Fetal Weight Estimation in Diabetic Pregnancies and Suspected Fetal Macrosomia: The Real Facts

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Pregnancy is often complicated by diabetes, either preexisting or diagnosed during gestation. The reported prevalence of gestational diabetes mellitus (GDM) is 3% to 5% of all live births [1], and even higher in selected populations, such as Mexican-Americans, Asians, and Indians [2,3]. Clinicians have witnessed a significant improvement in outcome of diabetic pregnancies owing to improved perinatal maternal glycemic control, close antepartum surveillance, and advances in neonatal care, although the risk of fetal macrosomia and adverse perinatal outcome has not been eliminated.

Ultrasound is an important tool for monitoring diabetic pregnancies. It is used to assess gestational age, congenital anomalies, fetal well-being (dynamic assessment), and growth abnormalities such as macrosomia and fetal growth restriction. However, the role of fetal weight estimation by ultrasound in predicting adverse perinatal outcome remains controversial. The failure to correctly estimate fetal weight has important clinical implications and has been incorporated in litigations involving complicated deliveries, which in rare cases can result in persistent brachial plexus injury.

This paper reviews the literature on the accuracy of ultrasound in estimating fetal weight in diabetic pregnancies. We focused specifically on its role in the prediction and clinical management of fetal macrosomia.

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Macrosomia

Excessive fetal growth is defined in two ways. Infants large for gestational age (LGA) have a birth weight equal to or greater than the 90th percentile for their gestational age. This factor, however, varies according to the specific population under study. In the United States, for example, a recent national survey reported that fetal weight in the 90th percentile at 37, 40, and 42 weeks of gestation is 3,755, 4,060, and 4,098 gr, respectively [4]. Fetal macrosomia is defined as growth beyond a specific weight, usually 4,000 or 4,500 gr, regardless of gestational age. The risk of morbidity in infants and mothers when the birth weight is between 4,000 and 4,500 gr is greater than that in the general obstetric population, and it increases sharply beyond 4,500 gr. This cutoff is supported by recent large cohort studies [5].

Ten percent of all live-born infants in the United States weigh more than 4,000 gr, and 1.5% weigh more than 4,500 gr [1]. Both gestational and pregestational diabetes are associated with fetal macrosomia. In one study, 6% of mothers with untreated borderline GDM delivered infants weighing more than 4,500 gr, compared with only 2% of women with normal glucose tolerance [6]. If full-blown GDM is unrecognized and untreated, the risk of macrosomia may be as high as 20% [7].

Shoulder dystocia

Shoulder dystocia is the most serious complication of fetal macrosomia; the risk is 1.4% for all vaginal deliveries [8], and it rises dramatically to 9.2% - 24% when the birth weight exceeds 4,500 gr [9, 10]. In diabetic pregnancies, birth weights greater than 4,500 gr have been associated with 19.9% to

50% rates of shoulder dystocia [9, 10]. Shoulder dystocia may also be associated with other birth traumas, such as Erb's palsy, clavicular fracture, fetal distress, low Apgar score, and birth asphyxia [11], although 25 to 75% of brachial plexus injuries are unrelated to antecedent shoulder dystocia [12].

Macrosomia due to maternal diabetes is different from macrosomia due to other predisposing factors [13, 14]. Macrosomic infants of diabetic mothers tend to have greater total body fat, greater shoulder and upper-extremity circumferences, greater upper-extremity skin-fold measurements, and smaller head-to-abdominal-circumference ratios than macrosomic infants of nondiabetic mothers. This may explain the higher incidence of shoulder dystocia in these infants [14].

Ideally, clinicians should diagnose macrosomia in the antenatal period so that they can offer the optimal mode of delivery for preventing shoulder dystocia on the one hand, and sparing unnecessary cesarean sections on the other.

