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Macrosomia

Suspected macrosomia is encountered commonly in obstetric practice. As birth weight increases, the likelihood of labor abnormalities, shoulder dystocia, birth trauma, and permanent injury to the newborn increases. The purpose of this document is to quantify those risks, address the accuracy and limitations of methods for estimating fetal weight, and suggest clinical management for a pregnancy with suspected macrosomia. This document has been revised to include recent literature and updated information on the prevention of macrosomia.

Background

Definition

Two terms are applied to excessive fetal growth: "large for gestational age" (LGA) and "macrosomia." Large for gestational age generally implies a birth weight equal to or more than the 90th percentile for a given gestational age. The term "macrosomia" implies growth beyond an absolute birth weight, historically 4,000 g or 4,500 g, regardless of the gestational age, although establishing a universally accepted definition for macrosomia is challenging. A study using the 2011 U.S. Live Birth File of the National Center for Health Statistics provides a national reference for birth weight based on the best obstetric estimate of gestational age for more than 3.2 million births (1). The 50th, 90th, and 95th percentiles for birth weight from 37 completed weeks of gestation to 42 completed weeks of gestation are shown in Table 1.

The risk of morbidity for infants and women when birth weight is either LGA or between 4,000 g and 4,500 g is more than that of the general obstetric population, and it increases sharply when the birth weight is more than 4,500 g (2–5). A retrospective cohort study using U.S. Vital Statistics from 2011 to 2013 noted that delivery at 37–39 weeks of gestation of a newborn with a birth weight that is 90% or more for gestational age but less than 4,000 g was associated with increased composite maternal and infant morbidity (5). A large cohort study of 8.3 million births in the National Center for Health Statistics analyzed live-birth and infant death files for the United States and demonstrated that labor abnormalities and newborn complications (eg, a 5-minute Apgar score of less than 4, assisted ventilation longer than 30 minutes, birth injuries) increase within the birth weight category 4,000–4,499 g, newborn morbidity increases further within the birth weight category 4,500–4,999 g, and newborn mortality increases with birth weights more than 5,000 g (Fig. 1) (3). Another large cohort study of more than 6 million birth and infant death records demonstrated that perinatal outcomes were no different in the group weighing 4,000–4,499 g compared with those weighing less than 4,000 g, but morbidity and mortality, including stillbirth, increased significantly in newborns weighing 4,500 g or more and more so in those weighing 5,000 g or more (4). The risks associated with increasing birth weight increase on a continuum without a clear threshold. Nonetheless, based on this data, many authors and clinicians divide macrosomia into three categories, each with differing types and levels of risk: 1) 4,000–4,499 g, 2) 4,500–4,999 g, and 3) more than 5,000 g.

Frequency of Occurrence

Data from the National Center for Health Statistics show that 7.8% of all live-born newborns in the United States weigh 4,000 g or more (6). Only 1% weigh more than

Table 1. Birth Weight Percentiles for Gestational Age: U.S. 2011 Single Live Births to Resident Women Between 37 Completed Weeks of Pregnancy and 42 Completed Weeks of Pregnancy (Based on Best Obstetric Estimate of Gestational Age)

	Birth Weight (g)		
Gestational Age	50th Percentile	90th Percentile	95th Percentile
37	3,025	3,612	3,818
38	3,219	3,799	3,995
39	3,374	3,941	4,125
40	3,499	4,057	4,232
41	3,600	4,167	4,340
42	3,686	4,290	4,474

Modified from Duryea EL, Hawkins JS, McIntire DD, Casey BM, Leveno KJ. A revised birth weight reference for the United States. Obstet Gynecol 2014; 124:16–22.

4,500 g and 0.1% more than 5,000 g. The rate of newborns weighing at least 4,000 g has decreased in the United States from the reported rate of 10% in 1996 (7). Women with gestational diabetes mellitus (GDM) or obesity have higher rates of LGA newborns (8, 9). In a study of nearly 10,000 women, the rate of LGA newborns without GDM was 7.7% in normal-weight women and 12.7% in obese women. In women with GDM, the rates were 13.6% in normal-weight women and 22.3% in obese women (9).

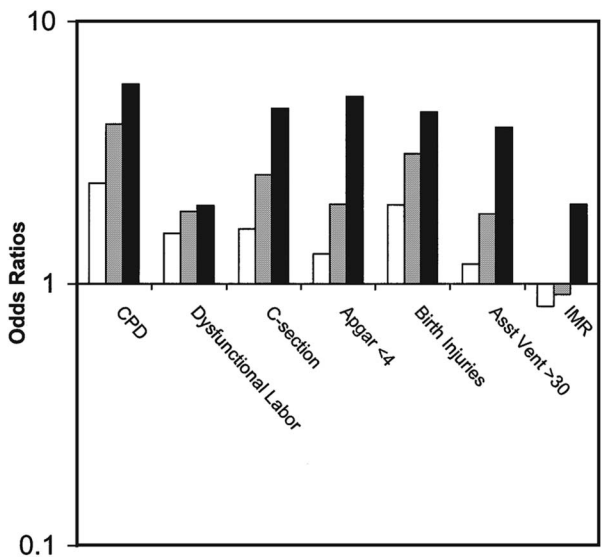

Figure 1. Increased risk of adverse outcomes by macrosomia category. Open bars, Category 1 (4,000–4,499 g); gray bars, category 2 (4,500–4,999 g); black bars, category 3 (5,000+ g). The reference group is 3,000–3,999 g. All bars more than an odds ratio of 1 are significant at $P<.05$. Abbreviations: Asst Vent > 30, assisted ventilation more than 30 minutes; CPD, cephalopelvic disproportions; IMR, infant mortality rate. (Modified from Boulet SL, Alexander GR, Salihu HM, Pass M. Macrosomic births in the United States: determinants, outcomes, and proposed grades of risk. Am J Obstet Gynecol 2003;188:1372–8.)

