

# Fetal Growth Basic Concepts and Diagnostic Approaches

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## Disclosures

Wesley Lee, MD

GE Healthcare	Faculty Honorarium - Voluson Training Course
Samsung Medison	Limited Research Support - Speaker
Philips Ultrasound	Consultant

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## Learning Objectives

After completing this presentation, the participant should be able to:

1. Describe the use and potential limitations of population-based weight reference ranges/standards for fetal size assessment
2. Discuss other approaches for fetal size assessment including customized growth curves and individualized growth assessment
3. List indications for maternal and fetal Doppler ultrasound in detecting and monitoring fetuses with growth abnormalities
4. Explain how fetal soft tissue assessment can improve the precision of fetal weight estimation

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## Outline

1. Fetal Growth Overview
2. Sonographic Criteria for Dating Pregnancies
3. Fetal Macrosomia
4. Fetal Growth Restriction
5. Doppler Ultrasonography for Fetal Growth
6. Fetal Soft Tissue Evaluation
7. Conclusions

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## I. Fetal Growth General Overview

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### Fetal malnutrition: Its incidence, causes, and effects

KENNETH E. SCOTT, M.D., C.M.\*  
ROBERT USHER, M.D., C.M.  
Montreal, Quebec, Canada

*"Fetal growth is a function of both seed and soil. It is dependent upon the growth potential of the fetus and the availability of intrauterine nutrition, in its broadest sense, to fulfill this potential. The result of these two factors is a wide distribution of birth size at any one gestational age, and a wide variation in the state of nutrition at birth."*

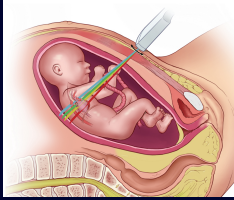
Am J Obstet Gynecol 1966;94:951-963

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# Growth Abnormalities

Depends on how pathological growth processes are defined



Fetal Size Assessment

Neonatal Growth Outcome

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## ARTICLES

### INTRAUTERINE GROWTH AS ESTIMATED FROM LIVEBORN BIRTH-WEIGHT DATA AT 24 TO 42 WEEKS OF GESTATION

Lula O. Lubchenco, M.D., Charlotte Hansman, M.D., Marion Dressler, M.D., and Edith Boyd, M.D.

Premature Infant Center, Department of Pediatrics, and Child Research Council, University of Colorado Medical Center, Denver, Colorado

Pediatrics 32: 1963:793-800



"Small for Gestational Age" = Infants with BW < 10th pct for Gestational Age

"Large for Gestational Age" = Infants with BW > 90th pct for Gestational Age

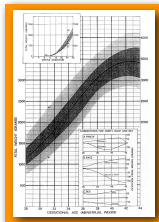
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Battaglia FC, Lubchenco LO. J Pediatr 1967;71:159-63

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## A standard of fetal growth for the United States of America

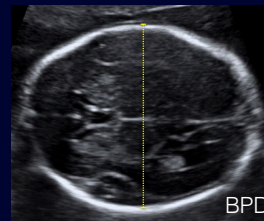
WILLIAM E. BRENNER, M.D.  
DAVID A. EDELMAN, Ph.D.  
CHARLES H. HENDRICKS, M.D.  
Chapel Hill and Research Triangle Park, North Carolina



The appropriate interpretation of monitored fetal growth throughout pregnancy in individual patients and populations is dependent upon the availability of adequate standards. There is no adequate standard of fetal weight throughout pregnancy that is suitable for patients in the U. S. A. To determine such a standard for infants delivered at about sea level the 10th, 25th, 50th, 75th, and 90th percentiles of fetal weight for each menstrual week of gestation were calculated from 430 fetuses at 8 to 20 menstrual weeks' gestation aborted with prostaglandins and from 30,772 liveborn infants delivered of patients at 21 to 44 menstrual weeks' gestation. Median fetal crown-to-rump lengths and crown-to-heel lengths were derived from measurements of 496 aborted fetuses of 8 to 21 weeks' gestation. Fetal weight correction factors for parity, race (socioeconomic status), and fetal sex were calculated. The derived fetal growth curves are useful for clinical, public health, and investigational purposes. (Am. J. OBSTET. GYNECOL. 126: 555, 1976.)

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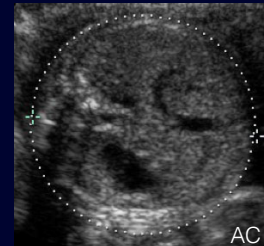
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BPD



HC



AC



FDL

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## Birth Weight vs EFW

Birth weight (BW) is directly measured as an indicator of neonatal growth outcome.



Estimated fetal weight (EFW) is calculated to indirectly evaluate fetal nutritional status



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## Sonographic Fetal Weight Estimation

Which Model Should Be Used?

Nir Melamed, MD, MSc, Yariv Yogeve, MD, Israel Meizner, MD, Reuven Mashlach, MD, Ron Bardin, MD, Avi Ben-Haroush, MD

26 different birth weight prediction models

3,705 sonographic EFW < 3 days delivery

For most models, estimates were within 15% of actual BW in more than 80% of cases.

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J Ultrasound Med 2009; 28: 617-29

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## Sonographic Estimated Fetal Weight

Considerable variation among different models, although most showed good overall accuracy.

Models with 3-4 fetal biometric indices were better than models with only 1 or 2 indices (BW range 1000 - 4500 g)

Accuracy decreased at BW extremes, with overestimation in low-BW categories vs underestimation for BW > 4000 g

Model precision was lowest in the low-BW groups.

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J Ultrasound Med 2009; 28: 61-29

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## Example of Weight Prediction Model - Hadlock (1985)

Estimation of fetal weight with the use of head, body, and femur measurements—A prospective study

Frank P. Hadlock, M.D., R. B. Harrist, Ph.D., Ralph S. Sharman, M.D., Russell L. Deter, M.D., and Seung K. Park, M.D.  
Houston, Texas

In utero estimates of fetal weight were evaluated prospectively in 109 fetuses with the use of sonographic models developed in a previous study. This report confirms that the best in utero weight estimates result from the use of models based on measurements of head size, abdominal size, and femur length. Since the accuracy of these models (1 SD = 7.5%) is significantly better than those based on measurements of head and body (e.g., biparietal diameter, abdominal circumference), we recommend routine use of such models in obstetric sonography. (AM J Obstet Gynecol, 1985; 151:333-7.)

