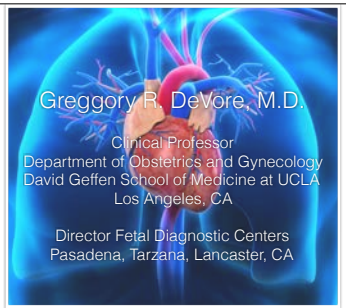


Evaluating Cardiac Function of the Four-Chamber View in Fetuses with IUGR: New Perspectives

We shall not cease from exploration. And the end of all our exploring will be to arrive where we started and know the place for the first time.

T.S. Eliot

Putting It All Together

1: Hobbins JC, Gumina DL, Zaretsky M, Driver C, Wilcox A, DeVore GR. Size and Shape of the Four-Chamber View of the Fetal Heart in Fetuses with an Estimated Fetal Weight Less than the Tenth Centile. Am J Obstet Gynecol. 2019 Nov;221(5):495.e1-495.e9.]

2: DeVore GR, Gumina DL, Hobbins JC. Assessment of Ventricular Contractility in Fetuses with an Estimated Fetal Weight Less than the Tenth Centile. Am J Obstet Gynecol. 2019 Nov;221(5):498.e1-498.e22

3: DeVore GR, Jone PN, Satou G, Sklansky M, Cuneo BF. Aortic Coarctation: A Comprehensive Analysis of Shape, Size, and Contractility of the Fetal Heart. Fetal Diagn Ther. 2019 May 27:1-11.

4: DeVore GR, Klas B, Satou G, Sklansky M. Evaluation of Fetal Left Ventricular Size and Function Using Speckle-Tracking and the Simpson Rule. J Ultrasound Med. 2019 May;38(5):1209-1221

5: DeVore GR, Klas B, Satou G, Sklansky M. Speckle Tracking of the Basal Lateral and Septal Wall Annular Plane Systolic Excursion of the Right and Left Ventricles of the Fetal Heart. J Ultrasound Med. 2019 May;38(5):1309-1318

6: DeVore GR, Cuneo B, Klas B, Satou G, Sklansky M. Comprehensive Evaluation of Fetal Cardiac Ventricular Widths and Ratios Using a 24-Segment Speckle Tracking Technique. J Ultrasound Med. 2019 Apr;38(4):1039-1047

7: DeVore GR, Klas B, Satou G, Sklansky M. Quantitative evaluation of fetal right and left ventricular fractional area change using speckle-tracking technology. Ultrasound Obstet Gynecol. 2019 Feb;53(2):219-228.

8: DeVore GR, Zaretsky M, Gumina DL, Hobbins JC. Right and left ventricular 24-segment sphericity index is abnormal in small-for-gestational-age fetuses. Ultrasound Obstet Gynecol. 2018 Aug;52(2):243-249.

9: DeVore GR, Klas B, Satou G, Sklansky M. Longitudinal Annular Systolic Displacement Compared to Global Strain in Normal Fetal Hearts and Those With Cardiac Abnormalities. J Ultrasound Med. 2018 May;37(5):1159-1171

10: DeVore GR, Klas B, Satou G, Sklansky M. Twenty-four Segment Transverse Ventricular Fractional Shortening: A New Technique to Evaluate Fetal Cardiac Function. J Ultrasound Med. 2018 May;37(5):1129-1141.

11: DeVore GR, Klas B, Satou G, Sklansky M. 24-segment sphericity index: a new technique to evaluate fetal cardiac diastolic shape. Ultrasound Obstet Gynecol. 2018 May;51(5):650-658

12: DeVore GR, Klas B, Satou G, Sklansky M. Evaluation of the right and left ventricles: An integrated approach measuring the area, length, and width of the chambers in normal fetuses. Prenat Diagn. 2017 Dec;37(12):1203-1212.

13: DeVore GR, Satou G, Sklansky M. Abnormal Fetal Findings Associated With a Global Sphericity Index of the 4-Chamber View Below the 5th Centile. J UltrasoundMed. 2017 Nov;36(11):2309-2318.

14: DeVore GR, Satou G, Sklansky M. Area of the fetal heart's four-chamber view: a practical screening tool to improve detection of cardiac abnormalities in a low-risk population. Prenat Diagn. 2017 Feb;37(2):151-155

15 DeVore GR, Tabsh K, Polanco B, Satou G, Sklansky M. Fetal Heart Size: A Comparison Between the Point-to-Point Trace and Automated Ellipse Methods Between 20 and 40 Weeks' Gestation. J Ultrasound Med. 2016 Dec;35(12):2543-2562.

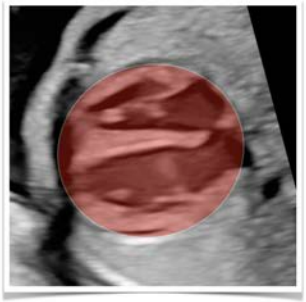
16: DeVore GR, Polanco B, Satou G, Sklansky M. Two-Dimensional Speckle Tracking of the Fetal Heart: A Practical Step-by-Step Approach for the Fetal Sonologist. J Ultrasound Med. 2016 Aug;35(8):1765-81.

2015 to Present
Published 16 Peer-Reviewed Papers

What Should Be Evaluated in the Fetal Heart?

What Should Be Evaluated?

1. Shape and Size of the 4-Chamber View
2. Shape, Size and Contractility of the Ventricles



What Should Be Evaluated?

1. Shape and Size of the 4-Chamber View

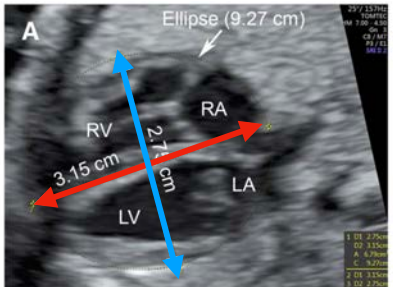
Shape of the 4-Chamber View

Abnormal Fetal Findings Associated With a Global Sphericity Index of the 4-Chamber View Below the 5th Centile

Greggory R. DeVore, MD, Gary Satou, MD, Mark Sklansky, MD

2017

J Ultrasound Med. 2017 Nov;36(11):2309-2318.



GSI

Length/Width

Mean: 1.2
SD: 0.09
5th Centile: 1.08

Size of the 4-Chamber View

Fetal Heart Size

A Comparison Between the Point-to-Point Trace and Automated Ellipse Methods Between 20 and 40 Weeks' Gestation

Greggory R. DeVore, MD, Karsyon Tabsh, MD, Barda Polanco, RDMS, PhD, Gary Satou, MD, Mark Sklansky, MD

J Ultrasound Med. 2016 Dec;35(12):2543-2562.

2016

Table 1. Fetal and Placental Abnormalities Associated With Cardiomegaly

Category	Findings
4-Chamber view	
Ventricles	Aneurysm[5]
Tricuspid valve	Tricuspid regurgitation[7,26]
	Ebstein's malformation[5,9,24,48,53,61,69]
	Tricuspid valve dysplasia[34,54,56]
	Tricuspid valve atresia[54]
Mitral valve	Mitral regurgitation, atresia[35]
Cardiomyopathies	Unspecified[7]
	Myocardial dysplasia or noncompaction[2,3,42,51]
Outflow tracts	
Aortic valve	Absent aortic valve[49,65]
	Critical aortic stenosis[35]
Pulmonary valve	Pulmonary hypoplasia/atresia[31,46]
	Pulmonary regurgitation[42]
	Pulmonary arteriovenous malformation[71]
Heart rate	
Arrhythmia	Congenital heart block[45]

Table 1. Fetal and Placental Abnormalities Associated With Cardiomegaly

Category	Findings
Peripheral vessels	
Ductus venosus	Agenesis[1,24,28,33,54,55,58,62]
Vein of Galen	Aneurysm[17,18,22,24,53,63,67]
Umbilical vein	Aberrant, varix[4,10,23]
Arteriovenous fistula	Intracranial, pulmonary[20,30]
Other fetal/placental conditions	
Fetal anemia	Parvovirus[59,66]
	Bart hemoglobinopathy[1,12,32,38,50]
	Twin-twin transfusion[2,10,14,64]
Viral infections	Cytomegalovirus[60,68]
Placenta	Chorioangioma[9,,39]
Liver	Hemangioendothelioma[40]
Thyroid	Goiter[41,43]
Spine	Sacrococcygeal teratoma[5,16,45]
Lymphatic system	Lymphangioma[70]
Connective tissue	Marfan syndrome[36]
Mucopolysaccharidosis	Type II (Hunter syndrome)[3]
Abdomen	Ascites[52]
Chromosomes	Trisomy, tetrasomy[8,29]
Fetal drug exposure	Topiramate, oxcarbazepine, indomethacin[19,55]

Size of the 4-Chamber View

Fetal Heart Size

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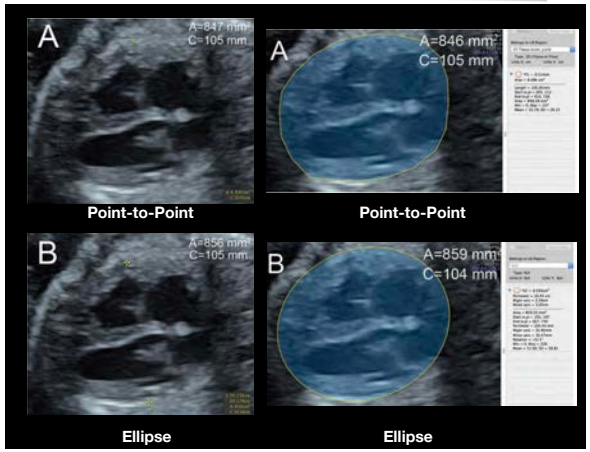

Size of the 4-Chamber View

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Table 4. Area (mm²) Regression Equations for the Point-to-Point Trace Method

