Three Dimensional Ultrasound in Obstetrics

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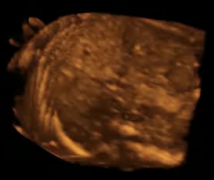
Outline

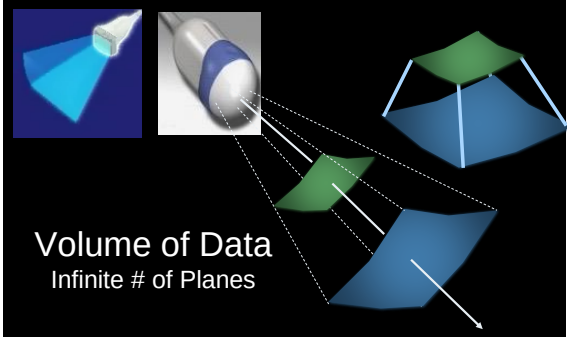
- What is 3D ultrasound?
- How to optimize your 3D image?
- Provide you with 10 compelling clinical advantages of 3D ultrasound in the Ob practice?
- Highlight the scientific evidence for 3D over 2D in Obstetric ultrasound?
- Present my view into the future of 3D

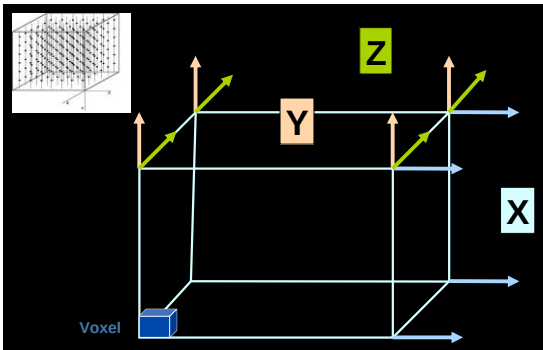
What is 3D ultrasound ?

2D US 3D US

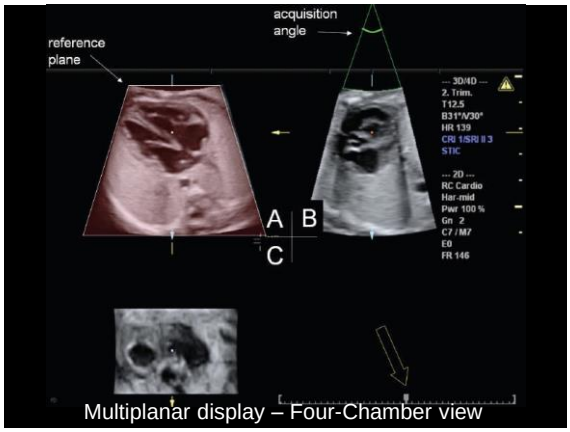


3D Ultrasound

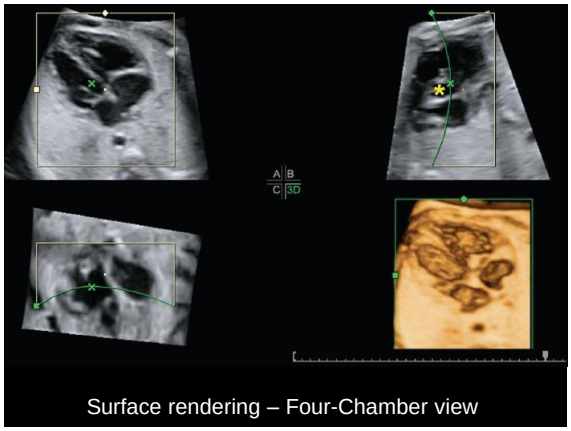




Volume Sonography



Multiplanar display – Four-Chamber view



Surface rendering – Four-Chamber view

How to Optimize Your 3D Image?

- Minimize the depth on the screen
- Narrow the sector width
- Adjust the focal zone to the target level
- Avoid shadowing by skeleton
- Enhance 2D image first
- Place your acquisition box close to target organ
- Maximize speed of acquisition

How to Optimize Your 3D Image?

- In general, the darker the amniotic fluid – the better your 3D volume (surface rendering and resolution in planes B and C)

How to Optimize Your 3D Image?