Ultrasonographic diagnosis of fetal macrosomia

The diagnosis of fetal macrosomia has been the subject of much clinical concern and scientific investigation. Over the past 30 years, investigators have introduced formulas based on sonographic measurements of fetal organs to estimate fetal weight. The older formulas used the fetal head, abdomen, and femur, either alone [15] or in combination [16, 17]. Some authors demonstrated differences in accuracy and precision among these formulas [18, 19]. Regardless of the formula used, the accuracy of the fetal weight estimation decreased with increasing birth weight [20-22]. For example, Hadlock's formula has a mean absolute percent error of 13% for infants weighing more than 4,500 gr but only 8% for nonmacrosomic infants [23]. Others showed that in women without diabetes, ultrasound biometry used to detect macrosomia has a sensitivity of 22–44%, specificity of 99%, positive predictive value of 30–44%, and negative predictive value of 97–99% [18, 24]. In addition, the error rates of the regression functions that generate the sonographic estimates of fetal weight are similar to the error rates of the clinical estimates [25]. Ultrasonographic fetal weight estimation at the 90th percentile or above has a sensitivity range of 6.7-89%, and a specificity range of 62-98%. The same calculation for birth weight of 4,000 gr or more has a sensitivity range of 11-100% and a specificity range of 48-100% [25]. O'Reilly-Green and Divon [24] and Miller et al. [26] found that the optimal cutoff for sonographic fetal weight estimation in predicting a birth weight of ≥4,000 gr is 3,700 gr. The prediction of macrosomia in fetuses in breech presentation is more difficult than in fetuses in cephalic presentation [27]. The reported mean absolute percent error for breech and cephalic presentations are 12.9% and 9.5%, respectively.

To overcome these drawbacks, alternative sonographic markers for fetal macrosomia have been proposed which take advantage of the presumed correlation between subcutaneous fat deposition and fetal weight. Three-dimensional ultrasound measurements of fetal upper arm volume [28, 29], fetal chest [30], abdominal [31] and humeral [32] soft tissue thickness, and cheek-to-cheek diameter [33], as well as of the subcutaneous tissue/femur length ratio [34, 35], are associated with varying efficacies. Sacks and Chen [36] reviewed population-based studies of the clinical performance of ultrasound in predicting macrosomia. They concluded that only 15 to 81% of babies (median 67%) predicted to be macrosomic are indeed macrosomic at birth, and that 50 to 100% (median 62%) of all cases of macrosomia are successfully predicted by sonographic measurements. Therefore, like with clinical estimates of fetal weight, the true value of ultrasonography in the management of fetal macrosomia may be its ability to rule out the diagnosis (negative predictive value) [5]. This is especially important given the fact that clinicians who suspected fetal macrosomia on the basis of an ultrasonogram were more likely to diagnose labor abnormalities and were more likely to perform cesarean deliveries despite normal birth weights [37].

Individualized fetal growth estimation curves, such as the complex mathematical model of Rossavik, have not proven more accurate. The prediction error of Rossavik's model averaged 6.1% and ranged from 3.6% to16.5% [25]. By contrast, serial measurement of the abdominal circumference (AC) had a sensitivity and specificity of 84% and 100%, respectively, in predicting birth weight in the 90th percentile or above [38]. For single measurement the sensitivity and specificity were 54% and 89%, respectively. A single measurement of abdominal circumference above the 90th percentile has a relative risk of only 5.5 for birth weight in the 90th percentile or above, whereas serial measurements have a relative risk of 32 [25].

Other techniques for estimating fetal weight have been reported as well, such as magnetic resonance imaging, which yielded estimates within 3% of the actual birth weight in 11 patients with babies weighing 1,600 – 3,300 gr. This compared favo-

rably with the 6.5% error by sonographic examination of the same patients [39].