Parameter	Mean Equation and Excel Equivalent Equation	SD	R^2	P*
Head circumference (HC), cm	Mean = A0 + A1 × LN(x) + A2 × 1/√x = (−53160.7 + (11372.48) × LN(HC) + (50725.65) × 1/SQRT(HC))	SD = C0 + C1 × x = (−147723+(10.03508)*HC)	0.893	.26
Biparietal diameter (BPD), cm	Mean = A0 + A1 × x + A2 × 1/x = (13402.54 − (55624.98) × 1/SQRT(BPD) + (50390.94) × 1/BPD)	SD = C0 + C1 × x = (−123.9368 + (36.40396) × BPD)	0.965	.50
Abdominal circumference (AC), cm	Mean = A0 + A1 × x² + A2 × x²LN(x) = (−41.05621 + (0.3081076) × AC^2 − (0.0757831) × LN(AC) × AC^2)	SD = C0 + C1 × x = (−50.78769 + (6.865886) × AC)	0.899	.36
Femur length (FL), cm	Mean = A0 + A1 × √x + A2 × 1/√x = (−11733.62 + (3615.738) × SQRT(FL) + (10398.27) × 1/SQRT(FL))	SD = C0 + C1 × x = (−95.96828 + (40.50402) × FL)	0.882	.78
Estimated fetal weight (EFW), g[b]	Mean = A0 + A1 × x + A2 × x² = (144.8262 + (0.6340345) × EFW − (6.943136E−05) × EFW^2)	SD = C0 + C1 × x = (38.67399 + (0.0442273) × EFW)	0.917	.36
Ultrasound mean gestational age (US_MGA), wk	Mean = A0 + A1 × 1/√x + A2 × 1/x = (5471.58 − (12480.19) × 1/SQRT(US_MGA) + (270094.5) × 1/US_MGA)	SD = C0 + C1 × x = (−143.8312 + (8.672193) × US_MGA)	0.913	.85
Last menstrual period gestational age (LMP_GA), wk	Mean = A0 + A1 × 1/x² + A2 × LN(x)/x² = (3622.367 + (6266.126) × 1/(LMP_GA × LMP_GA) − (2524608) × LN(LMP_GA)/(LMP_GA × LMP_GA))	SD = C0 + C1 × x = (−143.6124 + (8.931337) × LMP_GA)	0.91	.37

*Shapiro-Wilk Test for Normality. Cannot reject normality if P > .05.
[b]The Hadlock equation was used to compute the estimated fetal weight.[30]

Table 5. Area (mm²) Regression Equations for the Ellipse Method

Parameter	Mean Equation and Excel Equivalent Equation	SD	R^2	P*
Head circumference (HC), cm	Mean = A0 + A1 × √x + A2 × LN(x) = (6309.386 + (3751.853) × SQRT(HC) − (7555.967) × LN(HC))	SD = C0 + C1 × x = (−146.2643 + (9.789473) × HC)	0.899	.08
Biparietal diameter (BPD), cm	Mean = A0 + A1 × LN(x)/√x = (−22232.89 − (11751.27) × 1/SQRT(BPD) − (23020.51) × LN(BPD)/SQRT(BPD))	SD = C0 + C1 × x = (−117.4646 + (33.92559) × BPD)	0.885	.41
Abdominal circumference (AC), cm	Mean = A0 + A1 × x² + A2 × x²LN(x) = (−26.17839 + (0.2986196) × AC^3 − (0.0736732) × LN(AC) × AC^3)	SD = C0 + C1 × x = (−95.83346 + (6.923881) × AC)	0.905	.47
Femur length (FL), cm	Mean = A0 + A1 × √x + A2 × LN(x) = (−4222.318 + (5655.976) × SQRT(FL) − (4752.036) × LN(FL))	SD = C0 + C1 × x = (−93.41663 + (39.38545) × FL)	0.889	.86
Estimated fetal weight (EFW), g[b]	Mean = A0 + A1 × x + A2 × x² = (156.7914 + (0.6552249) × EFW − (6.483103E−05) × EFW^2)	SD = C0 + C1 × x = (36.58925 + (0.0431274) × EFW)	0.923	.96
Ultrasound mean gestational age (US_MGA), wk	Mean = A0 + A1 × LN(x) + A2 × 1/x = (−22732.1 + (5923.366) × LN(US_MGA) + (107066.5) × 1/US_MGA)	SD = C0 + C1 × x = (−143.9679 + (8.532114) × US_MGA)	0.91	.33
Last menstrual period gestational age (LMP_GA), wk	Mean = A0 + A1 × 1/x + A2 × 1/x² = (5296.251 − (186469.9) × 1/LMP_GA + (3793103) × 1/(LMP_GA × LMP_GA))	SD = C0 + C1 × x = (−155.3561 + (9.234506) × LMP_GA)	0.909	.36

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Size of the 4-Chamber View

Fetal Heart Size

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J Ultrasound Med. 2016 Dec;35(12):2543-2562.

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Z-Score

(Measured Value At Risk Fetus **- Mean** Control**)/SD** Control

Z-Score = Standard Deviation

Z-Score = Centile

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Size of the 4-Chamber View

Fetal Heart Size

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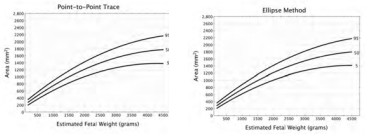

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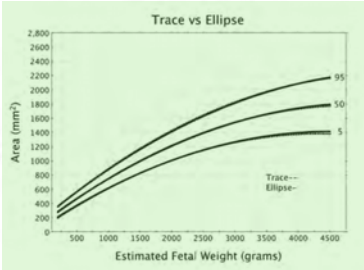
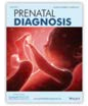


Size of the 4-Chamber View

Area of the fetal heart's four-chamber view: a practical screening tool to improve detection of cardiac abnormalities in a low-risk population

Gregory R. DeVore[1,2*], Gary Satas[3] and Mark Sklansky[2]

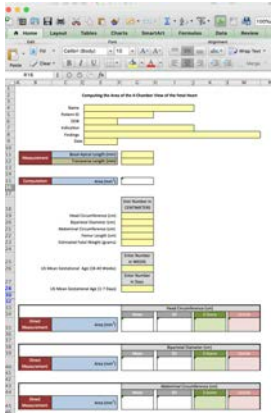
Prenat Diagn. 2017 Feb;37(2):151-155.



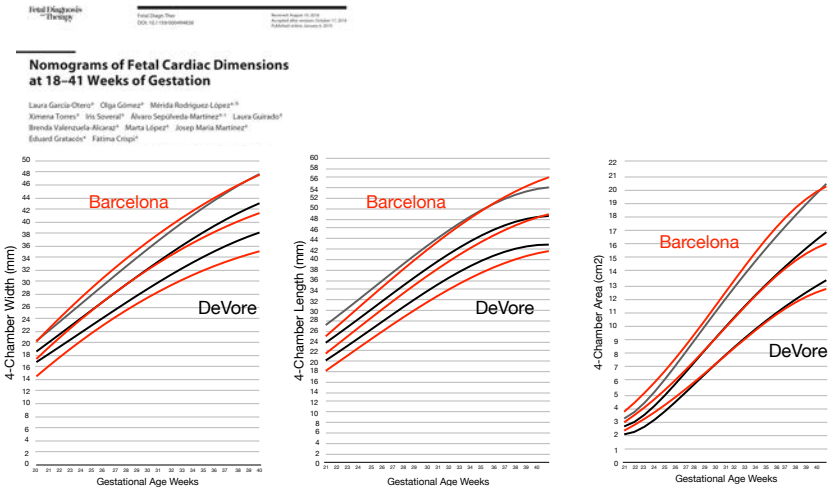
2017

Table 2 Regression equations of the area of the four-chamber view derived from the direct measurements of the basal–apical diameter and transverse diameter

	Mean equation and excel equivalent equation	SD	R^2	SW[a]
HC (cm)	y = A0 + A1 • √x + A2 • 1/√x	SD = C0 + C1 • x	0.896	0.211
	=(−17003.8 + (2132.157)•SQRT(HC) + (35354.88)•1/SQRT(HC))	=(−141.8154 + (9.58934)•HC)		
BPD (cm)	y = A0 + A1 • 1/√x + A2 • 1/x	SD = C0 + C1 • x	0.880	0.20
	=(12764.67 − (52804.66)•1/SQRT(BPD) + (56226.92)•1/BPD)	=(−107.7615 + (32.63521)•BPD)		
AC (cm)	y = A0 + A1 • x^3 + A2 • x^3 • ln(x)	SD = C0 + C1 • x	0.803	0.803
	=(−35.82666 + (0.2989367)•AC^3 − (0.07355595)•LN(AC)•AC^3)	=(−52.23767 + (6.768938)•AC)		
FL (cm)	y = A0 + A1 • √x + A2 • 1/√x	SD = C0 + C1 • x	0.885	0.494
	=(−11004.25 + (3321.805)•SQRT(FL) + (9691.876)•1/SQRT(FL))	=(−86.12199 + (37.7796)•FL)		
EFW (g)[b]	y = A0 + A1 • x + A2 • x^2	SD = C0 + C1 • x	0.920	0.975
	=(143.4991 + (0.653461)•EFW − (6.821093E-05)•EFW^2)	=(36.74356 + (0.0434537)•EFW)		
US_MGA (weeks)	y = A0 + A1 • 1/√x + A2 • ln(x)/√x	SD = C0 + C1 • x	0.916	0.853
	=(23346.89 + (43444.87)•1/SQRT(US_MEAN_GEST_AGE) − (48828.71)•LN(US_MEAN_GEST_AGE)/SQRT(US_MEAN_GEST_AGE))	=(−144.1987 + (8.599538)•US_MEAN_GEST_AGE)		



Calculator



Ventricular Evaluation

2 Shape, Size and Contractility of the Ventricles

What Would Be The Characteristics of the Ideal Measurement Tool to Evaluate the Right and Left Ventricles?