Amniotic Fluid

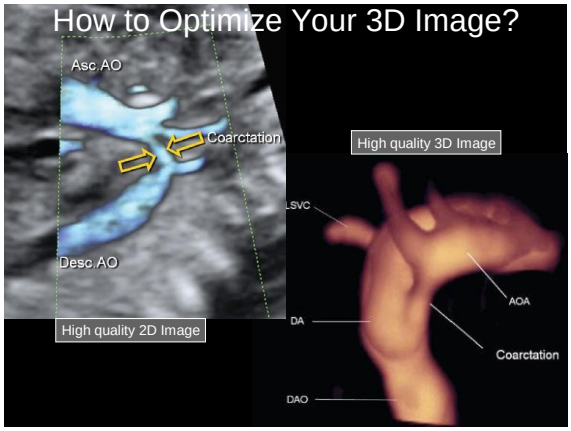
How to Optimize Your 3D Image?

How to Optimize Your 3D Image?

What The Experts Don't Tell You:

- The quality of 3D is so much dependent on the quality of 2D imaging in all its aspects –
- Major limitation of current 3D ultrasound

How to Optimize Your 3D Image?

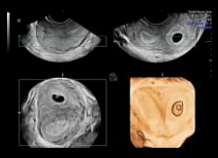


advantages of 3D US ?

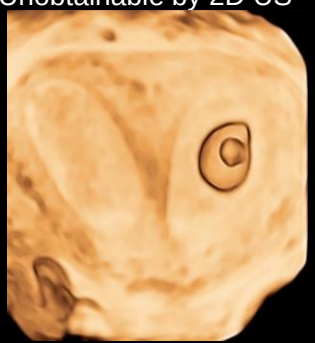
Advantages of 3D Ultrasound

1- Review Planes Unobtainable by 2D Ultrasound

Review Planes Unobtainable by 2D US



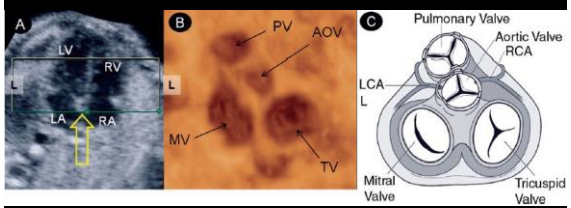
	Sensitivity	Specificity
Ultrasound 3D	98-100%	100%
MR	28.6-100%	66-100%



Coronal view of uterus - Septate

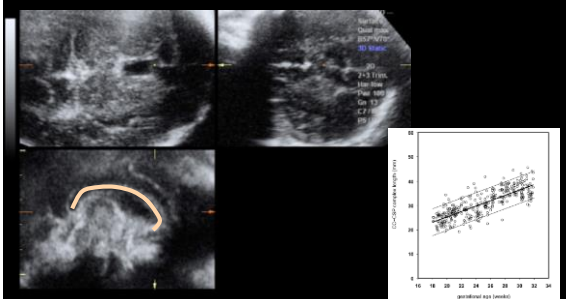
J Ultrasound Med. 2008;27:413-23.

Review Planes Unobtainable by 2D US



Surface rendering – cardiac valves

Review Planes Unobtainable by 2D US



Mid-Sagittal plane of fetal brain

Normal Length of CC

J Ultrasound Med 2011;30:47-53

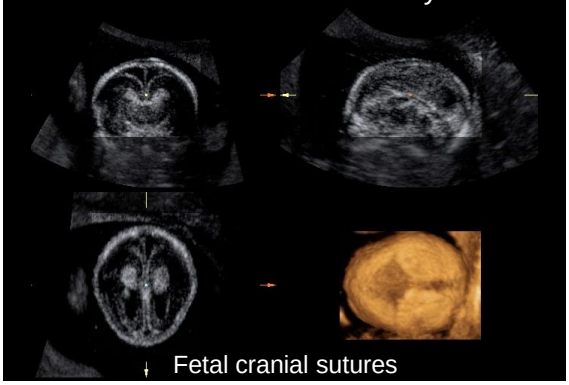
Review Planes Unobtainable by 2D US

Midline Anomalies of Fetal Brain

- 3D median planes are more easily obtained
- Allow for accurate diagnosis of anomalies
- Valuable approach for rapid assessment of corpus callosum and cerebellar vermis

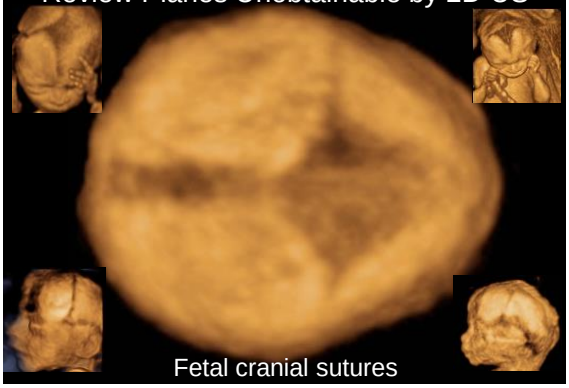
Ultrasound Obstet Gynecol, 2006 Oct;28(5):742
Ultrasound Obstet Gynecol 2012; 39:279-287

