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REVIEW ARTICLE

Suspicion and treatment of the macrosomic fetus: A review

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KEY WORDS
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Objective: To review the prevalence of and our ability to identify macrosomic (birthweight >4000 g) fetuses. Additionally, based on the current evidence, propose an algorithm for treatment of suspected macrosomia.

Study design: A review.

Results: According to the National Vital Statistics, in the United States, the prevalence of newborns weighing at least 4000 g has decreased by 10% in seven years (10.2% in 1996 and 9.2% in 2002) and 19% for newborns with weights >5000 g (0.16% and 0.13%, respectively). Bayesian calculations indicates that the posttest probability of detecting a macrosomic fetus in an uncomplicated pregnancy is variable, ranging from 15% to 79% with sonographic estimates of birth weight, and 40 to 52% with clinical estimates. Among diabetic patients the post-test probability of identifying a newborn weighing >4000 g clinically and sonographically is over 60%. Among uncomplicated pregnancies, there is sufficient evidence that suspected macrosomia is not an indication for induction or for primary cesarean delivery. For pregnancies complicated by diabetes, with a prior cesarean delivery or shoulder dystocia, delivery of a macrosomic fetus increases the rate of complications, but there is insufficient evidence about the threshold of estimated fetal weight that should prompt cesarean delivery.

Conclusion: Due to the inaccuracies, among uncomplicated pregnancies suspicion of macrosomia is not an indication for induction or for primary cesarean delivery.
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The delivery of a macrosomic fetus (defined as a birth weight of at least 4000 g) is associated with prolonged labor, an increased likelihood of operative delivery, shoulder dystocia, and brachial plexus injury[1] that may be permanent and lead to litigation.[2] Newborn infants with a weight ≥4500 g are at increased risk for neonatal morbidity, which includes assisted ventilation and meconium aspiration. Those infants who weigh at least 5000 g have increased infant mortality rates, when compared with infants with weights between 4000 and 4499 g.[3] Maternal complications that are associated with the delivery of macrosomic infants are the result of an operative delivery and include postpartum hemorrhage,[4]

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Table I Prevalence of macrosomia in the United States (National Vital Statistics Report[13-19])

Variable	2002 (n)	2001 (n)	2000 (n)	1999 (n)	1998 (n)	1997 (n)	1996 (n)	*P* value*
Total births	4,021,726	4,025,933	4,058,814	3,959,417	3,941,553	3,880,894	3,891,494	
Macrosomia	368,184 (9.2%)	378,976 (9.4%)	401,340 (9.9%)	392,683 (9.9%)	396,096 (10.1%)	390,071 (10.1%)	398,340 (10.2%)	< .0001
4000-4499 g	314,182 (7.8%)	322,346 (8.0%)	340,384 (8.4%)	332,863 (8.4%)	330,894 (8.5%)	330,894 (8.5%)	336,514 (8.6%)	< .0001
4500-4999 g	48,606 (1.2%)	51,132 (1.3%)	54,748 (1.3%)	53,751 (1.4%)	53,936 (1.4%)	53,936 (1.4%)	55,558 (1.4%)	< .0001
≥5000 g	5396 (0.1%)	5498 (0.1%)	6208 (0.2%)	6069 (0.2%)	5941 (0.2%)	5941 (0.2%)	6268 (0.2%)	< .0001

* χ^2 test for trend.

laceration of the anal sphincter,[5,6] and postpartum infection.[5]

To avoid these potential complications, it seems reasonable to intervene, either with induction[7] or cesarean delivery,[8] if the fetus is suspected of being macrosomic. But systemic review[9] and a randomized study[10] have not shown any benefit of induction. A cost analysis suggests that the option of elective cesarean delivery is undesirable.[11] Despite the clinical evidence against intervention for suspected macrosomia, there is a continued tendency to either induce labor[7] or to proceed with cesarean delivery.[8,12]

The disconnect between clinical evidence and practice prompted us to review the accuracy of the detection of a macrosomic newborn infant and the management of a pregnancy that is suspected of having a fetus who weighs at least 4000 g.

Changing prevalence of macrosomia

The rate of macrosomia is decreasing in the United States (Figure 1).[13-19] Review of National Vital Statistics from the Center for Disease Control and Prevention indicates that the rate of macrosomia was 10.2% in 1996 and that since then the rate has declined steadily (Figure 1). In 2002, only 9.2% of all neonates (368,184/4,021,726) weighed ≥4000 g. The significant decrease in the prevalence of macrosomia is apparent for newborn infants with weights between 4000 and 4499 g and 4500 and 4999 g and for infants who weigh at least 5000 g (Table I).[13-19] Compared with 1996, in 2002 the rate of neonates with birth weights ≥4000 g was significantly lower (odds ratio [OR], 0.88; 95% CI, 0.89, 0.90), as it was for newborn infants with birth weights between 4000 and 4449 g (OR, 0.89; 95% CI, 0.88, 0.90), 4500 and 4999 g (OR, 0.84; 95% CI, 0.83, 0.86) and ≥5000 g (OR, 0.83; 95% CI, 0.80, 0.86). Concomitant with the decrease in newborn infants who weigh ≥4000 g, there has been an increase in the prevalence of newborn infants who weigh <3000 g (Figure 2).[13-19]

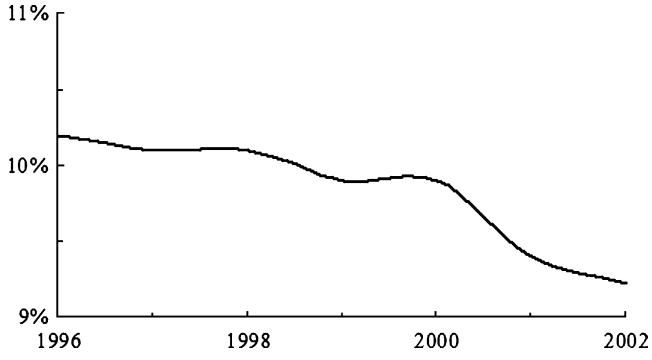

Figure 1 Prevalence of macrosomia in the United States.[13-19]