The Ideal Diagnostic Tool

1
- Measure the Size of the Ventricles
- Measure the Shape of the Ventricles
- Measure the Contractility of the Ventricles

The Ideal Diagnostic Tool

1
- Measure the Size of the Ventricles
- Measure the Shape of the Ventricles
- Measure the Contractility of the Ventricles

2
- Simultaneously Make All of the Above Measurements

The Ideal Diagnostic Tool

1
- Measure the Size of the Ventricles
- Measure the Shape of the Ventricles
- Measure the Contractility of the Ventricles

2
- Simultaneously Make All of the Above Measurements

3
- Be Angle Independent of the Position of the 4-Chamber View

The Ideal Diagnostic Tool

1
- Measure the Size of the Ventricles
- Measure the Shape of the Ventricles
- Measure the Contractility of the Ventricles

2
- Simultaneously Make All of the Above Measurements

3
- Be Angle Independent of the Position of the 4-Chamber View

4
- Provide Results of Actual Measurements, Z-Scores, and Centiles Using Different Independent Variables of Fetal Biometry and Gestational Age

The Ideal Diagnostic Tool

1
- Measure the Size of the Ventricles
- Measure the Shape of the Ventricles
- Measure the Contractility of the Ventricles

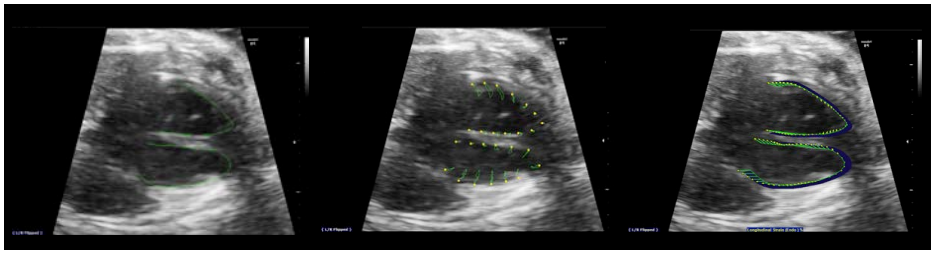
2
- Simultaneously Make All of the Above Measurements

3
- Be Angle Independent of the Position of the 4-Chamber View

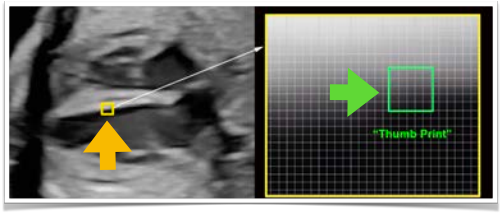
4
- Provide Results of Actual Measurements, Z-Scores, and Centiles Using Different Independent Variables of Fetal Biometry and Gestational Age

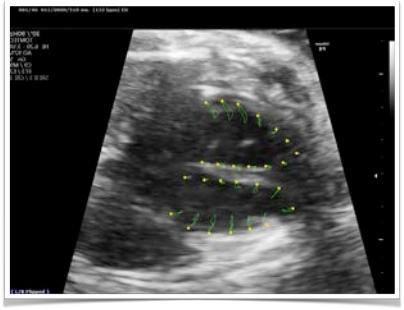
5
- Take Less Than 4 Minutes

Speckle Tracking Analysis Meets All of the Previous Criteria

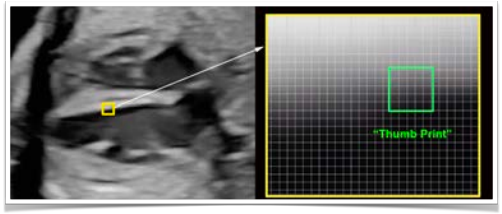


What is Speckle Tracking Analysis?

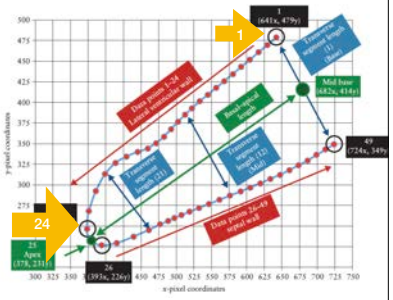




The "Deep Dive"

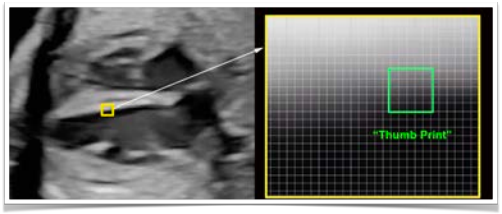


End-Diastolic Measurements
and
End-Systolic Measurements

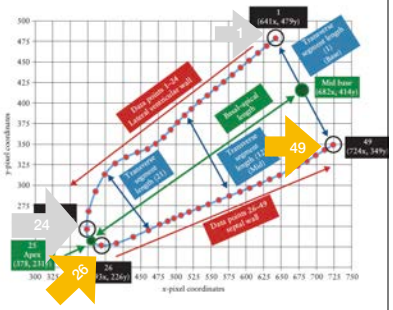


Software Divides the Ventricular Chamber Into 24 Equal Segments From the Base to the Apex

The “Deep Dive”

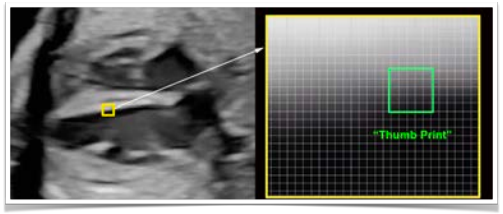


End-Diastolic Measurements
and
End-Systolic Measurements

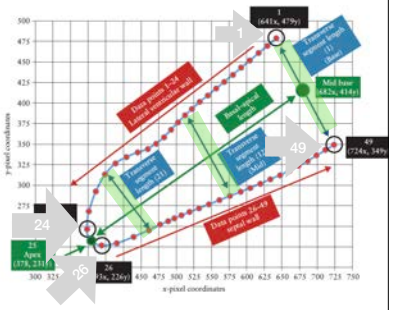


Software Divides the Ventricular Chamber Into 24 Equal Segments From the Base to the Apex

The “Deep Dive”

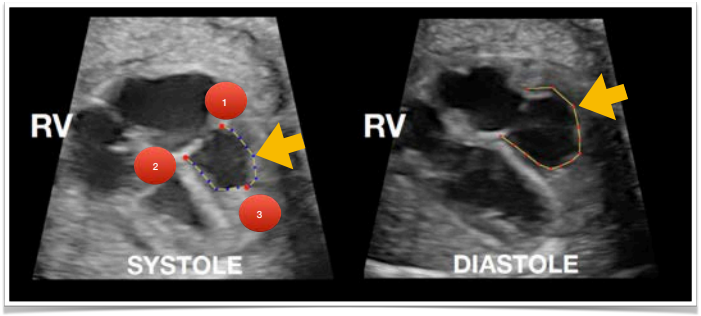


End-Diastolic Measurements
and
End-Systolic Measurements



Software Divides the Ventricular Chamber Into 24 Equal Segments From the Base to the Apex

What is Speckle Tracking Analysis?



Identification of the Endocardium of the Ventricles

Exported Research Data

Data Export

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Date 2017-04-08  12:25:13

Software version:       1.3.0.91 b.160728
Patient name:
StudyID:        "1 "
StudyUID:       "1.2.276.0.26.1.1.1.2.2016.344.50516.7492930"
PatientID:      "65354"

Axis    Long

segments_model  ASE16

Bpm     155.227500

ed      frame   1       time    0 ms
es      frame   17      time    222 ms
PixelDimension  0.146240        mm

TracePointsEndoXYpixel
335     277
344     286
353     296
363     305
374     312
386     317
391     329
386     340
373     342
359     340
346     339
334     334
320     336
307     334
294     332

TracePointsEndoXYmm
48.99   40.51
50.31   41.82
51.62   43.29
53.09   44.60
54.69   45.63
56.45   46.36
57.18   48.11
56.45   49.72
54.55   50.01
52.50   49.72
50.60   49.50
48.84   48.84
46.80   49.14
44.90   48.84
42.99   48.55
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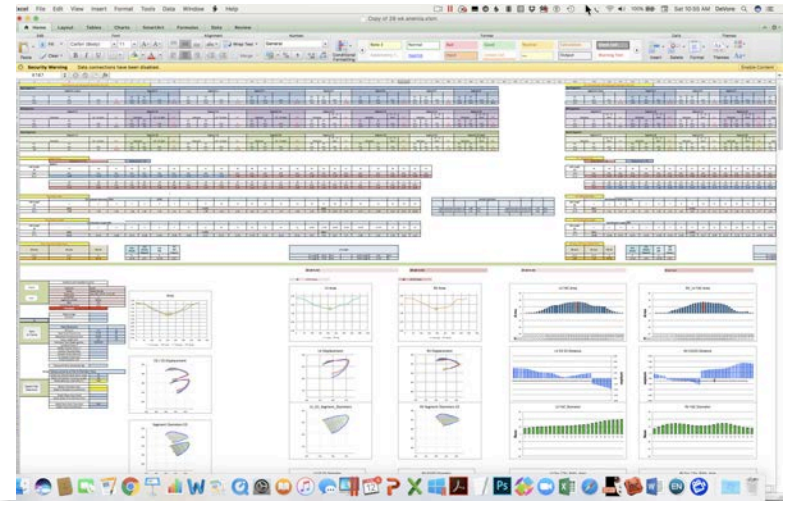
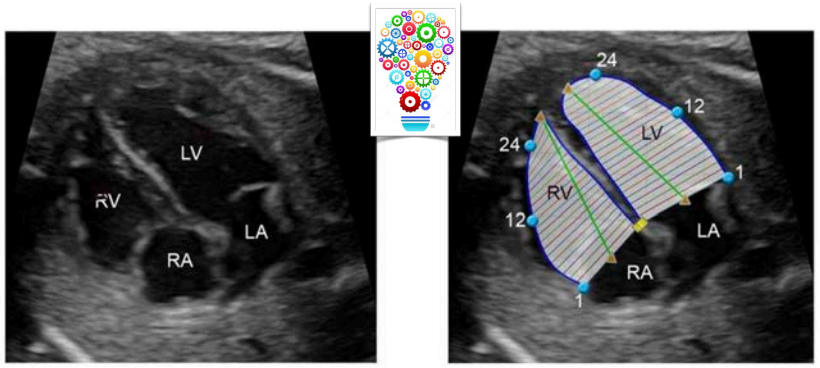


What Can Be Measured?

New Concepts

24-Segment End-Diastolic and Systolic Measurements



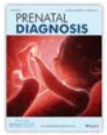
24-Segment End-Diastolic and Systolic Measurements

1 Measuring the Size of the Ventricles

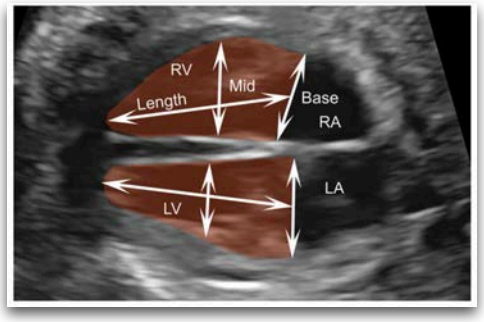
ORIGINAL ARTICLE

Evaluation of the right and left ventricles: An integrated approach measuring the area, length, and width of the chambers in normal fetuses

Greggory R. DeVore[1,2] | Berthold Klas[3] | Gary Satou[4] | Mark Sklansky[4]



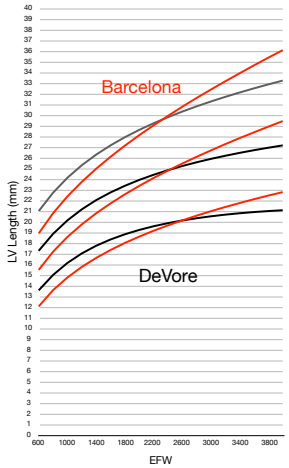
Prenatal Diagnosis. 2017;37:1203–1212.

