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IS SHOULDER DYSTOCIA WITH BRACHIAL PLEXUS INJURY PREVENTABLE?

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INTRODUCTION

The sequelae of shoulder dystocia with persistent brachial plexus injury (BPI) are among the most serious of obstetrical complications.[1–5] Shoulder dystocia with BPI generally places second or third in the list of the top causes of permanent birth-related neonatal injuries. Apart from the devastating medical and social consequences of lifelong impairment for the family, ensuing litigation with its allegations regarding poor care exacts a heavy toll on the medical profession.

Rising rates of maternal obesity and its association with large for gestational age babies are likely to place more pregnancies at increased risk for shoulder dystocia.[6,7] Furthermore, both elevated maternal BMI and fetal weight over 4500g raise the rate of associated BPI when shoulder dystocia does occur.[8] Consequently the problem is unlikely to abate and there is considerable motivation to develop means to reduce the rate of shoulder dystocia with persistent injury.

Traditionally clinicians have employed two general strategies to attempt to accomplish this.

1. Reduce the incidence of shoulder dystocia by offering elective caesarean to women who are at greatest risk.
2. Lessen the rate of associated injury by educating and rehearsing teams to respond better when shoulder dystocia does occur.[9–12]

Alas, developing a method to predict a significant portion of women who will have shoulder dystocia, without a high rate of false positives, has challenged and discouraged most who have tried.[1,2,13–17] The purpose of this chapter is to

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trace the general evolution of reasoning leading to the conclusion that shoulder dystocia is mostly unpredictable and unpreventable. We will then challenge the assumed corollary that *shoulder dystocia with brachial plexus injury* is also mostly unpredictable and unpreventable. Techniques to help obstetrical teams successfully resolve shoulder dystocia will not be addressed.

DEFINITION OF SHOULDER DYSTOCIA

No discussion of shoulder dystocia can proceed without first addressing the problems associated with its definition. Shoulder dystocia is most often defined clinically as a delivery requiring use of specialized maneuvers, beyond gentle downward traction of the head, in order to deliver the shoulders. The perceived need for these maneuvers can vary from clinician to clinician. Moreover, some women are placed in McRobert's position prophylactically. Thus it is difficult to know exactly what is meant by a charted notation of "shoulder dystocia", even when a common clinical definition is used.

If the absolute number of deliveries with shoulder dystocia is measured unreliably, for any of the reasons described above, it follows that any ratio using it, such as the incidence or associated rate of injury inherits the same lack of precision.

To counter the subjectivity factor, other authors have proposed a measurable parameter such as a prolonged interval between delivery of the head and shoulder.[18,19] Use of this objective definition increases the "observed" rate of shoulder dystocia several fold to 13.7% to 16% of vaginal births. Most of the increase is in the mild variety with little clinical consequence. Obviously the associated rate of injury must fall accordingly. Hence, with no change in clinical conditions, we can see the rate of shoulder dystocia increase and the rate of associated injury decrease simply by virtue of changing the definition.

Even with the most clear and consistent definition, shoulder dystocia covers a wide continuum, ranging from transient and innocuous to the rare form that can be severe, prolonged and potentially even fatal. Grouping them together produces a sort of "average" that is not truly reflective of either end of the spectrum. Graded classifications of most diseases, for example malignancy, hypertension and diabetes, have enabled clinicians to better diagnose and appropriately treat these conditions. Likewise, the shoulder dystocia definition dilemma can be resolved in part by further subclassifying shoulder dystocia according to the presence or absence of a measurable marker such as neonatal fracture or BPI or low Apgar score. This enables the clinician to focus on specific subsets with well-defined clinical significance.

Definition issues are very pertinent to prediction problems. Predicting "bad weather" is not very useful when "bad weather" can range from showers to a hurricane.

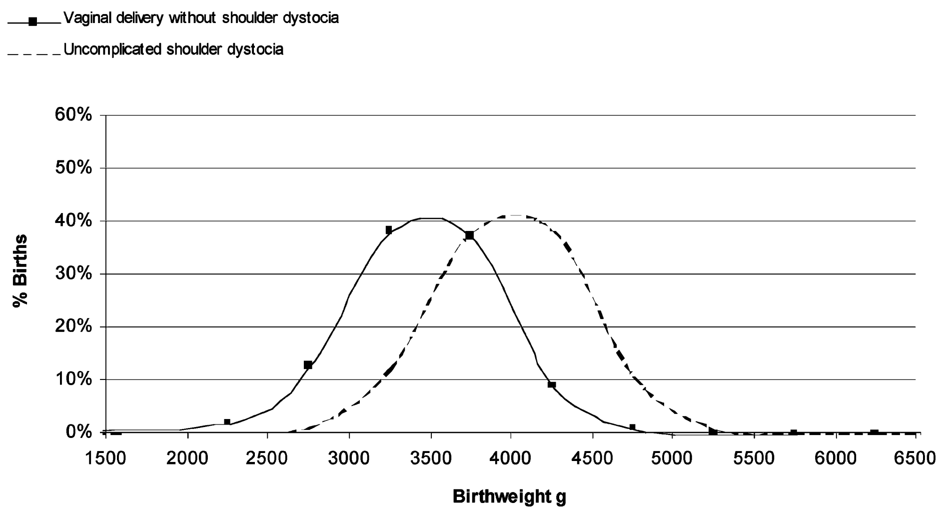

Figure 1 Distributions of birthweight in vaginal births with and without shoulder dystocia.