Risk Factors for Macrosomia

A variety of maternal factors predispose a newborn to macrosomia, including constitutional factors, preexisting diabetes and GDM, maternal prepregnancy obesity, excessive gestational weight gain, abnormal fasting and postprandial glucose levels, dyslipidemia, a prior macrosomic newborn (weight more than 4,000 g), and postterm pregnancy (3, 8, 10–16). The interplay of these risk factors is complex and varies by prepregnancy body mass index (BMI), race, and ethnicity (8, 17, 18).

Gestational age influences birth weight and the risk of macrosomia. Among all women in the United States in 2014, the risk of birth weight more than 4,500 g increases from 1.3% at 39 weeks of gestation to 40 weeks of gestation and to 2.9% when gestational age exceeds 41 weeks (19).

Maternal hyperglycemia increases the risk of macrosomia. When maternal glucose passes through the placenta, it can lead to fetal hyperglycemia with fetal release of insulin, insulin-like growth factors, and growth hormone. This, in turn, can lead to increased fetal fat deposition and larger fetal size (20). Findings from the Hyperglycemia and Adverse Pregnancy Outcomes study showed a strong linear relationship between maternal glucose concentration and LGA fetuses, fetal adiposity, and fetal hyperinsulinemia (21). A subsequent meta-analysis of the relationship between macrosomia (weight more than 4,000 g) and maternal glucose levels in women without diabetes demonstrated that a fasting blood glucose level or any abnormal value on oral glucose tolerance testing was associated with macrosomia, but the fasting glucose level was more strongly associated (13). In women with GDM, the risk of macrosomia increases twofold to threefold even with treatment (8, 18).

In a cohort of nearly 13,000 women, LGA newborns occurred in 29% of women with GDM type A1, 30% of women with GDM type A2, and 38% of women with preexisting diabetes (8).

Anthropometric studies suggest that macrosomia produced by maternal glucose intolerance is different from macrosomia associated with other predisposing factors (22, 23). Newborns who are macrosomic because of maternal glucose intolerance tend to have more total body fat, larger shoulder and upper-extremity circumferences, higher upper-extremity skin-fold measurements, and smaller head-to-abdominal-circumference ratios compared with macrosomic newborns of women without diabetes. It has been suggested that this altered fetal body shape is responsible for the higher incidence of shoulder dystocia seen among newborns of women with diabetes (23). Regardless of birth weight, newborns of women with diabetes have an increased risk of shoulder dystocia, clavicular fracture, and brachial plexus palsy (2, 24–26).

Gestational diabetes and hyperglycemia often occur in conjunction with prepregnancy obesity and excessive gestational weight gain making it difficult to distinguish the independent contributions of each to macrosomia. Furthermore, GDM and obesity share common metabolic characteristics such as increased insulin resistance, hyperglycemia, and hyperinsulinemia. There is little doubt that birth weight, in general, increases with maternal BMI (8–11, 17, 27). Although obese women are more likely than normal-weight women to have large newborns, several issues confound this observation (8, 10, 11, 27). First, obese women are more likely to have diabetes (28). Second, excess weight gain during pregnancy is itself a risk factor for excessive fetal growth (9, 10, 12, 16, 17, 29), and the risk of newborn macrosomia (more than 4,000 g) associated with excessive maternal weight gain is higher for obese women than for nonobese women (9–12, 17).

Multiple studies show that GDM, obesity, and excess gestational weight gain are each independently associated with macrosomia (9, 11, 18) and their effects appear to be synergistic. In a multivariate analysis of nearly 106,000 pregnancies stratified by race and ethnicity from the Consortium on Safe Labor, the presence of any of obesity, GDM, or excess weight gain increased the odds of LGA newborns by 2–2.5 (18). When any two of those factors were present, the odds ratio (OR) was 3.5–5, and when all three were present, the OR was 5–11. Ranges in the OR are due to stratification by race or ethnicity. Each race and ethnicity group had differing patterns of response to the various risk factors, but within all race or ethnicity groups, each of the three factors was associated with LGA newborns. Because of the increasing prevalence of maternal obesity compared with diabetes, maternal obesity plays a larger role in macrosomia at a population level (8, 9).

A number of historic maternal factors and habits also influence neonatal birth weight. A woman who previously has given birth to a newborn weighing more than 4,000 g is 5–10 times more likely to give birth to a newborn weighing more than 4,500 g than a woman without such a history (18, 30, 31). A history of macrosomia was the single strongest individual risk factor for macrosomia in a large study controlling jointly for BMI, excess weight gain, diabetes, race, parity, and age (18). To a degree, maternal birth weight may predict newborn weight. Women whose birth weights exceeded 8 lbs (approximately 3,600 g) are twice as likely to give birth to newborns weighing more than 4,000 g than are women whose birth weights were between 6 and 7.9 lbs (approximately 2,700 g to 3,500 g) (32). Two cohort studies show that multiparity and grand multiparity increase the risk of macrosomia (4, 31).

Genetic factors, such as parental phenotype, also play a role in determining newborn birth weight. Tall women (in the 80th percentile or more) have a higher risk of macrosomia than short women (in the 20th percentile or less) even when controlled for weight (15). Male newborns typically weigh more than female newborns at any gestational age and, therefore, constitute a larger proportion of newborns with birth weights exceeding 4,500 g (4, 33).

Diagnosis

An accurate diagnosis of macrosomia can only be made by weighing the newborn after birth. The prenatal prediction of newborn birth weight is imprecise. Although published formulas for estimating fetal weight show a correlation with birth weight, the variability of the estimate is up to 20% with most of the formulas (34). Ultrasonography enables the direct measurement of various fetal body parts, but its accuracy in predicting macrosomia is poor. A meta-analysis of 29 studies found a sensitivity of 56% and specificity of 92% for predicting birth weight more than 4,000 g (35). Ultrasound accuracy decreases with increasing fetal weight beyond 4,000 g (36, 37) such that an ultrasound-estimated fetal weight of more than 4,500 g accurately predicts birth weight more than 4,500 g in only 33–44% of cases (35–40).