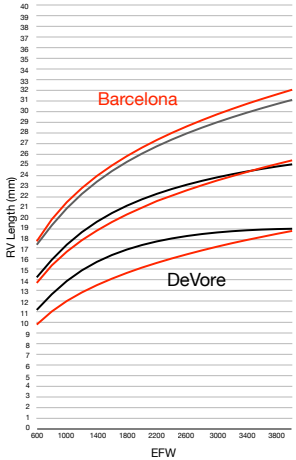


Nomograms of Fetal Cardiac Dimensions at 18–41 Weeks of Gestation

Laura García-Otero[a] Olga Gómez[a] Mérida Rodríguez-López[a,b]
Ximena Torres[a] Iris Soveral[a] Álvaro Sepúlveda-Martínez[a,c] Laura Guirado[a]
Brenda Valenzuela-Alcaraz[a] Marta López[a] Josep María Martínez[a]
Eduard Gratacós[a] Fátima Crispi[a]

VENTRICULAR LENGTH





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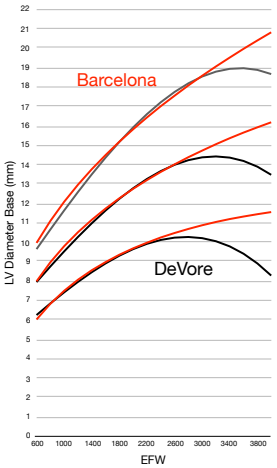
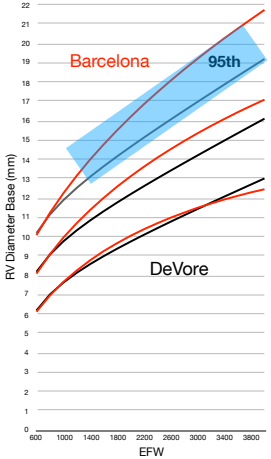
Brenda Valenzuela-Alcaraz[a] Marta López[a] Josep María Martínez[a]
Eduard Gratacós[a] Fátima Crispi[a]

VENTRICULAR WIDTH -BASE-





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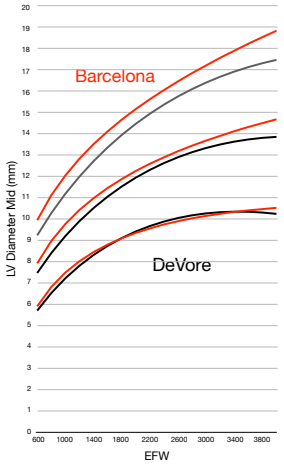
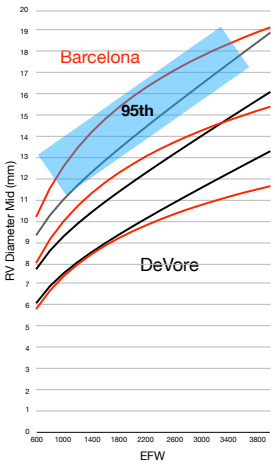
Brenda Valenzuela-Alcaraz[a] Marta López[a] Josep María Martínez[a]
Eduard Gratacós[a] Fátima Crispi[a]

VENTRICULAR WIDTH -MID-

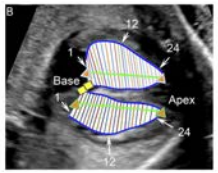




2 Measuring the RV/LV 24-Segment Ratios

Comprehensive Evaluation of Fetal Cardiac Ventricular Widths and Ratios Using a 24-Segment Speckle Tracking Technique

Greggory R. DeVore, MD, Bettina Cuneo, MD, Berthold Klas, BS, Gary Satou, MD, Mark Sklansky, MD



2018 by the American Institute of Ultrasound in Medicine
J Ultrasound Med 2018; 00:1–9

Table 1. The 24-Segment Right-to-Left Ventricular Ratios

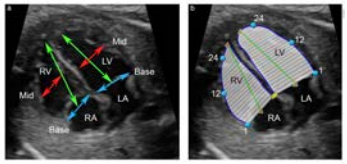
Segment	Mean	Standard Deviation
Base		
1	1.002	0.197
2	1.012	0.189
3	1.019	0.185
4	1.026	0.184
5	1.033	0.185
6	1.038	0.185
7	1.043	0.185
8	1.045	0.186
Mid		
9	1.045	0.188
10	1.043	0.189
11	1.038	0.191
12	1.031	0.195
13	1.023	0.201
14	1.014	0.211
15	1.003	0.221
16	0.988	0.228
Apex		
17	0.967	0.228
18	0.940	0.219
19	0.911	0.210
20	0.886	0.208
21	0.867	0.211
22	0.856	0.217
23	0.849	0.221
24	0.844	0.224

3 Measuring the Shape of the Ventricles

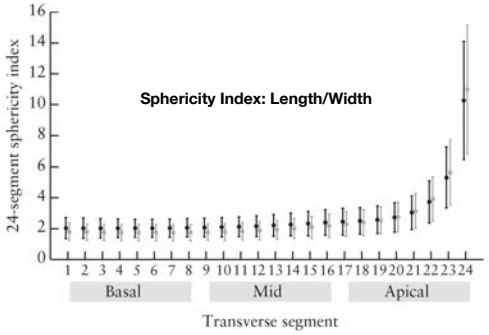
Ultrasound Obstet Gynecol 2018; 51: 650–658
Published online in Wiley Online Library (wileyonlinelibrary.com). DOI: 10.1002/uog.17505

24-segment sphericity index: a new technique to evaluate fetal cardiac diastolic shape

G. R. DEVORE[1,2], B. KLAS[3], G. SATOU[4] and M. SKLANSKY[4]



Ultrasound Obstet Gynecol 2018; 51: 650–658

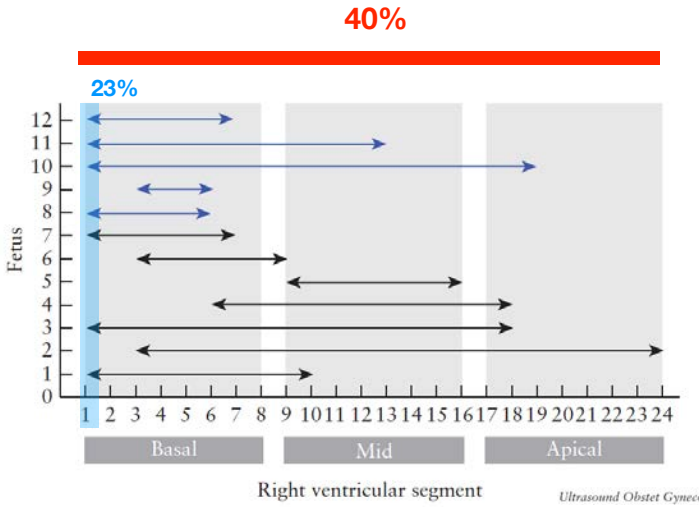


Ultrasound Obstet Gynecol 2018; **52**: 243–249
Published online in Wiley Online Library (wileyonlinelibrary.com). **DOI:** 10.1002/uog.18820

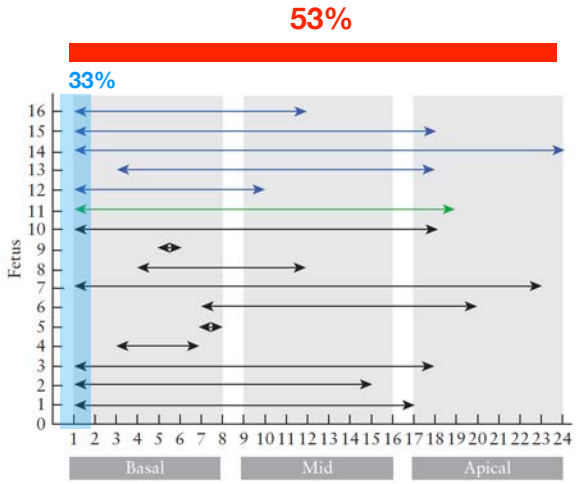
Right and left ventricular 24-segment sphericity index is abnormal in small-for-gestational-age fetuses

G. R. DEVORE[1,2], M. ZARETSKY[3], D. L. GUMINA[3] and J. C. HOBBINS[3]

[1]*Division of Maternal-Fetal Medicine, Department of Obstetrics and Gynecology, David Geffen School of Medicine at UCLA, Los Angeles, CA, USA;* [2]*Fetal Diagnostic Centers, Pasadena, Tarzana and Lancaster, CA, USA;* [3]*Department of Obstetrics and Gynecology, University of Colorado School of Medicine, Denver, CO, USA*

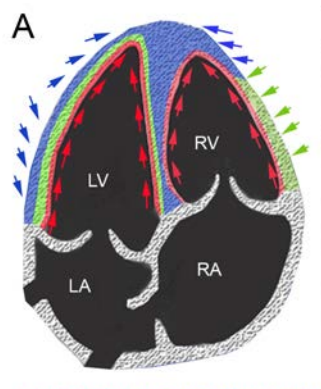


Ultrasound Obstet Gynecol 2018; **52**: 243–249

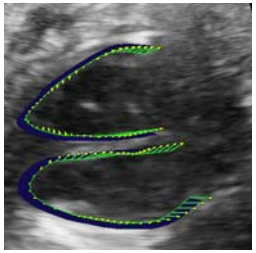


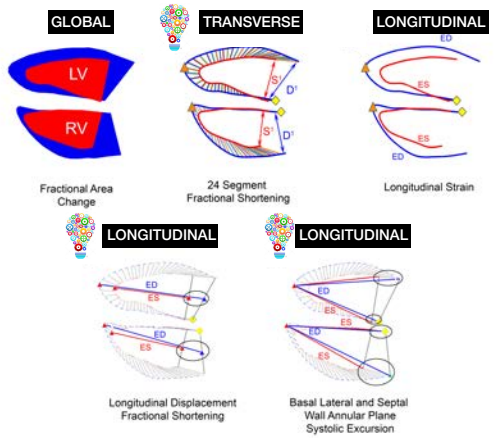
Ultrasound Obstet Gynecol 2018; **52**: 243–249