PREDICTING WHO WILL HAVE SHOULDER DYSTOCIA IS PROBLEMATIC

It is useful to review the three basic arguments leading to the conclusion that shoulder dystocia can not be predicted.

1 Increasing birthweight is associated with increasing rates of shoulder dystocia. However, the mean birthweight of babies with shoulder dystocia is around 4000g and not greatly above the mean birthweight of term babies.
2 Lowering the birthweight criteria in order to detect the majority of shoulder dystocia deliveries produces an excessive number of false positives in women who deliver vaginally without shoulder dystocia. Adding information about maternal diabetes improves prediction somewhat.
3 Estimating birthweight prenatally is inaccurate and this further limits its poor predictive ability.

These statements have been supported by numerous independent analyses and extensive reviews.[1,2,20–24] The problem is evident in Figure 1 which displays the overlapping distributions of birthweights from babies with and without shoulder dystocia.

A natural extension of this line of reasoning was to investigate if other risk factors in addition to and independent from birthweight would be helpful. As summarized in Table 1, maternal diabetes and instrumental delivery were the most consistently identified factors associated with increased risk of shoulder dystocia.[17,25] Induction of labour and previous macrosomia also appeared. However, none of these factors was sufficiently discriminating alone to be useful as an indication for prophylactic caesarean section.

Table 1 Risk factors for shoulder dystocia (SD) versus vaginal deliveries without shoulder dystocia

Authors	Study population	Factors considered	Statistical technique	Conclusions
Robinson H et al 2003[17] Is maternal obesity a predictor of shoulder dystocia?	413 shoulder dystocia compared with 845 randomly selected vaginal deliveries (cephalic >2500 g)	Obesity Macrosomia Maternal age Parity Pregnancy induced hypertension Post date pregnancy Prolonged second stage Diabetes Midpelvic instrumental delivery Previous macrosomic delivery	Multivariate regression analysis	1. Significant independent factors: Fetal macrosomia >4.5 k OR 9.5 4–4.5 k OR 9.0 Previous macrosomia OR 3.8 Diabetes OR 3.5 Instrumental delivery Mid pelvic OR 4.1 Low pelvic OR 1.7 2. Maternal obesity not a significant independent factor
Nesbitt TS et al 1998[25] Shoulder dystocia and associated risk factors with macrosomic infants born in California	6,238 with Shoulder dystocia including 350 BPI compared to 169,638 vaginal births using data on birth certificate and hospital discharge records	Assisted vaginal delivery Induction of labour Maternal diabetes Insurance status Ethnicity Birthweight <4.0 k 4–4.5 k >4.5 k Post term Parity	Logistic regression to establish factor effects on the odds ratio for the incidence of shoulder dystocia	1. Assisted delivery increases rate of SD OR = 1.90 2. Diabetes increases risk of SD OR 1.71 3. Induction of labour increases rate of SD OR 1.27 4. Hispanic ethnicity reduces rate of SD OR = 0.83

Abbreviations: OR, odds ratio; k, kilograms.

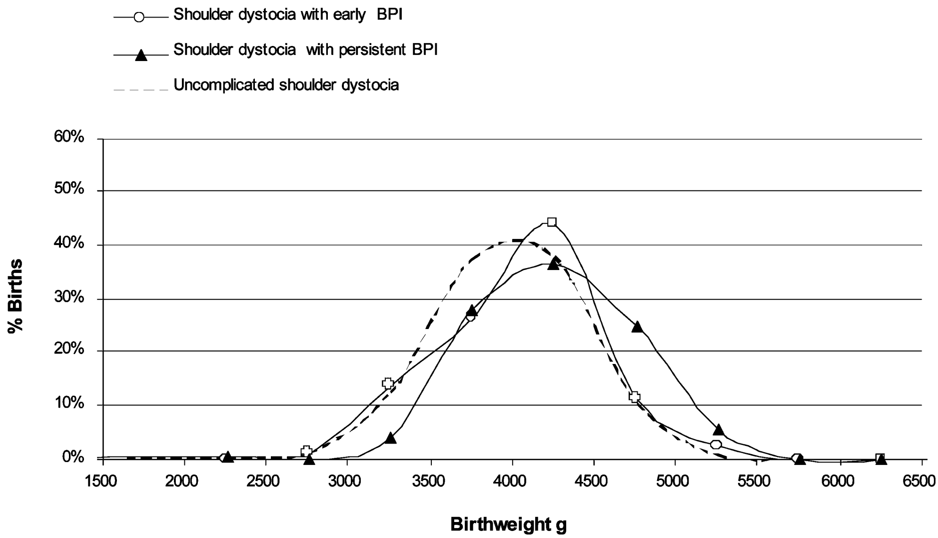

Figure 2 Distributions of birthweight in births complicated by shoulder dystocia with and without complications.