The decrease in the rate of macrosomia is neither recognized nor explained in the reports by National Vital Statistics and is counterintuitive. Obesity is a risk factor for macrosomia[1] and its prevalence is increasing[20]; thus, it is reasonable to expect a higher prevalence of macrosomia.[21] Considering the source of the data, the sample size, and the objective definition of macrosomia, the observed decrease is irrefutable (Figure 1). We speculate that the decline may be explained by routine testing for gestational diabetes mellitus, the increasing rates of multiple gestations,[22] preterm deliveries,[23] and repeat elective cesarean delivery,[24] which was scheduled before a patient becomes postterm. Additional factors that are responsible for the decrease in the prevalence can be gleaned by a review of the reports that have noted an increase in the rate of macrosomia.[25]

In contrast to the United States, the rate of macrosomia actually has increased in Denmark. Orskou et al[25] reported that in 1990 the rate of neonates with birth weights ≥4000 g was 16.7% and 20.0% in 1999, a significant increase ($P < .05$). By comparing the risk factors and the maternal characteristics of patients who were delivered in 1996 and in 1999, the investigators noted that differences in prepregnancy height, weight, smoking habits, educational level, and caffeine intake explained the increase in the rate of macrosomia.[26] Perhaps there are some maternal characteristics in the

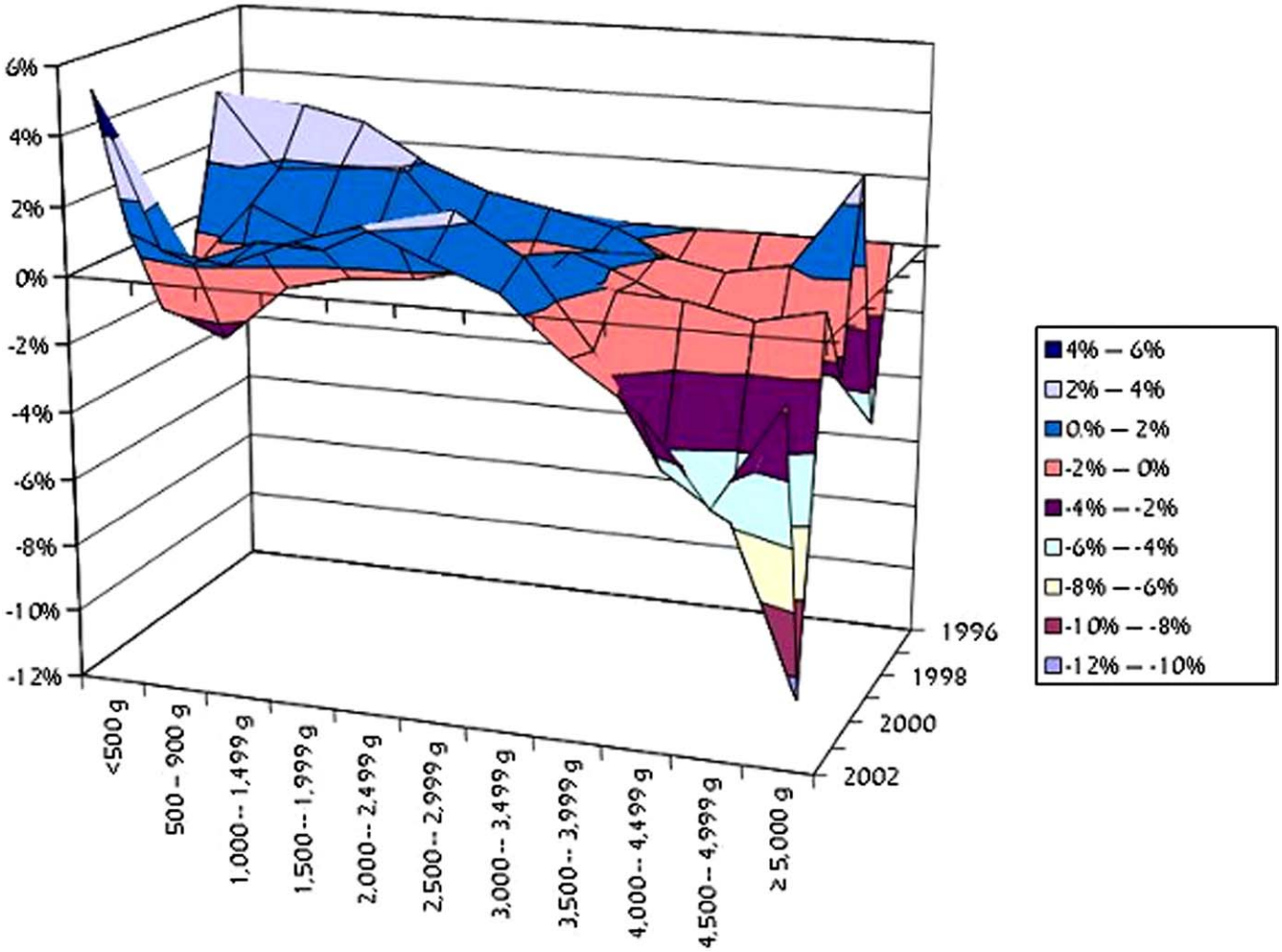

Figure 2 Changes in the prevalence (from year-year) of birth weight from 1996 through 2002.[13-19]

United States that have caused a decrease in the rate of macrosomic fetuses.

A review of articles from foreign countries with a sample size of at least 1000 cases and with a documented prevalence of newborn infants with weights ≥4000 g reveals a wide range (1%-28%) in different countries (Table II).[25,27-54] The prevalence of macrosomia was ≤3% in reports from Nigeria,[39] Pakistan,[40] Thailand,[47,48] and Taiwan[46]; Denmark[25,31] and the Republic of Croatia[43] had a prevalence of ≥20%. The incidence of neonates who weighed at least 4500 g varied from 0.5% to 6% (Table III).[25,27,29-31,34,38,43,48,49,54-58] The variability in the prevalence of macrosomia probably is related to the different extent of maternal characteristics that predispose to excessive fetal growth that are present in diverse populations, ascertainment bias, and sample size. There are, for example, 4 reports from the United Kingdom, and the prevalence of macrosomia among them ranged from 2% to 10% (Table II).[53,54] A valid comparison of the prevalence of macrosomia in the United States (Table I) and other countries (Tables II and III) is not possible because these data were derived from birth certificates of all deliveries in the United States, whereas the data from foreign countries were obtained from deliveries at a specific hospital. Nonetheless, these data do let us gauge the prevalence of macrosomia in different populations.