Table II. New regression models based on an expanded sample population (n = 276 fetuses)

Fetal parameters	Regression equation*
Abdominal circumference, femur length	$\text{Log}_{10} \text{ weight} = 1.304 + 0.05281 \text{ AC} + 0.1938 \text{ FL} - 0.004 \text{ AC} \times \text{FL}$
Biparietal diameter, abdominal circumference, femur length	$\text{Log}_{10} \text{ weight} = 1.335 - 0.0034 \text{ AC} \times \text{FL} + 0.0316 \text{ BPD} + 0.0457 \text{ AC} + 0.1623 \text{ FL}$
Head circumference, abdominal circumference, femur length	$\text{Log}_{10} \text{ weight} = 1.526 - 0.00326 \text{ AC} \times \text{FL} + 0.0107 \text{ HC} + 0.0438 \text{ AC} + 0.158 \text{ FL}$
Biparietal diameter, head circumference, abdominal circumference, femur length	$\text{Log}_{10} \text{ weight} = 1.3596 - 0.00386 \text{ AC} \times \text{FL} + 0.0064 \text{ HC} + 0.00061 \text{ BPD} \times \text{AC} + 0.0424 \text{ AC} + 0.174 \text{ FL}$

\*AC, abdominal circumference; FL, femur length; BPD, biparietal diameter; HC, head circumference.

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## Obstetrical Ultrasound

Frank P. Hadlock, MD • Ronald B. Harrist, PhD • Juan Martinez-Payer, MD

### In Utero Analysis of Fetal Growth: A Sonographic Weight Standard<sup>1</sup>

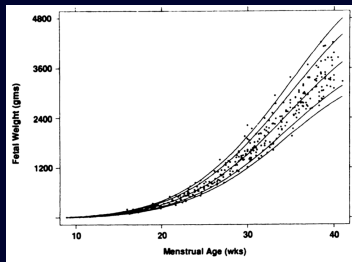
Regression analysis was used to develop an in utero fetal weight model from a population of 92 prenatal, serially measured fetal weight estimates with normal neonatal histories. There was a gradual increase in fetal weight from 17 to 40 weeks for 3419 g at 40 weeks, with uniform variance of 1.127% at standard deviations.

The prenatal diagnosis of abnormal fetal growth patterns such as 95th percentile boundaries for normal fetal growth. This is consistent with the fact that previously published US models have failed to discriminate significant differences in basic in utero fetal measurements (Biparietal diameter, head circumference, abdominal circumference, femur length) in

Once EFW is calculated, this result is compared to a population-based standard

Radiology 1991;181:129-133

Menstrual Week	Percentiles (g)				
	3rd	10th	50th	90th	95th
10	36	29	35	41	44
11	34	37	45	53	56
12	41	48	56	68	73
13	50	61	73	85	91
14	70	77	93	109	116
15	108	97	117	137	144
16	119	121	141	171	184
17	130	130	161	213	236
18	157	149	181	241	279
19	205	237	273	319	341
20	248	275	321	387	414
21	299	333	399	467	499
22	342	386	458	539	588
23	422	466	548	639	708
24	525	566	650	764	830
25	588	626	713	830	908
26	685	728	813	926	1,041
27	793	836	925	1,034	1,159
28	906	1,004	1,100	1,213	1,313
29	1,034	1,145	1,239	1,413	1,524
30	1,169	1,286	1,389	1,534	1,649
31	1,313	1,433	1,521	1,689	1,789
32	1,461	1,581	1,666	1,841	1,941
33	1,622	1,744	1,823	1,993	2,093
34	1,793	1,915	1,993	2,151	2,251
35	1,966	2,104	2,181	2,316	2,444
36	2,151	2,293	2,371	2,516	2,644
37	2,373	2,513	2,593	2,741	2,870
38	2,622	2,766	2,826	2,986	3,136
39	2,879	3,023	3,083	3,246	3,396
40	3,214	3,304	3,419	3,524	3,634



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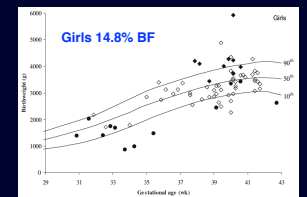
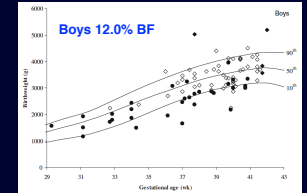
Eur J Pediatr (2007) 166:161-167  
DOI 10.1007/s00431-006-0299-x

## ORIGINAL PAPER

### Birth weight categorization according to gestational age does not reflect percentage body fat in term and preterm newborns

Hansjörg Rudolf Schmelz • Dung Nguyen Quang • Gerhard Fusch • Christoph Fusch

- % BF < 10th%
- % BF = 10 - 20%
- △ % BF > 20th%



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## Customised Birth Weight Standards

Weight for gestational age percentiles are individualized for maternal influences on fetal growth

### Stepwise Multiple Regression

- maternal height
- pre-pregnancy BMI
- ethnicity
- parity
- fetal gender



optimal 280 day BW predicted for each infant

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Gardosi J, et al. Lancet 1992; 339:283-287

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## Customised Birth Weight Standards

Since not all babies are born at 280 days, the target BW is extrapolated to the exact GA at birth using a Hadlock proportionality formula (1991)

Infant's BW is compared to target BW

Any newborn with actual BW < 10th pct of assumed distribution around target weight is considered SGA

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Gardosi J, et al. Lancet 1992; 339:283-287

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doi: 10.1111/j.1365-3016.2010.01155.x

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### The case against customised birthweight standards

Jennifer A. Hutcheon<sup>a</sup>, Xun Zhang<sup>a</sup>, Robert W. Platt<sup>b,c</sup>, Sven Cnattingius<sup>d</sup> and Michael S. Kramer<sup>b,c</sup>

<sup>a</sup>Department of Obstetrics & Gynaecology, University of British Columbia, Vancouver, Canada, <sup>b</sup>Department of Pediatrics, and <sup>c</sup>Department of Epidemiology, Biostatistics, and Occupational Health, McGill University, Montreal, Canada, <sup>d</sup>Clinical Epidemiology Unit, Department of Medicine, Karolinska Institutet, Stockholm, Sweden

“Customised birthweight standards are widely recognised to improve the prediction of adverse perinatal outcomes compared with conventional birthweight-for-gestational-age charts.”

Paediatr Perinat Epidemiol. 2011;25:11-6

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doi: 10.1111/j.1365-3016.2010.01155.x

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“However, their apparent benefits are more likely to have been derived from their incorporation of intrauterine-based (EFW) reference values at preterm ages than their adjustment for maternal characteristics.”

Paediatr Perinat Epidemiol. 2011;25:11-6

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doi: 10.1111/j.1365-3016.2010.01155.x

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“Although maternal characteristics are able to explain population-level differences in birthweight, they are not strong enough predictors for individual-level prediction of birthweight.”

Paediatr Perinat Epidemiol. 2011;25:11-6

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doi: 10.1111/j.1365-3016.2010.01155.x

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“With maternal characteristics accounting for only a small percent of total factors influencing BW, the best estimate of an infant’s BW remains close to the population average, explaining the ineffectiveness of adjusting for maternal characteristics.”