Combining factors was also discouraging. Either sensitivity was poor and/or an excessive false positive rate accompanied the combinations with good sensitivity. Summaries of four reports that studied combinations of factors are provided in Table 2.[13–16] It is important to note what factors were studied and how they were combined.

With the development of larger databases it became possible to study shoulder dystocia with neonatal complications. The search for independent factors to distinguish between uncomplicated and complicated shoulder dystocia began. Birthweight alone was unhelpful as evidenced by the very similar birthweight distributions shown in Figure 2.

A summary of five recent studies examining other differences between shoulder dystocia deliveries with or without some degree of BPI is presented in Table 3.[26–30] No single factor was identified consistently as an independent risk factor. Maternal diabetes and higher birthweight occurred more often in women with shoulder dystocia and permanent BPI compared to women with shoulder dystocia and transient BPI.[26] Neither birthweight nor the rate of diabetes was different in the study comparing deliveries with shoulder dystocia and some form of BPI to deliveries with shoulder dystocia without BPI.[27,28] The study by Poggi et al (2003) could not examine the association with birthweight and diabetes because the comparison group was matched for diabetes, gestational age and birthweight.[30] Only maternal age was found to be different. In contrast, maternal age differences were not found in the other studies. None of these studies examined the performance of combinations of factors in terms of sensitivity or measured specificity in uncomplicated vaginal delivery groups.

Table 2 Prediction models for shoulder dystocia (SD) using multiple factors

Authors	Study population	Factors considered	Statistical technique	Conclusions
Chauhan SP et al 2006[13] A scoring system for detection of macrosomia and prediction of shoulder dystocia: a disappointment	255 pregnancies referred for suspicion of macrosomia 105 vaginal deliveries without SD 15 with SD 0/15 brachial plexus injury (BPI) 2/15 fractured clavicle	Sonographic biometry parameters (BPD, HC, AC, FL, AFI) Scoring based equal weight to each sonographic factor 0 pts if under 90th percentile 2 pts if over 90th percentile	Sensitivity and false positive rate for shoulder dystocia at each score level	1. Score could not detect births associated with SD with adequate sensitivity and false positive rates 2. Sensitivity 20% (4–48%) 3. False positive rate 9% (4–16%) 4. AUC 0.49 $\pm$ 0.08
Belfort MA et al 2006[14] Prediction of Shoulder Dystocia Using Multivariate Analysis	100 births over 37 weeks with SD 3 with BPI Compared with vaginal deliveries matched by delivery time	86 variables considered 3 factors significantly related in the multivariate analysis Birthweight (BWT) 1 hour glucola score (GLU) Operative vaginal delivery (OVD)	Multivariate stepwise logistic regression (Logit Score approach)	1. Best predictor of SD was a combination of 3 factors BWT, GLU, OVD 2. Sensitivity 84% 3. False positive 20%
Ouzounian JG et al 2005[15] Are historic risk factors reliable predictors of shoulder dystocia	1,686 shoulder dystocia cases compare to 265,542 vaginal births from multicenter perinatal database	Operative vaginal delivery Diabetes Epidural use Multiparity Postdatism Labour induction Oxytocin use BWT >4500	Comparison of proportions Calculation of odds ratios	1. Best prediction occurred with a triad of Labour induction, oxytocin use and BWT > 4500g 2. Cumulative odds ratio 23.2 (17.3–31.0) 3. Sensitivity 12.4% 4. False positive 2.2% 5. PPV 3.4%
Gross TL et al 1987[16] Shoulder dystocia: a fetal-physician risk	Babies with birthweight >= 4000 gm including 29 births with uncomplicated SD 20 births with SD and trauma 394 total vaginal births	9 perinatal factors 5 labour patterns in babies with birthweight >= 4000g,	Three way stepwise discriminant analysis	1. Best prediction with birthweight, prolonged deceleration phase and length of second stage 2. Sensitivity for SD <10% 3. Sensitivity for SD with injury 16% 4. False positive rate 6%

Table 3 Comparisons of shoulder dystocia (SD) deliveries with and without brachial plexus injury (BPI)