Measuring the Contractility of the Ventricles



Measuring the Contractility of the Ventricles



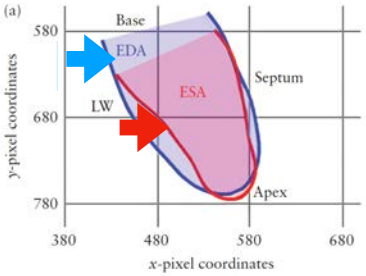


4 Measuring GLOBAL Contractility

Quantitative evaluation of fetal right and left ventricular fractional area change using speckle-tracking technology

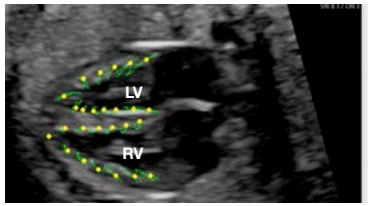
G. R. DEVORE[1,2]*, B. KLAS[3], G. SATOU[4] and M. SKLANSKY[4]

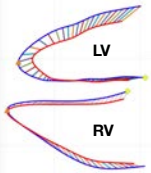
Ultrasound Obstet Gynecol 2019; 53: 219–228



$$\text{FAC} = \frac{\text{End-Diastolic Area - End-Systolic Area}}{\text{End-Diastolic Area}} \times 100$$

5 Measuring Transverse Contractility





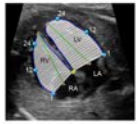
24-Segment
Fractional Shortening

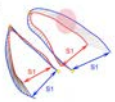
5 Measuring TRANSVERSE Contractility

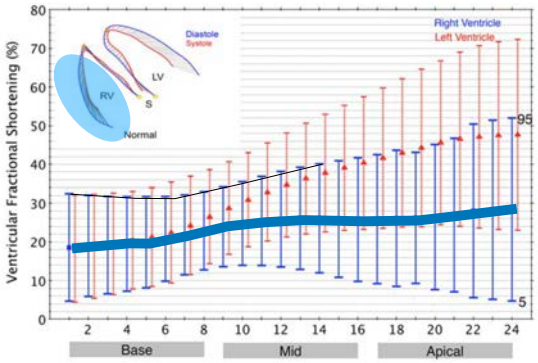
Twenty-four Segment Transverse Ventricular Fractional Shortening

A New Technique to Evaluate Fetal Cardiac Function

Greggory R. DeVore, MD, Berthold Klas, BS, Gary Satou, MD, Mark Sklansky, MD







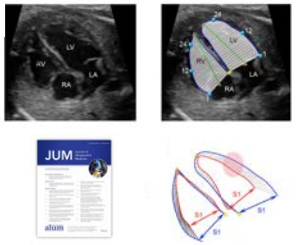
J UltrasoundMed 2018; 37:1129–1141

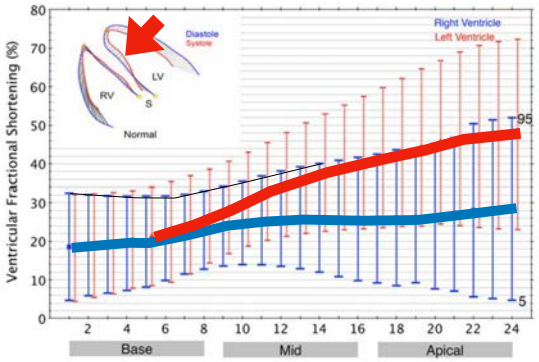
5 Measuring TRANSVERSE Contractility

Twenty-four Segment Transverse Ventricular Fractional Shortening

A New Technique to Evaluate Fetal Cardiac Function

Greggory R. DeVore, MD, Berthold Klas, BS, Gary Satou, MD, Mark Sklansky, MD



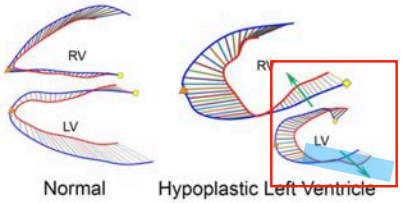


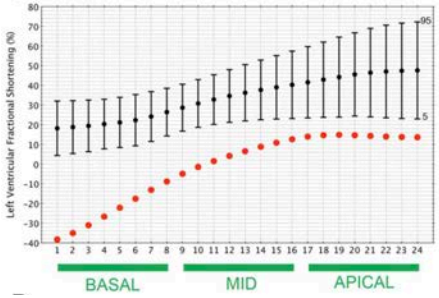
J UltrasoundMed 2018; 37:1129–1141

Twenty-four Segment Transverse Ventricular Fractional Shortening

A New Technique to Evaluate Fetal Cardiac Function

Greggory R. DeVore, MD, Berthold Klas, BS, Gary Satou, MD, Mark Sklansky, MD

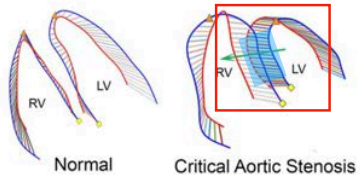


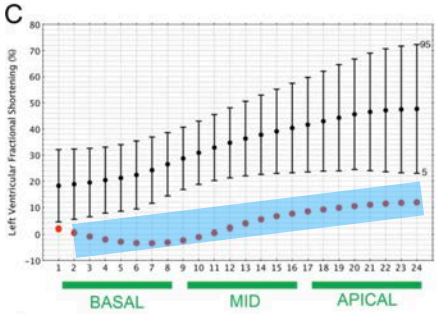


Twenty-four Segment Transverse Ventricular Fractional Shortening

A New Technique to Evaluate Fetal Cardiac Function

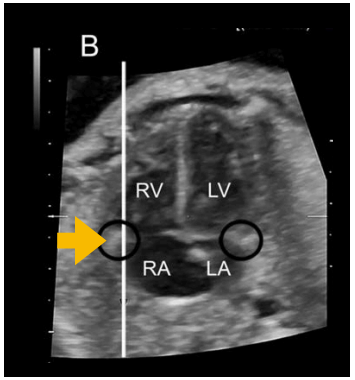
Greggory R. DeVore, MD, Berthold Klas, BS, Gary Satou, MD, Mark Sklansky, MD

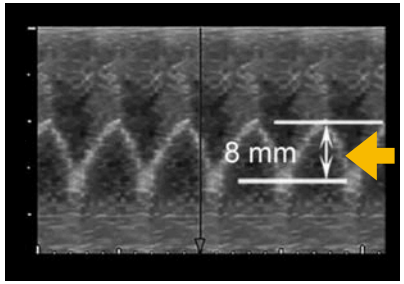




Measuring Longitudinal Contractility

Annular Plane Systolic Excursion





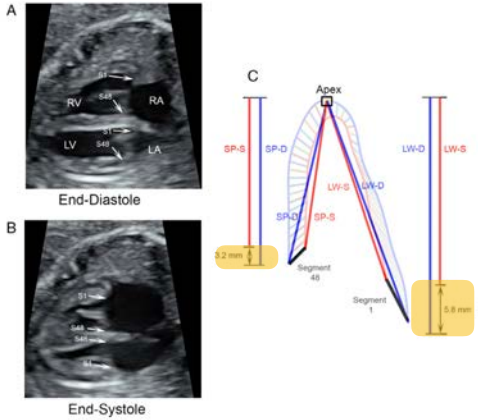
6

Annular Plane Systolic Excursion

Speckle Tracking of the Basal Lateral and Septal Wall Annular Plane Systolic Excursion of the Right and Left Ventricles of the Fetal Heart

Greggory R. DeVore, MD, Berthold Klas, BS, Gary Satou, MD, Mark Sklansky, MD

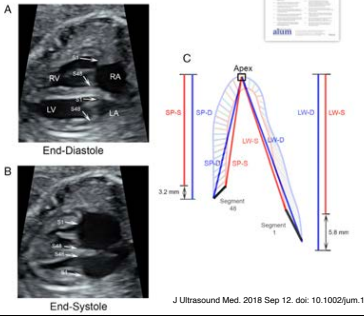
J Ultrasound Med. 2018 Sep 12. doi: 10.1002/jum.14811. [Epub ahead of print]

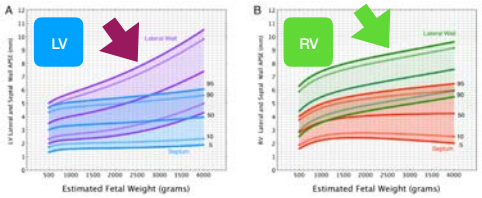


6 Annular Plane Systolic Excursion

Speckle Tracking of the Basal Lateral and Septal Wall Annular Plane Systolic Excursion of the Right and Left Ventricles of the Fetal Heart

Greggory R. DeVore, MD, Berthold Klas, BS, Gary Satou, MD, Mark Sklansky, MD





J Ultrasound Med. 2018 Sep 12. doi: 10.1002/jum.14811. [Epub ahead of print]

6 Annular Plane Systolic Excursion

Speckle Tracking of the Basal Lateral and Septal Wall Annular Plane Systolic Excursion of the Right and Left Ventricles of the Fetal Heart

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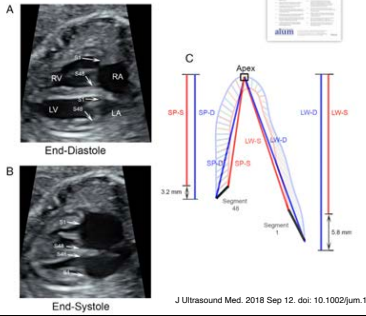
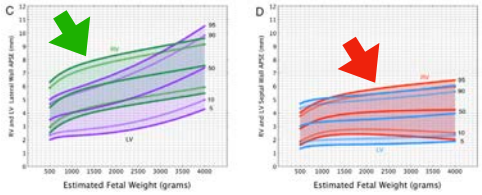


