Ultrasound Tomography: A Breast Imaging Modality Whose Time Has Come

Neb Duric[1,2], Peter Littrup[2,3], Olivier Roy[2], Cuiping Li[2], Steve Schmidt[2], Heather Rone[2]
[1]Karmanos Cancer Institute, Wayne State University, Detroit, MI
[2]Delphinus Medical Technologies, Plymouth MI
[3]Brown University, Providence RI

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Disclosure

Neb Duric and Peter Littrup have financial interests in Delphinus Medical Technologies. Potential financial conflicts of interest are managed by Wayne State University.

Ultrasound Tomography (UST)
a form of ABUS

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History of Medical Ultrasound Tomography

- 1950's – Pulse-echo technique (Wild and Reid)
- 1950's – Mechanical rotation in a water bath
- First Cross-sectional images of breast (Howry et al)
- 1978 – First cross-sectional transmission images of the breast
- Use of sound speed and attenuation to characterize tissue (Glover et al, Greenleaf and Johnson)
- 1981 - First cross sectional images that combine reflection and transmission imaging (Carson et al)
- 1997 – First clinical use of diffraction tomography (Andre et al)
- 2007 – Full wave-based reconstructions of sound speed and attenuation for whole breast (Johnson et al; Techniscan Medical)
- 2007 – Simultaneous reflection and transmission imaging of the whole breast (Duric et al)
- 2008 – Attenuation based tomography (Marmarelis et al)
- 2010 – True 3-D reflection tomography (Ruiter et al)
- 2013/2014 – FDA clearances for the SoftVue system (Delphinus Medical)

Screening Dense Breasts

- X-ray mammography detects ~ 5 cancers per 1000 screens
  - Low sensitivity in women with dense breast tissue
- Tomosynthesis may help
  - unlikely to create a paradigm shift in performance
  - generates even higher levels of ionizing radiation
- MRI can address these limitations, but
  - long exam times and the use of contrast agents.
  - expensive for routine use although "fast MRI" holds promise
- PEM and MBI limited by cost and radiation concerns.
- Other modalities such as OCT and PAT are still in early development
- Studies show effectiveness of HHUS and ABUS for women with dense breasts.
  - Up to 4.5 extra cancers detected per 1000 screens.
  - Predominantly node negative invasive cancers

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Screening Ultrasound (US) Studies

Author (Year)	Center	Type	Exams	US Only Cancers	Yield per 1000
Brem, et al (2014)	**Multi**	**ABUS**	**15,318**	**30**	**1.96**
Berg, et al (2012)	**Multi**	**HHUS**	**7,473**	**32**	**4.28**
Hooley, et al (2012)	Single	HHUS	935	3	3.21
Kelly, et al (2010)	**Multi**	**AWBU**	**6,425**	**23**	**3.58**
Corsetti, et al (2008)	Multi	HHUS	9,157	37	4.04
Crystal, et al (2003)	Single	HHUS	1,517	7	4.61
Leconte, et al (2003)	**Single**	**HHUS**	**4,236**	**16**	**3.78**
Kolb, et al (2002)	**Single**	**HHUS**	**13,547**	**37**	**2.73**
Kaplan (2001)	Single	HHUS	1,862	6	3.22
Buchberger, et al (2000)	Single	HHUS	8,103	32	3.95
Gordon, et al (1995)	Single	HHUS	12,706	44	3.46

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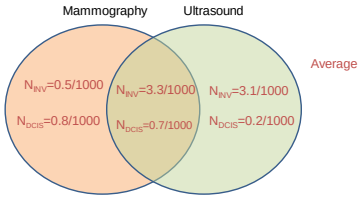
Study Averages



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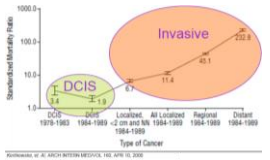
The Dense Breast Screening Challenge



- US almost doubles invasive cancer detection
- Recall rates also doubled
- Cost benefit trade-off uncertain