Author	Sample	Methods	Differences	Comments
Gherman et al 2003[26] A comparison of shoulder dystocia associated transient and permanent brachial plexus palsies	49 permanent BPI with SD form national birth injury registry compared with 49 transient BPI with SD from local database	Comparison of proportions and means Factors examined 7 maternal 8 intrapartum 16 neonatal	Maternal Diabetes OR 4.68, 34.7% vs. 19.2% Mean birthweight 4519 ± 94.3 vs. $4143 \pm 56.5\%$ Over 4.5 k 16.3% vs. 38.8%	1. Rates of maternal diabetes, birthweight over 4.5 k and mean birthweight were higher in the permanent injury group. 2. Maternal age, operative vaginal delivery rates and number of manoeuvers were not different
Chauhan SP et al 2007[27] Shoulder dystocia with and without Brachial Plexus Injury: Experience from Three Centers	38 SD with early BPI (persistence not determined) vs 586 SD without BPI	27 factors examined with multivariate analysis	4 factors significantly associated with BPI Ethnicity OR 3.83 Instrumental vaginal delivery OR 3.95 Numbers of maneuvers>3 OR 6.8 Fracture of the clavicle OR 50.5	1. Instrumental delivery increased the likelihood of injury 2. African American and Hispanic ethnicity increased likelihood of injury 3. Two of the associated factor are evident only after the shoulder dystocia appears and thus are not useful for prediction. 4. Maternal age, Diabetes and Birthweight were not different
Chauhan SP et al 2007[28] Shoulder Dystocia without versus with brachial plexus injury: a case control study	46 SD without BPI 46 SD with BPI	Comparison of proportions and means 3 Antepartum factors 6 Intrapartum factors	Fracture occurred less often in SD without BPI compared to SD with BPI 2% vs. 17 % OR 0.10	1. Fractured clavicle occurs after shoulder dystocia appears and thus is not useful for prediction. 2. No other intrapartum nor antepartum factor differentiated the patient who will have SD with BPI from those who will have SD without BPI.
Mackenzie et al 2007[29] Management of Shoulder dystocia trends in incidence and maternal and neonatal morbidity	470 SD without BPI 44 SD with BPI Persistence not noted Also 79, 267 vaginal delivery without SD	Comparisons of proportions and means 5 maternal and fetal characteristics 7 labour related factors	SD without BPI vs SD with BPI Nulliparity more common 33% vs 55% First stage >8 h in multiparas 12 vs.35% Assisted vaginal delivery 33% vs. 57%	1. Rates of nulliparity, first stage >8 hr is multips and assisted vaginal delivery significantly more common
Poggi et al 2003[30] Intrapartum Risk factors for permanent brachial plexus injury	80 SD with persistent BPI compared with 80 SD without BPI	Comparison of proportions and means 7 factors examined Comparison group matched for birthweight, parity and diabetes	Maternal age Older in index group 27.4 ± 5.1 vs. 23.9 ± 6.2	1. After controlling for parity, birthweight and diabetic status only maternal age was different. 2. This may have been related to an unusually young population in the hospital where the comparison group was obtained.

Abbreviations: OR, odds ratio; k, kilograms.

Table 4 Summary statements of general conclusions

Clinical Statement	Logical statement	Reference
Vaginal births without shoulder dystocia (A) are not substantially different from uncomplicated shoulder dystocia births (B)	A is not substantially different from B.	Factors and methods noted in Table 1.
Uncomplicated shoulder dystocia births (B) are not substantially different from births with shoulder dystocia and early BPI (C)	B is not substantially different from C.	Factors and methods noted in Table 2.
Shoulder dystocia and early BPI births (C) are not substantially different from births with shoulder dystocia and persistent BPI (D)	C is not substantially different from D	Factors and methods noted in Table 3.

RESTATING THE PROBLEM

It is useful to summarize the conclusions in clinical terms and then restate them simply as an exercise in logic as is outlined in Table 4. We have reviewed several studies that found some statistically significant differences between certain groups. However, such statistical differences are not useful clinically because they lack satisfactory sensitivity and good specificity. Without such discriminating ability, one group is not substantially different from another with respect to these factors for clinical purposes.

For many the most germane question is "Are A and D substantially different?" It is highly relevant for the majority of mothers who will deliver without shoulder dystocia (A) and for the very few who will have shoulder dystocia with persistent injury (D). Likewise, health economists demonstrate an interest in these two specific groups when requesting the "number needed to treat" or more accurately with this condition the number of extra caesareans needed to prevent one persistent injury. Finally the mother with a handicapped child may understand that shoulder dystocia in general can not be predicted but asks why such a severe form was not more evident in advance.

Logically it does not necessarily follow that we can surmise the relationship between (A) and (D) from the studies described earlier. Small or statistically insignificant differences between adjacent levels may add up to substantial differences when comparing the two outer levels. We found no studies that directly examined this comparison with statistical modeling.

A DIFFERENT APPROACH

Mindful of these historical findings, we thought that the problem should not be an absolute and insurmountable challenge for modern medicine. Perhaps past failures reflected limitations in the chosen methods.

The impressive advances made with statistical modeling applied to the problem of screening for trisomy 21 were especially pertinent. Maternal age, serum biochemistry and ultrasound markers are weakly related to Trisomy 21 and individually of limited predictive value. However, arranged together in a formula, they became much more useful. This situation was similar to shoulder dystocia with its many weak and interrelated risk factors.

The following sections describe three important differences used in this statistical modeling approach.

1 The first methodological difference was adapted from a common tactic in general problem solving. If a problem is too vast to solve, perhaps breaking it into parts and attacking a smaller part will lead to some success. Thus shoulder dystocia associated with persistent BPI was compared to vaginal births uncomplicated by shoulder dystocia. This alleviated several definition related obstacles immediately. This specific definition was reliable, with a narrow range of well-defined clinical consequences. Detection rates in these two groups would produce useful statistical information (sensitivity and specificity). In turn, this would produce answers to clinically pertinent questions. How often would the new test cause unnecessary intervention among women who represent the great majority of patients? How often would it help avoid a rare but serious injury? How many interventions would be needed to avoid one persistent injury? Although the other categories of shoulder dystocia were not part of the formal modeling process they are relevant and will be assessed later.
2 The second difference was based on mechanical principles. The genesis of shoulder dystocia involves an anatomical misfit related to size and position of both mother and baby. Indeed the maneuvers to resolve a shoulder dystocia are mechanical techniques designed to change relative dimensions and avoid undue forces on the brachial plexus. This led to focus on the size of baby in conjunction with the size of the mother. Both Manzouni et al (2006) and Gumundsson et al (2005) have reported a relationship between the ratio of maternal height to infant weight and shoulder dystocia.[31,32] None of the studies noted in Tables 1,2,3 examined ratios or the first-order interaction between maternal and fetal size.
3 The third deviation from the traditional approach was to include a direct marker of large for gestational age status, namely birthweight percentile, rather than an indirect marker such as diabetes. Many index babies were noted to be large for gestational age but not infants of diabetic mothers.