Paediatr Perinat Epidemiol. 2011;25:11-6

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### International standards for fetal growth based on serial ultrasound measurements: the Fetal Growth Longitudinal Study of the INTERGROWTH-21<sup>st</sup> Project

Aris T Papageorgiou, Eric O Ohuma, Douglas G Altman, Tullia Todros, Lella Cheikh Ismail, Ann Lambert, Yasmin A Jaffer, Enrico Bertino, Michael G Gravett, Manorama Purwar, J Alison Noble, Ruyan Pang, Cesar G Victora, Fernando C Barros, Maria Carvalho, Laurent J Salomon, Zulfiqar A Bhutta\*, Stephen H Kennedy\*, José Villar\*, [for the International Fetal and Newborn Growth Consortium for the 21st Century (INTERGROWTH-21)\*]

**Summary**

**Background** In 2006, WHO produced international growth standards for infants and children up to age 5 years on the basis of recommendations from a WHO expert committee. Using the same methods and conceptual approach, the Fetal Growth Longitudinal Study (FGLS), part of the INTERGROWTH-21<sup>st</sup> Project, aimed to develop international growth and size standards for fetuses.

4,321 women - prospective longitudinal study

8 countries

Fetal biometry obtained q 5 weeks (14-42 weeks)

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Lancet 2014;384:869-79.

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### REPORT OF MAJOR IMPACT

ajog.org

### Racial/ethnic standards for fetal growth: the NICHD Fetal Growth Studies

Germaine M. Buck Louis, PhD, MS; Jagteshwar Grewal, PhD, MPH; Paul S. Albert, PhD; Anthony Sciscione, DO; Deborah A. Wing, MD; William A. Grobman, MD, MBA; Roger B. Newman, MD; Ronald Wapner, MD; Mary E. D’Alton, MD; Daniel Skupski, MD; Michael P. Nageotte, MD; Angela C. Ranzini, MD; John Owen, MD, MSPH; Edward K. Chien, MD; Sabrina Craigo, MD; Mary L. Hediger, PhD; Sungduk Kim, PhD; Cuilin Zhang, MD, MPH, PhD; Katherine L. Grantz, MD, MS

1,737 women - prospective longitudinal US study

Low risk singleton pregnancies

Fetal growth differences observed among 4 ethnic/racial groups

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Am J Obstet Gynecol. 2015;213:449.e1-449.e41.

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RESEARCH ARTICLE

### The World Health Organization Fetal Growth Charts: A Multinational Longitudinal Study of Ultrasound Biometric Measurements and Estimated Fetal Weight

Torvid Kiserud<sup>1,2\*</sup>, Gilda Piaggio<sup>3,4\*</sup>, Guillermo Carroli<sup>5</sup>, Mariana Widmer<sup>6\*</sup>, José Carvalho<sup>7</sup>, Lisa Neerup-Jensen<sup>8</sup>, Daniel Giordano<sup>9</sup>, José Guilherme Cecatti<sup>10</sup>, Hany Abdel Aleem<sup>11</sup>, Sameera A. Talegawkar<sup>12</sup>, Alexandra Benachi<sup>13</sup>, Anke Diemert<sup>12</sup>, Antoinette Tshetu Kitoto<sup>13</sup>, Jadsada Thinkhamrop<sup>14</sup>, Pisake Lumbiganon<sup>14</sup>, Ann Tabor<sup>7</sup>, Alka Kriplani<sup>15</sup>, Rogelio Gonzalez Perez<sup>16</sup>, Kurt Hecher<sup>12</sup>, Mark A. Hanson<sup>17</sup>, A. Metin Gülmezoglu<sup>18</sup>, Lawrence D. Platt<sup>18,19</sup>

1,387 women - prospective longitudinal US study (7 scans)

Low risk singleton pregnancies

Fetal growth variation observed among 10 countries

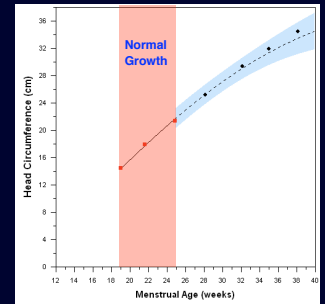
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## Individualized Growth Assessment

### Rossvik Growth Model

$$P = c(t)^{k+s}$$

- c growth regulation
- k anatomic characteristic of size parameter
- s growth controller specified by coefficient c
- t duration of parameter growth



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## Individualized Growth Assessment

2nd TM growth velocities provide estimates of growth potential and predict 3rd TM size trajectories/birth characteristics

- Each fetus serves as its own control
- Biological variability is substantially reduced
- Fetal growth characterized by individual/composite anatomical parameters

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## 2. Sonographic Criteria for Dating Pregnancies

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**COMMITTEE OPINION**  
Number 611 • October 2014  
**Method for Estimating Due Date**  
Committee on Obstetric Practice  
American Institute of Ultrasound in Medicine  
Society for Maternal-Fetal Medicine

### Accurate Dating is Crucial for Fetal Growth Assessment


- US measurement of embryo or fetus  $\leq 13$  6/7 weeks most accurate way to establish or confirm age
- Prioritize use of assisted reproductive technology (ART), if available, based on age of embryo and date of transfer


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## ACOG/SMFM/AIUM Guidelines for Dating Based on Ultrasonography

Menstrual Age Range	Method of Measurement	Re-Dating Criteria US vs LMP Discrepancy
13 6/7 wk $\leq 8$ 6/7 wk 9 0/7 - 13 6/7 wk	CRL	> 5 days > 7 days
14 0/7 - 15 6/7 wk	BPD, HC, AC, FDL	> 7 days
16 0/7 - 21 6/7 wk	BPD, HC, AC, FDL	> 10 days
22 0/7 - 27 6/7 wk	BPD, HC, AC, FDL	> 14 days
> 28 0/8 weeks	BPD, HC, AC, FDL	> 21 days

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 WOMEN'S HEALTH CARE PROFESSIONALS


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 AMERICAN INSTITUTE OF ULTRASOUND IN MEDICINE



 Society for Maternal-Fetal Medicine


**COMMITTEE OPINION**  
 Number 611 • October 2014 (See also Committee Opinion No. 578)  
**Method for Estimating Due Date**  
 Committee on Obstetric Practice  
 American Institute of Ultrasound in Medicine  
 Society for Maternal-Fetal Medicine  
This document reflects emerging clinical and scientific advances as of the date issued and is subject to change. The information should not be construed as dictating an exclusive course of treatment or procedure to be followed.


As soon as data from the last menstrual period (LMP), the first accurate ultrasound examination, or both are obtained, the gestational age and the EDD should be determined, discussed with the patient, and documented clearly in the medical record.

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 WOMEN'S HEALTH CARE PROFESSIONALS


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 AMERICAN INSTITUTE OF ULTRASOUND IN MEDICINE


 Society for Maternal-Fetal Medicine

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Subsequent changes to the EDD should be reserved for rare circumstances, discussed with the patient, and documented clearly in the medical record.