Review Planes Unobtainable by 2D US



Fetal cranial sutures

Review Planes Unobtainable by 2D US



Fetal cranial sutures

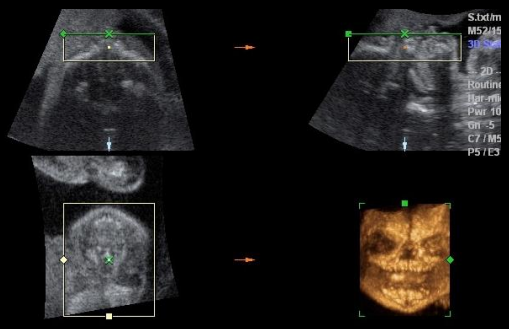
Review Planes Unobtainable by 2D US

Fetal Cranial Sutures

- Patterns of normal and abnormal development described
- Premature closure of coronal sutures in Apert syndrome
- Development of sutures in Trisomy 21 described

Ultrasound Obstet Gynecol, 2006 Mar;27(3):286
Ultrasound Obstet Gynecol, 2006 Jan;27(1):28
Ultrasound Obstet Gynecol, 2005 Dec;26(7):761

Review Planes Unobtainable by 2D US



Fetal lip and palate

Review Planes Unobtainable by 2D US

Fetal lip and palate

Review Planes Unobtainable by 2D US

Fetal lip and palate

Review Planes Unobtainable by 2D US

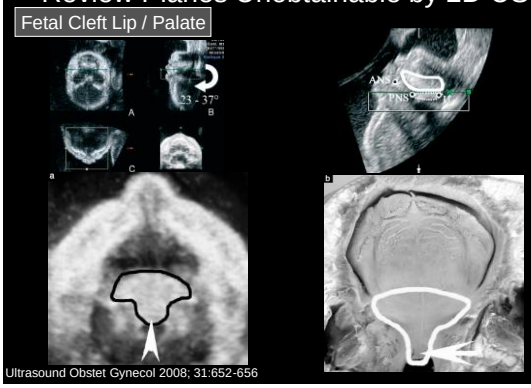
Fetal Cleft Lip / Palate

- Flipped face view
- Reverse face view
- Underside view
- 30º inclined axial view

Ultrasound Obstet Gynecol 2007 Feb;29(2):159 - Ultrasound Obstet Gynecol 2005 Jan;25(1):12
J Ultrasound Med 2006 Nov;25(11):1423 - Ultrasound Obstet Gynecol 2008; 31:652-656

Review Planes Unobtainable by 2D US

Fetal Cleft Lip / Palate



Ultrasound Obstet Gynecol 2008; 31:652-656

Review Planes Unobtainable by 2D US

Fetal Cleft Lip / Palate

- Prospective study, low risk
- 1856 second trimester pregnancies
- Diagnosis at first scan:
  87 % (3D) vs 78 % (2D)

J Evid Based Dent Pract 2006 Dec;6(4):278

Review Planes Unobtainable by 2D US

Fetal Facial / Neck Anomalies

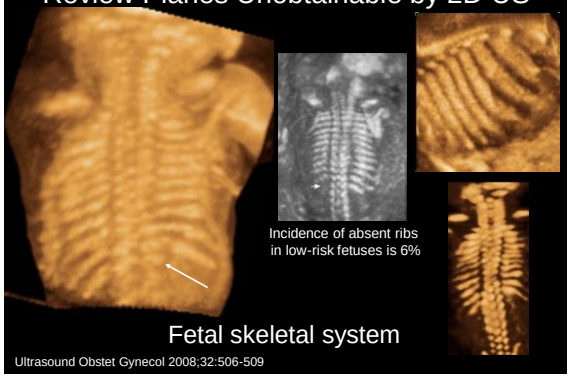
Table 2. Diagnostic Accuracy of 3D/4DUS and 2DUS in Detecting 131 Anomalies in Fetuses With Trisomy 18

	Sensitivity, %		PPV, %	
Anomalies	3D/4DUS	2DUS	3D/4DUS	2DUS
CNS	96.55	86.21	80	75.76
Face/neck	100.0[a]	65.38	78.13	77.27
Abdomen	92.86	85.71	86.67	85.71
Extremities	96.3a	48.15	89.66	81.25
Chest	80	60	92.31	90
Other	95	100	100	100
Total	93.89[a]	73.28	86.01	83.47

PPV indicates positive predictive value.
[a]$P < .05$.