Table 5 outlines several characteristics of the study groups. Persistent injuries were gathered from closed litigation cases throughout the US. All the others in the shoulder dystocia group or the vaginal delivery comparison group were collected from 5 university or community hospitals. The vaginal delivery comparison group included only singleton cephalic presenting babies at 36 weeks gestation or greater.

Table 5 Characteristics of the study groups

	Litigation series	Hospital series		
	SD with persistent BPI N = 221	SD with early BPI N = 160	SD without injury N = 496	Vaginal delivery without shoulder dystocia N = 2051
Multipara	135 (61.1%)	90 (56.2%)	311 (62.7%)	1262 (61.5%)
Diabetes	56 (25.3%)	19 (11.9%)	67 (13.5%)	105 (5.1%)
High birthweight (>5000g without diabetes or >4500g with diabetes)	33 (14.9%)	5 (3.1%)	11 (2.2%)	4 (0.1%)
Gestational age wk	39.5 ± 1.4	39.6 ± 1.4	39.9 ± 1.2	39.6 ± 1.2
Maternal height m	1.63 ± 0.07	1.63 ± 0.08	1.63 ± 0.07	1.64 ± 0.07
Maternal weight kg	99.5 ± 22.0	82.3 ± 24.8	80. ± 617.8	80.9 ± 15.2
BMI	37.1 ± 7.3	30.8 ± 9.1	30.2 ± 6.4	29.9 ± 5.1
Birthweight g	4263 ± 493	4043 ± 498	3986 ± 439	346 ± 4 449
Birthweight percentile	86.7 ± 17.4	78.1 ± 24.6	74.8 ± 22.6	44.8 ± 27.4

STATISTICAL TECHNIQUES

This model was developed using the same statistical techniques as described in an earlier publication.[33] The modeling techniques are designed to find the combination of the fewest variables that will best separate the two populations and generalize well with independent data. In brief, the process began with 10 basic factors that translated to over 250 different possible variables, including various combinations of the factors, their ratios, first order interactions, as well as their logarithmic and exponential expressions.

Resampling with backward and forward selection was employed to find the best set of potential models containing ten variables or less. From these potential models, the top 36 models were selected based on an index of stability, or how frequently they appeared in the resampling process.

Cross validation is a technique to reduce overfit bias, namely to provide estimates of model parameters that yield valid predictions if applied to a new independent sample from the same population. This was accomplished by splitting the data randomly into two parts: a learning sample of approximately two-thirds of the total size, and a test sample consisting of the remaining one third. The learning sample was used to estimate the coefficients of the model. The test sample was used to measure the performance of the model produced from the learning sample. The splitting was repeated 700 times to assess and account for variation due to the random splitting. From the 36 top models, 8 were superior based on the cross-validated statistical deviance.

These 8 top models were further evaluated by comparing three cross-validated indices of model performance; deviance (−2log-likelihood), Generalized Coefficient of Determination R^2 and c statistics, defined as the area under the Receiver Operating

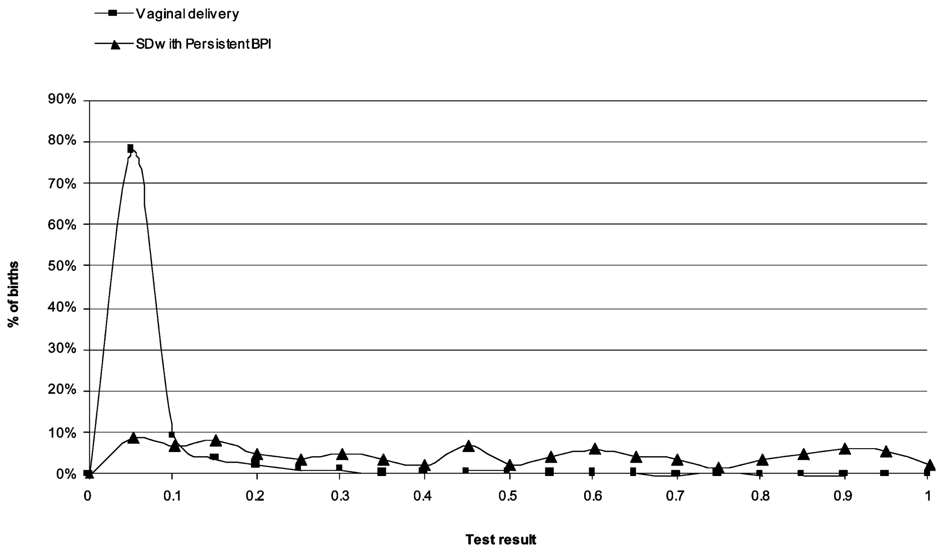

Figure 3 Distributions of the test results

Characteristic (ROC) curve. The final equation contained 6 factors. The basic structure was $y = e^x/(1 + e^x)$