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### 3. Fetal Macrosomia

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### Fetal Macrosomia - Increased Risks



- cesarean delivery
- shoulder dystocia
- clavicular fracture
- brachial plexus injury

ACOG Practice Bulletin. Fetal Macrosomia. No. 22, 2000, reaffirmed 2015

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### Fetal Macrosomia Incidence

Menstrual Age	50th Percentile	90th Percentile	95th Percentile
37 weeks	3,117	3,755	3,956
38 weeks	3,263	3,867	4,027
39 weeks	3,400	3,980	4,107
40 weeks	3,495	4,060	4,185
41 weeks	3,527	4,094	4,217
42 weeks	3,522	4,098	4,213

Alexander GR, et al. Obstet Gynecol 1996;87:163-168

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### Fetal Macrosomia Prediction

- 1717 women with singleton pregnancies
- EFW performed during preceding week
- clinical EFW before ruptured membranes

EFW (grams)	Clinical EFW	US EFW	p-value
All infants	-0.01 ± 10.4%	-1.4 ± 10.7%	< 0.0001
< 2500 (134)	10.0 ± 15.4%	6.8 ± 12.6%	< 0.015
2500 - 4000 (1389)	0.2 ± 9.2%	-1.2 ± 10.3%	< 0.001
> 4000 (194)	-8.2 ± 6.9%	-8.3 ± 7.9%	NS

Sherman DJ, et al. Obstet Gynecol 1998; 91:212-217

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**Accuracy of ultrasound biometry in the prediction of macrosomia: a systematic quantitative review**

- Reviewed 63 accuracy studies (51 EFW, 12 AC)
- ROC curves for predicting EFW > 4,000 grams
- No differences between EFW or AC > 36 cm seen

*"No difference in accuracy between ultrasonographically EFW and AC in the prediction of a macrosomic baby at birth. A positive test result is more accurate for ruling in macrosomia than a negative test result for ruling it out."*

Coomarasamy A, et al. BJOG 2005;112:1461-6

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**ACOG  
PRACTICE  
BULLETIN**

CLINICAL MANAGEMENT GUIDELINES FOR  
OBSTETRICIAN-GYNECOLOGISTS  
NUMBER 22, NOVEMBER 2000  
(Replaces Technical Bulletin Number 159, September 1991)

**Fetal Macrosomia**

*Suspected fetal macrosomia is a common obstetric condition. As birth weight increases, the likelihood of labor abnormalities, shoulder dystocia, birth trauma, and permanent injury to the neonate increases. The purpose of this document is to quantify these risks, address the accuracy and limitations of methods for estimating fetal weight, and suggest clinical management for the pregnancy with suspected fetal macrosomia.*

"The diagnosis of fetal macrosomia is imprecise. For suspected macrosomia, the EFW using ultrasound biometry is no better than obtained with clinical palpation." (Level A)

- suspected fetal macrosomia is not an indication for labor induction because induction does not improve maternal - fetal outcomes (Level B)
- labor and vaginal delivery are not contraindicated for women with EFW up to 5,000 g in the absence of maternal diabetes (Level B)
- with EFW > 4,500 grams, a prolonged 2nd stage of labor or arrest of descent in the second stage is an indication for delivery (Level B)

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Level C

Consensus and Expert Opinion

- consider cesarean delivery for suspected fetal macrosomia with EFW > 5,000 g in women without diabetes and > 4,500 g in women with diabetes
- suspected fetal macrosomia is not a contraindication to attempted vaginal birth after a previous cesarean delivery

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## 4. Fetal Growth Restriction

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1 in every 12 newborns in the United States are delivered with low birth weight (< 2,500 grams)

- perinatal death
- developmental delay
- learning disabilities
- cerebral palsy
- hearing loss



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WOMEN'S HEALTH CARE PHYSICIANS



Society for  
Maternal-Fetal Medicine

## PRACTICE BULLETIN

CLINICAL MANAGEMENT GUIDELINES FOR OBSTETRICIAN-GYNECOLOGISTS

NUMBER 134, MAY 2013

(Replaces Practice Bulletin Number 12, January 2000)

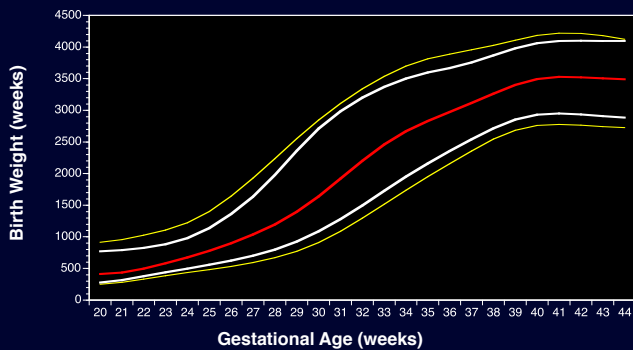
### Fetal Growth Restriction

*Fetal growth restriction, also known as intrauterine growth restriction, is a common complication of pregnancy that has been associated with a variety of adverse perinatal outcomes. There is a lack of consensus regarding terminology, etiology, and diagnostic criteria for fetal growth restriction, with uncertainty surrounding the optimal management and timing of delivery for the growth-restricted fetus. An additional challenge is the difficulty in differentiating between the fetus that is constitutionally small and fulfilling its growth potential and the small fetus that is not fulfilling its growth potential because of an underlying pathologic condition. The purpose of this document is to review the topic of fetal growth restriction with a focus on terminology, etiology, diagnostic and surveillance tools, and guidance for management and timing of delivery.*

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## Birth Weight (g) for Gestational Age 1991 Single Live Births - US Vital Statistics

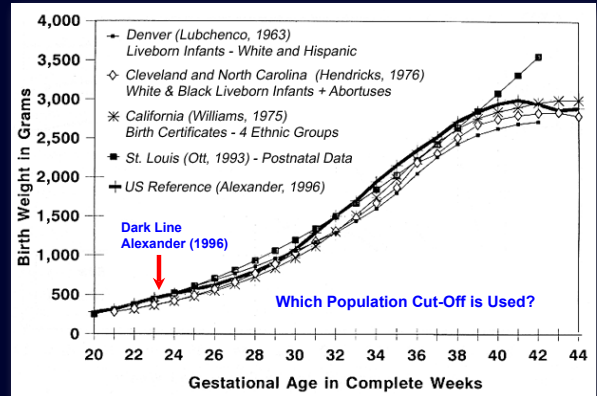


Adapted from Alexander GR, et al. *Obstet Gynecol* 1996;87:163-8

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## Variable Definitions - FGR



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Adapted from *Engl J Med* 1999;340:1234-8

### BIRTH WEIGHT IN RELATION TO MORBIDITY AND MORTALITY AMONG NEWBORN INFANTS

DONALD D. MCINTIRE, PH.D., STEVEN L. BLOOM, M.D., BRIAN M. CASEY, M.D., AND KENNETH J. LEVENO, M.D.