J Ultrasound Med 2008; 27: 1041-1051

Review Planes Unobtainable by 2D US



Incidence of absent ribs in low-risk fetuses is 6%

Fetal skeletal system

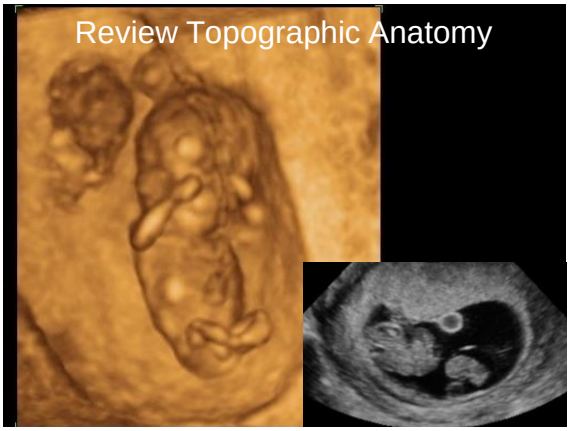
Ultrasound Obstet Gynecol 2008;32:506-509

Advantages of 3D Ultrasound

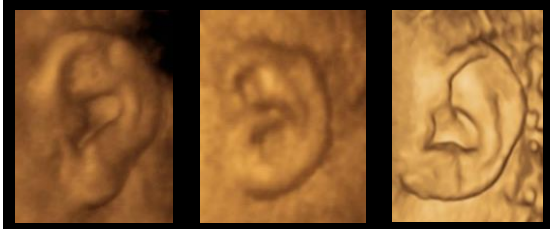
2- Review Topographic Anatomy (skin)

Review Topographic Anatomy

Review Topographic Anatomy



Review Topographic Anatomy



Fetal Ears

Review Topographic Anatomy

Fetal Extremities

Review Topographic Anatomy

Fetal Extremities

Review Planes Unobtainable by 2D US

Fetal Extremities

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Chest	80	60	92.31	90
Other	95	100	100	100
Total	93.89[a]	73.28	86.01	83.47

PPV indicates positive predictive value.
[a] $P < .05$.

J Ultrasound Med 2008; 27: 1041-1051

Review Topographic Anatomy

Fetal Chest

Advantages of 3D Ultrasound

3- Rotate Volumes To View All Sides

Rotate Volumes to View all Sides

Normal Fetal Face

Advantages of 3D Ultrasound

4- Highlight Elements Within Volumes

Highlight Elements Within Volumes

Fetal Achondrogenesis

Highlight Elements Within Volumes

Prune Belly Syndrome

Highlight Elements Within Volumes (Inverse Mode)