Given the poor predictive ability of ultrasonography at term to predict macrosomia, a variety of other techniques and formulas have been investigated. Neither longitudinal ultrasound examinations nor individual growth-curve modeling improves the prediction of macrosomia (41). Using customized growth curves to

detect fetal overgrowth and its complications has proved to be no better than using population-based growth curves (42). Small studies of three-dimensional ultrasonography have shown mixed results (35, 43–45). A formula using biacromial diameter (46) and a macrosomic-specific formula (47) have shown high rates of accuracy but are from single institutions, and validation studies have not been reported. Magnetic resonance imaging has been shown to have higher sensitivity and specificity than ultrasonography (35, 48) but given its cost and discomfort, as well as its size limitations for obese women, further study is needed to determine the appropriate clinical use of magnetic resonance imaging in this setting.

Studies comparing the accuracy of ultrasonography with that of physical examination for the detection of macrosomia have had inconsistent findings, and none have shown that ultrasonography is superior to physical examination in a clinically meaningful way (39, 49). Parous women appear to be able to predict the weight of their newborns as well as clinicians who use ultrasonography or clinical palpation maneuvers (50, 51).

Risks Associated With Macrosomia

Maternal Morbidity

The primary maternal risk associated with macrosomia is an increased risk of cesarean birth. Studies show that with birth weights more than 4,500 g, the risk of cesarean birth for women attempting a vaginal delivery is at least double that of controls (2–4, 52, 53). Labor protraction and arrest disorders are more frequent with macrosomia (3, 54), and almost all of the increased risk of cesarean birth is attributed to labor abnormalities (55). Studies have demonstrated consistently that the inaccurate ultrasonographic prediction of macrosomia predisposes women to the diagnosis of labor abnormalities and cesarean birth independent of actual birth weight (56–59). One group reported that, as an indication for cesarean birth, macrosomia was responsible for 10% of the overall increase in cesarean birth rates over the 7-year study period despite no change in the true rate of newborn macrosomia (birth weight more than 4,500 g) during that time (60).

The risks of postpartum hemorrhage, chorioamnionitis, and significant vaginal lacerations are elevated with macrosomia (54). In a multivariate analysis of nearly 9,000 deliveries, after adjustment for age, parity, diabetes, and labor induction, birth weight more than 4,500 g was associated with significantly increased risks of chorioamnionitis (OR 2.4), shoulder dystocia (OR 7.1), third-degree or fourth-degree lacerations (OR 1.7), and postpartum hemorrhage (OR 3.1) (54). The risk of third-degree and fourth-degree lacerations is increased twofold to threefold with macrosomia (33, 61, 62); this is especially true if delivery is complicated by shoulder dystocia (63).

Fetal Morbidity and Mortality

Macrosomia increases the risk of shoulder dystocia. Shoulder dystocia occurs in 0.2–3.0% of all vaginal deliveries (64) and the risk increases to 9–14% when birth weight is more than 4,500 g (2, 33, 65). In the presence of maternal diabetes, a birth weight of 4,500 g or more has been associated with rates of shoulder dystocia from 20% to 50% (2, 33). Figure 2 shows the relationship between birth weight, maternal diabetes status, spontaneous or assisted vaginal delivery, and the mean frequency of shoulder dystocia based on a study of more than 175,000 births in California in 1992 (2). The fetal injuries most commonly associated with macrosomia and shoulder dystocia are fracture of the clavicle and damage to the nerves of the brachial plexus, specifically at vertebrae C5 and C6, which can produce Erb–Duchenne paralysis. Fracture of the clavicle complicates 0.4–0.6% of all births and typically resolves without permanent sequelae (66, 67). For macrosomic newborns, the risk of clavicular fracture is increased approximately 10-fold (67). It is important to note that although macrosomia clearly increases risk, most instances of shoulder dystocia occur unpredictably among newborns of normal birth weight (68), and most macrosomic newborns do not experience shoulder dystocia (2, 33, 65).

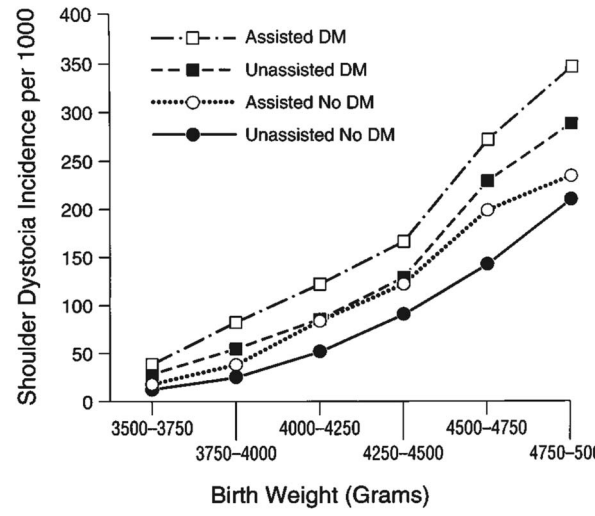

Figure 2. Frequency of shoulder dystocia for increasing birth weight by maternal diabetes status and method of vaginal delivery—spontaneous or assisted. (Reprinted from Nesbitt TS, Gilbert WM, Herrchen B. Shoulder dystocia and associated risk factors with macrosomic infants born in California. Am J Obstet Gynecol 1998;179: 476–80.)

According to U.S. studies, the rate of neonatal brachial plexus palsy is low, with an incidence of both transient and persistent neonatal brachial plexus palsy of 1.5 per 1,000 total births (68). Case–control studies demonstrate that the risk of brachial plexus palsy among newborns delivered vaginally is increased 18-fold to 21-fold when birth weight exceeds 4,500 g (25, 67, 69), with absolute rates between 2.6% and 7% (70, 71). Brachial plexus palsy also can occur in the absence of shoulder dystocia or with cesarean birth (68). Most cases of brachial plexus palsy resolve without permanent disability. Other large case series confirm that 80–90% of cases of brachial plexus palsy will resolve by age 1 year (72, 73). Persistent injury is more common with higher birth weights and, in particular, birth weights more than 4,500 g (74, 75).