12,317 singleton infants (1988-1996)  $\geq$  37 weeks gestation

Birth Weight %	$\leq$ 3rd	4th-5th	6-10th	11-15th	16-25th	26th-75th
Number of Infants	3184	2065	5254	5400	10,857	55,601
Apgar $\leq$ 3, 5 min	7 (0.2)*	1 (<0.1)	6 (0.1)	5 (0.1)	9 (0.1)	38 (0.1)
UA Cord pH $\leq$ 7.0	28 (0.9)*	12 (0.6)	28 (0.5)	27 (0.5)	37 (0.3)	212 (0.4)
Intubation Del Rm	70 (2.2)*	11 (0.5)	39 (0.7)	39 (0.7)	70 (0.6)	317 (0.6)
Seizures (1st 24 hrs)	14 (0.4)*	4 (0.2)	14 (0.3)*	9 (0.2)	16 (0.1)	68 (0.1)
Sepsis (+ blood cult)	15 (0.5)*	6 (0.3)	12 (0.2)	15 (0.3)	28 (0.3)	125 (0.2)
Death (1st 28 days)	9 (0.3)*	2 (0.1)	2 (<0.1)	3 (0.1)	3 (<0.1)	18 (<0.1)

\*  $p < 0.05$  refers to data compared to 26th-75th percentile

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## Fetal Growth Restriction - Dx

Requires Accurate Gestational Dating Criteria

- certain LMP with regular menstrual cycles
- early pregnancy scan (e.g. 1st trimester)

Suspect FGR in the presence of US findings

- EFW  $<$  10th percentile
- decreased amniotic fluid volume
- abnormal fetal Doppler study (UA, MCA, CPR)

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## Early Fetal Growth Restriction $<$ 32 weeks

### Findings:

- Maternal-fetal placental vascular abnormality
- High-resistance uterine artery flow velocity
- 40-70% risk of associated pre-eclampsia
- Elevated fetal UA pulsatility index common

### Management:

- Revolves around prematurity and hypertensive disease

Seravelli V, Baschat AA. *Obstet Gynecol Clin N Am* 2015;42: 275-288

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## Late Fetal Growth Restriction $>$ 31-34 weeks

### Findings:

- Placental villous diffusion and perfusion defects
- Variable cerebral or UA Doppler abnormalities

### Management:

- Emphasizes timing of diagnosis and stillbirth prevention

Seravelli V, Baschat AA. *Obstet Gynecol Clin N Am* 2015;42: 275-288

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### Growth Restricted Newborn

Sharma D et al. Clin Med Insights Pediatr. 2016;10:67-83, With Permission

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### SGA Infant - Risk Factors

#### Maternal Risk Factors

short maternal stature  
low maternal weight  
Indian or Asian ethnicity  
nulliparity  
mother was SGA  
cigarette smoking  
cocaine use

#### Maternal Disease

chronic hypertension  
renal disease  
anti-phospholipid syndrome  
malaria

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McCowan L, et al. Best Pract Res Clin Obstet Gynaecol. 2009;23:779-793

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### SGA Infant - Risk Factors

#### Obstetrical Factors

heavy 1st TM bleeding  
placental abruption  
preeclampsia  
gestational hypertension

#### Short or Long Inter-Pregnancy Interval

#### Previous SGA infant

#### Prior Stillbirth

McCowan L, et al. Best Pract Res Clin Obstet Gynaecol. 2009;23:779-793

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### SGA Infant - Postnatal Sequelae

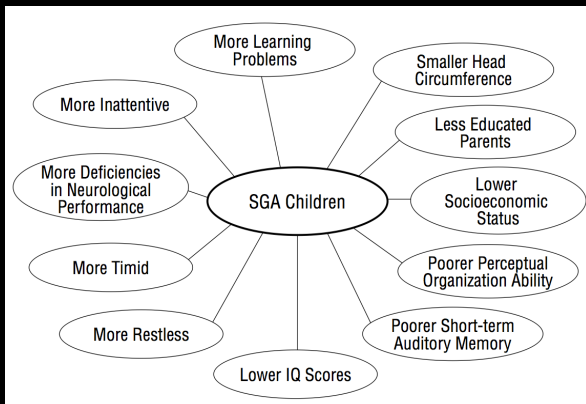
- intrauterine demise
- neonatal morbidity
  - hypoglycemia
  - hyperbilirubinemia
  - hypothermia
  - intraventricular hemorrhage
  - necrotizing enterocolitis
  - seizures
  - sepsis
  - respiratory distress syndrome
- neonatal death
- cognitive delays in childhood
- adult diseases

Sharma D, et al. J Matern Fetal Neonatal Med. 2016 Mar 15: 1-12 [Epub ahead of print]

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### Long Term Outcomes - SGA Children at Age 10

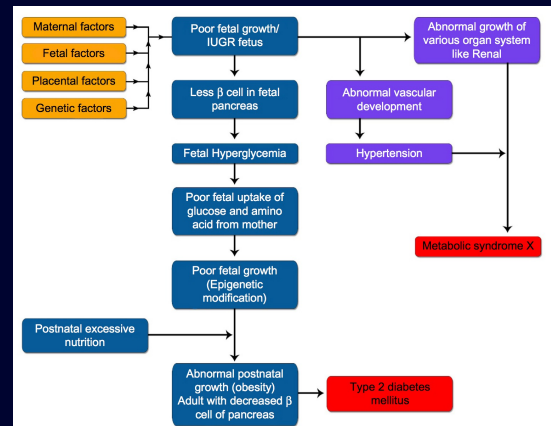


Hollo O, et al. Arch Pediatr Adolesc Med. 2002; 156:179-87

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### Fetal Origins of Adult Disease - Barker Hypothesis



Sharma D et al. Clin Med Insights Pediatr. 2016;10:67-83, With Permission

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**Screening for fetal growth restriction with universal third trimester ultrasonography in nulliparous women in the Pregnancy Outcome Prediction (POP) study: a prospective cohort study**

Ulla Sovio, Ian R White, Alison Dacey, Dharmintra Pasupathy, Gordon C S Smith

**Prospective Cohort Study (2008-2012)**

- 4,512 nulliparous Women
- fetal biometry at 20, 28, 36 weeks gestation

**Universal 3rd trimester fetal biometry roughly tripled detection of SGA infants**

Lancet. 2015 Nov 21;386(10008):2089-97.