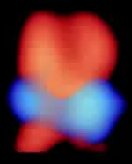
Prune Belly Syndrome

Advantages of 3D Ultrasound

5- Better Display of Vasculature within Volumes or Organs

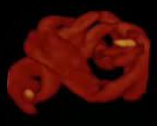
Display of Vasculature

11 wks



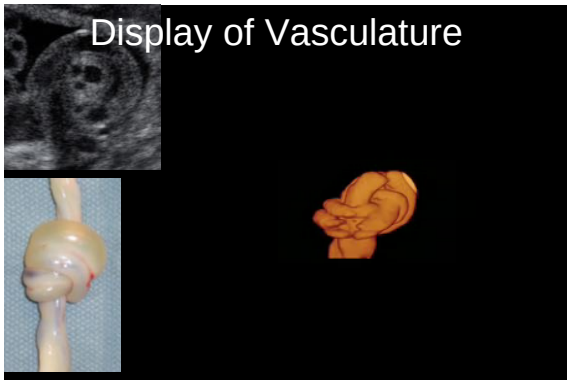
4-Chamber View - Normal

Display of Vasculature



True Knot in Cord – Loose Knot

Display of Vasculature

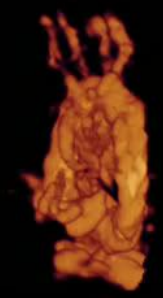


True Knot in Cord – Tight Knot

Display of Vasculature

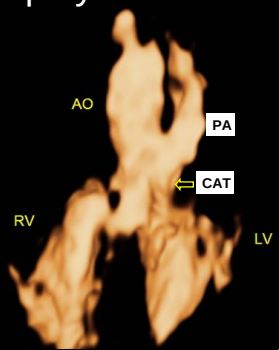
Conjoined Twins

Display of Vasculature



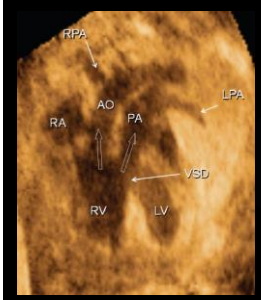
Conjoined Twins - Vasculature

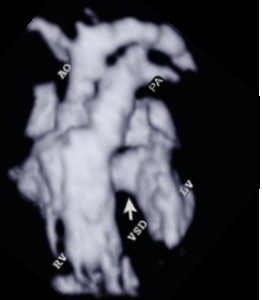
Display of Vasculature



CAT – Inverse mode

Display of Vasculature

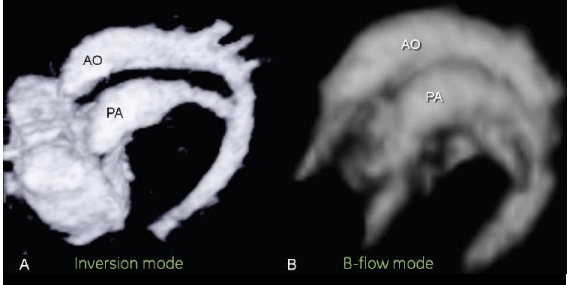




DORV

From Practical Guide To Fetal Echocardiography – Abuhamad, Chaoui – 2nd Edition

Display of Vasculature

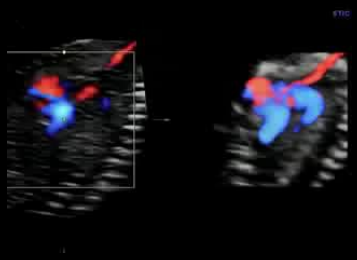


TGA

From Practical Guide To Fetal Echocardiography – Abuhamad, Chaoui – 2nd Edition

Display of Vasculature

12 wks



Coarctation of the aorta

Advantages of 3D Ultrasound

6- Enhanced Accuracy of Organ Volume Measurements

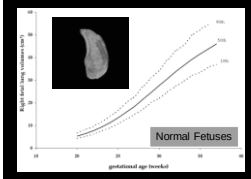
Volume Measurements

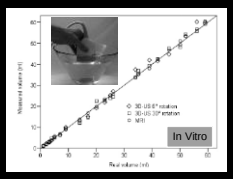
Lung Volume / Pulmonary Hypoplasia

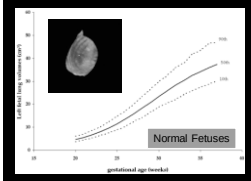
- 3D US had best diagnostic accuracy
- PPV: 100%, NPV: 92%
- Superior to 2D biometric parameters

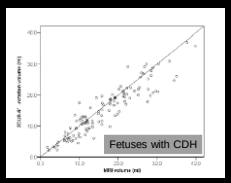
Prenat Diagn, 2007 Mar;27(3):216

Fetal Lung Volumes









J Ultrasound Med 2006:25;701 – J Ultrasound Med 2011; 30:1539-45 – J Ultrasound Med 30:1085-91

Volume Measurements

Accuracy

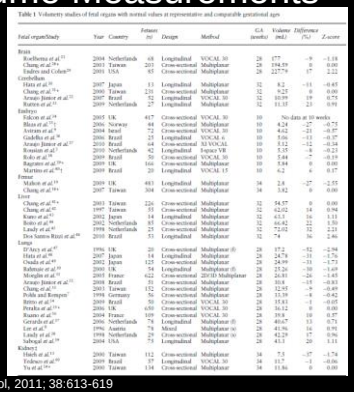


Table 1 Volumetry studies of fetal organs with normal values at representative and comparable gestational ages