Suspicion of macrosomia: Methods and accuracy

Accurate identification of a macrosomic fetus is desirable in our efforts to avoid the peripartum complications that are associated with traumatic delivery. According to the American College of Obstetricians and Gynecologists (ACOG) Practice Bulletin on macrosomia,[1] the 3 methods of identifying a fetus with a weight of ≥4000 g are sonographic, clinical, and maternal. Biometric measurements of fetal parts (biparietal diameter, femur length, head or abdominal circumference in some combination) with ultrasonography in conjunction with regression equations can predict the birth weight.[59]

Table II Prevalence of macrosomia in foreign countries

Study	Country	Study period	Sample size (n)	Birth weight ≥4000 g (n)	Percentage
Martin and Clarke[27]	Antigua and Barbuda	1991-1995	3995	185	5
Abena Obama et al[28]	Cameroon	1992-1993	1591	102	6
Rodrigues et al[29]	Canada	1990-1996	5644	767	14
Sermer et al[30]	Canada	1989-1992	3637	520	14
Orskou et al[25]	Denmark	1990-1999	41,649	8173	20
Jensen et al[31]	Denmark	1992-1996	2904	809	28
Wollschlaeger et al[32]	Germany	1990-1997	10,505	956	9
Bergmann et al[33]	Germany	1993-1999	185,322	19975	11
Cheung et al[34]	Hong Kong	1987	2826	129	5
Ohel et al[35]	Israel	1991-1992	2776	126	5
Feinstein et al[36]	Israel	1988-1999	93,266	4508	5
Goldman et al[37]	Israel	1988-1990	3057	591	19
Soni et al[38]	Libya	1983	7829	279	4
Adesina and Olayemi[39]	Nigeria	1998-2000	3759	130	3
Najmi[40]	Pakistan	1994-1996	6142	203	3
Karim et al[41]	Pakistan	1986-1991	6093	234	4
Khan et al[42]	Pakistan	1988	1482	68	5
Mikulandra et al[43]	Republic of Croatia	1984-1990	9980	2021	20
Meshari et al[44]	Saudi Arabia	1984-1986	3461	283	8
Jimenez-Moleon et al[45]	Spain	1995	1962	94	5
Chen et al[46]	Taiwan	1989-1991	1056	32	3
Serirat et al[47]	Thailand	NA	17,065	203	1
Bassaw et al[48]	Thailand	1981-1988	46,707	1421	3
Oral et al[49]	Turkey	1988-1992	16,112	1000	6
Kumari and Badrinath[50]	United Arab Emirates	1992-1998	4721	513	11
Baker et al[51]	UK	1991	4352	77	2
Gupta et al[52]	UK	1990-1999	16,172	1040	6
Jolly et al[53]	UK	1988-1998	350,311	36,462	10
Maulik et al[54]	UK	1989-1999	8617	763	9
Total			862,993	81,664	9

Alternatively, the measurement of fundal height (with Leopold maneuvers) and a review of obstetric history as part of routine prenatal care can be used to estimate fetal weight.[60] The third method, which is least investigated, involves asking parous patients, based on their experience with a previous pregnancy, to approximate the weight of a term fetus.[61] With 3 techniques available, it is reasonable to inquire about their relative accuracies and determine how these methods compare between uncomplicated and complicated pregnancies, including diabetes mellitus and the prolonged pregnancy.

The accuracy of birth weight prediction often is assessed by calculation of the mean error, mean standardized error, or the percentage of estimates within 10% of the actual weight. For this review, we selected articles that provided the sensitivity and specificity of identifying newborn infants who weighed at least 4000 g or ≥4500 g. Because the predictive value of a screening test is influenced by the prevalence of the abnormal condition, we used Bayesian calculations and sensitivity, specificity, and previous probability to determine the posttest probability. These calculations were done with GraphPad StatMate software (GraphPad Software, Inc, San Diego, Calif). For the general obstetric population, we assumed that the prevalence of macrosomia is 9%[13]; for women with diabetes mellitus (pregestational and gestational) and pregnancies of at least 41 weeks gestational age, we assumed the prevalence to be 20%. At the outset, we assumed that the posttest probability should be consistently (ie, noted by different groups of investigators) ≥60% for the diagnostic test for it to be considered reliable and reproducible. A posttest probability of 60% suggests that, if the estimate indicates the fetus to be macrosomic, there is a 40% chance that it will not be. We chose this probability because it permits correct identification of 3 abnormal cases for every 2 cases of misclassification, although we acknowledge that other investigators may choose a different cutoff.

Table IV provides a summary of 20 articles that calculated the sensitivity and specificity of sonographic estimated fetal weight of ≥4000 g to correctly identify a macrosomic fetus.[46,62-80] The articles have been subdivided into general obstetric, diabetes mellitus, and prolonged pregnancies. Although some of the articles

Table III Birth weight ≥4500 g in foreign countries

Study	Country	Study Period	Sample Size (n)	Birth weight ≥4500 g (n)	Percentage
Martin and Clarke[27]	Antigua and Barbuda	1991-1997	6558	65	1
Rodrigues et al[29]	Canada	1990-1996	5644	101	2
Sermer et al[30]	Canada	1989-1992	3637	80	2
Jensen et al[31]	Denmark	1992-1996	2904	179	6
Orskou et al[25]	Denmark	1990-1999	41,649	1558	4
Berard et al[55]	France	1991-1996	10,500	100	1
Cheung et al[34]	Hong Kong	1987	2826	14	0.5
Mocanu et al[56]	Ireland	1991-1995	32,834	828	2.5
Gonen et al[57]	Israel	1995-1999	16,146	133	0.8
Soni et al[38]	Libya	1983	7829	111	1
Mikulandra et al[43]	Republic of Croatia	1984-1990	9980	276	3
Bassaw et al[48]	Thailand	1981-1988	46,707	267	1
Oral et al[49]	Turkey	1988-1992	16,112	167	1
Maulik et al[54]	UK	1989-1999	8617	97	1
Smith et al[58]	UK	No mention	3512	16	0.5
Total			215,455	3992	2

that were categorized in the general obstetric group had diabetic patients and perhaps prolonged pregnancies, most of the pregnancies were uncomplicated.[46,62-74] Articles that have a range of sensitivities and specificities used >1 regression equation[46,63,64] to derive the estimated fetal weight or the prediction was obtained by 2 different groups of clinicians.[71]

It is interesting that most of the articles (80%; 16/20) that met the inclusion criteria of providing sensitivity and specificity of detecting macrosomic fetuses were published from centers in the United States.[62-67,69-71,74-80] The incidence of macrosomia among 14 reports from the general obstetrics population ranged from 3% to 55%, and the time interval between sonographic examination and delivery varied between 2 to 21 days. The report by Best and Pressman[70] used a gestation-adjusted projection method to determine whether sonographic examination could identify a macrosomic fetus among diabetic and control patients. What is noteworthy is that there is a very wide range of sensitivities and specificities in the detection of this abnormal condition among general obstetric populations. Consequently, the posttest probability of sonographic estimated fetal weight of ≥4000 g to identify a macrosomic newborn varied from 15% to 79% (Table IV).