Prediction of macrosomia in diabetic pregnancies

The estimation of fetal weight in diabetic pregnancies involves special considerations. Because of the disproportionate contribution of fat to fetal body weight and the lower density of fat compared to lean body tissue, equations derived from cross-sectional data may theoretically overestimate the fetal weight when applied to the GDM population [40]. Furthermore, the time from examination to delivery may influence the accuracy and precision of the sonographic estimates [24, 41, 42].

Currently, no single sonographic measurement is capable of distinguishing between LGA and appropriate-for gestational-age (AGA) infants in diabetic pregnancies. Although the finding of an abdominal circumference above the 90th percentile in the second or third trimester is positively associated with fetal macrosomia, the actual birth weights of the babies predicted to be macrosomic on this basis overlap with those of AGA babies in a substantial proportion of cases [43].

Clinical studies have found no significant differences in absolute percent error of birth weight between infants of women with and without diabetes [23]. The accuracy of birth weight prediction by ultrasound and by clinical estimates has been analyzed in a number of studies [44-49]. When the sample was limited to babies with an actual birth weight of >4,000 gr, no significant differences were found between the clinical and ultrasound estimates at or near the onset of labor. The sensitivity of the sonographic estimates in predicting birth weight at the 90th percentile or above in diabetic pregnancies ranged from 70-96%, and specificity ranged from 77-100% [25]. Corresponding values for predicting a birth weight of ≥ 4,000 gr were 33-69% and 77-98%.

Other measurements did not prove superior in diabetic pregnancies [25]. These included the femur length/ abdominal circumference ratio, the abdominal diameter/ femur length ratio, the chest/ biparietal diameter ratio, and soft tissue thickness. Cohen et al [50], in a study of the value of the difference between the abdominal and biparietal diameters in predicting shoulder dystocia in diabetic pregnancies, found that the cutoff value of ≥2.6 cm had a sensitivity of 100% and a specificity of 56%.

Hendrix et al [51] reported that when birth weight was 4,000 gr or more, the absolute error of the clinical estimates was 5.3% and of the sonographic estimates, 13%. Ninety-two percent of the clinical estimates were within 10% of the birth weight compared with 33% of the sonographic estimates. McLaren et al. [52] showed that the 90% prediction limits for an estimated fetal weight of 4,000 gr in diabetic pregnancies included birth weights from 3,410 to 4,675 gr. When the birth weight exceeded 4,500 gr, only 50% of the fetuses actually weighed within 10% of the ultrasound-derived estimate [53].

Role of ultrasound in the management of diabetic pregnancy

Glucose intolerance and fetal abdominal circumference

Parretti et al. [54] recently showed that fetal abdominal circumference, which is considered as a parameter of growth of insulin-sensitive tissues, is influenced by postprandial glucose peaks even in nondiabetic pregnancies. They examined the correlations between maternal glucose levels and sonographic parameters of fetal growth in a longitudinal study of 51 Caucasian nonobese pregnant women with normal glucose challenge tests. Results showed that concomitant with a slight but progressive increase in daily mean glucose levels from 28 weeks (71.9 ± 5.7 mg/dl) to 38 weeks (78.3 ± 5.4 mg/dl), demonstrating the known deterioration of glucose tolerance during the course of normal pregnancy, there was a significant positive correlation at 28 and 36 weeks of gestation between postprandial glucose values and fetal abdominal circumference, and a negative correlation between head-abdominal circumference ratio and 1-h postprandial blood glucose values.

These findings are in agreement with those of diabetic pregnancies, in which a 1-h postprandial maternal blood glucose concentration in the third trimester is considered a strong predictor of infant birth weight and fetal macrosomia [55]. Furthermore, in diabetic pregnancies, fetal hyperinsulinism and birth weight have been found to correlate best with 1-h postprandial glucose values [56]

Insulin treatment

Buchanan et al. [57] suggested that insulin may treat early macrosomia diagnosed in ultrasound. They randomized 98 women at 29-33 weeks' gestation with a fetal abdominal circumference exceeding the 75th percentile for gestational age to either diet therapy alone or diet therapy with twice-daily insulin. They found that the addition of insulin decreased the likelihood of birth weight greater than the 90th percentile from 45% among those treated with diet only to 13% among those rece-

iving insulin.

