenuation, speed of sound