It is difficult to understand the reason that the ability to detect a macrosomic fetus varied so much among general obstetric cohorts. These 14 publications were published between 1993 and 2003. Although ultrasonographic equipment and our experience with sonographic examination have improved, the detection of the macrosomic fetus has not. The regression equation that is used to predict birth weight is not the reason for the inconsistent results. The formula that was proposed by Hadlock et al[81] was used by 57% of the reports (8/14),[62-67,69-70] and among these reports the posttest probability ranged from 17% to 76%.[62,63] Three publications[63,66,68] used the equation that was suggested by Shepard et al[82] and the posttest variability was 16% to 32%.[68,73] Nahum et al[74] applied the 27 equations that were available to estimate fetal weight and noted that the sensitivity ranged from 25% to 75% and posttest probability ranged from 27% to 47%. The time interval between sonographic examination and delivery does not influence the accuracy. Delivery within 7 days of examination had similar posttest probability (range, 15%-72%),[64,72] when compared with predictions for infants who were born within 14 to 21 days of biometric measurements (posttest probability range, 39%-76%).[63,66] Last, the background of the sonographer who performs the examinations does not influence the accuracy. Humphries et al[71] reported that, regardless of whether the assessment is done by registered diagnostic medical sonographers or maternal-fetal medicine specialists, the posttest probability to detect a macrosomic fetus is 53% and 56%, respectively. Perhaps, as with detection of newborn infants who weigh <1500 g among preterm deliveries,[83] the identification of macrosomic fetuses varies considerably from institute to institute because of the inherent interobserver variability of sonographic examinations.[84]

Unlike the general obstetric population, it is feasible for sonographic estimated fetal weight to identify a macrosomic fetus consistently among pregnancies that are complicated by diabetes mellitus[70,75,76] and prolonged pregnancies (Table IV).[77-80] McLaren et al,[76] who used 7 regression equations, did report that the posttest probability of the detection of a fetus with a weight of 4000 g ranged from 44% to 81%, which suggests that it is feasible to identify excessive growth among diabetic patients. Similarly, Benson et al[75] and Best and

Table IV Detection of macrosomia with sonographic estimated fetal weight

Study	Location	Study period	Inclusion criteria	N	Birth weight ≥4.0 kg (%)	Time interval* (d)	Sensitivity (%)	Specifcity (%)	Posttest probability (%)
General obstetric†									
Chen et al[46]	Taiwan	1989-1991	Gestational age ≥28 wk	1056	3	5	41-50	99-98	76-79
Combs et al[62]	USA	1990-1992	Gestational age ≥37 wk, large for gestional age‡	262	18	No mention	61	70	17
Rossavik and Joslin[63]	USA	1988-1990	Gestational age ≥38 wk	498	7	14	61-75	98-93	76-52
Chauhan et al[64]	USA	NM	Gestational age ≥37 wk	92	13	3	25-42	99-90	30-72
Sood et al[65]	USA	1992-1993	Size > dates, diabetes mellitus, previous macrosomia	95	55	7	71	91	44
O'Reilly-Green and Divon[66]	USA	1991-1992	Gestational age >40.4 wk	445	24	21	56	91	39
Chauhan et al[67]	USA	No mention	Gestational age ≥37 wk	661	12	3	71	92	47
Ocker et al[68]	Turkey	1993-1996	Sonographic estimate of fetal weight >3200 g	636	29	2	48	98	16
Hendrix et al[69]	USA	1996-1998	Gestational age ≥37 wk	367	11	3	12	99	55
Best and Pressman[70]	USA	1994-2000	Gestational age 34-36 wk	1690	9	23.4 ± 12.6	52	95	51
Humphries et al[71]	USA	No mention	Gestational age ≥37 wk	238	12	14	34-38	97	53-56
Weiner et al[72]	Israel	1998-1999	Clinical estimate of fetal weight >3700 g	315	41	4	58	68	15
Ben-Haroush et al[73]	Israel	1999-2000	Suspected macrosomia or diabetes mellitus	298	16	3	56	88	32
Nahum et al[74]	USA	2000	Gestational age ≥37 wk	74	16	21	25-75	No mention	27-47§
Diabetes mellitus‖									
Benson et al[75]	USA	1983-1985	Diabetes mellitus	160	26	7	48	95	71
McLaren et al[76]	USA	1991-1994	Gestational age ≥37 wk	149	19	7	33-69	98-77	81-44
Best and Pressman[70]	USA	1994-2000	Diabetes mellitus	133	23	19.4 ± 11.0	68	96	81
Prolonged‖									
Chervenak et al[77]	USA	1987-1988	Gestational age ≥41 wk	371	33	No mention	61	91	63
Pollack et al[78]	USA	1989-1990	Gestational age ≥41 wk	519	23	7	56	91	61
Chauhan et al[79]	USA	1990-1992	Gestational age ≥41 wk	84	24	3	55	91	63
Sylvestre et al[80]	USA	1994-1997	Gestational age ≥41 wk	656	22	No mention	65	90	62

* Between sonographic estimated fetal weight and delivery.
† For calculation of posttest probability, we assumed that the previous probability of macrosomia was 9%.
‡ Greater than 90% for gestational age.
§ We used the likelihood ratio to calculate the posttest probability.
‖ For calculation of posttest probability, we assumed that the previous probability of macrosomia was 20%.

Pressman[70] noted that macrosomia was detected in 70% to 80% of pregnancies that are complicated by diabetes mellitus. In 4 reports, among prolonged pregnancies, the posttest probability of the detection of a macrosomic fetus was within a narrow range (61%-63%).[77-80] The simplest reason for the improved accuracy to detect an abnormal condition with these 2 groups may be the higher prevalence of macrosomia.

