3D/4D Pelvic Sonography: Instrumentation, Techniques and Clinical Applications

Arthur C. Fleischer, M.D.
Cornelius Vanderbilt Professor
Vanderbilt Medical Center
Depts of Radiology and Ob/Gyn

Disclosures/Acknowledgements

- I have no commercial conflicts of interest regarding this topic
- Some images c/o B Benacerraf, MD; A Lex, RDMS
  Philips Healthcare Medical Systems;
  B Carrano, GE

Press for more information and discussion.
Objectives

- Describe the techniques used in 3D, Tomographic Ultrasound Imaging (TUI), “live 3D” or 4D US
- Describe clinical applications of 3D US in ob/gyn
- Encourage thought/discussion
Clinical Applications
- Uterine malformations
- Endometrial polyps
- Fibroids, Adenomyosis
- Ovarian/Paraovarian masses
- Ectopic pregnancies
- Tubal disorders
- IUD localization
- Pelvic Floor Disorders

Transducer Development

<table>
<thead>
<tr>
<th>Type</th>
<th>Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical / Annular Array</td>
<td>2D, M-Mode, Doppler</td>
</tr>
<tr>
<td>Linear / Sector Electronic Array</td>
<td>2D, M-Mode, Doppler, Color Doppler</td>
</tr>
<tr>
<td>Curved Electronic Array</td>
<td>2D, M-Mode, Doppler, Color Doppler</td>
</tr>
<tr>
<td>Mechanical Curved / Linear Hybrid Array</td>
<td>2D, M-Mode, Doppler, Color Doppler, 3D/4D, MPR</td>
</tr>
<tr>
<td>2D Electronic Matrix Array</td>
<td>2D, M-Mode, Doppler, Color Doppler, 3D/4D, Biplane, MPR</td>
</tr>
</tbody>
</table>
New clinical optimization for 3D9-3v transducer

- Next generation volume imaging for transvaginal US
- New tissue specific imaging optimization for Gyn and OB applications with expanded 2D OPT control
- Improved contrast and detail resolution with new advanced XRES algorithm and harmonics
- Improved performance on deep pelvic structures
- Improved Doppler and color Doppler
- Improved volume imaging performance including new VISION settings (Dynamic Colorization)
Mechanical Array 3D Probe

Key terms
- Acquisition scan plane
- Multiplanar Reconstruction (MPR)
- Volumetric rendering
- Surface rendering
- Inversion rendition
- Selection of scan plane from volume
60 yo F presents with 6 months of vaginal bleeding.

Uterus with ascites (volume acquisition)
Normal ovary with follicles

PHILIPS

PHILIPS

OVARIAN VOLUME

OVARIAN VOLUME INVERT IMAGING
Uterine Malformations -important concepts-

- Septate uterus more common than bicornuate, assoc with reduced implantation
- Bicornuate uterus has fundal cleft
- Depict fundal contour on coronal to distinguish these
- Many variants of fusion anomalies - make sure to evaluate kidneys
Bicornuate uterus with rudimentary R horn

? Gestational sac within a bicornuate uterus (2D)

? Gestational sac within a bicornuate uterus (2D)
5 week IUP in a bicornuate uterus (coronal view-3D)

Twin Gestational Sacs within Subseptate Uterus (c/o BB)

Subseptate, 2 Cx’s (3D)
Uterus didelphys (3D)

Bicornuate/Bicollis Uterus

Bicollus (2 cervixes)
Normal on 2D

Unicornuate Uterus on 3D (c/o BB)

Intraluminal Disorders
- Polyps: delineate pedicle/feeding vessel(s)
- Synechiae
- Submucosal fibroids: evaluate extent of myometrial involvement
Polyp (3D)

3D of sessile polyp (loop of 3D)

Polyps
Polyp with vessels on 3D (c/o BB)

Vascular Polyp (c/o BB)

SHG using 3D
SHG-polyp (c/o BB)

SHG-Polyp Rendering (c/o BB)

SHG/polyp (3D)
Submucosal Fibroid (c/o BB)