Macrosomia is associated with a number of other risks to the newborn, including increased risks of depressed 5-minute Apgar scores, hypoglycemia, respiratory problems, polycythemia, meconium aspiration, and increased rates of admission and prolonged admission (more than 3 days) to a neonatal intensive care unit (3, 54, 70, 76). Macrosomic newborns are more likely than normal-weight newborns to be overweight and obese later in life (77, 78).

Clinical Considerations and Recommendations

▶ *How accurate are clinical estimates of fetal weight?*

The prediction of birth weight is imprecise by ultrasonography or clinical measurement. For suspected macrosomia, the accuracy of estimated fetal weight using ultrasound biometry is no better than that obtained with abdominal palpation. In several prospective studies, clinical palpation alone, irrespective of the obstetrician's or other obstetric care provider's level of clinical training, predicted macrosomia as accurately as any reported ultrasound method (39, 79, 80–83). The effect of maternal obesity on clinical estimates of birth weight is unclear. Studies have shown either no effect or overestimation of birth weight due to maternal obesity (84, 85). Data in women with morbid obesity (BMI of 40 or more) is limited; one study demonstrated no effect on clinical estimation of fetal weight when compared with women with a BMI more than 25. (85).

Measurement of the symphysis to fundal height is commonly used during prenatal care to detect size discrepancies for referral to ultrasonography, but fundal height alone is a poor predictor of macrosomia. Retrospective studies suggest that the sensitivity of fundal height measurement alone for the detection of macrosomia is 20–70% depending on the thresholds used (85–88), although the specificity is more than 90%, indicating that it is more effective for ruling out macrosomia than ruling it in.

Prospective studies of women in labor or before induction that were designed to evaluate abdominal palpation maneuvers for the detection of macrosomia report sensitivity of 16–68%, specificity of 90–99%, and positive predictive values between 38% and 80% (39, 81, 89, 90). Using an algorithm of ultrasonography performed on women with clinically estimated fetal weights of 3,700 g or more did not improve positive predictive value (89). In a prospective study of women presenting in active labor, extrapolated estimated fetal weight based on an earlier ultrasonogram was similarly accurate to clinically estimated fetal weight and more accurate than ultrasonography in labor (83). Prospective studies among women with diabetes also have shown that clinical estimates of macrosomia are as predictive as those derived with ultrasonography (91).

Simply asking a parous woman for her estimate of the birth weight may provide an estimate as accurate as any other. In two studies, a parous woman's ability to predict birth weight more than 4,000 g was as accurate as that of clinicians using clinical palpation maneuvers alone (51, 90).

▶ *How accurate is ultrasonographic measurement in predicting macrosomia?*

Most commercially available ultrasound units have one or more estimated fetal weight equations already programmed into the system software (92, 93). However, most of the regression formulas currently in use are associated with significant errors when the newborn is predicted to be macrosomic. For example, the Hadlock formula to estimate fetal weight has a mean absolute percent error of 13% for newborns weighing more than 4,500 g, compared with 8% for nonmacrosomic newborns (36, 94), and the absolute error increases with increasing estimated fetal weight (37, 40).

For clinical care, the ability to predict birth weight more than 4,500 g or more than 5,000 g would be useful. However, ultrasonography is less effective at identifying newborns with birth weights more than 4,500 g. Among women without diabetes, ultrasound biometry used to detect birth weight more than 4,500 g has a sensitivity of only 10–45%, a specificity of 57–99%, a positive predictive value of 11–44%, and a negative predictive value of 92–99% (39, 40, 89, 95). When birth weight exceeds 4,500 g, only 40–60% of newborns weigh within 10% of

the ultrasonography-derived estimate (36, 40). Reports demonstrating higher accuracy generally rely on less stringent criteria for macrosomia, such as birth weight more than 4,000 g or weight exceeding the 90th percentile for a given gestational age. In a meta-analysis of 56 studies, the pooled sensitivity and specificity were 56% and 92%, respectively, for predicting birth weight more than 4,000 g (35). Furthermore, estimations derived from ultrasonography most commonly overestimate the actual birth weight (37, 96). These observations suggest that the utility of ultrasonography for obtaining estimated weights is limited. Key sources of inaccuracy include large intraobserver and interobserver variability or technical difficulties obtaining accurate fetal measurements in late gestation (96, 97).

No single formula based on ultrasound biometry performs significantly better than others for the detection of macrosomia more than 4,500 g. One study compared the accuracy of 36 different published formulae for estimating fetal weight with ultrasonography, and none was superior to the others in a clinically meaningful way (98). Another large study that evaluated 21 formulae found considerable variation in sensitivity (14–99%) and specificity (64–99.8%), but estimates based on three or four biometric parameters performed better than estimates based on the abdominal circumference alone (99).