Lateral Wall Comparison **Septal Wall Comparison**



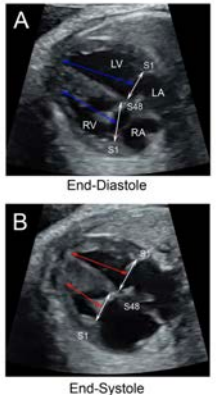
J Ultrasound Med. 2018 Sep 12. doi: 10.1002/jum.14811. [Epub ahead of print]

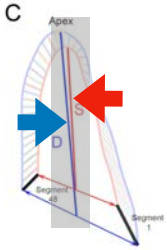
7 Longitudinal Annular Displacement Fractional Shortening

Longitudinal Annular Systolic Displacement Compared to Global Strain in Normal Fetal Hearts and Those With Cardiac Abnormalities

Greggory R. DeVore, MD, Berthold Klas, BS, Gary Satou, MD, Mark Sklansky, MD

J Ultrasound Med. 2018 May;37(5):1159-1171





$$\frac{\text{End-Diastole} - \text{End-Systole}}{\text{End-Diastole}} \times 100$$

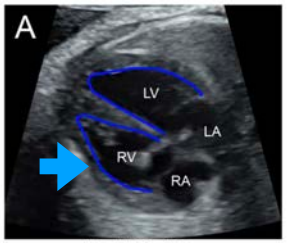
8 Longitudinal Global Strain

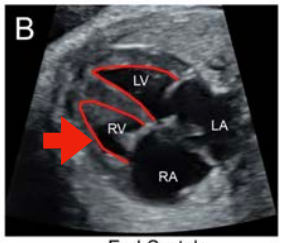
GLOBAL LONGITUDINAL STRAIN

Longitudinal Annular Systolic Displacement Compared to Global Strain in Normal Fetal Hearts and Those With Cardiac Abnormalities

Greggory R. DeVore, MD, Berthold Klas, BS, Gary Satou, MD, Mark Sklansky, MD

J Ultrasound Med. 2018 May;37(5):1159-1171



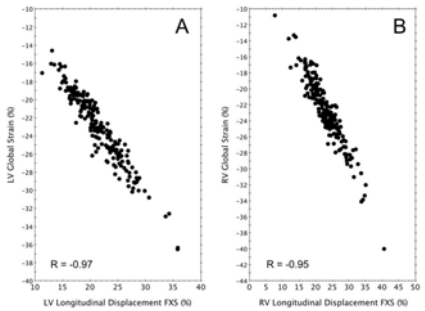


$$\frac{\text{End-Systolic Length} - \text{End-Diastolic Length}}{\text{End-Diastolic length}} \times 100$$

NEGATIVE VALUE

Longitudinal Displacement Fractional Shortening Vs Global Strain

Measurement	Mean
LV longitudinal displacement fractional shortening, %	21.05
RV longitudinal displacement fractional shortening, %	22.94
LV global strain, %	−22.93
RV global strain, %	−22.70



Longitudinal Annular Systolic Displacement Compared to Global Strain in Normal Fetal Hearts and Those With Cardiac Abnormalities

J Ultrasound Med 2018; 37:1159–1171 | 0278-4297

Greggory R. DeVore, MD, Berthold Klas, BS, Gary Satou, MD, Mark Sklansky, MD

Table 4. Global Strain of The LV From Published Studies

Author	Year	No. Studied	Gestational Age, wk	Analysis Program[a]	Study Mean	Study SD	ΔZ Score[b]
Di Salvo[20]	2008	100	20–32	GE	−25.0	4.0	−0.59
Kapusta[23]	2012	78	20–24	GE	−24.89	4.57	−0.64
Matsui[58]	2012	124	14–39	Siemens	−21.9	3.7	0.29
Matsui[26]	2011	93	14–39	Siemens	−21.6	NR	0.38
Fan[21]	2014	40	33	Siemens	−18.36	1.11	1.30
Crispi[18]	2014	37	32	GE	−18.2	4.4	1.34
Barker[16]	2009	33	17–38	Siemens	−17.7	6.4	1.49
Enzensberger[56]	2017	101	17–39	Toshiba	−17.54	NR	1.53
Zuo[57]	2012	20	35–40	Siemens	−17.5	1.95	1.54
Brooks[17]	2014	48	18–40	Siemens	−16.7	3.2	1.77
Kapusta[24]	2013	44	30–34	GE	−24.68	4.81	2.00
Truong[32]	2013	54	15–38	Siemens	−15.6	3.3	2.08
Van Mieghem[33]	2010	59	16–36	GE	−15.1	5.2	2.20
Ishii[22]	2012	81	19–42	Siemens	−15.2	2.7	2.20

NR indicates not reported.
[a]GE Healthcare (Milwaukee, WI); Siemens Medical Solutions (Mountain View, CA); and Toshiba Medical Systems Co, Ltd (Tokyo, Japan).
[b]ΔZ score is computed as [study mean − (−22.93)]/3.52. ΔZ score values of less than 1 and negative values are not significantly different from this study.

Longitudinal Annular Systolic Displacement Compared to Global Strain in Normal Fetal Hearts and Those With Cardiac Abnormalities

J Ultrasound Med 2018; 37:1159–1171 | 0278-4297

Greggory R. DeVore, MD, Berthold Klas, BS, Gary Satou, MD, Mark Sklansky, MD

Table 5. Global Strain of the RV From Published Studies

Author	Year	No. Studied	Gestational Age, wk	Analysis Program[a]	Study Mean	Study SD	ΔZ Score[b]
Kapusta[23]	2012	78	20–24	GE	−25.35	NR	−0.65
Di Salvo[20]	2008	100	20–32	GE	−24.0	4.0	−0.32
Kapusta[24]	2013	54	30–34	GE	−23.2	3.9	−0.12
Matsui[26]	2011	93	14–39	Siemens	−22.3	NR	0.07
Matsui[58]	2012	144	14–39	Siemens	−22.0	3.7	0.17
Zuo[57]	2012	20	35–40	Siemens	−18.7	2.2	0.98
Van Mieghem[33]	2010	59	16–36	GE	−18.5	6.8	1.03
Crispi[18]	2014	37	32	GE	−17.3	4.5	1.33
Truong[32]	2013	54	15–38	Siemens	−16.5	NR	1.52
Enzensberger[56]	2017	101	17–39	Toshiba	−16.47	NR	1.53
Ishii[22]	2012	81	19–42	Siemens	−16.0	3.3	1.65
Barker[16]	2009	33	17–38	Siemens	−17.4	6.4	4.53

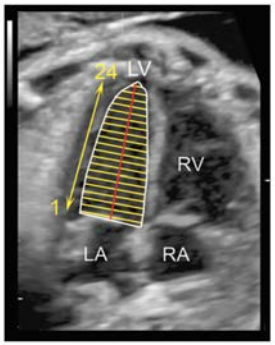
NR indicates not reported.
[a]GE Healthcare (Milwaukee, WI); Siemens Medical Solutions (Mountain View, CA); and Toshiba Medical Systems Co, Ltd (Tokyo, Japan).
[b]ΔZ score is computed as [study mean − (−22.70)/4.07. ΔZ score values of less than 1 and negative values are not significantly different from this study.

Measuring **Left Ventricular Function**

Evaluation of Fetal Left Ventricular Size and Function Using Speckle-Tracking and the Simpson Rule

Greggory R. DeVore, MD, Berthold Klas, BS, Gary Satou, MD, Mark Sklansky, MD

J Ultrasound Med. 2018 Sep 23. doi: 10.1002/jum.14799. [Epub ahead of print]



Simpson's Rule

Stroke Volume

Cardiac Output

Cardiac Output/kg

Ejection Fraction

Measuring **Left Ventricular Function**

Evaluation of Fetal Left Ventricular Size and Function Using Speckle-Tracking and the Simpson Rule

Greggory R. DeVore, MD, Berthold Klas, BS, Gary Satou, MD, Mark Sklansky, MD

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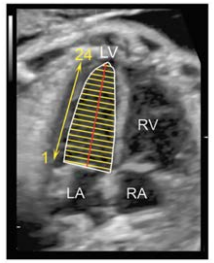
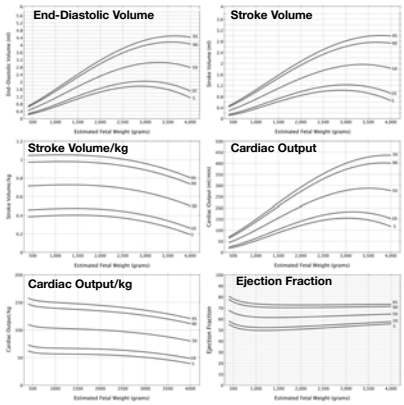


Simpson's Rule



Abnormal Fetal Growth <10th Centile

Original Research

OBSTETRICS

Assessment of ventricular contractility in fetuses with an estimated fetal weight less than the tenth centile

Greggory R. DeVore, MD; Diane L. Gumina, MS; John C. Hobbins, MD

Am J Obstet Gynecol. 2019 May 30. pii: S0002-9378(19)30714-8. doi: 10.1016/j.ajog.2019.05.042. [Epub ahead of print]

Ultrasound Obstet Gynecol 2016; **48**: 333–339
Published online in Wiley Online Library (wileyonlinelibrary.com). **DOI:** 10.1002/uog.15884

Consensus definition of fetal growth restriction: a Delphi procedure

S. J. GORDIJN*, I. M. BEUNE*, B. THILAGANATHAN†, A. PAPAGEORGHIOU†, A. A. BASCHAT‡, P. N. BAKER§, R. M. SILVER¶, K. WYNIA** and W. GANZEVOORT††

50 Fetuses EFW <10th Centile

25 Normal UAPI and CPR

Small for Gestational Age

Not At Risk for Adverse Outcome?