Recently, the same group of investigators [58] compared management based on maternal glycemic criteria with management based also on fetal abdominal circumference measurements in order to select patients for insulin treatment of GDM. Ninety-eight women with GDM and fasting hyperglycemia were randomized to two groups: insulin treatment or insulin treatment only if abdominal circumference was at the 70th percentile or greater and/or if any venous fasting plasma glucose measurement was >120 mg/dl. The authors found no between-group differences in birth weight, frequency of birth weight above the 90th percentile (6.3% vs 8.3%), or neonatal morbidity. Thus, in women with GDM and fasting hyperglycemia, measurements of glucose plus fetal abdominal circumference identified pregnancies at low risk of macrosomia and sparing in 38% of the patients of insulin therapy with no increase in neonatal morbidity.

Fetal weight estimation and prophylactic cesarean delivery

Macrosomia is distinctly more common in women with GDM, and shoulder dystocia is more likely at a given birth weight in pregnancies complicated by diabetes than in nondiabetic pregnancies. Therefore, it may be reasonable, to recommend cesarean delivery without a trial of labor at some particular threshold of fetal weight. However, the clinical effectiveness of this practice has not yet been established [5]. According to one observational study in which 1,337 women with diabetes were offered either elective cesarean delivery if the ultrasound-derived fetal weight estimate was beyond 4,250 gr or induction of labor if the ultrasound predicted an LGA infant but weighing less than 4,250 gr [59]. Findings were compared with a historic control group of 1,227 women with diabetes. Results yielded a nonsignificant reduction in the risk of shoulder dystocia from 2.4% in controls to 1.1% in the intervention group, and a significant increase in cesarean delivery rate from 21.7% in controls to 25.1% in the intervention group.

In two additional reports analyzing the policy of prophylactic cesarean delivery for macrosomia, which took into account the reported sensitivity and specificity of ultrasonography, the authors calculated that 3,695 cesarean deliveries would be required to prevent one permanent injury, at a cost of $8.7 million for each injury avoided [60,61]. For pregnancies complicated by diabetes, these figures were still high at 443 cesarean deliveries to prevent a single permanent injury.

On the basis of these findings, the American College of Obstetricians and Gynecologists [5] stated that, "Because of the lack of well-designed and well-executed randomized clinical trials, a policy of prophylactic cesarean delivery for suspected fetal macrosomia less than 5,000 g may not be effective for pregnancies without diabetes. Furthermore, even for pregnancies complicated by diabetes, the cost-effectiveness of such a policy is doubtful." They concluded that, "Although the diagnosis of fetal macrosomia is imprecise, prophylactic cesarean delivery may be considered for suspected fetal macrosomia with estimated fetal weights greater than 5,000 g in women without diabetes and greater than 4,500 g in women with diabetes". However, these conclusions were modified in their latest Practice Bulletin [62], which suggested that, "Because of the higher likelihood of shoulder dystocia at a given birth weight in the pregnancies of women with diabetes, it may be best to apply the above recommendation to an estimated fetal weight greater than 4,000 g for GDM. Operative deliveries from the midpelvis should be avoided, if possible, in patients with GDM who have an estimated fetal weight of 4,000 g or more and a prolonged second stage of labor "

Summary

Ultrasound is a useful predictor of macrosomia from a statistical point of view [25], but it has limited applications in clinical practice because of its substantial false-positive and false-negative rates [25]. Serial sonographic measurements can increase the positive predictive value. One study suggested that sonographic laboratories might improve their results by performing receiver operator characteristics (ROC) curve analysis on their own data, in order to select a better cutoff value to predict macrosomia [25].