In addition to inaccuracy, ultrasonographic determination of fetal weight appears to predispose women to the diagnosis of labor abnormalities and cesarean birth independent of actual birth weight (89, 100–103). In a prospective study, women with a clinically estimated fetal weight more than 3,700 g near term had an ultrasound examination, and women with an estimated fetal weight more than 4,000 g were told of the potential for birth trauma. If the estimated fetal weight was more than 4,500 g, cesarean birth was recommended. The cesarean birth rate was doubled (51% versus 25%, $P<.05$) when ultrasonography-derived estimated fetal weight was more than 4,000 g versus less than 4,000 g, although actual birth weight of 4,000 g or more was seen in 56% and 30% of individuals, respectively (89). In a retrospective cohort of macrosomic neonates (weight more than 4,000 g), the adjusted OR of cesarean birth in women who received an ultrasound examination versus women who did not receive an ultrasound examination within 1 month of delivery was 2.1 (95% CI, 1.06 to 4.3) (100). Similarly, in a Maternal-Fetal Medicine Units Network analysis, after adjustment for actual birth weight, the adjusted OR of cesarean birth was 1.44 (95% CI, 1.31 to 1.58) for women with an ultrasonography-derived estimated fetal weight, regardless of the result of the ultrasonogram. The OR increased to 2.15 (95% CI, 1.55 to 2.98) when the ultrasonography-derived estimated fetal weight was more than 4,000 g versus less than 3,500 g (101). A randomized controlled trial that compared women who received routine ultrasound examinations at 18 weeks of gestation and an additional ultrasound examination at 33 weeks of gestation with women who received a single routine ultrasound examination at 18 weeks demonstrated a slight reduction in induction of labor and scheduled cesarean birth for suspected macrosomia (104). However, this study failed to demonstrate any significant differences in perinatal outcomes. Similar to clinical estimates of fetal weight, ultrasonography can be used most effectively as a tool to rule out macrosomia, which may help avoid maternal and fetal morbidity.

▶ *Are there effective interventions for treating or preventing suspected macrosomia?*

Interventions shown to reduce macrosomia include exercise during pregnancy, low glycemic diet in women with GDM, and prepregnancy bariatric surgery in women with class 2 or class 3 obesity. A meta-analysis of 28 randomized clinical trials in 5,322 women that compared standard care with supervised prenatal exercise found a decreased risk of macrosomia or LGA newborns (OR 0.69; 95% CI, 0.55 to 0.86) without an increase in small for gestational age (SGA) or preterm delivery (105). In addition, women randomized to exercise gained less weight and had a 20% lower rate of cesarean birth. Most studies included normal-weight women without GDM. One half of the exercise programs were aerobic and the other half were combined aerobic and resistance training. A newer meta-analysis of 15 high-quality randomized controlled trials that included 3,670 women and any type of exercise found that for exercise-only interventions (as opposed to exercise plus other interventions), macrosomia was reduced by 39% (OR 0.61; 95% CI, 0.41–0.92) (106). A subgroup analysis showed that combining more than one type of exercise further reduced the odds of macrosomia (OR 0.46; 95% CI, 0.29–0.73); SGA and preterm delivery were not increased. These studies add further evidence of the benefit of exercise during pregnancy (107). Women without contraindications should be encouraged to engage in aerobic and strength-conditioning exercises during pregnancy to reduce the risk of macrosomia.

In women without diabetes, dietary interventions that do not include exercise have shown modest-to-no benefit in preventing macrosomia. A Cochrane review of 65 randomized control trials of diet, exercise, or both, to prevent excessive weight gain in pregnancy found a reduction of excessive weight gain of 20% (relative risk [RR] 0.80; 95% CI, 0.73 to 0.87) but did not find a decrease in macrosomia (108). However, in a subgroup

analysis of overweight women or women with GDM, combined diet plus exercise resulted in a 15% reduced risk of macrosomia (RR 0.85; 95% CI, 0.73 to 1.00). Similarly, in a recent meta-analysis using individual participant data, there was no decrease in LGA or GDM, although less weight gain occurred in the dietary intervention arms compared with the control group (109).

Control of maternal hyperglycemia reduces the risk of macrosomia; therefore, maternal glucose management is recommended for pregnancies complicated by diabetes. One clinical trial suggests that the addition of insulin to diet therapy may benefit women at risk of LGA newborns diagnosed between 29 weeks of gestation and 33 weeks of gestation (110). This study randomized 98 women with GDM and a fetal abdominal circumference exceeding the 75th percentile for gestational age to either diet therapy alone or diet therapy with twice-daily insulin. The addition of insulin therapy decreased the likelihood of birth weight more than the 90th percentile from 45% among those treated with diet only to 13% among those receiving insulin ($P<.01$) (110). These results are consistent with larger trials designed to determine the effects of treatment of GDM with diet and insulin (if indicated) on newborn outcomes. In the Australian Carbohydrate Intolerance Study in Pregnant Women trial, the risk of a birth weight more than 4,000 g was reduced from 21% to 10% (RR, 0.47; 95% CI, 0.34 to 0.64; $P=.001$) (111). Similarly, in a large multicenter randomized trial of treatment of mild GDM, the risk of a birth weight more than 4,000 g was reduced from 14.3% to 5.9% (RR, 0.41; 95% CI, 0.26–0.66; $P=.001$) (112). Specific diets also have been investigated. A meta-analysis of five randomized controlled trials that included 300 women with GDM compared low glycemic diets to usual care and found a 73% decrease in macrosomia (OR, 0.27; 95% CI, 0.10 to 0.71) (113). Diets that included additional dietary fiber further decreased the risk. Together, these trials confirm that control of maternal hyperglycemia is important in the prevention of macrosomia among women in whom gestational diabetes has been diagnosed.

For women with class 2 or class 3 obesity (BMI more than 35 or more than 40 respectively), having had bariatric surgery before pregnancy is associated with decreased odds of GDM (OR 0.31 and 0.47, respectively) and LGA newborns (OR 0.40 and 0.46, respectively) in meta-analyses of observational studies (114, 115). However, previous bariatric surgery also was associated with an increase in SGA newborns and a possible increase in preterm delivery. The largest study used the Swedish medical birth registry and included 2,562 women who had undergone bariatric surgery matched to other women in the registry by early pregnancy BMI and other factors (116). The rate for LGA newborns was lower in those who had undergone bariatric surgery (4.2% versus 7.3%; OR 0.6), but the rate of SGA newborns was higher (5.2% versus 3.0%: OR 2.0) as was preterm birth (9.7% versus 6.1%: OR 1.7). Studies in these meta-analyses matched on postsurgical BMI rather than pre-surgical BMI. A more appropriate comparison would be to match prebariatric surgery BMI to prepregnancy BMI in women who had not undergone bariatric surgery. This type of comparison was done in a follow-up study using the same Swedish medical birth registry (117). Among 670 women who had bariatric surgery, there were lower rates of GDM (1.9% versus 6.8%; OR 0.25) and LGA newborns (8.6% versus 22.4%; OR 0.33). Preterm births were not significantly different. However, there was an increase in SGA newborns (15.6% versus 7.6%; OR 2.20) and a nonsignificant increase in stillbirth (1.7% versus 0.7%; $P=.06$). Given the health benefits, particularly for pregnancy outcomes, prepregnancy counseling of morbidly obese patients regarding the benefits and risks of bariatric surgery is recommended.