Fetal organ/Study	Year	Country	Fetuses (n)	Design	Method	GA (weeks)	Volume (mL)	Difference (%)	Z-score
Brain									
Roelfsema et al.[33]	2004	Netherlands	68	Longitudinal	VOCAL 30	28	577	−9	−1.16
Chang, et al.[34]	2003	Taiwan	203	Cross-sectional	Multiplanar	28	194.59	8	0.00
Endres and Cohen[29]	2001	USA	95	Cross-sectional	Multiplanar	28	227.78	17	2.22
Cerebellum									
Ohno et al.[35]	2007	Japan	53	Longitudinal	Multiplanar	32	8.2	−11	−0.65
Chang et al.[34]	2000	Taiwan	231	Cross-sectional	Multiplanar	32	9.25	0	0.00
Arnaiz-Jiménez et al.[32]	2007	Brazil	52	Longitudinal	VOCAL 30	32	10.99	19	0.75
Rutten et al.[31]	2009	Netherlands	27	Longitudinal	Multiplanar	32	11.35	23	0.98
Embryo									
Edcon et al.[36]	2005	UK	417	Cross-sectional	VOCAL 30	10	No data at 10 weeks		
Blaas et al.[37]	2006	Norway	44	Cross-sectional	VOCAL 30	10	4.24	−27	−0.75
Ivitzen et al.[5]	2004	Israel	72	Cross-sectional	VOCAL 30	10	4.42	−23	−0.57
Gadelha et al.[38]	2006	Brazil	25	Longitudinal	VOCAL 6	10	5.06	−13	−0.37
Arnaiz-Jiménez et al.[32]	2010	Brazil	64	Cross-sectional	3D VOCAL	10	5.12	−12	−0.34
Rousian et al.[3]	2010	Netherlands	42	Longitudinal	I-space VR	10	5.35	−8	−0.23
Rolo et al.[39]	2009	Brazil	50	Cross-sectional	VOCAL 30	10	5.44	−7	−0.19
Ragavan et al.[40]	2009	UK	166	Cross-sectional	Multiplanar	10	5.84	0	0.00
Martins et al.[41]	2009	Brazil	20	Longitudinal	VOCAL 15	10	6.2	6	0.17
Femur									
Mahon et al.[19]	2009	UK	693	Longitudinal	Multiplanar	34	2.8	−27	−2.55
Chang, et al.[34]	2007	Taiwan	304	Cross-sectional	Multiplanar	34	3.82	0	0.00
Liver									
Chang, et al.[34]	2003	Taiwan	226	Cross-sectional	Multiplanar	32	54.57	0	0.00
Chang, et al.[42]	1997	Taiwan	55	Cross-sectional	Multiplanar	32	62.02	14	0.94
Kuno et al.[43]	2002	Japan	54	Longitudinal	Multiplanar	32	63.5	16	1.11
Bolio et al.[44]	2002	Netherlands	85	Cross-sectional	Multiplanar	32	66.42	22	1.50
Lerady et al.[45]	1998	Netherlands	25	Cross-sectional	Multiplanar	32	72.02	32	2.23
Dos Santos Rizzi et al.[46]	2010	Brazil	53	Longitudinal	Multiplanar	32	74	36	2.46
Lungs									
D'Ercy et al.[47]	1996	UK	20	Cross-sectional	Multiplanar (I)	28	57.2	−32	−2.94
Hata et al.[48]	2007	Japan	54	Longitudinal	Multiplanar	28	24.78	−31	−1.76
Osada et al.[49]	2002	Japan	125	Cross-sectional	Multiplanar	28	24.99	−31	−1.73
Rabinjan et al.[50]	2000	UK	54	Longitudinal	Multiplanar (I)	28	27.26	−30	−1.69
Mongilin et al.[51]	2005	France	622	Cross-sectional	2D/3D Multiplanar	28	26.81	−26	−1.45
Arnaiz-Jiménez et al.[32]	2008	Brazil	51	Cross-sectional	Multiplanar	28	30.8	−15	−0.83
Chang, et al.[34]	2003	Taiwan	152	Cross-sectional	Multiplanar	28	32.95	−9	−0.49
Wilda and Rempen[52]	1998	Germany	50	Cross-sectional	Multiplanar	28	34.35	−5	−0.29
Brito et al.[53]	2009	Brazil	70	Cross-sectional	VOCAL 30	28	35.82	0	0.00
Rolo et al.[39]	2009	Brazil	650	Cross-sectional	VOCAL 30	28	35.82	0	0.00
Ruano et al.[54]	2004	France	109	Cross-sectional	VOCAL 30	28	39.8	10	0.57
Gerards et al.[55]	2006	Netherlands	78	Longitudinal	Multiplanar (I)	28	40.67	13	0.71
Lee et al.[9]	1996	Austria	78	Mixed	Multiplanar (o)	28	41.96	16	0.91
Lerady et al.[56]	1998	Netherlands	29	Cross-sectional	Multiplanar (o)	28	42.28	17	0.96
Subrajali et al.[28]	2004	USA	73	Longitudinal	Multiplanar	28	43.3	20	1.11
Kidney									
Hsieh et al.[57]	2000	Taiwan	112	Cross-sectional	Multiplanar	34	7.5	−37	−1.74
Tedesco et al.[58]	2009	Brazil	57	Longitudinal	VOCAL 30	34	11.7	−1	−0.06
Yu et al.[59]	2000	Taiwan	134	Cross-sectional	Multiplanar	34	11.86	0	0.00