Sprague BL et al Ann Intern Med. 2015 Feb 3;162

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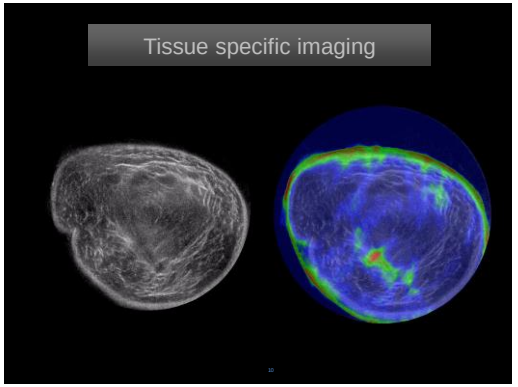
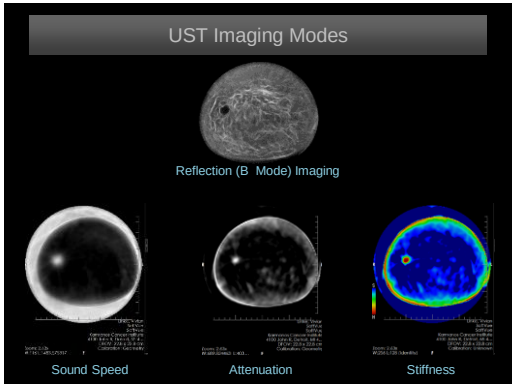
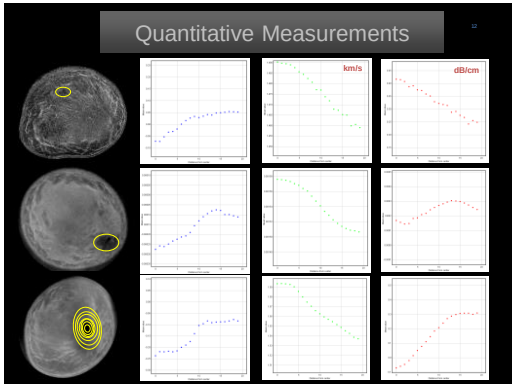
Results from UST Scanner at KCI

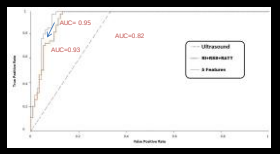
Table 1. SoftVue operating parameters	
Number of transducer elements	2048
Number of receive channels	512
Number of transmit channels	512
Operating frequency	3 MHz
Data resolution	14 bits
Image resolution (B-mode)	0.7 mm
Slice thickness	2.5mm
Max. breast diameter	22 cm
Reconstruction time per slice	15 s


Tissue specific imaging


UST Imaging Modes
Reflection (B Mode) Imaging
Sound Speed
Attenuation
Stiffness


Quantitative Measurements
km/s
dB/cm

ROC Analysis



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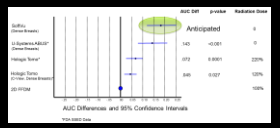

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Future of UST

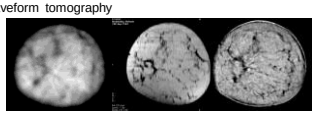
High image quality relies on

- Dense sampling of the scattered field
- Uniform and strong illumination of the object.
- Physics-based reconstruction algorithms

→ Solution requires large amounts of data to satisfy the sampling constraint and advanced computing power to enable physics based modeling for generating the output image.

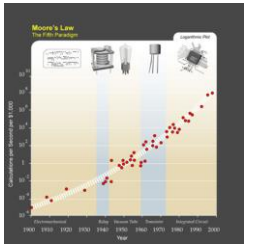
Image reconstruction techniques

- Beamforming or SAT techniques for reflection imaging
- Straight ray tomography (backprojection) for transmission imaging
- Curved ray tomography
- Waveform tomography



Computational complexity

Moore's Law



The Economist (Oct, 2011)

Conclusions

- Adjunctive screening with US increases sensitivity in dense breasts
  - Almost doubles invasive cancer detection
  - Increases call back rates
- UST may lower barriers to adoption for screening
  - UST's tissue specific imaging may help reduce call back rates
  - Diagnostic studies suggest AUC improvement
  - UST will rapidly improve with time by riding Moore's Law

➡ PMA trial for supplemental screening planned

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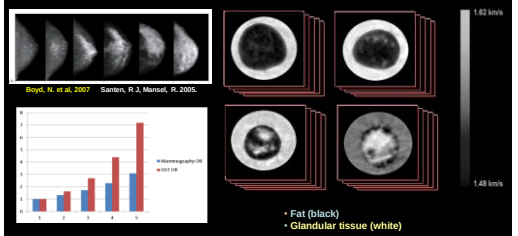
Sound speed measure of breast density as a biomarker for breast cancer risk

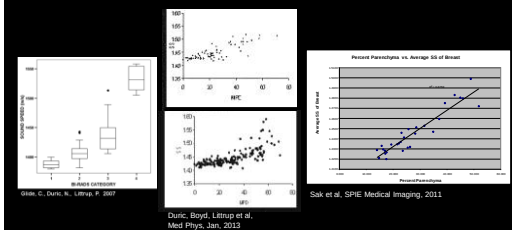
Mammography **Ultrasound Tomography**



Boyd, N. et al, 2007 Santen, R J, Manset, R. 2005.

- **Fat (black)**
- **Glandular tissue (white)**

UST vs Mammography & MRI



Glide, C., Duric, N., Littrup, P. 2007

Duric, Boyd, Littrup et al, Med Phys, Jan, 2013

Sak et al, SPIE Medical Imaging, 2011

Sound Speed correlates with MPD

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