▶ *Is there a role for induction of labor in the management of term patients with suspected macrosomia?*

Evidence from retrospective cohort studies that examined a policy of induction of labor in term patients with suspected macrosomia is inconsistent. Some reports show that induction of labor increases the risk of cesarean birth without reducing shoulder dystocia or newborn morbidity (118–120). Others suggest a slight decrease or no effect on the risk of cesarean birth and no difference in the rate of shoulder dystocia with induction of labor (121, 122). Some of these studies are limited by sample size, and all are compromised because of possible bias introduced by their retrospective nature.

Two randomized clinical trials have examined the effect of a policy of induction of labor at term for ultrasonography-derived estimated fetal weight more than the 90th percentile. In the first trial, a total of 273 women at 38 weeks of gestation or later with ultrasonography-derived estimated fetal weights between 4,000 g and 4,500 g were randomized to either planned induction of labor or expectant management (123). The cesarean birth rates were similar: 19.4% for the induction group and 21.6% for the expectant group. There were 11 cases of shoulder dystocia: five in the induction group and six in the expectant group. All were managed without brachial plexus palsy or other trauma. In a second European trial, a total of 822 women with estimated fetal weights above the 95th percentile for gestational age at 37 weeks of gestation to 38 weeks of gestation were

randomized to induction of labor within 3 days or to expectant management (124). With induction of labor, the risk of significant shoulder dystocia was reduced from 4% to 1% (RR, 0.32; 95% CI, 0.12 to 0.85). Importantly, there were no instances of brachial plexus palsy in either group, and the cesarean birth rates were similar: 28% in the induction group and 32% in the expectant management group (RR, 0.89; 95% CI, 0.72 to 1.09). The only significant differences in newborn outcomes were a decrease in fractures from 1% to 0.8% and an increase in neonatal hyperbilirubinemia and the need for phototherapy, especially in the group that gave birth before 38 completed weeks of gestation. Two meta-analyses, including these trials and two smaller unpublished trials involving a total of 1,190 women with suspected macrosomia (a heterogeneous cohort of nulliparous women, multiparous women, women with diabetes, and women without diabetes), have been published (125, 126). Compared with expectant management, induction of labor for suspected macrosomia reduced the risk of shoulder dystocia (RR, 0.60; 95% CI, 0.37 to 0.98) and any type of fracture (RR, 0.20; 95% CI, 0.05 to 0.79) with no change in the risk of cesarean birth (RR 0.91; 95% CI, 0.76 to 1.09) or instrumental delivery (RR, 0.86; 95% CI, 0.65 to 1.13) (125). However, there were no differences between the groups for brachial plexus palsy, although this outcome was infrequent (RR, 0.21; 95% CI, 0.01 to 4.28).

The American College of Obstetricians and Gynecologists recommends against delivery before 39 0/7 weeks of gestation unless it is medically indicated (127). Whether intervention is better than expectant management for suspected LGA fetuses and the gestational age at which delivery should be performed are unclear (128). Although the meta-analysis of available trials is provocative and raises questions for further study, it is not clear that a reduction in shoulder dystocia would be seen with induction of labor after 39 0/7 weeks of gestation (125, 126). At this time, and until additional studies are reported, suspected macrosomia or LGA fetus is not an indication for induction of labor before 39 0/7 weeks of gestation because there is insufficient evidence that benefits of reducing shoulder dystocia risk would outweigh the harms of early delivery.

▶ *When should scheduled cesarean birth be considered for suspected macrosomia at a particular estimated fetal weight?*

The goal of scheduled cesarean birth for suspected macrosomia is to reduce fetal morbidity or maternal morbidity, or both. Although fetal and maternal morbidity increase with birth weights more than 4,000 g, most births of macrosomic newborns are uncomplicated (33, 54, 75, 129). For example, in a Norwegian study that included nearly 68,000 infants with birth weights more than 4,500 g, shoulder dystocia occurred in 2.6% of newborns weighing 4,000–4,500 g, 6.7% of newborns weighing 4,500–5,000 g, and 15% of newborns weighing more than 5,000 g (129). Transient brachial plexus palsy is estimated to occur in 1–17% of births complicated by shoulder dystocia and of these, 3–33% persist at 1 year after birth (68). Of note, the risk of permanent brachial plexus palsy increases with birth weight (68, 65). The risk of maternal morbidity also increases with increasing birth weight, but most vaginal deliveries are uncomplicated. In a cohort of 8,800 births of newborns weighing more than 4,000 g, increased rates of chorioamnionitis (12.4% versus 17%), third-degree or fourth-degree lacerations (4.5% versus 6.1%), postpartum hemorrhage (2.3% versus 7.8%) and length of stay 5 or more days (5.6% versus 10%) were observed compared with newborns who weighed less than 4000 g (54).

Cesarean birth reduces, but does not eliminate, the risk of birth trauma and neonatal brachial plexus palsy associated with macrosomia (25, 130, 131). Although the prediction of macrosomia is imprecise, scheduled cesarean birth may be beneficial for newborns with suspected macrosomia who have an estimated fetal weight of at least 5,000 g in women without diabetes and an estimated fetal weight of at least 4,500 g in women with diabetes. However, given the absence of randomized clinical trials, planned cesarean birth for suspected macrosomia is controversial and is based on expert opinion.