25 Abnormal UAPI and/or CPR

Fetal Growth Restriction

At Risk for Adverse Outcome

Small for Gestational Age

Any Abnormality of Contractility of the RV and LV

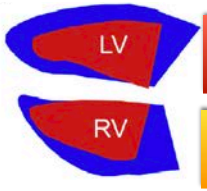
ABNORMAL FOR ONE OR BOTH VENTRICLES 84%

ABNORMAL RIGHT VENTRICLE 80%

ABNORMAL LEFT VENTRICLE 56%

Small for Gestational Age

Global Contractility

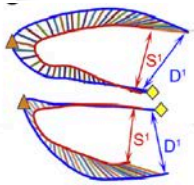


LEFT VENTRICLE 40%

RIGHT VENTRICLE 40%

Fractional Area Change

24-Segment Transverse Fractional Shortening

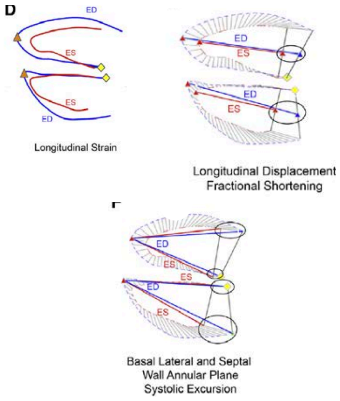


LEFT VENTRICLE 36%

RIGHT VENTRICLE 68%

24 Segment Fractional Shortening

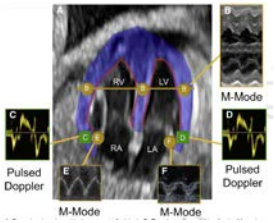
Small for Gestational Age



Longitudinal Contractility

ABNORMAL RIGHT VENTRICLE 44%

ABNORMAL LEFT VENTRICLE 36%



GIRSEN STUDY NO SIGNIFICANT DIFFERENCE IN CARDIAC FUNCTION TESTS BETWEEN CONTROLS AND GROUP I (SGA) FETUSES

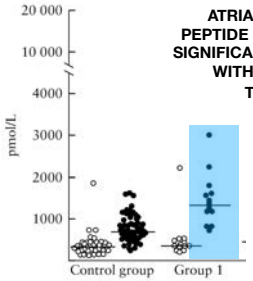
ABNORMAL CARDIAC CONTRACTILITY FOR ONE OR BOTH VENTRICLES 84%

Ultrasound Obstet Gynecol 2007; **29**: 296–303
Published online in Wiley InterScience (www.interscience.wiley.com); **DOI:** 10.1002/uog.3934

Cardiovascular hemodynamics and umbilical artery N-terminal peptide of proB-type natriuretic peptide in human fetuses with growth restriction

A. GIRSEN*, M. ALA-KOPSALA†, K. MÄKIKALLIO*, O. VUOLTEENAHO† and J. RÄSÄNEN*
*Department of Obstetrics and Gynaecology and †Department of Physiology, Biocenter Oulu, University of Oulu, Oulu, Finland

Control vs Fetuses EFW<10th and Normal Doppler UAPI and CPR



ATRIAL TYPE NATRIURETIC PEPTIDE (VOLUME LOADING) WAS SIGNIFICANTLY HIGHER IN FETUSES WITH EFW <10TH CENTILE THAN CONTROLS

Fetal Growth Restriction

-Absent or Reversed Umbilical Artery Doppler Flow-

Fetal Growth Restriction

-Absent or Reversed Umbilical Artery Doppler Flow-

51 Fetuses with EFW <10th Centile

13 Perinatal Deaths

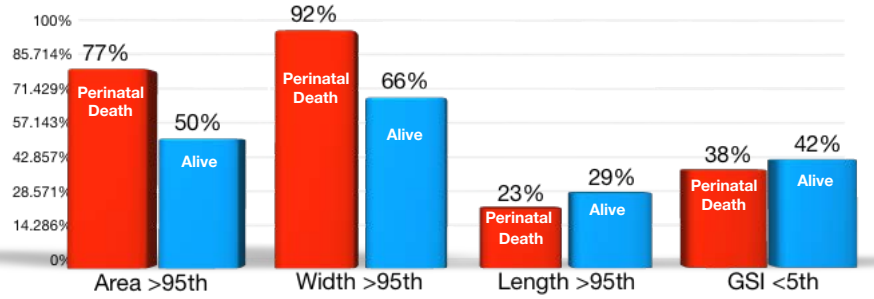
38 Alive

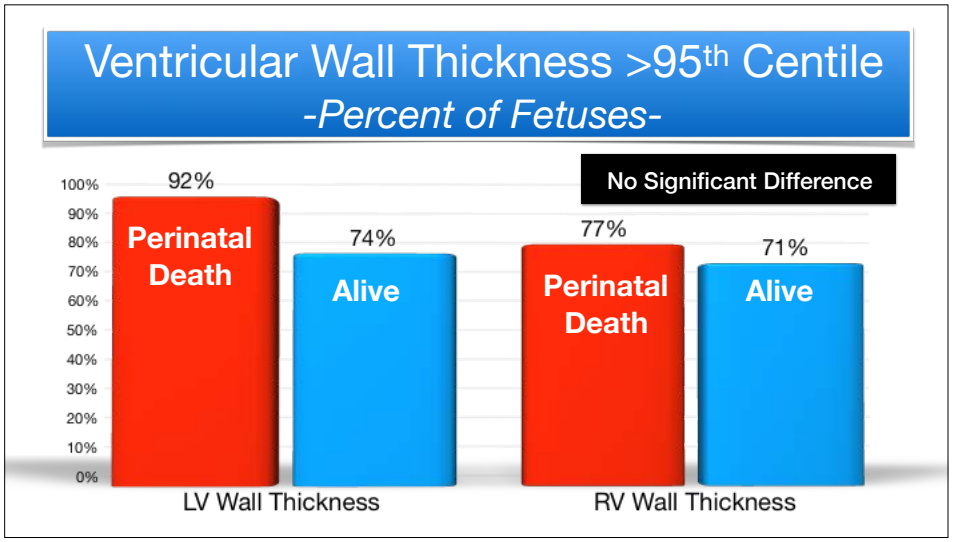
Collaboration with the Perinatal Research Branch
National Institutes of Health
Detroit, MI

