3D ULTRASOUND: Techniques and Applications

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DISCLOSURES: NONE

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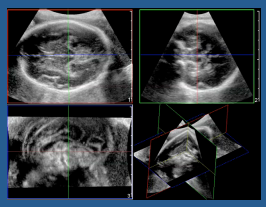
Lecture Outline

- Why use 3D Ultrasound?
- 3D Ultrasound:
  - Image Acquisition
  - Processing
  - Artifacts
- Clinical Utility
  - Neurologic
  - Genitourinary



Why Use 3D US?

- 2D US dependent on skill of operator
- Mental integration of multiple 2D images
  - inefficient
  - Subjective
  - Time-consuming
- 2D volume approximations sometimes not precise
- Reproduction of previous imaging planes for follow-up studies difficult

Benefits of 3D Acquisition

- Reduce probe time up to 60%
- Reduce potential rescans up to 50%
- Improve diagnostic confidence
- Improve physician workflow
- Improve throughput up to 30%

3D US Limitations

- 3D images depend on high-quality 2D datasets
  - Anisotropic
- Patient motion
- Field of View restrictions

Other Considerations

- Need for new machine / probes ($$)
- MD / Tech learning curve for 3D image processing and scan technique
- DICOM image output / PACS storage issues
- Reimbursement??
  - http://uscpt.gehealthcare.com/us_cpt/cpt.jsp

3D Image Acquisition

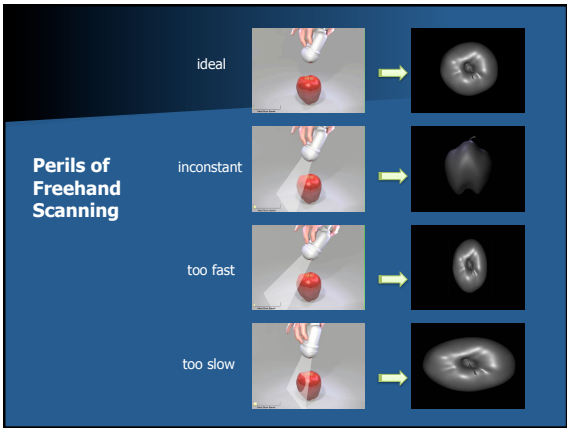
- 3D datasets derived from serial 2D US datasets, +/- positional information

OR:

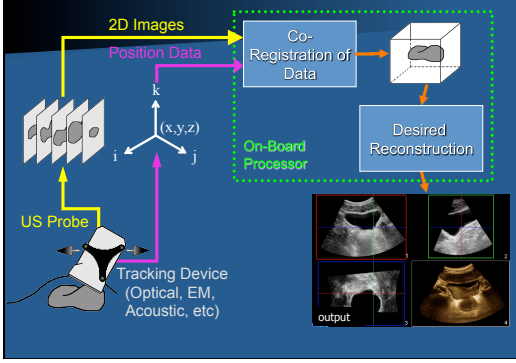
- True "volume" acquisition by 2D phased array transducer → pyramidal volume

Freehand Scanning

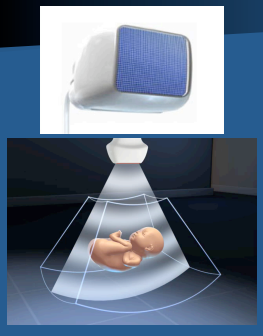
- Freehand Scanning without location co-registration
  - Assumes constant interval between 2D images
  - Measurements not reliable



Freehand Scanning with "GPS"



"Volume Transducers"

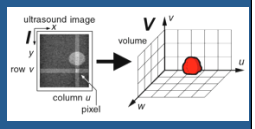


- Mechanically-steered arrays, OR
- 2D phased-array matrix transducer
  - Electronic scanning, transducer is stationary
  - ~2500 elements
  - Can display bi-plane images at full resolution
- Creates pyramidal scan volume
- Some resolution penalty for 4D

Image Reconstruction

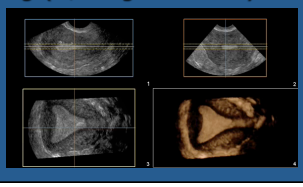
3D Reconstruction

- Feature-Based Reconstruction
  - Echo – ventricular volumes
  - IVUS
- Voxel-based Reconstruction
  - Cartesian grid of 2D data
  - Interpolation of voxels
  - Gaps >1/2 elevational resolution lead to spurious information



Display Options

- Surface Rendering
- Multiplanar Reconstruction (MPR)
- Cube View
- Volume Rendering (+/- segmentation)
- MIP / MINIP



3D US Artifacts

- Resolution Artifacts
- Attenuation Artifacts
- Propagation Artifacts
- Color / Power Doppler Artifacts
- Other (thresholding, rendering, etc)

Resolution Artifacts

- 2D US images are not isotropic
- 3D US recon assumes isotropy
- Resolution: depends on MHz, beam shaping, focus depth, etc.
  - Axial (in depth)
  - Lateral (side to side)
  - Elevational (plane thickness)
- Small structures may appear thicker

Attenuation Artifacts

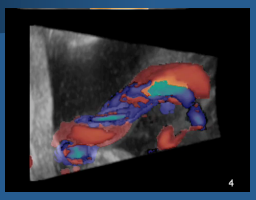
- 2D US artifacts are also seen at 3D
  - Shadowing
  - Acoustic enhancement
- 3D recon may yield unusual images
  - Shadowing →"cyst", truncated long bones
  - Signal enhancement → enlargement or ballooning of organ size
- MUST review 2D images!!
- Re-Scan 3D dataset in a different plane if ??