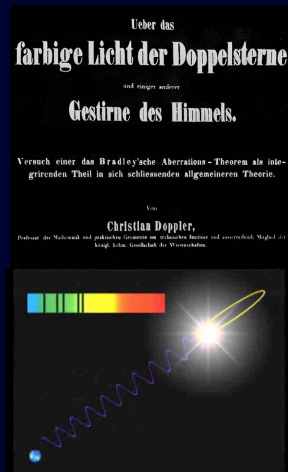
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**5. Doppler Ultrasonography for Fetal Growth**

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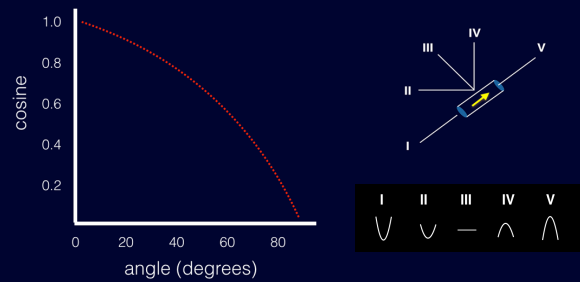


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**Doppler Equation**

$$\text{blood velocity} = \frac{(\text{frequency shift}) (\text{sound velocity})}{2 (\text{transducer frequency}) \cos \theta}$$



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The Society for Maternal-Fetal Medicine



**Five Things Physicians and Patients Should Question**

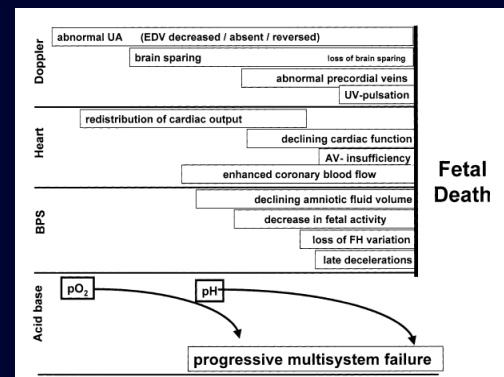
*"Don't screen for intrauterine growth restriction with Doppler flow studies"*

Society for Maternal-Fetal Medicine Publications Committee. Am J Obstet Gynecol 2012; 206:300-8  
Allirevic Z, et al. Cochrane Database of Systematic Reviews 2015, Issue 4. Art. No.: CD001450

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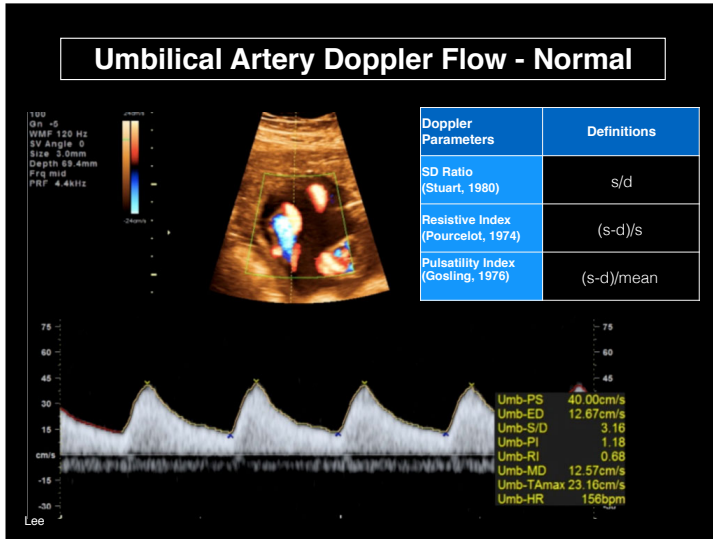
**Fetal Cardiovascular and Behavioral Variables With Decline in Metabolic Status in Fetal Growth Restriction**



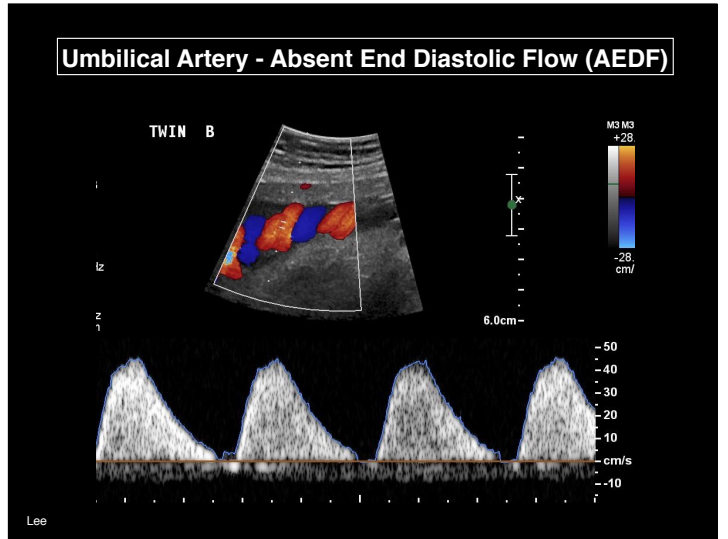
Baschat AA, et al. Sem Perinatol 2004; 28: 67-80

