EMERGING TECHNOLOGIES

Futures in Ultrasonic Diagnosis

Michigan Sonographers’ Society - 2016
Novi, MI

Presented by: Jim Baun, BS, RDMS RVT, FSDMS
Mindray ZONARE
Course Outline

- Single crystal transducer technology
- ZONE Sonography Technology (ZST) - ZONARE
- Elastographic methods:
  - Acoustic radiation force impulse (ARFI)
  - Shear wave elastography (SWE)
- Virtual histology - IVUS
- Photoacoustic imaging
- Vector Flow Imaging (VFI)
Single Crystal Technology

- PZT has dominated transducer technology for decades
- Ceramic PZT consists of random micro crystal dipoles
- New “recipes” for growing piezoelectric crystals yield oriented dipoles
  - Less voltage required
  - Broader transmit and receive bandwidths
  - Better sensitivity
  - Improved S/N ratio
SINGLE CRYSTAL TECHNOLOGY

Photomicrographs

1-a. Polycrystalline PZT
1-b. Single crystalline PMN-PT

PZT  PMN - PT
Advantages

• More powerful, pure and efficient acoustic beam
• 85% more efficient than PZT crystals
• Improved spatial and contrast resolution at depth
• Minimal signal loss in harmonic imaging
• Particularly beneficial in cardiology applications
SINGLE CRYSTAL TECHNOLOGY

Disadvantages

- Impractical to use with center frequencies >6 MHz
  - Exceptional fragility
  - Low sound velocity
  - Low coercive force

- Impractical to use with low center frequencies <3 MHz with small elements
  - Very high electrical impedance
  - Causes severe mismatch to cable and system
  - Underperforms PZT
ZONE Sonography Technology

- New core imaging technology - 1998
- Software-based vs. hardware-based
- Data acquired in large ZONES vs. line-by-line
- High speed, high-capacity digital signal processing
- Image created pixel-by-pixel
- Automatic sound speed compensation
# Acoustic Data Acquisition

## Traditional Beamformer

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## ZONE Sonography

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**10X FASTER**
Acoustic Data Acquisition

Clinical benefits:

- Extremely fast and accurate display of anatomical motions and hemodynamic states
- Reduces tissue motion artifacts
- Superior image quality across all US modes
Extremely fast and accurate display of anatomical motion and hemodynamic states
Reduces tissue motion artifact
Exceptional frame rates virtually unchanged with multiple modalities activated
Every frame crystal clear = perfect cine back

Clinical benefits:
Advanced Acoustic Acquisition™
ZONE SONOGRAPHY TECHNOLOGY
## Acoustic Data Processing

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Dynamic Pixel Focusing™

Pixel-by-pixel focusing on transmit AND receive:
   • Every Frame
   • Every Depth
   • Every Time

Enhanced spatial resolution:
   • Axial
   • Lateral
   • Elevational
ZONE SONOGRAPHY TECHNOLOGY

Dynamic Pixel Focusing™

Traditional Beamformer

fr15
ZONE SONOGRAPHY TECHNOLOGY

Dynamic Pixel Focusing™

Traditional Beamformer  fr 15

ZONE Sonography  fr 60
Sound Speed Compensation™

- Conventional SS calibration - 1540 m/sec
- Sound speed varies in human soft tissue 1,450-1,650 m/sec
ZONE SONOGRAPHY TECHNOLOGY

Sound Speed Compensation™

Trial Frames Different V

SW Decision
Clinical benefits:

- Improved spatial and contrast resolution
- Improved imaging at depth
- Improved imaging of dense organs
- Improved imaging in diffusely diseased organs
ZONE SONOGRAPHY TECHNOLOGY
Elastographic Methods

- General principles
- Acoustic radiation force impulse (ARFI)
- Shear wave elastography (SWE)
ELASTOGRAPHIC METHODS

General Elements

• Noninvasive US method of assessing biomechanical properties of soft tissue

• Palpable “hardness” of human soft tissue

• Difference in cellular composition of one tissue compared to adjacent or “control” tissue

• Biomechanical properties of human soft tissue:
  • Rigidity
Biomechanical Properties

• Determinants of elasticity:
  • Metals & crystals - atomic lattice
  • Polymers - stretchability of polymer chains
  • Human soft tissue - composition of extracellular matrix
ELASTOGRAPHIC METHODS