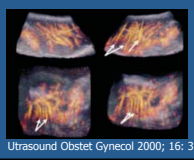
Propagation Artifacts

- Difference in expected / actual speed of sound in tissues
  - Esp. 2 adjacent tissues w/ marked difference
    - Water: 1540 m/s
    - Fat: 1450 m/s
  - Will distort shape of structure in planes other than original acquisition plane
- Newer algorithms can decrease distortion and improve image uniformity

Color / Power Doppler Artifacts

- Gain artifacts
  - See fewer or no patent vessels
- Directional artifacts
  - Flow toward and away
- Motion artifacts
  - Mimic vessels; cause not obvious on 3D





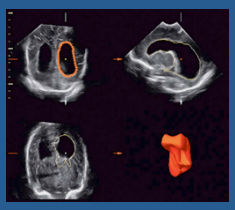
Utrasound Obstet Gynecol 2000; 16: 374-383

Utility of 3D US in Pediatrics

- Neurologic
- GU

Neonatal Brain

- Reformatted 3D datasets allow easy comparison to CT / MR data
- Measurement of ventricular volumes, tumors, cysts, infarcts more accurate and reproducible



Neonatal Brain

- Germinal matrix hemorrhage: shorter patient exam time*, more accurate than 2D
  - Less neonatal stimulation → Less hypoglycemia, hypoxia
- Less operator dependent

* Junewick JDMS 2007, 23:339-342

Intra-op Neurosurgery

- Pre-op CT/MR Co-registered to 3D US
- Improved precision and accuracy for tumor removal
  - Less normal tissue removed
  - Instant feedback on adequacy of resection

Roth Ped Neurosurg 2007; 43:185-191

Neonatal Ischemic Stroke

- 3D Power Doppler US can show vascular occlusions in neonates w/ ischemic stroke*
  - Clinical presentation of AIS may be non-focal
  - Underdiagnosed
- Can be done in NICU w/ no sedation or radiation

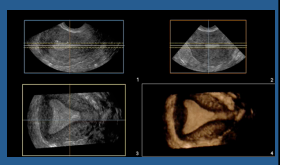
* Pogliani, et al. J. Clin. Imag. 2008; 32:141-143

Neonatal spine

- May allow better visualization of bony and neural defects in MM
- "Bird's Eye" surface rendering of bony pathology

GU Imaging

- Renal Volume
- Bladder Evaluation

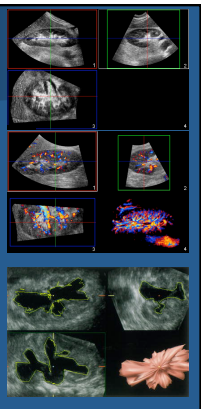


Renal Volumes – 2D US

- Measurements are based on estimates and volumetric assumptions
  - Assumptions do not hold true in irregularly-shaped or non-geometrical organs
  - Operator dependency can affect reproducibility

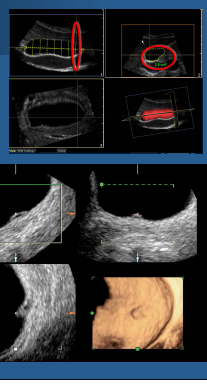
Renal Volumes – 3D US

- Measurement based on true renal volume (HYDRO)
- Especially important for irregularly shaped kidneys (e.g. infection, cysts)
- Volume measurement is as accurate as CT or MR
- Better inter- and intra- observer variation than 2D US
  - Follow-up changes more accurate



Bladder

- 3D US much more accurate for irregular shapes, also to calculate PVR
- Better F/U comparison
- "Virtual cystoscopy" can be performed for lesions



GU Caveats

- Small renal cysts / lesions missed by 3D US
- Parenchymal disease not as well viz.
- Patient motion is problematic
  - 10/80 non-dx studies*

* Riccabona, Eur Radiol 2003; 13: 2680-2687

Conclusions

- 3D US evaluation of pediatric patients is technically feasible and robust
- Volumetric measurements are more accurate and reproducible than 2D US
- Can cut patient imaging time (therefore environmental exposure) by 40-50% for some exams
- Must review 2D datasets!!

Thank You!!

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- Holly Schwab, RTRM, RDMS, RVT
- Laura Roth, RDMS, RVT
- Image Guidance Laboratories, Stanford University School of Medicine

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