Lee

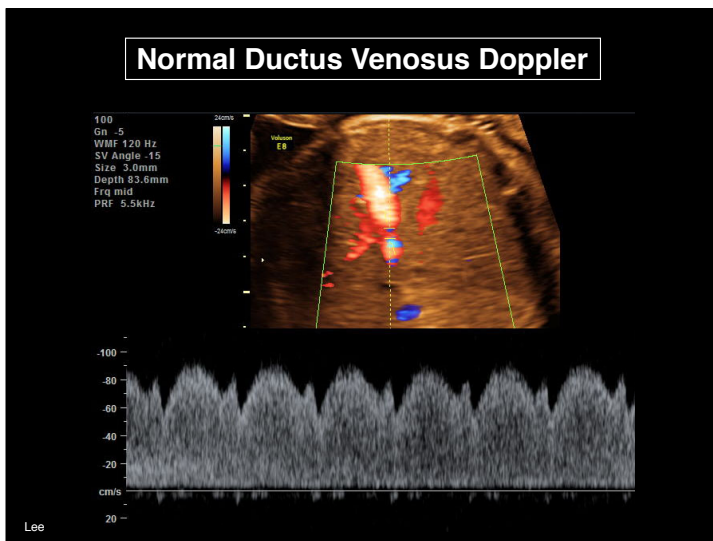
60



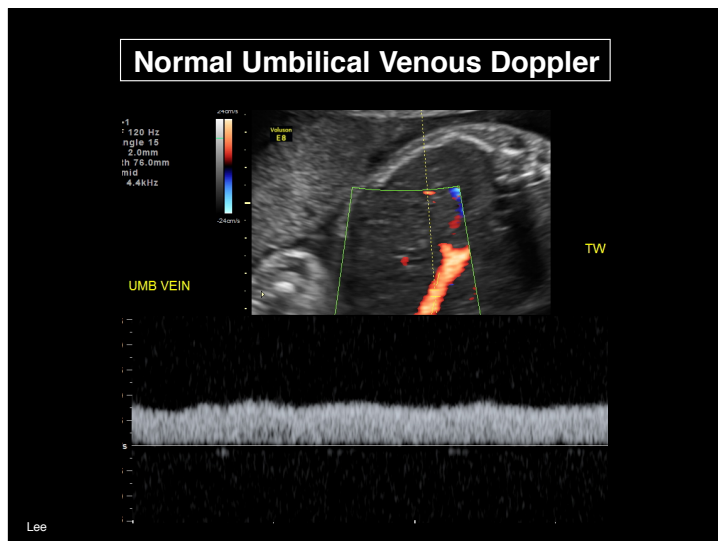
61



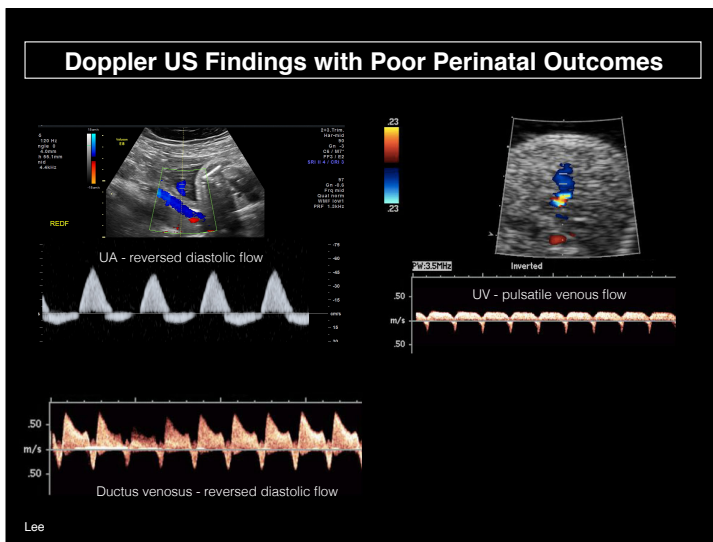
62



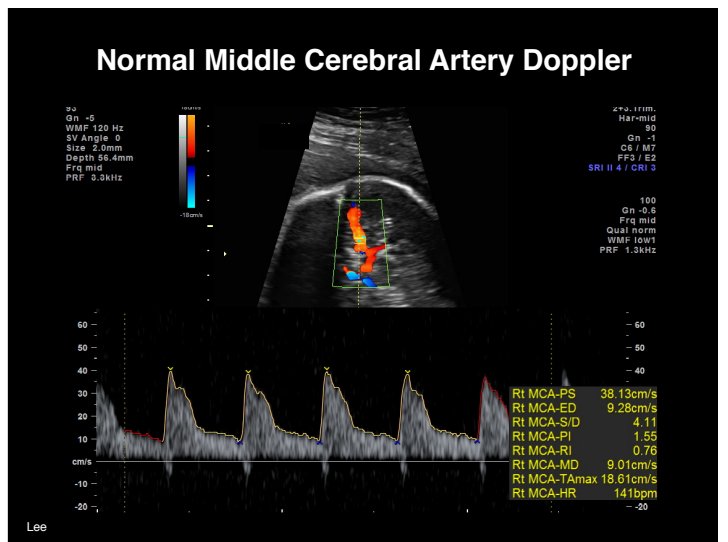
63



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65



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## Cerebroplacental Ratio (CPR)

Predictor of Adverse Outcome

MCA PI  
UA PI

Moore KL. The Developing Human. 1988

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## Cerebroplacental Ratio

Evaluation of Well-Being in SGA and AGA Fetuses

Study	Year	Study type	Doppler indices	Computation of ratio	Abnormal criteria
Arbelle et al <sup>1</sup>	1988	Cross-sectional	S-D/S	MCA/UA	Ratio <1
Arias <sup>2</sup>	1994	Cross-sectional	RI	MCA/UA	Ratio <1
Gramellini et al <sup>3</sup>	1992	Cross-sectional	PI	MCA/UA	Ratio <1.08
Bahado-Singh et al <sup>4</sup>	1999	Cross-sectional	PI	MCA/UA MoM	Ratio <0.05 MoM
Baschat and Gembruch <sup>5</sup>	2003	Cross-sectional	PI	MCA/UA	Less than fifth centile
Odibo et al <sup>10</sup>	2005	Cross-sectional	PI	MCA/UA	Ratio <1.08
Ebbing et al <sup>11</sup>	2007	Longitudinal	PI	MCA/UA	<2.5th centile
Morales et al <sup>12</sup>	2014	Cross-sectional	PI	MCA/UA	Less than fifth centile or MoM <0.6765

MCA, middle cerebral artery; MoM, multiple of the median; PI, pulsatility index; RI, resistance index; S-D, systolic/diastolic ratio; UA, umbilical artery; DeVore. Cerebroplacental ratio in fetal well-being in SGA and AGA fetuses. *Am J Obstet Gynecol* 2015.

PI CPR < 1    Sensitivity 66%    Odds Ratio 11.7 for detection of Adverse Perinatal Outcome  
 Specificity 85%

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DeVore GR. *Am J Obstet Gynecol* 2015;213:5-15

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Category	SGA (decreased CPR)	SGA (normal CPR)	Controls
Cesarean delivery	~65*	~30*	~20
Cesarean delivery for fetal distress	~48*	~22*	~5
Neonatal acidosis	~10*	~5	~2

Cruz-Martinez et al. *Obstet Gynecol* 2011;117:618-26

Lee

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Ultrasound *Obstet Gynecol* 2015; 45: 156-161  
Published online 5 January 2015 in Wiley Online Library (wileyonlinelibrary.com). DOI: 10.1002/uog.14647

## Poor neonatal acid–base status in term fetuses with low cerebroplacental ratio

J. MORALES-ROSELLÓ\*, A. KHALIL†, M. MORLANDO†, A. BHIDE†, A. PAPAGEORGHIOU† and B. THILAGANATHAN†

\*Servicio de Obstetricia y Ginecología, Hospital Universitario y Politécnico La Fe, Valencia, Spain; †Fetal Medicine Unit, St George's Hospital, London, UK

**retrospective study of 2927 term fetuses**

“Low CPR in AGA fetuses is an equally important marker of low neonatal pH secondary to placental underperfusion as is being SGA”

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RESEARCH ajog.org

OBSTETRICS

## Is fetal cerebroplacental ratio an independent predictor of intrapartum fetal compromise and neonatal unit admission?

Asma A. Khalil, MD, MRCOG; José Morales-Rosello, MD; Maddalena Morlando, MD; Hasina Hannan, MD; Amar Bhide, MD, MRCOG; Aris Papageorghiou, MD, MRCOG; Basky Thilaganathan, PhD, MRCOG

retrospective cohort study - 9772 singleton pregnancies

“Third-trimester CPR is an independent predictor of stillbirth and perinatal mortality”

Am J Obstet Gynecol 2015; 213: 54.e1-10

Lee

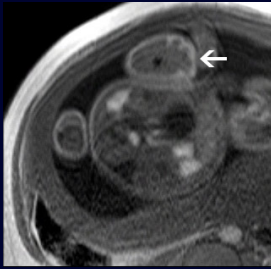
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## 6. Fetal Soft Tissue Assessment

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## Fetal Soft Tissue MR Imaging



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## Why is Fetal Soft Tissue Important?