On the basis of the data collected so far, several key statements can be made regarding the accuracy of ultrasound in predicting fetal macrosomia:

1. Regardless of the formula used, the accuracy of the EFW decreases with increasing birth weight.

2. A disparity in ultrasound measurements between by different operators in individual subjects should be taken into account.

3. Formulas incorporating measurements of the fetal head are of less clinical value for patients in labor.

4. The time elapsed between the fetal weight estimation and delivery may influence the accuracy and precision of the estimate.

5. Although variations in either maternal obesity or amniotic fluid index alone do not significantly influence predictive accuracy, the combination of maternal obesity, anterior placentation and oligohydramnios may eliminate the possibility of accurately measuring fetal parts.

6. The diagnosis of fetal macrosomia is imprecise. For suspected fetal macrosomia, the EFW using ultrasound biometry is believed to be no more accurate than the EFW obtained by clinical palpation [5, 49]. However, a recent prospective study showed that the accuracy of ultrasound estimation of fetal weight was better than maternal and clinical estimation of fetal weight [63].

7. To date, non of the management algorithms developed for selective interventions that are based on the sonographic EFW have demonstrated any efficacy in reducing the incidence of either shoulder dystocia or brachial plexus injury.

Should ultrasound be used to identify fetal macrosomia in low-risk pregnancies or in pregnancies complicated by diabetes? It is clear that ultrasound-derived fetal weight estimates alone are not sufficient grounds for deciding the route of delivery [5, 64]. To asses the risk of macrosomia in both diabetic and nondiabetic pregnancies, other known risk factors should also be taken into account, such as prior history of macrosomia, maternal pre-pregnancy weight, weight gain during pregnancy, multiparity, fetal sex (male), gestational age (>40 weeks), ethnicity, maternal birth weight, and maternal height [5]. To determine the mode of delivery, the clinical fetal weight estimate, subjective maternal weight estimate, and clinical pelvimetry findings should be added to the sonographic fetal weight estimate (preferably by serial measurements which include the abdominal circumference), with consideration of the above risk factors for macrosomia. Furthermore, as suggested recently [65], the use of additional examiners to perform the sonographic estimates may reduce the absolute weight difference, especially with repeated measurements of abdominal circumference.

In the future, three-dimensional ultrasound and magnetic resonance imaging are expected to generate better ROC curves than those of two-dimensional ultrasound or clinical estimates [25].