Where $x = \alpha(BWT/MHT) + \beta(MHT) + \chi e^{(BWT\ percentile)} - \delta(PAR) + \varepsilon$
BWT = birthweight
MHT = maternal height
BMI = body mass index
BWT = birthweight percentile
PAR = parity factor

The interaction between birthweight and maternal BMI, birthweight and maternal height were more influential than birthweight alone. Birthweight percentile, maternal height and parity were the other major contributors. The equation produced a number from 0 to 1, with a higher result corresponding to a greater likelihood of shoulder dystocia with persistent injury. The distributions of the test results for the vaginal delivery group and the shoulder dystocia with persistent BPI group, shown in Figure 3, reveal a very different picture from their overlapping birthweight graphs as shown in Figures 1 and 2.

The clinical significance bears emphasis. Over 93% of the vaginal delivery group is clustered below 0.2 whereas 70.6% of the persistent injury group is found above this level. In short, a multifactorial model of this nature has greatly advanced our capacity to discriminate between the persistent injury group and the vaginal delivery group. This degree of separation was impossible using birthweight alone or any of the other individual factors listed in Table 5. Using the 0.4 level to define a positive test detected 54.8% of the persistent injury group and 2.5% of the vaginal delivery group. This corresponds to 335 caesareans to prevent one persistent injury which

Table 6 Numbers and percentages of births over various test result cut points

	SD persistent BPI N = 221		SD early BPI N = 160		SD no injury N = 496		Vaginal delivery N = 2051	
Test level	n	%	n	%	n	%	n	%
>0.2	156	70.6%	74	46.3%	151	30.4%	126	6.1%
>0.3	135	61.1%	54	33.8%	118	23.8%	71	3.5%
>0.4	121	54.8%	37	23.1%	82	16.5%	51	2.5%
>0.5	99	44.8%	30	18.8%	57	11.5%	29	1.4%

Abbreviations: SD; Shoulder dystocia, BPI; brachial plexus injury.

is similar to the estimated 443 associated with the existing ACOG guidelines.[34] Based on the performance listed in Table 6, these extra caesareans would have also potentially avoided 4 early brachial plexus injuries and 28 uncomplicated shoulder dystocia deliveries.

The numbers and percentages of cases falling above selected thresholds in the index group – shoulder dystocia with persistent injury – and in the comparison group- vaginal delivery – are summarized in Table 6. Results in the other shoulder dystocia subgroups are included as well. As expected, the percentage of babies exceeding any elevated test threshold was highest in the persistent injury group. At each test threshold fewer were detected in the early BPI group and fewer still in the uncomplicated shoulder dystocia group. This parallels their increasing similarity to the vaginal comparison group with respect to maternal and fetal anthropometric characteristics listed in Table 5.

POST-TEST PROBABILITIES

Sensitivity and false positive rates are key parameters to evaluate the performance of a test. They answer two fundamental questions: how often does the test correctly identify the adverse condition and how often does it incorrectly misclassify someone without the condition as having the condition. These measures are not affected by the background incidence of the condition. However, the background incidence of a condition is very relevant for those who may experience the condition. Furthermore, an individual is likely to be most interested in knowing her own likelihood of the condition given her specific characteristics rather than general population averages or the performance of a test.

It is possible with statistical models to translate each test result to a post-test probability of the condition, provided one knows the background incidence. The numbers in Table 7 are the point estimates of risk. The assumed background incidences reflect an average of a large number of studies that report both the number of vaginal births and the numbers of babies with shoulder dystocia and BPI.

Table 7 Post-test probabilities of shoulder dystocia with brachial plexus injury (BPI)

Test value	Estimated number of vaginal births to see 1 shoulder dystocia with persistent BPI*	Estimated number of vaginal births to see 1 shoulder dystocia with early BPI**
0.1	24,847	1,454
0.15	9,338	784
0.2	4,664	506
0.25	2,722	360
0.3	1,753	273
0.35	1,208	216
0.4	875	176
0.45	659	147
0.5	511	125
0.55	406	108
0.6	329	95
0.65	271	84
0.7	227	75
0.75	192	68
0.8	164	61
0.85	142	56
0.9	124	51
0.95	109	47
1	96	44
	*assumed background rate 1 in 7381	**assumed background rate 1in 1018

There are several important caveats to consider when using a statistical model in general and this one in particular.