We identified 6 reports that determined the ability to detect a macrosomic fetus with clinical examination (Table V).[67,69,72,79,85,86] As with sonographically derived assessment of weight at birth, clinical estimation of fetal weight was poor (posttest probability, 40%-53%)[67,69,72] at the detection of newborn infants with weights of ≥4000 g in a general obstetric population but was reasonable among pregnancies that were complicated by

Table V Clinical estimate of fetal weight and detection of macrosomia

Study	Location	Study period	Study population	N	Birth weight ≥4.0 kg (%)	Sensitivity (%)	Specificity (%)	Posttest probability (%)
General obstetric*								
Chauhan et al[67]	USA	No mention	Gestational age ≥37 wk	661	12	54	95	52
Hendrix et al[69]	USA	1996-1998	Gestational age ≥37 wk	391	10	34	97	53
Weiner et al[72]	Israel	1998-1999	Clinical estimate of fetal weight ≥3700 g	555	23	68	90	40
Diabetes mellitus†								
Hendrix et al[85]	USA	1994-1995	Gestational age ≥37 wk	94	13	82	87	61
Prolonged†								
Chauhan et al[79]	USA	1990-1992	Gestational age ≥41 wk	84	24	50	98	86
Chauhan et al[86]	USA	No mention	Gestational age ≥41 wk	70	26	62	92	66

* For calculation of posttest probability, we assumed that the previous probability of macrosomia was 9%.
† For calculation of posttest probability, we assumed that the previous probability of macrosomia was 20%.

Table VI Detection of newborn infants with birth weight ≥4500 g

Authors	Location	N	Diagnostic threshold	Time interval (d)*	Sensitivity (%)	Specificity (%)	Posttest probability (%)†
Sonographic							
Smith et al[87]	UK	3512	Abdominal circumference ≥380 mm	7	69	98	31
			Sonographic estimate of fetal weight ≥4500 g	7	44	99	37
O'Reilly-Green and Divon[66]	USA	445	Sonographic estimate of fetal weight ≥4500 g	21	22	99	22
Chauhan et al[67]	USA	661	Sonographic estimate of fetal weight ≥4500 g	3	58	98	28
Clinical							
Gonen et al[88]	Israel	4480	Clinical estimate of fetal weight ≥4500 g	—	43	99.8	36
Chauhan et al[67]	USA	661	Clinical estimate of fetal weight ≥4500 g	3	10	99	12

* Between estimation of birth weight and delivery.
† Calculations were based on pretest probability that 1.3% of newborn infants will have an actual birth weight of ≥4500 g.

diabetes mellitus[85] and prolonged pregnancies[79-86] (posttest probability, 61%-86%).

There is only 1 report that determined the ability of a maternal estimated fetal weight of 4000 g to detect a macrosomic fetus. Among 70 postterm parturients, the sensitivity was 56%, and the specificity was 94%.[86] If the pretest probability of macrosomia is 20%, then the posttest probability is 70%, which is comparable to the predictive accuracy of sonographic estimates of birth weight among prolonged pregnancies (Table IV). The accuracy of the maternal estimates of birth weight among women with diabetes mellitus has not been studied adequately.

Because neonatal morbidity caused by birth trauma may not start until the actual birth weight is ≥4500 g, we reviewed all reports that provided sensitivity and specificity to detect infants of this size. We found 4 reports that provided such data among the general obstetric population (Table VI),[66,67,87,88] but none for pregnancies that are complicated by diabetes mellitus. Two reports used sonographic examinations,[66,87] 1 report estimated birth weight clinically,[88] and 1 report compared both methods to detect neonates who weighed ≥4500 g.[67] Assuming the prevalence of newborn infants with weights ≥4500 g to be 1.3%,[13] the posttest probability to detect this condition ranged from 22% to 37% for sonographic examination and from 12% to 36% for a clinical estimate of birth weight. Thus, it seems that both techniques are poor at the identification of newborn infants who weigh ≥4500 g.

In summary, the detection of macrosomia is reliable sonographically and clinically and by asking the parous patient, if the incidence of macrosomia in the cohorts is at least 20%. At present, there is no suggestion that it is feasible to accurately identify neonates who weigh ≥4500 g. Posttest probability suggests that, if a fetus

is suspected of being in excess of 4500 g, the newborn infant is more likely (63%-88%) to weigh less than the threshold. There are no data about the ability to identify newborn infants with weights $\geq$5000 g.

Treatment of suspected macrosomia

General obstetric population

There is consistent evidence that increasing birth weight heightens the risk of both shoulder dystocia and permanent brachial plexus injury. On the basis of this relationship, some investigators have suggested changes in medical treatment that may ameliorate the adverse outcomes that are associated with macrosomia. Two tactics that have been proposed are the "liberal" or routine use of cesarean delivery when a fetus has reached a certain estimated weight.[89] Another tactic is the undertaking of labor induction, to avoid not only traumatic vaginal deliveries but also the increased number of cesarean deliveries that would be expected to occur with continued growth. Unfortunately, however appealing these strategies may appear, neither strategy has been demonstrated to be of clear benefit in women with otherwise uncomplicated pregnancies.

Several investigators have advocated for routine cesarean delivery when the fetus reaches a "macrosomic" weight, although there has been no consensus on what that weight should be. Benedetti and Gabbe,[90] for example, considered an infant to be macrosomic when it was in excess of 4000 g, given the significantly increased risk of shoulder dystocia in this group. Alternatively, some investigators have suggested that the most appropriate fetal weight indication for cesarean delivery should be 4500 g, although others, such as ACOG (level C evidence), have recommended 5000 g.[57,91,92]

The inconsistency of these recommendations is itself evidence of the absence of actual data that routine cesarean delivery and the complications it may engender, at any estimated fetal weight, is the best course of action in an uncomplicated pregnancy. Although neonatal complications are more frequent at greater birth weights, at any of the different "macrosomic" weights that have been suggested, they still occur in only a distinct minority of the population. Correspondingly, multiple investigators who have examined complications that are associated with birth weight have failed to identify a reasonable threshold for routine cesarean delivery in the uncomplicated parturient.[57,94,95] Also, shoulder dystocia, which has often been the outcome of interest in studies that advocate for routine cesarean delivery, is not only an intermediate outcome but also is plagued by ascertainment bias.[96,97] Those studies that have used persistent brachial plexus injury because the outcome of interest has illustrated how infrequently this event occurs and the limited usefulness of any weight threshold as an indicator for elective cesarean delivery.[98-100] Moreover, the frequency of neonatal complications that have been reported is predicated often on actual neonatal weights, not the estimated weights on which decisions would need to be made. Because these estimated weights have associated inaccuracy (Tables IV-VI), the frequency of adverse neonatal outcomes at any given birth weight will overestimate the frequency of this outcome at the same estimated fetal weight, making routine cesarean delivery even less of a useful strategy. Rouse et al[11] used an analytic model to illustrate that no estimated fetal weight threshold in an otherwise uncomplicated pregnancy could justify the adverse maternal health and financial consequences engendered by routine cesarean delivery. Gonen et al[57] came to a similar conclusion after they implemented a policy of elective cesarean delivery for macrosomic fetuses ($>$4500 g) and did not find any significant reduction of brachial plexus injury. Thus, at this time, there is not compelling evidence that any estimated fetal weight in an uncomplicated pregnancy should mandate routine elective cesarean delivery.