REFERENCES

1. Ventura SJ, Martin JA, Curtin SC, Mathews TJ, Park MS. Births: Final data for 1998. National Vital Statistics Reports 2000;48:1-100.
2. King H. Epidemiology of glucose intolerance and gestational diabetes in women of childbearing age. Diabetes 1998;2 (Suppl.2):9-13.
3. Engelgau NM, Herman WH, Smith PI, German RR, Aubert RE. The epidemiology of diabetes and pregnancy in the US. Diabetes Care. 1998;18:1029-1033.
4. Alexander GR, Himes JH, Kaufman RB, Mor J, Kogan M. A United States national reference for fetal growth. Obstet Gynecol 1996;87:163–168.
5. American College of Obstetricians and Gynecologists Practice Bulletin. Fetal Macrosomia. Number 22, November 2000.
6. Naylor CD, Sermer M, Chen E, Sykora K. Cesarean delivery in relation to birth weight and gestational glucose tolerance: pathophysiology or practice style? Toronto Trihospital Gestational Diabetes Investigators. JAMA 1996;275: 1165–1170.
7. Adams KM, Li H, Nelson RL, Ogburn PL Jr, Danilenko-Dixon DR. Sequelae of unrecognized gestational diabetes. Am J Obstet Gynecol 1998;178:1321–1332.
8. Gonik B, Hollyer L, Allen R. Shoulder dystocia recognition: differences in neonatal risks for injury. Am J Perinatol 1991;8:31–34.
9. Acker DB, Sachs BP, Friedman EA. Risk factors for shoulder dystocia. Obstet Gynecol 1985;66:762–768.
10. Nesbitt TS, Gilbert WM, Herrchen B. Shoulder dystocia and associated risk factors with macrosomic infants born in California. Am J Obstet Gynecol 1998;179:476–480.
11. Levine MG, Holroyde S, Woods JR, Siddiqi TA, MacHenry S, Miodovnik M. Birth trauma: Incidence and predisposing factors. Obstet Gynecol 1984;63:792-795.
12. Gherman RB, Goodwin TM, Ouzounian JG. Brachial plexus palsy associated with cesarean section: an in utero injury? Am J Obstet Gynecol 1997;177:1162-1164.
13. Nasrat H, Abalkhail B, Fageeh W, Shabat A, el Zahrany F. Anthropometric measurements of newborns of gestational diabetic mothers: does it indicate disproportionate fetal growth? J Matern Fetal Med 1997;6:291–295.
14. McFarland MB, Trylovich CG, Langer O. Anthropometric differences in macrosomic infants of diabetic and nondiabetic mothers. J Matern Fetal Med 1998;7:292–295.
15. Campbell S, Wilkin D. Ultrasonic measurements of fetal abdomen circumference in the estimation of fetal weight. Br J Obstet Gynecol 1975;82:689-697.
16. Hadlock FP, Harrist RB, Carpenter RJ, Deter RL, Park SK. Sonographic estimation of fetal weight: The value of femur length in addition to head and abdomen measurements. Radiology 1984;150:535-540.
17. Shepard MJ, Richards VA, Berkowitz RL, Warsof RL, Hobbins JC. An evaluation of two equations for predicting fetal weight by ultrasound. Am J Obstet Gynecol 1982;142:47-54.
18. Smith GCB, Smith MFS, McNay MB, Fleming JEE. The relation between fetal abdominal circumference and birthweight: findings in 3512 pregnancies. Br J Obstet Gyneacol 1997;104:186-190.
19. Shamley KT, Landon MB. Accuracy and modifying factors for ultrasonographic determination of fetal weight at term. Obstet Gyncol 1994;84:926-930.