Ultrasound Obstet Gynecol, 2011; 38:613-619

Advantages of 3D Ultrasound

7- Enhanced Estimation of Fetal Weight

3D Ultrasound

Estimation of Fetal Weight

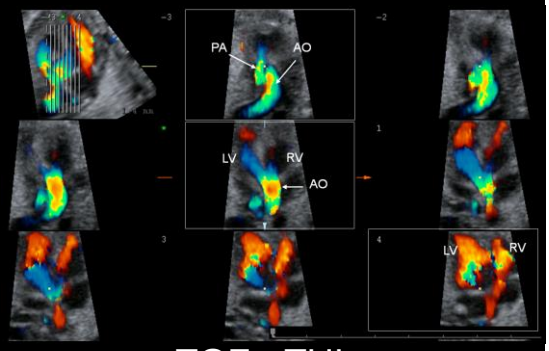
- Fractional limb volume (EFW)
- Upper arm volume (IUGR)

J Ultrasound Med. 2001 Dec;20(12):1283
Ultrasound Med Biol. 2005 Nov;31(11):1435

Advantages of 3D Ultrasound

8- Display of Multiple Planes in One View

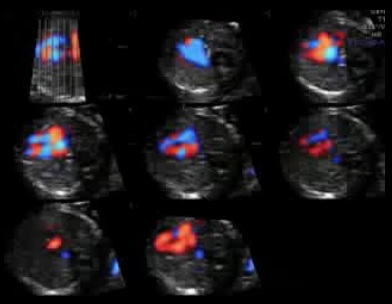
Display of Multiple Planes in One View



TOF - TUI

Display of Multiple Planes in One View

11 wks



Advantages of 3D Ultrasound

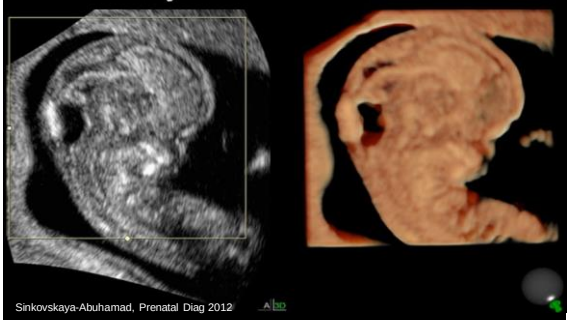
9- Enhanced Display of 2D Ultrasound

Enhance Display of 2D Planes

Pentalogy of Cantrell

Enhance Display of 2D Planes

Dandy Walker – 11 weeks

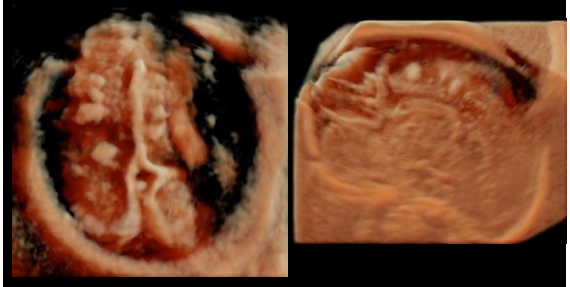


Sinkovskaya-Abuhamad, Prenatal Diag 2012

Enhance Display of 2D Planes

Tuberous Lesions - Brain

Enhance Display of 2D Planes



Tuberous Lesions - Brain

Advantages of 3D Ultrasound

10- Ability to submit Volumes for Remote Expert Review

Submit 3D Volumes for Review

CNS Anomalies

Table 2. Diagnostic Indices of 3-Dimensional Volumes in the Identification of Fetal Central Nervous System Anomalies

Volumes	Sensitivity, %	Specificity, %	PPV, %	NPV, %	FP, %	FN,%
All	93.3	96.5	96.5	93.3	3.5	6.7
Transabdominal acquisition	93.6	98.3	98.3	93.5	1.7	6.5
Transvaginal acquisition	92.0	94.5	96.8	86.7	3.2	13.3
Gestational age 18–24 wk	92.2	96.8	96.5	92.9	3.5	7.1
Gestational age 24–30 wk	98.4	93.6	96.4	97.2	3.6	2.8

FN indicates false-negative rate; FP, false-positive rate; NPV, negative predictive value; and PPV, positive predictive value.