It should be noted that, even if an elective cesarean delivery is not performed, estimated fetal weight may still play an important role in labor management. Several studies have documented the significantly increased rate of both shoulder dystocia and brachial plexus injury and birth trauma in women who have a fetus with an estimated fetal weight of $>$4000 g and who undergo an operative vaginal delivery, particularly after an arrest of descent and/or when the fetal vertex is in the mid pelvis.[90,93,101-103] The magnitude of this increase varies among studies; in some cases, the absolute risk of lasting sequelae after operative delivery is relatively low.[98] Based on the available data, it seems reasonable to state that the decision to proceed with an operative vaginal delivery should be made judiciously, all the more so when the indication is an arrest of descent or when the vertex is in the mid pelvis. That said, the entire clinical scenario should be taken into account, and operative delivery of an infant with an estimated weight $>$4000 g should not be precluded if there is reason to believe that the risks to the fetus or mother that are incurred by undertaking a cesarean delivery outweigh the risks of operative vaginal delivery.

Induction of labor

In an effort to avoid continued fetal weight gain and the corresponding increase in cesarean deliveries and fetal injury that may be expected to occur, some investigators have advocated for labor induction when it is suspected that the fetus exceeds a given weight.[104] However, there is reason to suspect that the logic underlying the decision to proceed with labor induction in this circumstance is specious. First, although the fetus continues

to grow at term, it does so at a reduced rate when compared with earlier in gestation, and even a few weeks of continued in utero life after 39 weeks of gestation should not change birth weight profoundly.[105,106] Second, the induction of labor itself has been associated with an increased risk of cesarean delivery, which raises the possibility that an induction of labor more likely could make the cesarean delivery a reality that one desired to avoid.[107] Multiple observational studies have demonstrated consistently that those women with suspected macrosomia whose labor is induced have an increased risk of cesarean delivery when compared with those women who spontaneously labor.[9] Moreover, a randomized trial failed to demonstrate that cesarean delivery rates were decreased with labor induction.[10] There is also no evidence from either observational or randomized trials that the induction of labor for macrosomia prevents shoulder dystocia, brachial plexus injury, or other adverse neonatal outcome. Based on this information, there is no evidence to suggest that the induction of labor in the presence of any estimated fetal weight is a beneficial strategy.

Women with diabetes mellitus

Elective cesarean delivery

Both gestational and pregestational diabetes mellitus are independent risk factors for neonatal birth trauma, and multiple studies have demonstrated that these conditions increase the risk of neonatal injury.[93,94,101] For example, Acker et al[93] found that shoulder dystocia was 5 times as frequent in women with diabetes mellitus, which is an association that persisted across all birth weight categories. A similar magnitude of increased risk that is associated with diabetes mellitus has been documented for brachial plexus injury.[101] Thus, infants of diabetic mothers who were born with a birth weight of >5000 g have been reported to have rates of shoulder dystocia and brachial plexus injury as high as 38.5% and 20%, respectively.[94,100,101] The increased rate of neonatal injury and the increased prevalence of macrosomia in the fetuses of women with diabetes mellitus suggest that the policy of routine cesarean delivery for a given birth weight threshold could be more applied rationally to this select population.

What remains controversial is the birth weight threshold that is optimal. Acker et al[93] recommended cesarean delivery when the fetus of a diabetic woman weighs 4000 g. Langer et al[94] thought that this threshold was too low and, based on their own observational data, argued that an estimated fetal weight of ≥ 4250 g should trigger the recommendation of cesarean delivery. The use of this threshold, when prospectively instituted by Conway and Langer,[108] lowered the risk of shoulder dystocia at their institution. Yet, the absolute risk reduction of this outcome was approximately 1.0%; the reduction occurred in a study group with significantly fewer macrosomic infants than were in the comparison group, and there was no difference in brachial plexus injuries. Other investigators have suggested that estimated weight thresholds of either 4500 g or 5000 g would be more appropriate, because these are most likely to identify those infants at greatest risk of adverse outcome without incurring unreasonable maternal morbidity.[11,91,100,101] Ultimately, the data are not sufficient to state with certainty an estimated fetal weight above which women with diabetes mellitus uniformly should undergo a cesarean delivery. That said, the neonatal outcomes that are associated with the combined presence of diabetes mellitus and an estimated fetal weight of at least 4500 g suggest that it is appropriate to discuss and offer elective cesarean delivery as an option.

Induction of labor

There is no trial that has examined the specific question of whether women with diabetes mellitus who have a macrosomic fetus should undergo an induction of labor for that indication alone. Although Kjos et al[109] randomly assigned women with diabetes mellitus to either induction at 38 weeks of gestation or expectant treatment, macrosomia was not a specific inclusion criteria, and in fact, women with fetuses >4200 g were induced even after randomization to the expectant treatment group. Those women who underwent induction, when compared with women who underwent expectant treatment, were no less likely to undergo cesarean delivery or experience shoulder dystocia, other neonatal birth trauma, or persistent brachial plexus injury. There are no other data that suggest that the induction of labor, with macrosomia as the indication, in women with diabetes mellitus is a beneficial strategy; thus, this practice should be avoided, with induction of labor being reserved for other indications.