20. Dudley NJ. Selection of appropriate ultrasound methods for the estimation of fetal weight. Br J Radiol 1995;68:385-388.
21. Hirata GI, Medearis AL, Horenstein J. Ultrasonographic estimation of fetal weight in the clinically macrosomic fetus. Am J Obstet Gynecol 1990;162:238-242.
22. Miller JM, Korndorffer FA, Gabert HA. Fetal weight estimates in late pregnancy with emphasis on macrosomia. J Clin Ultrasound 1986;14:437-442.
23. Alsulyman OM, Ouzounian JG, Kjos SL. The accuracy of intrapartum ultrasonographic fetal weight estimation in diabetic pregnancies. Am J Obstet Gynecol 1997;177:503-506.
24. O'Reilly-Green CP, Divon MY. Receiver operating characteristics curves of sonographic estimated fetal weight for prediction of macrosomia in prolonged pregnancies. Ultrasound Obstet Gynecol 1997;9:403-408.
25. O'Reilly-Green C, Divon M. Sonographic and clinical methods in the diagnosis of macrosomia. Clin Obstet Gynecol. 2000; 43:309-320.
26. Miller JM Jr, Brown HL, Khawli OF, Pastorek JG 2nd, Gabert HA. Ultrasonographic identification of the macrosomic fetus. Am J Obstet Gynecol. 1988;159:1110-1114.
27. Chauhan SP, Magann EF, Naef RW 3rd, Martin JN Jr, Morrison JC. Sonographic assessment of birth weight among breech presentations.Ultrasound Obstet Gynecol. 1995;6:54-57.
28. Favre R, Bader A-M, Nisand G. Prospective study on fetal weight estimation using limb circumferences obtained by three-dimensional ultrasound. Ultrasound Obstet Gynecol 1995;6:140-144.
29. Liang R-I, Chang F-M, Yao B-L. Predicting birth weight by fetal upper- arm volume with use of three-dimensional ultrasonography. Am J Obstet Gynecol 1997;177:632-638.
30. Winn NH, Rauk PN, Petrie RH. Use of the fetal chest in estimating fetal weight. Am J Obstet Gynecol 1992;167:448-450.
31. Petrikovsky BM, Oleschuk C, Lesser M. Prediction of fetal macrosomia using sonographically measured abdominal subcutaneous tissue thickness. J Clin Ultrasound 1997;25: 378-382.
32. Sood AK, Yancey M, Richards D. Prediction of fetal macrosomia using humeral soft tissue thickness. Obstet Gynecol 1995;85:937-940.
33. Abramovicz JS, Sherer DM, Woods JR. Ultrasonographic measurements of cheek-to-cheek diameter in fetal growth disturbances. Am J Obstet Gynecol 1993;169:405-408.
34. Santolaya-Forgas J, Meyer WJ, Gautier DW. Intrapartum fetal subcutaneous tissue/femur length ratio: An ultrasonographic clue to fetal macrosomia. Am J Obstet Gynecol 1994;171:1072-1075.
35. Rotmensch S, Celentano C, Liberati M, Malinger G, Sadan O, Bellati U, Glezerman M. Screening efficacy of the subcutaneous tissue width/femur length ratio for fetal macrosomia in the non-diabetic pregnancy. Ultrasound Obstet Gynecol 1999;13:340-344.
36. Sacks DA, Chen W. Estimating fetal weight in the management of macrosomia. Obstet Gynecol Surv 2000;55:229-239.
37. Levine AB, Lockwood CJ, Brown B. Sonographic diagnosis of the large for gestational age fetus at term: does it make a difference? Obstet Gynecol 1992;79:55-58.
38. Hedriana HL, Moore TR. A comparison of single versus multiple growth ultrasonographic examinations in predicting birth weight. Am J Obstet Gynecol. 1994;170:1600-1604.
39. Baker PN, Johnson IR, Gowland PA. Fetal weight estimation by echo-planar magnetic resonance imaging. Lancet 1994;343:644-645.
40. Crane SS, Avallone DA, Thomas AJ. Sonographic estimation of fetal body composition with gestational diabetes mellitus at term. Obstet Gynecol 1996;88:849-854.
41. Rossavik IK, Joslin GL. Macrosomatia and ultrasonography: What is the problem? South Med J 1993:86:1129-1132.
42. Spinnato JA, Allen RD, Mendenhall HW. Birth weight prediction from remote ultrasonographic examination. Am J Obstet Gynecol 1989;161:742-747.
43. Keller JD, Metzger BE, Doodly SL. Infants of diabetic mothers with accelerated fetal growth by ultrasonography: are they all alike? Am J Obstet Gynecol 1990;163:893-897.
44. Raman S, Urquhart R, Yusof M. Clinical versus ultrasound estimation of fetal weight. Aust N Z Obstet Gynaecol 1992;32:196-199.