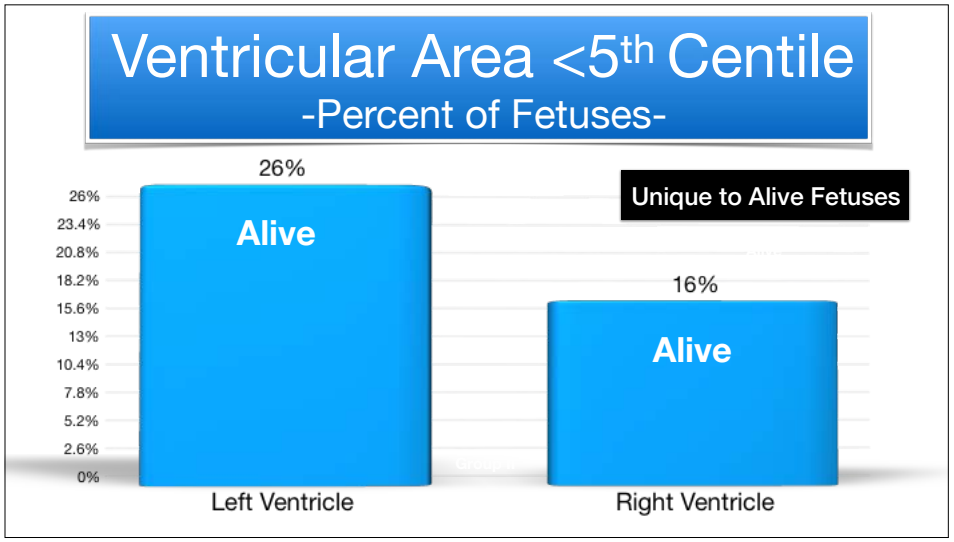
4-Chamber View

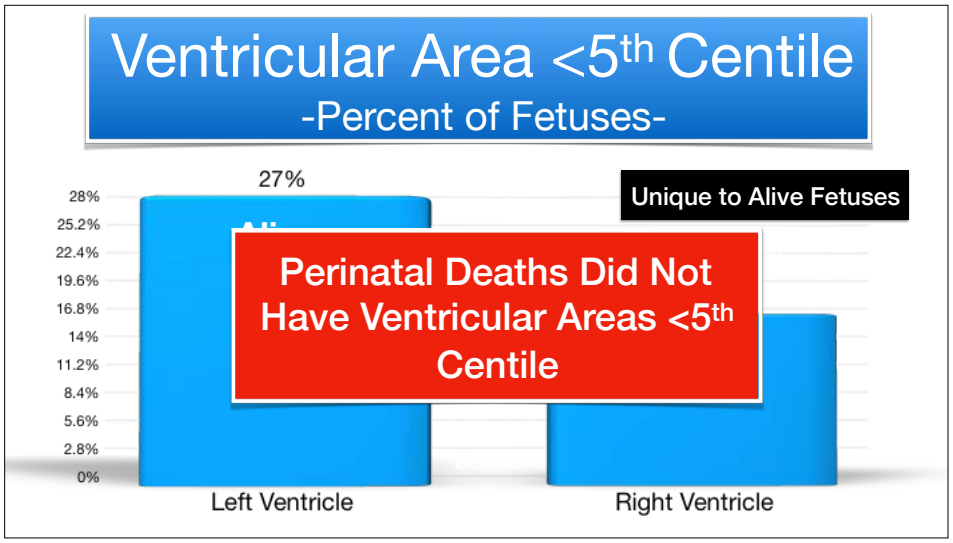
-Percent of Fetuses-

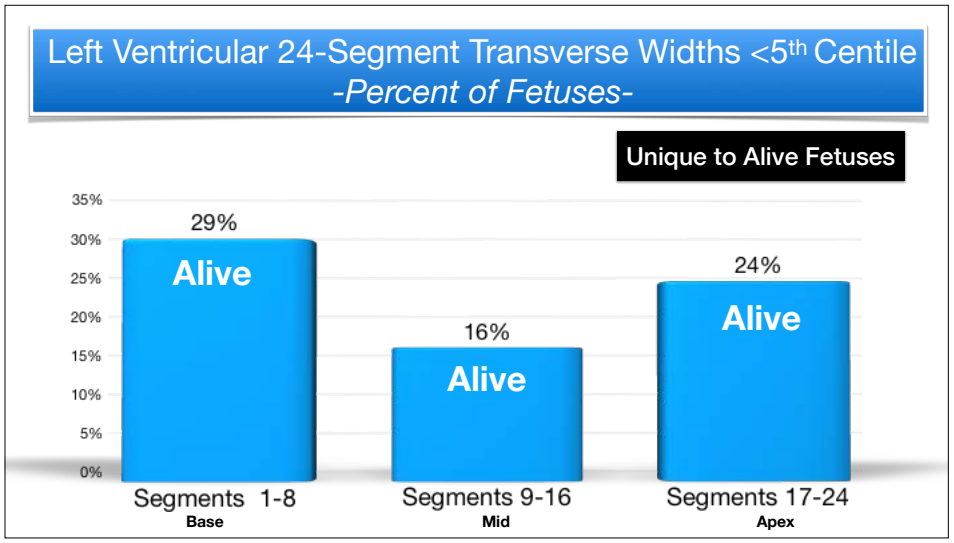
No Significant Difference



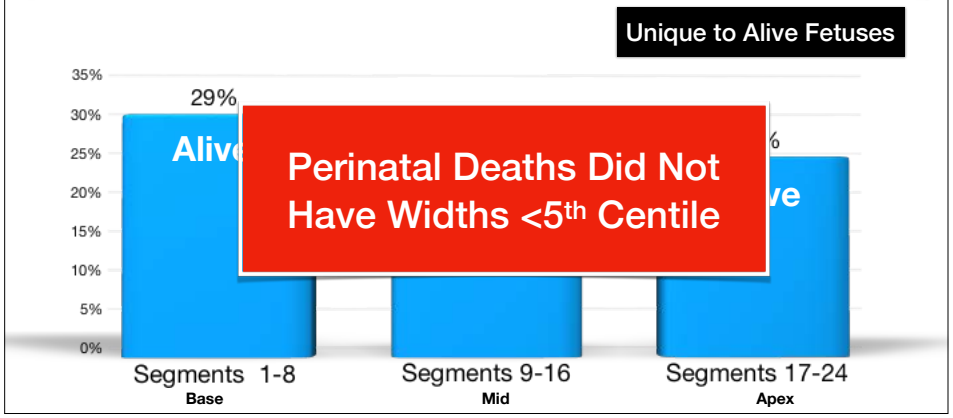

Ventricular Wall Thickness >95th Centile
-Percent of Fetuses-
No Significant Difference
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
92%
Perinatal Death
74%
Alive
77%
Perinatal Death
71%
Alive
LV Wall Thickness
RV Wall Thickness


Ventricular Area <5th Centile
-Percent of Fetuses-
Unique to Alive Fetuses
26%
26%
23.4%
20.8%
18.2%
15.6%
13%
10.4%
7.8%
5.2%
2.6%
0%
Alive
16%
Alive
Left Ventricle
Right Ventricle

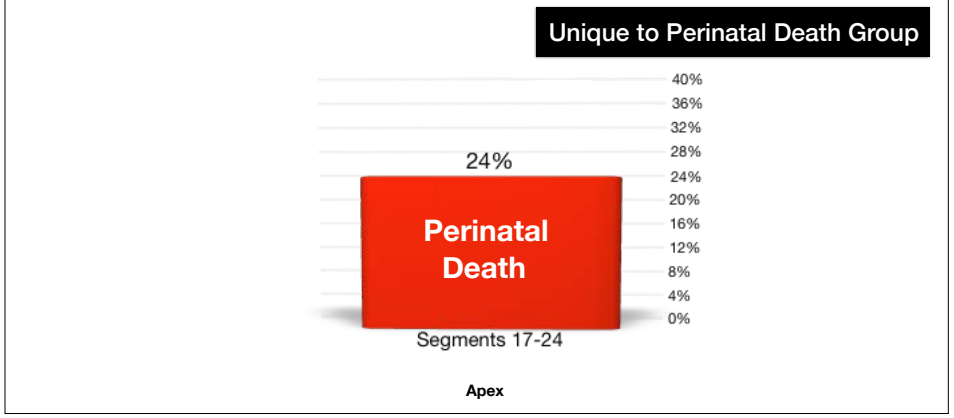

Ventricular Area <5th Centile
-Percent of Fetuses-
Unique to Alive Fetuses
28%
25.2%
22.4%
19.6%
16.8%
14%
11.2%
8.4%
5.6%
2.8%
0%
27%
Perinatal Deaths Did Not Have Ventricular Areas <5th Centile
Left Ventricle
Right Ventricle


Left Ventricular 24-Segment Transverse Widths <5th Centile
-Percent of Fetuses-
Unique to Alive Fetuses
35%
30%
25%
20%
15%
10%
5%
0%
29%
Alive
16%
Alive
24%
Alive
Segments 1-8
Base
Segments 9-16
Mid
Segments 17-24
Apex

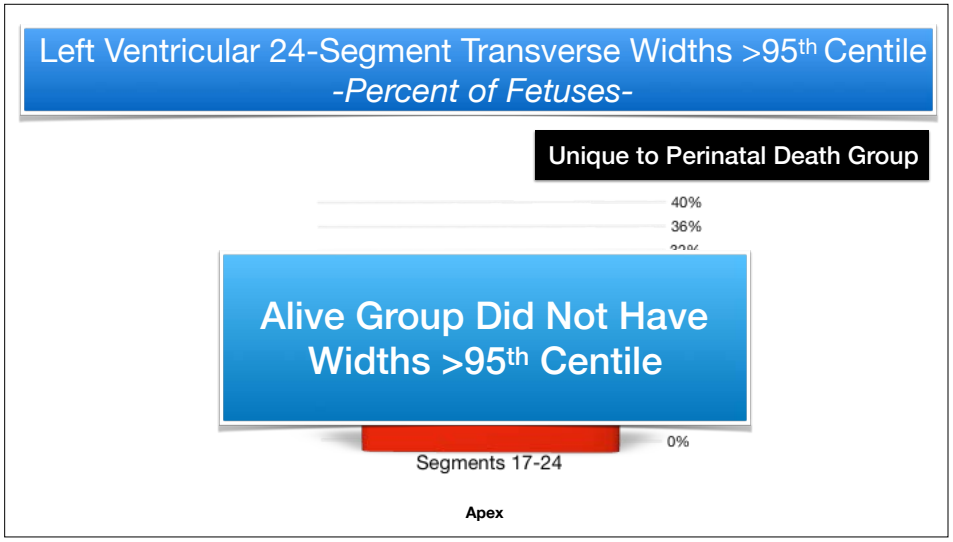
Left Ventricular 24-Segment Transverse Widths <5th Centile
-Percent of Fetuses-



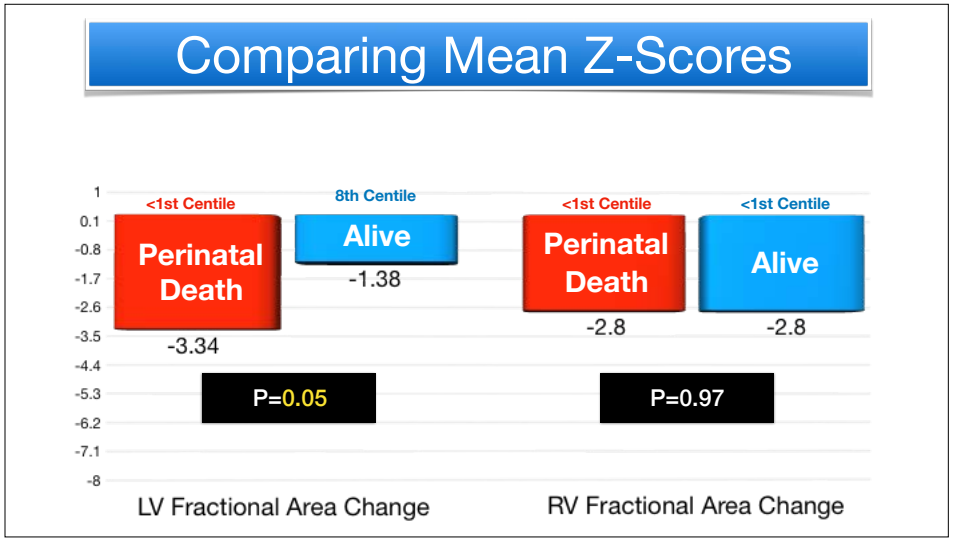
Left Ventricular 24-Segment Transverse Widths >95th Centile
-Percent of Fetuses-



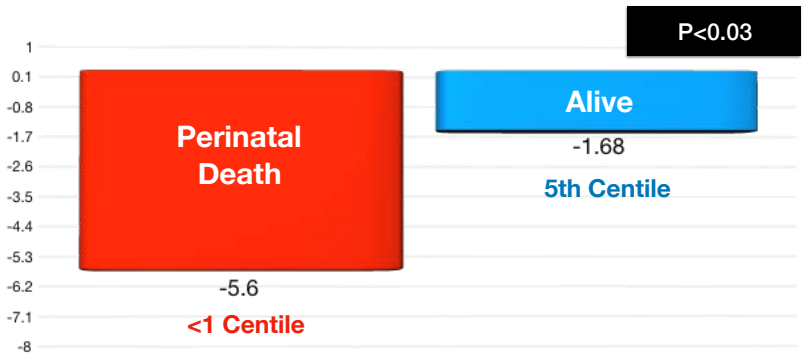
Left Ventricular 24-Segment Transverse Widths >95th Centile
-Percent of Fetuses-



Comparing Mean Z-Scores

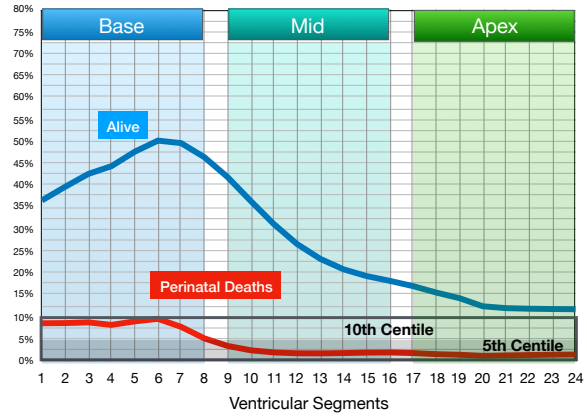


Comparing Mean Z-Scores



LV Ejection Fraction

Fractional Shortening Percentile -LEFT VENTRICLE-



Conclusions

- **Cardiomegaly is common for both groups of fetuses.**
- **Ventricular wall thickness is common for both groups of fetuses.**
- **A smaller left ventricular area is present in those who did not have a perinatal death.**
- **A larger left ventricle was present in fetuses who had a perinatal death.**
- **Decreased LV Contractility was present in fetuses with Perinatal Deaths as represented by the following:**

  -LV Ejection Fraction
  -LV Fractional Area Change
  -LV 24 Segment Fractional Shortening

We shall not cease from exploration. And the end of all our exploring of the Four-Chamber View will be to arrive where we started and know the place for the first time.

T.S. Eliot

Thank You