Previous cesarean delivery

Whether a trial of labor after cesarean delivery is appropriate for a woman who has a macrosomic fetus depends primarily on 2 questions: (1) Is her chance of ultimately achieving a vaginal delivery reasonably high? (2) Is her chance of avoiding uterine rupture reasonably low? Several studies give insight to the answers for these questions. Phelan et al,[110] who analyzed a cohort of women with a previous cesarean delivery who labored and were delivered of an infant who weighed >4000 g, concluded that the trial of labor was an acceptable option, given the vaginal delivery rate of 67% and $<1\%$ risk of uterine rupture. Flamm and Goings[111] supported this conclusion after studying 301 women who had a trial of labor with a fetus of >4000 g. Most women

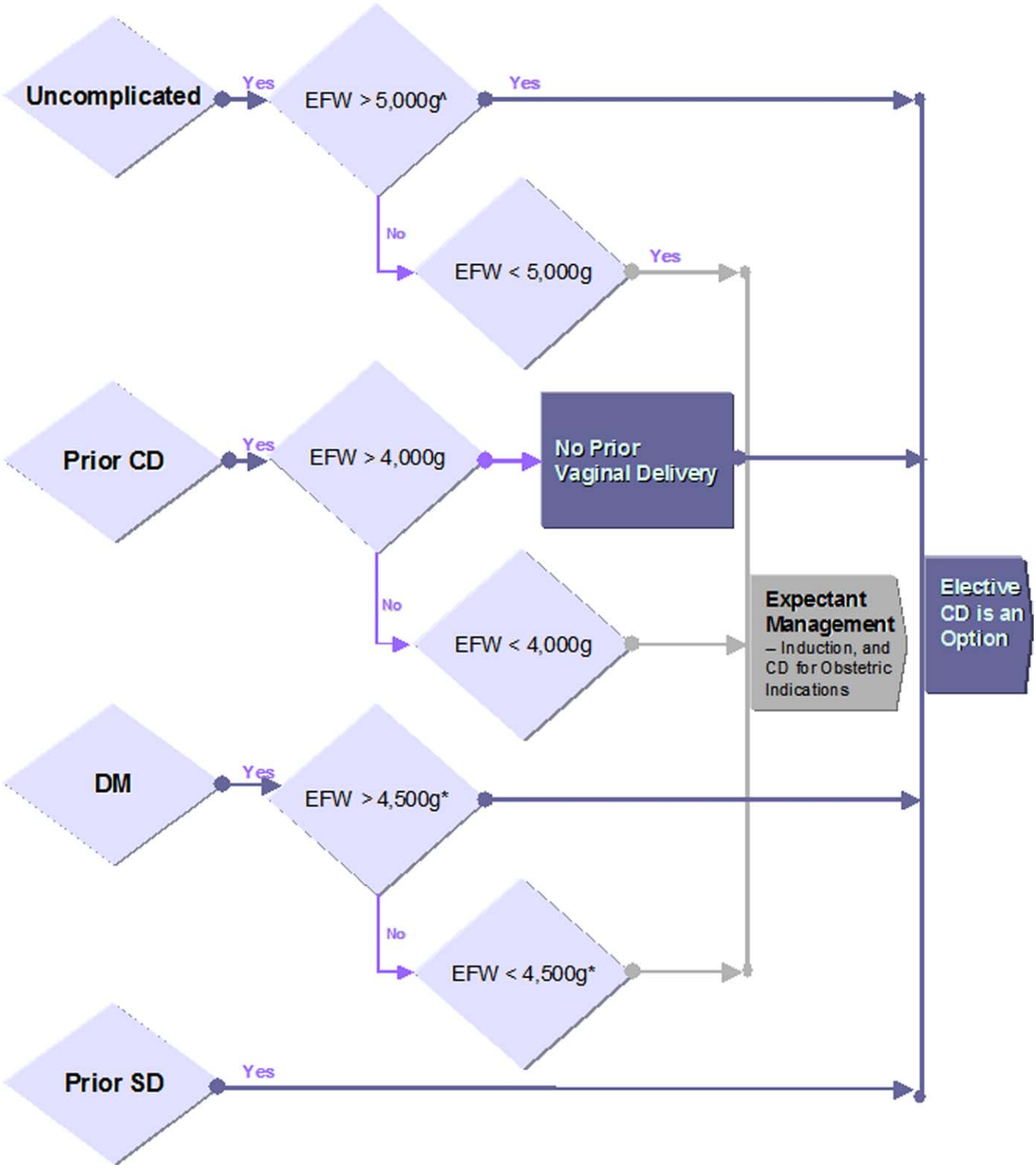

Figure 3 Algorithm for treatment of suspected macrosomia. *Carat,* there are no studies on the actual birth weights and outcomes with estimated fetal weight of $\geq$5000 g; thus, the management of these pregnancies is controversial. *Asterisk,* some investigators have used the threshold of 4000 g[57] or 4250 g[108] to offer elective cesarean delivery. *EFW*, Estimated fetal weight; *CD,* cesarean delivery; *DM,* diabetes mellitus; *SD,* shoulder dystocia.

(55%) whose infants weighed at least 4000 g were delivered vaginally; when these women were compared with women whose infants were <4000 g, there was no significant increase in the risk of uterine rupture, maternal morbidity, or neonatal morbidity. A more recent study by Zelop et al[112] limited the study to

women without a previous vaginal delivery and yielded results that were quite similar to those of Flamm and Goings[111] and Phelan et al,[110] which further supports the notion that macrosomia, in and of itself, is not a contraindication for a trial of labor.

The potential for other clinical factors to make helpful contributions to the decision to proceed with a trial of labor in the setting of a macrosomic fetus has been highlighted by Elkousy et al.[113] These investigators stratified vaginal delivery and uterine rupture rates, not by birth weight alone, but also by other demographic and intrapartum factors. The results of this study differed from those of Zelop et al[112] in that women without a previous vaginal delivery and an infant of at least 4000 g were delivered vaginally less than one-half of the time (42%) and had a higher rate of uterine rupture (3.6%) than women of similar reproductive history whose infants weighed <4000 g. These outcomes were improved for women with macrosomic fetuses who also had a previous vaginal delivery; their success rates were as high as 87%, and uterine rupture rates were not associated with birth weight. Other factors that were associated independently with lower success rates were a previous cesarean delivery for failure to progress and induction for the current trial of labor.

In summary, macrosomia in and of itself should not be a contraindication to trial of labor, because it appears that most women in this situation will experience a vaginal delivery; there is not consistent evidence of a greater risk of uterine rupture. The counseling that couples receive, however, should take into account the potential contributions of other relevant factors that may reduce the chance of a successful trial of labor (such as delivery history and need for labor induction).