1 A statistical model should be used with women whose characteristics are within the same general range as the study population.
2 Post-test probability calculations are based on assumptions about the background incidence of the condition. Therefore these post-test probabilities should not be used in a region where the background incidence is different from the assumed background rate shown in Table 7.
3 The post-test probability calculation is based upon all the values inserted into the formula. Maternal height and weight can be measured precisely. Birthweight can be estimated only. Thus the post-test probability is the calculated risk associated with that estimated birthweight. Clinicians may find it useful to calculate a range of probabilities covering a range of anticipated birthweights.
4 A vaginal delivery comparison group is by definition a very select group. It excludes all who delivered by caesarean for any reason, including existing policies to avoid shoulder dystocia. The estimated post-test probabilities in Table 7 are conditional upon having a vaginal birth.
5 Finally, a probabilistic model is a device to help quantify the relationship between a limited collection of variables with respect to a specific condition. Clinicians may

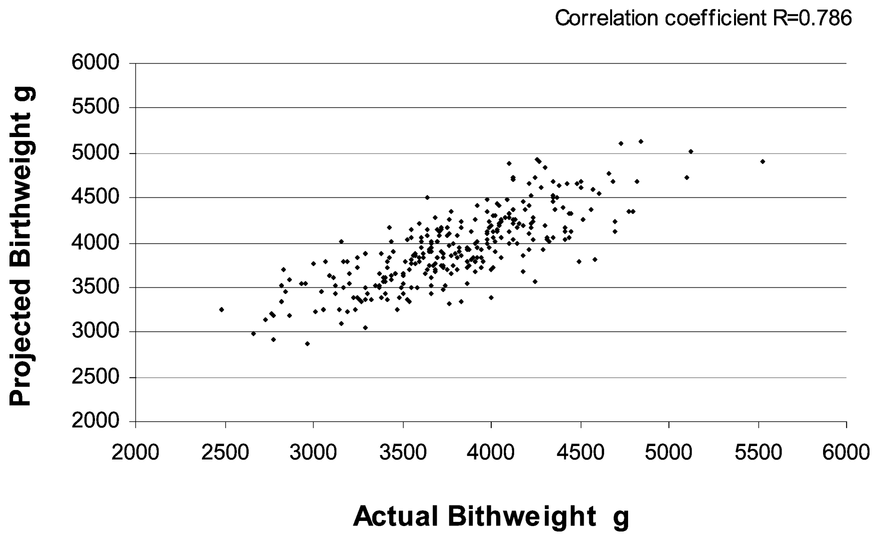

Figure 4 Projected birthweight from ultrasound versus actual birthweight

have additional information that would augment or override the statistical opinion. For example, the modeling exercise did not have access to past obstetrical history of shoulder dystocia, the course of labour or other conditions indicating need for operative delivery. All these factors are important to consider and should modify clinical judgment as they arise.

ESTIMATING FETAL WEIGHT

Estimation of fetal weight based on standard ultrasonic measurements has well known limitations. This too may be a function of our chosen methods rather than an insurmountable challenge. Volumetric techniques, 3 dimensional imaging and magnetic resonance imaging show promise for improved accuracy.[35–37] Nevertheless, most fetal weight estimation is based on 2D ultrasound measurements and this inaccuracy must be considered.

High maternal BMI and fetal macrosomia further stymie estimating fetal weight accurately. Rather than speculate upon the degree of inaccuracy, we measured the relationship between estimated fetal weight and actual birthweight in a sample of 290 women who were identified to be at risk for shoulder dystocia using classical risk factors. The correlation between estimated and actual birthweight is provided in Figure 4. Fetal weight estimations were based on the standard Hadlock 4 parameter formula, occasionally using equations with fewer factors when all the preferred measurements could not be obtained satisfactorily.

The frequency of differences between actual and projected birthweight are shown in Figure 5. About 31% of these mothers delivered infants with actual birthweights that

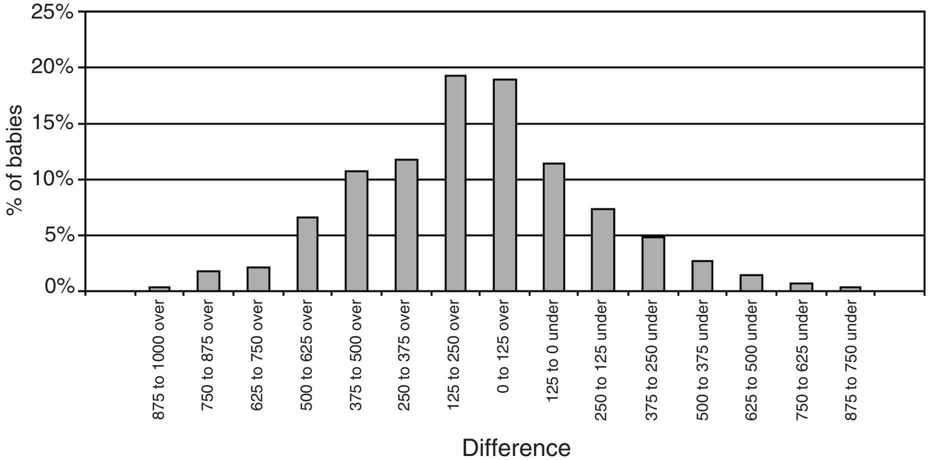

Figure 5 Differences between projected birthweight by ultrasound and actual birthweight

were within 125g of the ultrasonic projection and 57% were within 250g. While it is true that ultrasonic estimations were inaccurate in some cases, they were reasonably accurate most of the time. These observations are in keeping with the report by Mehta et al (2005) who observed that ultrasonic underestimation by 20% or more was infrequent and occurred equally often in deliveries with or without shoulder dystocia.