Submucosal fibroid

Submucosal fibroid
Submucosal fibroid

3D US of IUDs
- Coronal view-show shaft and arms
- Shadow “under” the IUD
- Use 3D Tomosonography for “Lost IUD/string
- Merina IUD may be hard to see
- Rarely arms of IUD fail to deploy
- Rarely IUD ends up in C-section scar
- Failure to deploy IUD arms
Low IUCD (c/o BB)

Embedded low IUCD (c/o BB)

Embedded IUCD (c/o BB)
Uterine tract-s/p IUD insertion

Intraluminal Air

3D US of Pelvic Masses
- Use select planes of volume redtion
- Look for papillary excrescences both inside and capsular
- Comment on thinness of septa/wall
- 3DUS excellent for tubal/paratubal disorders-
  - hydrosalpinx
  - ectopic
  - tubo-ovarian complex
Cyst with fibrin strands (3D)

Septated Cyst (c/o BB)

Hemorrhagic cyst with formed clot (3D)
Thick, irregular septations

Ovarian Tumor- Papillary Excrescences (c/o BB)

Papillary cystadenoma (3D)
Papillary excresence (3D)

Live 3D/4D Matrix Array Probe
Dermoid cyst (c/o BB)

Hydrosalpinx (3D)

Hydrosalpinx (3D)
Hydrosalpinx-inversion mode (c/o BB)

R/O Ectopic (2D)

R/O Ectopic (3D)
Interstitial ectopic

Tips to make the dx of interstitial ectopic:
Use 3D

- Lateral chorionic sac
- Thin myometrial layer
- Empty uterine cavity

Left interstitial ectopic
Normal 6 wk IUP in an arcuate uterus

Composition of Solid Tumors

Tumor Neovascularity

Kuszyk, B., AJR, 177:747, 2001

McDonald, Choyke Nat Med 9:713, 2003
Ovarian Cancer (MPR/3D)

Microbubble Sonography-
FDA approved! (as of 4/1/16)

Microbubble US Contrast

Perfusion
Bolus injection of UCA

3D of murine ovary

Contrasted Ovarian Sonogram
3D Contrasted Ovarian Mass

3D Color Doppler Pelvic Sonography Applications
- Complete evaluation of pelvic mass
  - location, organ of origin
  - relation to other pelvic structures
  - vascularity
- Serial assessment of fibroids
- Evaluation of uterine malformations
- Detection of tubal abnormalities

3D Color Doppler Pelvic Sonography Instrumentation/Technique
- Freehand vs automated scanning
- Volume rendered image can be manipulated to emphasize internal contents of surface
- 3D “feel” by manipulating images
3D Color Doppler Pelvic Sonography

- Affords complete delineation of pelvic mass - its organ of origin and vascularity
- Affords depiction of areas not readily obtainable with 2D
- Allows accurate determination of volumetric changes of fibroids, pelvic masses
- Affords depiction or vascularity within uterus, ovaries, tubes
- Improves evaluation of uterine malformations

Endometrioma

TUMOR VASCULARITY PATTERNS

- Stellate terminal vessels
- Perforating vessels
- Intratumoral arteries & capillaries
- Intra-parenchymal vessels
3D Volumetric CDS

- Qualitative assessment of microvasculature
  - Vessel caliber
  - Vessel branching
- Quantitative assessment of microvasculature
  - Vascular Index
  - Flow Index
  - Vascular Flow Index

Quantification of Vascularity

- Vascularity Index=% pixels/voxels with color/total
- Flow Index=power weighted pixel/voxel density/total
- Vascularity/Flow Index=product of VI x FI
- Fractal dimension
- Vessel branching/caliber

3D CDS of Ovarian Masses (Alcazar, J JUM 28:275, 2009)

Helps reduce false-positives
3D CDS of Ovarian Masses (Alcazar, J JUM 28:275, 2009)
- V.I.-sens 92%; spec 33%
- F.I.-sens 95%; spec 33%
- V.F.I.-sens 94%; spec 33%
- Helps reduce false-positives
Papillary serous Ca with feeding vessel

Tumor neovascularity

A Micro-aneurysm  C Abnormal branching
B Stenosis       D Venous lake
Conclusions
- 3D pelvic sonography has many applications including uterine (myometrial and endometrial) and adnexal (ovarian and tubal) disorders
- Best used as problem-solver
- Potential to obtain volumetric images
  - This has major operational implications -
    - Obtain Volume-then pick which slices important—improve "thru-put"?
  - THINK ABOUT THIS!!!!

