Ultrasound update—
Current concepts and principles including new techniques in US imaging

Ben Stenberg PhD
Consultant Sonographer
Newcastle upon Tyne
Standard model

• An ultrasound transducer is a straightforward concept but can be made perform amazing feats
• Crystal – matching layer – lens- tissue- reflection
A-mode to B-mode

• One crystal
• A-mode
  – The start of medical ultrasound
  – Lancet, 1958,
    – Donald, MacVicar, Brown,
    – Obstetrics/Gynae use

• Ovarian cyst
Real time B-mode

- Real time came in 1963. Vidoson, Siemens.
Real real-time
Manual elastography - frame rate

- Pictorial representation (pseudo-quantitative) of the compressibility of tissue using registration.
- Bounce the probe on the area of interest and see how much it squashes.
- Latest versions use respiration or arterial thump to generate strain.
Pixel tracking - frame rate

- Real time tracking of thousands of pixels
- Non-angle dependent
- Non-speed dependent

- Requires high frame rate in order to track pixel change
- Movement must be in plane.
Beam control

- Offset delay profile and you get beam steering
- Seeing “round corners”
- Compound imaging
- Focusing in the b-plane
• If you arrange crystals in both planes you can reduce beam thickness but also steer the beam in 3D.
**xPlane:** live dual plane imaging

- Truly unique to Matrix technology
- speeds up
  - examination time
  - perception of anatomical relationships
  - measurements
- xPlane significantly reduces
  - excessive wrist movement (>15%; RULA)
    - by an average of 70%
  - excessive pressure by operator
Matrix- Bi-plane imaging
xPlane: live dual plane imaging

• Acquire full 3d datasets in very rapid time
3DUS

• Not just baby faces
• Increased accuracy of volume measurement
  • Reduce error margins form 25% to 10%
• Reproducibility and full record of examination
• Speed up “on table” time
  • Obstetrics and Gynaecology examinations by 80%
    • Benacerraf et al, 2006, Three-dimensional US of the fetus: volume imaging, Radiology, 238 (3)
• Moves US to a CT/MRI model
  • Offline blind reporting as good as live scanning in detection of pathology
    • Stenberg and Elliott, 2010, Diagnosis of gallbladder problems using 3DUS, European Radiology, 20(4)
C-plane: renal artery origins
renal vasculature

L renal cell carcinoma

IVC tumour thrombus

infrarenal IVC

R renal vein

right renal vein
Imaging a renal cyst
Imaging a renal cyst

1mm slice intervals
3D - Automated segmentation

- Computer assisted processes
Foetal heart navigation

- Uses 3D US data and organ recognition to provide the standard heart views automatically.
- A computer model with standard anatomy and common anatomical variations is applied to the data. This can be done automatically or with minor assistance to detect the anatomical landmarks.
- The system can then provide the standard views of the foetal heart automatically using multi-planar reconstruction.
Auto-kidney MPR and segmentation

- Automatically detects the kidney within minimal or no input in over 90% of cases.
- Performing segmentation in under 1 second (average 0.85s)
- Using auto-segmentation can reduce intra- and inter-operator error margins from +/-10% for length and +/-25% for volume to under +/-1% (average 0.3%)
AAA segmentation

- Works 70% of the time with little or no input.
- 30% requires some user input
- Computer vs human had a correlation co-efficient of 0.98.
Frequency

• Change the frequency - change the resolution (and penetration)
Low frequency
High frequency
Guiding intervention

- Allows accurate intervention as well as diagnosis
High frequency probes
How do you snap a sternum?
Change in frequency - harmonics
Change in frequency - Doppler

- Uses the Doppler principle to detect a shift in frequency of returning sound from a moving object.

\[ f(d) = \frac{2}{C} f(t) V \cos \theta \]

- Power, colour and spectral all have their unique features and uses.
hepatic artery

Advanced Dynamic Flow
Toshiba, 2005
Superb Microvascular Imaging/MicroFlow Imaging

- High resolution and sensitivity Doppler ultrasound
- Good results in EVAR follow up.
- Cervical lymph nodes
- Kidney transplants
Power output

- Important in obstetrics – bone and tissue heating and cavitation (especially with contrast media)

- Exerts a force on the tissue
  - If that force is enough you can see or measure that effect
Shearwave Elasticity

- Sound travels faster through stiffer tissue.
- Pulse is passed through the area of interest causing ripples (shearwaves).
- Detection pulse detects the position of these waves and determines stiffness of tissue.
Shearwave elasticity

• Shearwave Elastography-attempt at quantification

• Validated in Hep B + C, sens (spec) 77% (81%) for F≥2 and 85 % (80%) for F4.