45. Chauhan SP, Cowan BD, Magann EF. Intrapartum detection of a macrosomic fetus: Clinical versus 8 sonographic models. Aust N Z J Obstet Gynaecol 1995;35:266-270.
46. Watson WJ, Soisson AP, Harlass FE. Estimated weight of the term fetus. Accuracy of ultrasound vs clinical examination. J Reprod Med 1998;33:369-371.
47. Sherman DJ, Arieli S, Tovbin J. A comparison of clinical and ultrasonic estimation of fetal weight. Obstet Gynecol 1998;91:212-217.
48. Chauhan SP, Hendrix NW, Magann EF. Limitation of clinical and sonographic estimates of birth weight: experience with 1034 parturients. Obstet Gynecol 1998;91:72-77.
49. Johnstone FD, Prescott RJ, Steel JM. Clinical and ultrasound prediction of macrosomia in diabetic pregnancy. Br J Obstet Gynaecol 1996;103:747-754.
50. Cohen B, Penning S, Major C, Ansley D, Porto M, Garite T. Sonographic prediction of shoulder dystocia in infants of diabetic mothers. Obstet Gynecol 1996;88:10-13.
51. Hendrix NW, Morrison JC, McLaren RA, Magann EF, Chauhan SP. Clinical and sonographic estimates of birth weight among diabetic parturients. J Matern Fetal Investig 1998;8:17-20.
52. McLaren RA, Puckett JL, Chauhan SP. Estimators of birth weight in pregnant women requiring insulin: a comparison of seven sonographic models. Obstet Gynecol 1995;85:565-569.
53. Benacerraf BR, Gelman R, Frigoletto FD Jr. Sonographically estimated fetal weights: accuracy and limitation. Am J Obstet Gynecol 1988;159;1118–1121.
54. Parretti E, Mecacci F, Papini M, Cioni R, Carignani L, Mignosa M, et al. Third-Trimester Maternal Glucose Levels From Diurnal Profiles in Nondiabetic Pregnancies: Correlation with sonographic parameters of fetal growth. Diabetes Care 2001;24:1319-1323.
55. Jovanovic-Peterson L, Peterson CM, Reed GF, Metzger BE, Mills JL, Knopp RH, Aarons JH. Maternal postprandial glucose levels and infant birth weight: the Diabetes in Early Pregnancy Study: the National Institute of Child Health and Human Development-Diabetes in Early Pregnancy Study. Am J Obstet Gynecol 1991;164:103–111.
56. Weiss PAM, Haeusler M, Kainer F, Pürstner P, Haas J. Toward universal criteria for gestational diabetes: relationships between seventy-five and one hundred gram glucose loads and between capillary and venous glucose concentrations. Am J Obstet Gynecol 1998;178:830–835.
57. Buchanan TA, Kjos SL, Montoro MN, Wu PY, Madrilejo NG, Gonzalez M. Use of fetal ultrasound to select metabolic therapy for pregnancies complicated by mild gestational diabetes. Diabetes Care 1994;17:275–283.
58. Kjos SL, Schaefer-Graf U, Sardesi S, Peters RK, Buley A, Xiang AH, Bryne JD, Sutherland C, Montoro MN, Buchanan TA. A randomized controlled trial using glycemic plus fetal ultrasound parameters versus glycemic parameters to determine insulin therapy in gestational diabetes with fasting hyperglycemia. Diabetes Care 2001;24:1904-1910.
59. Conway DL, Langer O. Elective delivery of infants with macrosomia in diabetic women: reduced shoulder dystocia versus increased cesarean deliveries. Am J Obstet Gynecol 1998;178:922–925.
60. Rouse DJ, Owen J, Goldenberg RL, Cliver SP. The effectiveness and costs of elective cesarean delivery for fetal macrosomia diagnosed by ultrasound. JAMA 1996;276: 1480–1486.

61. Rouse DJ, Owen J. Prophylactic cesarean delivery for fetal macrosomia diagnosed by means of ultrasonography—a Faustian bargain? Am J Obstet Gynecol 1999;181: 332–338.
62. American College of Obstetricians and Gynecologists Practice Bulletin. Gestational Diabetes. Number 30, November 2001.
63. Farrell T, Holms R, Stone P. The effect of body mass index on three methods of fetal weight estimation. BJOG 2002;109:651-657.
64. Rouse DJ, Owen J. Sonography, suspected macrosomia, and prophylactic cesarean: a limited partnership. Clin Obstet Gynecol 2000;43:326-334.
65. Gull I, Fait G, Har-Toov J, Kupferminc MJ, Lessing JB, Jaffa AJ, Wolman I. Prediction of fetal weight by ultrasound: the contribution of additional examiners. Ultrasound Obstet Gynecol 2002;20:57-60.