Biomechanical Properties

Extracellular Matrix
ELASTOGRAPHIC METHODS

Physical Principles

• Acoustic (US) wave propagation:
  • Mechanical waves
  • Longitudinal vs. transverse waves

• Speed of sound in soft tissue: how elasticity is calculated
Physical Principles

Longitudinal waves
V = 1540 m/sec

Shear waves
V = 1 - 10 m/sec
ELASTOGRAPHIC METHODS

Physical Principles

009 ms
081 ms
1.63 ms
2.46 ms

Shear Waves - Schlieren Photography
Types of US Elastography

- Transient elastography: electromechanical
- Strain elastography (SE): human mechanical
- Acoustic radiation force impulse imaging: US crystal
- Shear wave elastography imaging: US crystal
ARFI: General Principles

- **Source:** focused ultrasound “push pulse”
- **Qualitative & quantitative (subjective/objective)**
- **More consistent & reproducible results**
- **Less operator dependent**
- **Data output:**
  - Displacement image (elastogram)
  - Quantitative data (kPa calculated from time of flight)
  - Both
ELASTOGRAPHIC METHODS

ARFI Elements

\[ t=0.3\text{ms} \quad t=2\text{ms} \quad t=4\text{ms} \]
ARFI Elements
SWE: General Principles

- Source: ARFI
- Qualitative & quantitative
- Real-time elastogram
- Data output:
  - Displacement image (requires ultrafast PRF)
  - Quantitative data (kPa calculated from time of flight)
  - Both
ELASTOGRAPHIC METHODS

SWE Elements

Real-time Elastogram
ELASTOGRAPHIC METHODS

SWE Elements

Quantitative Output

<table>
<thead>
<tr>
<th>Measurement</th>
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<tbody>
<tr>
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Clinical Applications

- Liver - chronic progressive disease
- Breast cancer
- Prostate cancer
- Thyroid cancer
- Gynecologic - ovary, uterus, tubes
- Obstetric - placenta
- Bowel
Virtual Histology

• General principles

• Research applications
  • Cardiology
  • Liver disease
Quantitative US technique

Uses RF backscatter for tissue characterization
- Magnitude and frequency distribution
- First order statistic properties of echo envelope as a signature of tissue microstructure

Imaging method: color-coded pixel mapping of different tissue types

Non-imaging method: IQ data off-boarded to software program (MATLAB)
Research Applications - Cardiology

- IVUS Virtual Histology
- Imaging method
- Transducer catheter passed over coronary guide wire
- Provides detailed histological analysis of plaque
- Plaque types
  - Fibrous
  - Fibrofatty
  - Necrotic core
  - Dense calcium
VIRTUAL HISTOLOGY

Research Applications - Cardiology

Dense Calcium
Research Applications - Liver Disease

- Quantitative assessment of non-alcoholic fatty liver disease (NAFLD)
- Non-imaging method
- Computer-aided analysis of IQ data
- Using hepatic/renal echo-intensity and attenuation ratios
- 89% accuracy compared to quantitative MRI
Viscoelasticity

- Energy source: ARFI
- Shear waves analyzed for dispersion of propagation speed
- Measures elasticity and viscosity using SDUV:
  - Shear wave dispersion ultrasound vibrometry
- Data output:
  - Quantitative measurements (kPa)
VISCOELASTICITY

Research Applications

- Urinary bladder
- Liver fibrosis
- Breast cancer
- Renal disease
Photoacoustic Imaging

- Hybrid biomedical imaging modality
- Energy source: laser pulses
- Light energy → Heat → Acoustic energy
- US waves detected by transducers
- Data is processed to produce images
- RF pulses may be used → thermoacoustic imaging
Photoacoustic Imaging

Courtesy: Canon Medical Imaging
Photoacoustic Imaging

Courtesy: University College London
PHOTOACOUSTIC IMAGING

Research Applications

• Angiogenesis and anti-angiogenic response
  • Cancer detection
• Microcirculation (physiology and pathology)
  • Tissue metabolism imaging
• Early response to chemotherapy
Vector Flow Imaging

- Energy source: ultrasound
- Speckle tracking
- Non-angle dependent real-time display of blood flow
- Data output:
  - Color Doppler image
  - Automated flow velocity measurements
  - Automated volume flow measurement
Vector Flow Imaging
Research Applications

- Cardiac hemodynamics
- Arterial vascular hemodynamics
- Intraoperative blood flow estimation in ascending aorta (TEE)
- 3D visualization of velocity vectors.
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