Most fetuses with macrosomia who are delivered vaginally do not experience shoulder dystocia. Consequently, if all fetuses suspected of being macrosomic had a cesarean birth, the cesarean birth rate would increase disproportionately to the reduction in the rate of shoulder dystocia. Studies using estimates of the prevalence of permanent brachial plexus palsy at birth found that between 155 and 1,026 cesarean births would need to be performed to prevent one occurrence of permanent brachial plexus palsy for newborns with a birth weight of 4,500 g, and between 79 to 373 cesarean births for newborns with a birth weight of 5,000 g (25, 70). Because these analyses did not consider the imperfect predictive values of ultrasonography for macrosomia, they underestimated the number of cesarean births that would be needed to implement such a policy. In a decision analytic model that accounted for the reported sensitivity and specificity of ultrasonography for the detection of macrosomia (4,500 g or greater), it was calculated that for women without diabetes, 3,695 cesarean births would be required to prevent one permanent injury, at an additional cost of $8.7 million for each permanent injury avoided (132, 133).

For pregnancies complicated by diabetes, the estimated ratios of cesarean births and cost per permanent injury avoided were more favorable, although these figures were still high at 443 cesarean births performed at a cost of $930,000 for each permanent injury avoided. A cost-effective analysis compared the strategies of expectant management, induction of labor, and cesarean birth to prevent the occurrence of permanent brachial plexus palsy among women without diabetes whose newborns had an estimated fetal weight of 4,500 g (134) and concluded that expectant management was the most cost-effective option whereas induction and scheduled cesarean birth were similar to each other (134). The model accounts for the poor sensitivity of ultrasonographic diagnosis, which the authors posited would further favor expectant management (134). A policy of scheduled cesarean birth for suspected macrosomia in newborns weighing less than 5,000 g in women without diabetes would result in significant maternal morbidity and would be economically unsound.

Despite the poor predictive value of an estimated fetal weight of more than 5,000 g and a lack of evidence supporting cesarean birth, most, but not all, researchers agree that consideration should be given to cesarean birth in this situation because of the increased risk of stillbirth and higher rates of other morbidities in women and newborns weighing more than 5,000 g (2, 30, 70, 130). Among newborns with birth weights exceeding 5,000 g, there are reports of cesarean birth rates of 35–60%, brachial plexus palsy rates of 7–11%, and a neonatal death rate as high as 1.9% (3, 70, 130, 135). In contrast, some investigators suggest that ultrasonography-derived fetal weight estimates alone should not be used to determine the route of delivery because of the poor accuracy of ultrasonography for determining prenatally if this threshold has been exceeded (25, 38).

For women with gestational or preexisting diabetes, the risk of fetal and maternal morbidity increase when newborns weigh more than 4,500 g (2, 54). The number of cesarean births to prevent one occurrence of permanent brachial plexus palsy is more favorable than it is in women without diabetes, (132) supporting the recommendation for scheduled cesarean birth in women with diabetes with an estimated fetal weight more than 4,500 g. Pregnant women with suspected macrosomia should be provided individualized counseling about the risks and benefits of vaginal births and cesarean births based on the degree of suspected macrosomia, accounting for their relevant clinical considerations. Discussion should include the inability to estimate birth weight accurately, the low incidence of brachial plexus palsy and shoulder dystocia even in macrosomic fetuses, the fact that shoulder dystocia is challenging to predict, and the fact that the risk of brachial plexus palsy is not eliminated by cesarean birth.

▶ *How should a diagnosis of suspected macrosomia affect the management of labor and vaginal delivery?*

Prolonged first and second stages of labor are common when macrosomia is present (3, 54), leading to increased rates of conversion to cesarean during labor (2, 52). Many investigators have attempted to determine whether shoulder dystocia can be predicted. Labor abnormalities have been associated with shoulder dystocia in some, but not all, studies, and these abnormalities occur too frequently to be useful predictors (129, 136–138). Likewise, models that combine risk factors have not reliably predicted shoulder dystocia or brachial plexus palsy (139–141). However, some studies have shown that the combination of a macrosomic newborn weighing more than 4,500 g in addition to labor arrest is significantly associated with shoulder dystocia (140, 142). Therefore, when fetal weight is estimated to be more than 4,500 g, a prolonged second stage of labor or arrest of descent in the second stage above +2 out of +5 station is an indication for cesarean birth.

A clinician's suspicion of a large fetus on prenatal examination and communication of fetal size concerns to the patient have been associated with increased labor and delivery interventions. In a nationally representative survey of 2,000 U.S. women, those with "suspected large babies" had increased adjusted odds of medically induced labor (adjusted OR, 1.9; 95% CI, 1.4 to 2.6), were more likely to ask for cesarean births (adjusted OR, 4.6; 95% CI, 2.8 to 7.6), and were more likely to have planned cesarean births (adjusted OR, 1.8; 95% CI, 1.0 to 4.5). However, only 20% of these women gave birth to a newborn weighing 4,000 g or more (143). Communication to the patient about concerns of macrosomia may be one mechanism through which the cesarean birth rate is increased in those with suspected macrosomia.

Whether to conduct an operative vaginal delivery in cases of suspected macrosomia is another important consideration. Figure 2 shows that the risk of shoulder dystocia increases in assisted vaginal delivery. Observational studies consistently demonstrate an increased risk of shoulder dystocia when a macrosomic fetus is delivered using forceps or vacuum extraction. Two population-based cohort studies, each with more than 1 million births, found threefold to fivefold increased odds of shoulder dystocia with vacuum-assisted delivery (129, 144). A meta-analysis of four observational studies calculated a summary OR of 2.98 (95% CI, 2.3 to

3.9) (145). Whether forceps delivery of a macrosomic newborn increases the risk of shoulder dystocia is unclear. The largest study found no increased risk of shoulder dystocia with forceps delivery (OR 1.1) (129). Similarly, the meta-analysis found no increased risk of shoulder dystocia associated with forceps use compared with vacuum use (OR 1.1), but individual studies within the meta-analysis varied from a threefold increased risk with forceps use compared with a threefold decreased risk with vacuum use (145). The risk of shoulder dystocia at the time of operative vaginal delivery increases when more risk factors are present. For example, when an LGA newborn, diabetes, and vacuum delivery were all present, the OR was 33 (144). Thus, the clinician should have a heightened awareness for shoulder dystocia in these situations, although judicious use of operative vaginal delivery is reasonable even when risk factors are present. The patient should be counseled regarding these risks, caution should be exercised, and preparations should be made for the possibility of encountering shoulder dystocia.