Table 3. Diagnostic Indices of Different Central Nervous System Anomalies Identified by 3-Dimensional Volumes

Anomaly	Sensitivity, %	Specificity, %	PPV, %	NPV, %	FP, %	FN,%
Ventriculomegaly hydrocephaly	85.6	96.5	87.4	95.9	12.6	4.1
Corpus callosum anomalies	89.5	96.5	82.5	98.0	17.5	2.0
Posterior fossa anomalies	87.2	96.5	81.3	97.7	18.7	2.3
Holoprosencephaly	100.0	96.5	52.6	100.0	47.4	0.0
Neural tube defects	92.3	96.5	76.9	99.0	23.1	1.0
Cystic lesions	95.0	96.5	61.3	99.7	38.7	0.3
Cavum septi pellucidi anomalies	94.3	96.5	64.7	99.6	35.3	0.4
Other	70.0	96.5	53.8	98.2	46.2	1.8

FN indicates false-negative rate; FP, false-positive rate; NPV, negative predictive value; and PPV, positive predictive value.

J Ultrasound Med 2011;30:1003-8

3D Ultrasound

What is My View of the Future of 3D Ultrasound?

2 Important Concepts in 3D Sonography

3D Ultrasound

Concept 1:

Acquired volume of a structure contains all the anatomical 2D planes for a complete evaluation of this structure

3D Ultrasound

Concept 2:

For every organ, 2D anatomical planes that are needed for a complete evaluation are organized in a constant anatomic relationship to each others.

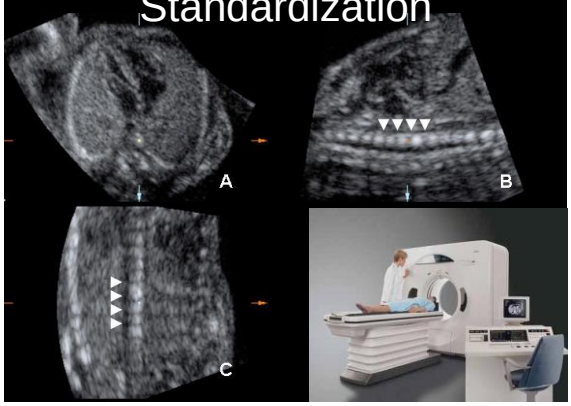
3D Ultrasound

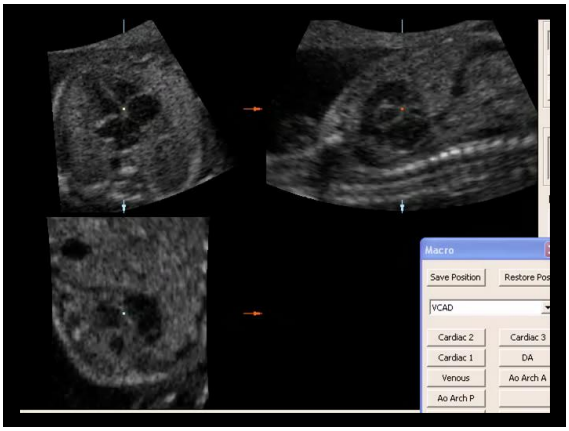
Obtain a volume of an organ

Computerized program to automatically display all 2D planes that are required for a complete evaluation of this particular organ.

Automated Sonography

Standardization





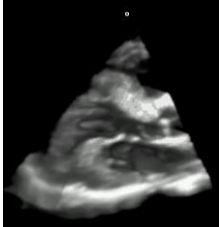
3D Ultrasound

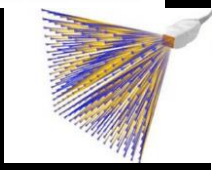
Will Lead to:

- Standardization
- Simplification
- Automation

of the ultrasound examination

Advanced 3D Probes





http://www.cardiovascularultrasound.com/content/1/1/12/suppl/S2
http://wikiradiography.com/page/Ultrasound+physics?t=anon

3D Ultrasound

- Optimization of display of 3D ultrasound is dependent on the quality of the 2D image
- Several 3D ultrasound clinical applications exist in advanced obstetrical imaging
- Future of 3D technology is promising especially in the field of ultrasound automation