- fetal growth is a complex process and should be characterized using a combination of skeletal and soft tissue parameters
- soft tissue assessment improves precision of EFW and now adds another key nutritional component to the weight estimation process



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## Neonatal Thighs



Growth Restriction - 2845 grams  
39.7 weeks, menstrual age



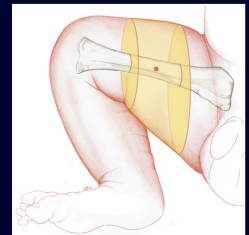
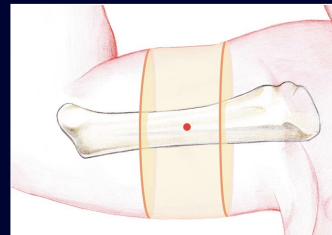
Macrosomia - 4368 grams  
38.4 weeks, menstrual age

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## Fractional Limb Volume

Limb Sub-Volume Based on 50% of Long Bone Diaphysis Length

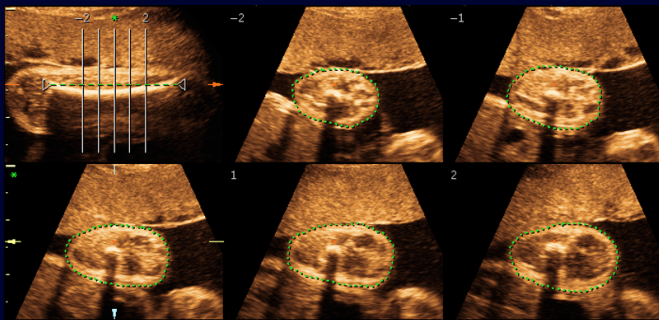


Lee W, et al. Ultrasound Obstet Gynecol 2009;33:427-440

Lee

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## Fractional Thigh Volume - 20 weeks



Lee

Lee W, et al. Ultrasound Obstet Gynecol 2009;33:427-440

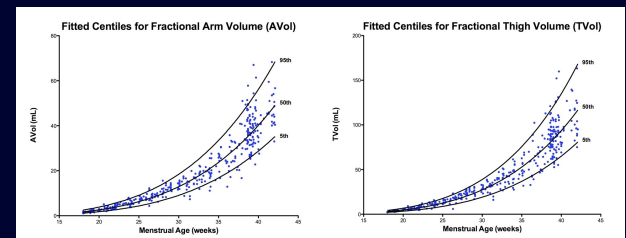
77

Ultrasound Obstet Gynecol 2009; 33: 427-440

## Fractional limb volume – a soft tissue parameter of fetal body composition: validation, technical considerations and normal ranges during pregnancy

W. LEE<sup>††</sup>, M. BALASUBRAMANIAM<sup>§</sup>, R. L. DETER<sup>¶</sup>, S. S. HASSAN<sup>††</sup>, F. GOTSCH<sup>††\*\*</sup>, J. P. KUSANOVIC<sup>†</sup>, L. F. GONCALVES<sup>††</sup> and R. ROMERO<sup>††\*\*</sup>

<sup>†</sup>Division of Fetal Imaging, Department of Obstetrics and Gynecology, William Beaumont Hospital and <sup>§</sup>Division of Biostatistics, William Beaumont Hospital Research Institute, Royal Oak, MI, <sup>¶</sup>Department of Obstetrics and Gynecology, Baylor College of Medicine, Houston, TX, <sup>\*\*</sup>Perinatology Research Branch, Eunice Kennedy Shriver National Institute of Child Health and Human Development, National Institutes of Health, Department of Health and Human Services, Bethesda, MD and <sup>††</sup>Department of Obstetrics and Gynecology, Wayne State University, Detroit, MI, USA



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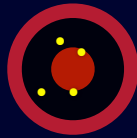
## Birth Weight Prediction Models



precise  
accurate



precise  
not accurate



not precise  
not accurate



**Accuracy**  
Systematic Error

$$\frac{\text{Predicted BW} - \text{Actual BW}}{\text{Actual BW}} \times 100$$



**Precision**  
Random Error

Standard Deviation of  
Percent Differences

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## Prospective validation of fetal weight estimation using fractional limb volume

W. LEE\*†‡§, R. DETER‡, H. SANGI-HAGHPEYKAR‡, L. YEO†§ and R. ROMERO†

\*Department of Obstetrics and Gynecology, Oakland University William Beaumont School of Medicine, Rochester, MI, USA; †Perinatology Research Branch, NICHD/NIH/DHHS, Bethesda, MD and Detroit, MI, USA; ‡Department of Obstetrics and Gynecology, Baylor College of Medicine, Houston, TX, USA; §Department of Obstetrics and Gynecology, Wayne State University School of Medicine, Detroit, MI, USA

2013

Best EFW precision (lowest random errors) occurred with volume-based weight models

Fetal Weight Estimation Model	Birth Weight All Infants (g)	Birth Weight < 2000 g	Birth Weight 2000-4000 g	Birth Weight > 4000 g
BPD, AC, FDL Original Hadlock (OH2)	4.9 ± 8.8* (n = 158)	4.9 ± 10.6* (n = 28)	4.4 ± 8.2* (n = 100)	6.7 ± 8.6* (n = 30)
BPD, AC, FDL Modified Hadlock (MH2)	1.1 ± 8.4 (n = 158)	1.0 ± 10.0 (n = 28)	1.2 ± 8.0 (n = 100)	0.5 ± 8.3 (n = 30)
BPD, AC, TVol New Model 6	1.9 ± 6.6* (n = 156)	0.4 ± 7.8 (n = 28)	1.5 ± 6.4* (n = 98)	4.3 ± 5.8* (n = 30)

\* systematic error significantly different from zero, one sample t-test

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## Conclusions

Fetal growth assessment requires accurate gestational dating criteria

- sure LMP with regular menstrual cycles
- early pregnancy scan (e.g. 1st trimester)

Suspect fetal macrosomia if EFW > 4,000 grams or > 90th percentile for gestational age

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## Conclusions

Suspect fetal growth restriction for US findings

- EFW < 10th percentile
- decreased amniotic fluid volume
- abnormal fetal Doppler study (UA, MCA, CPR)

Fractional limb volume can be used to assess fetal soft tissue development - this 3D parameter adds a nutritional component to the weight estimation process and improves the precision of EFW

Lee

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## Key References

American College of Obstetricians and Gynecologists. Committee Opinion No. 22. Fetal macrosomia. Obstet Gynecol 2000. Reaffirmed 2015.

American College of Obstetricians and Gynecologists. Committee Opinion No. 634. Fetal growth restriction. Obstet Gynecol 2013;121: 1122-33

American College of Obstetricians and Gynecologists. Committee Opinion No. 611. Method for estimating due date. Obstet Gynecol 2014;124: 863-6

DeVore GR. The importance of the cerebroplacental ratio in the evaluation of fetal well being and SGA and AGA fetuses. Am J Obstet Gynecol 2016;213: 5-15

Haddock FP, Harrist RB, Sharman RS, et al. Estimation of fetal weight with the use of head, body, and femur measurements - a prospective study. Am J Obstet Gynecol 1985;151: 333-7

Lee W, Balasubramaniam M, Deter RL, et al. Fractional limb volume: a soft tissue parameter of fetal body composition. validation, technical considerations, and normal ranges during pregnancy. Ultrasound Obstet Gynecol 2009; 33: 427-440.

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Questions??

wesley.lee@bcm.edu



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