Previous shoulder dystocia

Few studies have documented the risk of recurrent shoulder dystocia, and the studies that do exist are observational in nature, contain relatively small numbers of patients, and are not limited only to those women with a macrosomic fetus. Moreover, the frequency of recurrence has varied. Baskett and Allen,[114] for example, found a recurrence of shoulder dystocia in only 1 of 93 (1.1%) vaginal deliveries, despite 41% of the subsequent neonates weighing more than the neonate who experienced a shoulder dystocia. Other investigators have documented higher recurrence risks for shoulder dystocia, ranging from 9.8% to 16.7%.[115-117] Only 1 study noted that a recurrent shoulder dystocia was significantly more likely if the subsequent birth weight was greater than in the previous pregnancy.[115] These investigators specifically noted that macrosomia, which was defined as a birth weight of >4000 g, was significantly more likely to occur in women who had a recurrent shoulder dystocia than in women who did not (64.7% vs 9.4%). In this study, 11 of the 21 women with a previous shoulder dystocia and a macrosomic fetus experienced a recurrent shoulder dystocia, which represents a recurrence risk of 52% (95% CI, 30%-74%).[115] Some of the variations in frequency that have been noted may be due to the outcome measure of shoulder dystocia, which lacks a uniform definition, and may be coded differently by different physicians and at different institutions.[96,97] Also, it is difficult to make definitive conclusions regarding an optimal route of delivery on the basis of this intermediate outcome measure. As little information as there is on shoulder dystocia, there is even less regarding the recurrence risk of brachial plexus injury. In the study by Baskett and Allen,[114] none of the 8 women who had an infant with a brachial plexus injury had a recurrence of this injury during a subsequent vaginal delivery. Conversely, Al-Quattan and al-Karfy[118] reported the experience of 6 women who underwent subsequent vaginal delivery after having a child with a brachial plexus injury. Of their 9 subsequent pregnancies, 8 pregnancies were complicated by a recurrent neonatal brachial plexus injury. Many of the women whose cases were studied by these investigators had diabetes mellitus with infants in excess of 4000 g. No study has compared the outcomes, either of shoulder dystocia or brachial plexus injury, of women with a previous shoulder dystocia who have a trial of labor or an elective cesarean delivery.

A definitive determination regarding the desirability of routine cesarean delivery cannot be made, given the paucity and quality of information that exists. The little information that does exist suggests that women with a previous neonatal brachial plexus injury and a macrosomic fetus may be at high risk of a recurrence during a subsequent vaginal delivery, and it seems reasonable to offer these women an elective cesarean delivery. When the history includes the report of a shoulder dystocia without a corresponding neonatal injury, all efforts should be made to obtain the previous delivery records to determine the actual clinical events of the "shoulder dystocia" report. The degree of dystocia and other clinical factors (such as the presence of diabetes mellitus) should be used to help counsel the patient during her prenatal care, if possible, regarding the potential risks of a subsequent trial of labor. Although elective cesarean delivery will be a reasonable choice in many circumstances, the available data do not allow one to say that a trial of labor should be precluded universally. A simplified treatment algorithm, based on this discussion, is presented in Figure 3.

Comment

Despite the decreasing prevalence of macrosomia in the United States, an understanding of the risks that are

associated with delivery, of our ability to identify it accurately and treat it without unnecessary intervention, while avoiding permanent injury and litigation, is important. After analyzing the outcomes of >8 million deliveries at ≥37 weeks of gestation, Boulet et al[3] nicely categorized macrosomic newborn infants into 3 groups. Compared with control subjects of newborn infants with birth weights between 3000 and 3999 g, infants who weigh 4000 to 4500 g (grade 1) are at significant risk for labor and newborn complications (such as induction of labor, cesarean delivery, and birth injuries). Infants with grade 2 macrosomia, defined as weights between 4500 and 4999 g, are at significant risk for neonatal morbidity (such as a 5-minute Apgar score of <3, meconium aspiration, and hyaline membrane disease). Infants with grade 3 macrosomia, defined as a birth weight of at least 5000 g, are at a significant risk factor for infant death.[3]

With these categories of macrosomia in mind, it is noteworthy that there are no studies that have evaluated the ability to accurately identify grade 3 macrosomia or the peripartum outcome if the estimated weight is >5000 g. Thus, the ACOG recommendation to consider elective cesarean delivery for fetal weight of >5000 g should be accepted cautiously.[1,91] Additionally, there have been only 4 reports[66,67,87,88] that have determined the accuracy of the detection of, clinically or sonographically, neonates who weigh ≥4500 g (Table VI; among them, there were only 76 cohorts of grade 2 macrosomic fetuses. These 4 reports consistently confirmed that it is not feasible to identify newborn infants who weigh ≥4,500 g. The use of Bayes theorem and posttest probability indicates that, if the fetus is suspected of having at least a grade 2 macrosomia, there is a 63% to 88% probability that the newborn infant will weigh <4500 g.

What is forgotten in most studies that link birth weight and peripartum complications[2,3,5,6,91,101,103] is that the actual birth weight is unknowable until the newborn infant is actually weighed and by then the adverse sequelae have occurred. The few studies that have examined the relationship between clinical treatments based on suspected macrosomia and outcomes have noted that it increases either the rate of induction or cesarean delivery without diminishing the neonatal complications.[9,57] There is only 1 randomized clinical trial that allocated uncomplicated parturients with suspected macrosomia to induction versus expectant treatment, and it noted there is no benefit to intervention.[10] Thus, on the basis of the US Preventive Services Task Force guidelines, there is level I evidence that intervention for suspected macrosomia in patients without diabetes mellitus or previous cesarean delivery is unwarranted.

There are no randomized trials that have ascertained the optimum route of delivery for pregnancies with suspected macrosomia that are complicated by diabetes mellitus or previous cesarean delivery. Thus, it is understandable that different sources have varying thresholds for proceeding with cesarean delivery among women with diabetes mellitus. Gonen et al,[57] for example, considered cesarean delivery if the estimated weight of the fetus was at least 4000 g; Conway and Langer[108] considered it if the sonographic weight was >4250 g, and the ACOG guidelines considered it at 4500 g. Randomized trials for the optimum route of delivery for patients with a previous cesarean delivery irrespective of fetal weight are needed, as are trials for patients with previous cesarean delivery and suspected macrosomia. Without the benefit of level I evidence, it is difficult to determine the optimum route of delivery for a complicated pregnancy with suspected macrosomia.

Future studies on the detection and treatment of macrosomic fetuses should focus on identifying neonates with weights of at least 4500 g and determine the optimum route of delivery with grade 2 macrosomia. Considering the low prevalence of these neonates, a multicenter study is warranted.

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