• This is comparable with fibroscan 76% (71%) and 79% (84%). (NICE, 2015)

• Can hugely reduce the need for liver biopsy in these patients.

NICE guidance: Virtual Touch Quantification to diagnose and monitor liver fibrosis in chronic hepatitis B and C, September 2015
Power output- HIFU

• High intensity focussed ultrasound
• Used in treating various diseases by causing focal heat and destroying tissue
• Can raise the temperature of the targeted tissue to 80-90 degrees Celsius in 2-3 seconds.
• Physios use ultrasound in muscle, tendon and ligament damage to stimulate repair
• Can be used for ablations in cancer, fibroids, etc.
Power output

• Important in obstetrics
• Exerts a force on the tissue
• But also in utilizing the concept of linear and non-linear reflectors react differently to changes in power output
• Bubbles of gas are a perfect example of a non-linear reflector
CEUS

- Tiny bubble of sulphur hexafluoride in a phospholipid shell.
- Each bubble smaller than a red blood cell.
- Resonate at abdominal ultrasound frequency to improve signal return.
CEUS

- NICE 2013 and EFSUM/WFUMB 2012 guidelines
- Proven to work well in echo and liver
- Now blunt trauma (esp. kids following FDA approval for use in children)
- GB, Kidneys, EVAR, anywhere where you want to know about blood flow
CEUS ex-vivo perfusion
However...

• Sometimes you are following up a lesion with CEUS, biopsy or ablation from MR or CT and you can’t find it.

• “If you can’t see it you can’t interrogate it.”

• Particularly important in Ablation in theatre where MRI, PET or CT may not be available

• Not any more...
• We have Fusion
How does it work?
Auto registration
Final product...
Case 1- making a difference

• 72 YO male with NASH Cirrhosis
• MRI shows HCC
• Co morbidities make transplantation unlikely
• Ablation is only curative treatment option
Baseline MRI
Could not see HCC due to macronodular cirrhosis.
Tried CEUS but without a lesion to focus on very patchy enhancement makes it impossible.
Automatically detects vessels in MRI dataset and 3D US sweep through liver
• CEUS confirms the fusion.
• Makes ablation under auto-registration MRI/US fusion with CEUS possible
Not just for livers...
Requirements for fusion guided intervention

- Hardware same as diagnostic but also need a needle tracker.
Putting it all together
Other uses of probe tracking

• Breast tracking solution.
Artificial intelligence

- Assisted diagnosis
- Auto-labelling
- Auto-imaging

36 seconds
Miniaturisation - US guided TORS
New fields in ultrasound

- Used routinely in vet surgeries but also used in rare species breeding programs such as white rhinos, panda, etc.
New fields in ultrasound
Drug and Gene therapy delivery

- Bursting micro-bubbles causes sonoporation.
- Temporary break-down of cell walls
- Allows micro-bubbles contents to pass out of the intravascular space and over cell membranes.
Targeted drug delivery

• Microbubbles can be filled with a range of substances.
• Original research used fluorescent tracers.
• Testing delivering clot busting drugs, anti-angiogenesis drugs direct to tumours, targeted ablations.
• Genetic imaging allows targeted ligands specific to the patient or tumours specific genetic code.
Future of US machine
Future direction

• Difficult to say as companies are reluctant to give anything away.
  • Computer assisted diagnosis/ measurement
  • Novel beam forming and post-processing with parallel processing for b-mode and Doppler
  • Different control methods (voice, transducer, gesture)
  • New contrast media for longevity and differing frequencies
  • Drug delivery
  • Ergonomics making machines smaller, lighter, faster

• We shall have to wait and see!
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