3D Transperineal Sonography for Pelvic Floor Disorders (short version-overview)

Pelvic Floor Disorders and what you'd expect to see with TPS
- Stress urinary incontinence
  - Funneling of internal urethral meatus on Valsalva or at rest
  - Retroversical angle gr than 160 degrees on Valsalva
  - Bladder neck descent gr than 2.5 mm on Valsalva
- Pelvic organ prolapse
  - Movement of pelvic organs below reference line
  - (TPS more subjective than MR POPS)
- Fecal incontinence
  - Thinning/disruption of int/ext anal sphincters
Pelvic Floor Disorders, cont’d.

- Post op assessment of prolapse and/or incontinence surgery complications
- Status of bladder neck s/p culposuspension
  - depiction of tape/mesh i.e. - TVT, TOT (Monarc), Perigee, Apogee
  - depiction of injected bulking agents i.e. - Mastoplastique


- Effect up to 50% of postmenopausal women
- Of these, 10-20% will be symptomatic
- Of affected women, 1 in 10 will have surgery
- Over next 30 years, there is a projected 45% increase in demand

Pelvic Diaphragm (as viewed from below)

- Levator ani muscles
- Pubovisceral “complex” mm
  - Pubococcygeus m
  - Endopelvic fascia
  - Ligaments
Normal Pelvic Floor Dynamics
As Depicted with 3D TPS
Standard acquisition screen of 3D(4D) Transperineal Sonography

A and B show rectocele to be typically located at the anorectal junction and symmetrical. C and D illustrate that it occupies a very substantial part of levator hiatus.

Rectocele on 3D transperineal US

Suburethral slings as seen on TPS – midsagittal plane

Tranretzius (A) and transobturator (C) slings are essentially indistinguishable. Both are echogenic and located dorsal to midurethra.
Suburethral slings as seen on 3D TPS – axial plane

The distinction between slings is quite obvious in the axial plane. In B, a tension-free vaginal tape (TVT) is curving ventrally toward symphysis pubis, whereas in D, a Monarc tracks laterally toward insertion of puborectalis muscle and obturator foramen.

Rendered volume (axial plane) of typical unilateral avulsion

Prior insertion of muscle (long arrow), now completely devoid of any hyperechogenic tissue, and retracted puborectalis muscle (short arrow).

Right-sided avulsion of the puborectalis muscle

Delivery-related levator trauma as seen on exploration of large vaginal tear after vaginal delivery.

As imaged on 3D TPS.

As imaged on MR.
Quantification of trauma on multislice/tomographic ultrasound imaging (TUI)

Typical right-sided levator defect (*) measuring about 2 cm (dorsoventral) width and at least 1.75 cm in (craniocaudal) depth as it is apparent in all 8 slices.

Internal/external anal sphincters

Internal/external anal sphincters
Pelvic floor disorders are a common and complex problem
- Transperineal Sonography affords real-time (dynamic) imaging as well as 3D/4D and can visualize tape/slings/mesh
- TPS enables better understanding of the dynamics and potential treatment of pelvic floor disorders
Acknowledgements

- B. Benacerraf, MD, R. Andreotti, MD, G Sacks, MD, A. Lyshchik, MD, PhD.
- L Sheets, RDMS, S Rivers, RDMS, L Pertl, RDMS, P Kalman, RDMS, A Lex, RDMS (Philips Medical Systems)
- K Tisdale, RDMS, P Williams, RDMS, M Davis, RDMS and all VUMC and CWI sonographers

Think in 3D/4D!