▶ *Is suspected macrosomia a contraindication to labor after cesarean?*

It is appropriate for patients, obstetrician–gynecologists, and other obstetric care providers to consider past and predicted birth weights when making decisions regarding labor after cesarean; however, suspected macrosomia is not a contraindication to labor after cesarean. Women undergoing labor after cesarean with a suspected macrosomic fetus (birth weight more than 4,000 g) have a lower likelihood of vaginal birth after cesarean birth (VBAC) than women attempting labor after cesarean who have a nonmacrosomic fetus (62, 146–148). Although success rates of labor after cesarean decrease as newborn birth weights increase to 4,000 g or more (146, 147), this effect does not decrease absolute VBAC success rates to less than 50% in women who have had a previous vaginal delivery or previous VBAC (62, 146, 147). There may be a higher risk of uterine rupture during labor after cesarean with neonatal birth weights more than 4,000 g. A study of 10,000 women who underwent labor after cesarean found no increased risk of uterine rupture among 1,441 women with macrosomic newborns (149). However, in a literature review, the pooled OR of rupture from eight observational studies, including the one noted previously, was 1.52 (95% CI, 1.09 to 2.11) (62). Only one of these studies controlled for confounders and obtained an adjusted OR of 2.6 (95% CI, 1.00 to 6.85) with neonatal birth weight greater than 4,000 g (62). The rates of rupture were highest in women with no history of prior vaginal delivery and with increasing birth weight (146, 147). Because these studies used actual birth weight as opposed to estimated fetal weight, and because there is no accurate way to predict birth weight, especially for birth weights more than 4,000 g, these data have limited applicability in making decisions regarding mode of delivery before labor (7).

Summary of Recommendations

The following recommendations are based on good and consistent scientific evidence (Level A):

- The prediction of birth weight is imprecise by ultrasonography or clinical measurement. For suspected macrosomia, the accuracy of estimated fetal weight using ultrasound biometry is no better than that obtained with abdominal palpation.
- Women without contraindications should be encouraged to engage in aerobic and strength-conditioning exercises during pregnancy to reduce the risk of macrosomia.
- Control of maternal hyperglycemia reduces the risk of macrosomia; therefore, maternal glucose management is recommended for pregnancies complicated by diabetes.

The following recommendations are based on limited or inconsistent scientific evidence (Level B):

- Similar to clinical estimates of fetal weight, ultrasonography can be used most effectively as a tool to rule out macrosomia, which may help avoid maternal and fetal morbidity.
- Given the health benefits, particularly for pregnancy outcomes, prepregnancy counseling of morbidly obese patients regarding the benefits and risks of bariatric surgery is recommended.
- Suspected fetal macrosomia or LGA fetus is not an indication for induction of labor before 39 0/7 weeks of gestation because there is insufficient evidence that benefits of reducing shoulder dystocia risk would outweigh the harms of early delivery.

The following recommendations are based primarily on consensus and expert opinion (Level C):

- Although the prediction of macrosomia is imprecise, scheduled cesarean birth may be beneficial for newborns with suspected macrosomia who have an estimated fetal weight of at least 5,000 g in women without diabetes and an estimated fetal weight of at least 4,500 g in women with diabetes.

- ▶ Pregnant women with suspected macrosomia should be provided individualized counseling about the risks and benefits of vaginal births and cesarean births based on the degree of suspected macrosomia, accounting for their relevant clinical considerations.
- ▶ It is appropriate for patients, obstetrician–gynecologists, and other obstetric care providers to consider past and predicted birth weights when making decisions regarding labor after cesarean however, suspected macrosomia is not a contraindication to labor after cesarean.
- ▶ The term "macrosomia" implies growth beyond an absolute birth weight, historically 4,000 g or 4,500 g, regardless of the gestational age, although establishing a universally accepted definition for macrosomia is challenging.

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The MEDLINE database, the Cochrane Library, and the American College of Obstetricians and Gynecologists' own internal resources and documents were used to conduct a literature search to locate relevant articles published between January 2000–July 2019. The search was restricted to articles published in the English language. Priority was given to articles reporting results of original research, although review articles and commentaries also were consulted. Abstracts of research presented at symposia and scientific conferences were not considered adequate for inclusion in this document. Guidelines published by organizations or institutions such as the National Institutes of Health and the American College of Obstetricians and Gynecologists were reviewed, and additional studies were located by reviewing bibliographies of identified articles. When reliable research was not available, expert opinions from obstetrician–gynecologists were used.

Studies were reviewed and evaluated for quality according to the method outlined by the U.S. Preventive Services Task Force:

- I Evidence obtained from at least one properly designed randomized controlled trial.
- II-1 Evidence obtained from well-designed controlled trials without randomization.
- II-2 Evidence obtained from well-designed cohort or case–control analytic studies, preferably from more than one center or research group.
- II-3 Evidence obtained from multiple time series with or without the intervention. Dramatic results in uncontrolled experiments also could be regarded as this type of evidence.
- III Opinions of respected authorities, based on clinical experience, descriptive studies, or reports of expert committees.

Based on the highest level of evidence found in the data, recommendations are provided and graded according to the following categories:

Level A—Recommendations are based on good and consistent scientific evidence.

Level B—Recommendations are based on limited or inconsistent scientific evidence.

Level C—Recommendations are based primarily on consensus and expert opinion.

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