CONCLUSIONS

Art is said to imitate life and perhaps this can be said about the scientific study of shoulder dystocia. We study what we see and experience most frequently. Uncomplicated shoulder dystocia can be a highly impressionable experience. It occurs frequently in comparison to shoulder dystocia with injury. Data on uncomplicated shoulder dystocia has been relatively easy to collect and study. However, there are limitations with respect to what it can reveal about shoulder dystocia with injury.

This work has focused on shoulder dystocia with persistent injury. Posing a different question, combining different variables and using different statistical methods has produced a new way to assess the probability of one of the most serious of obstetrical injuries. It improves our capacity to identify who is at greatest risk compared to simple birthweight criteria. It also provides useful estimates of risk to inform each woman considering her own specific characteristics.

Predicting the potential occurrence of low-incidence and high-consequence events with risk factors that are very common and non-specific is a challenge. These conditions favour both recriminations after the fact that warning signs were ignored and unnecessary interventions. The statistical methods described here give obstetricians a better method to assess multiple factors and balance the increased morbidity associated with caesarean births against the morbidity of a significant lifetime disability for the newborn.

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REFERENCES

1 Royal College of Obstetricians and Gynaecologists. Shoulder dystocia. *Green-Top Guideline Number* **42**. London, UK: RCOG, 2005.

2 American College of Obstetricians and Gynecologists. Shoulder dystocia. *ACOG Practice Bulletin, Number* **40**. Washington, DC: ACOG, 2002.

3 Gherman RB. Shoulder dystocia: an evidence-based evaluation of the obstetric nightmare. *Clin Obstet Gynecol* 2002; **45**: 345–62.

4 Baskett TF. Shoulder dystocia. Best Practice & Research. *Clin Obstet Gynecol* 2002; **6**: 57–68.

5 Evans-Jones G, Kay SP, Weindling AM, Cranny G, Ward A, Bradshaw A *et al.* Congenital brachial palsy: incidence, causes, and outcome in the United Kingdom and Republic of Ireland. *Arch Dis Child Fetal Neonatal Ed*. 2003; **88**: F185–89.

6 Obesity and Overweight: Trends: U.S. Obesity Trends 1985–2006 | DNPAO | CDC http://www.cdc.gov/nccdphp/dnpa/obesity/trend/maps/

7 The challenge of obesity in the WHO European Region and the strategies for response WHO Regional Office for Europe, 2007 http://www.euro.who.int/document/e89858.pdf

8 Mehta SH, Blackwell SC, Bujold E, Sokol RJ.What factors are associated with neonatal injury following shoulder dystocia? *J Perinatol* 2006; **26**: 85–88.

9 Draycott TJ, Crofts JF, Ash JP, Wilson LV, Yard E, Sibanda T, Whitelaw A. Improving neonatal outcome through practical shoulder dystocia training. *Obstet Gynecol* 2008; **112**: 14–20.

10 Gurewitsch ED, Donithan M, Stallings SP, Moore PL, Agarwal S, Allen LM, Allen RH. Episiotomy versus fetal manipulation in managing severe shoulder dystocia: a comparison of outcomes. *Am J Obstet Gynecol* 2004; **191**: 911–16.

11 Gurewitsch ED, Kim EJ, Yang JH, Outland KE, McDonald MK, Allen RH. Comparing McRoberts' and Rubin's maneuvers for initial management of shoulder dystocia: an objective evaluation. *Am J Obstet Gynecol* 2005; **192**: 153–60.

12 Gherman RB, Chauhan S, Ouzounian JG, Lerner H, Gonik B, Goodwin TM. Shoulder dystocia: the unpreventable obstetric emergency with empiric management guidelines. *Am J Obstet Gynecol* 2006; **195**: 657–72.

13 Chauhan SP, Lynn NN, Sanderson M, Humphries J, Cole JH, Scardo JA. A scoring system for detection of macrosomia and prediction of shoulder dystocia: a disappointment. *J Matern Fetal Neonatal Med* 2006; **19**: 699–705.

14 Belfort MA, Dildy GA, Saade GR, Suarez V, Clark SL. Prediction of shoulder dystocia using multivariate analysis. *Am J Perinatol* 2007; **24**: 5–10.

15 Ouzounian JG, Gherman RB. Shoulder dystocia: are historic risk factors reliable predictors? *Am J Obstet Gynecol* 2005; **192**: 1933–35.

16 Gross TL, Sokol RJ, Williams T, Thompson K. Shoulder dystocia: a fetal-physician risk. *Am J Obstet Gynecol* 1987; **156**: 1408–18.

17 Robinson H, Tkatch S, Mayes DC, Bott N, Okun N. Is maternal obesity a predictor of shoulder dystocia? *Obstet Gynecol* 2003; **101**: 24–27.

18 Spong CY, Beall M, Rodrigues D, Ross MG. An objective definition of shoulder dystocia: prolonged head-to-body delivery intervals and/or the use of ancillary obstetric maneuvers. *Obstet Gynecol* 1995; **86**: 433–36.

19 Beall MH, Spong C, McKay J, Ross MG. Objective definition of shoulder dystocia: a prospective evaluation. *Am J Obstet Gynecol* 1998; **179**: 934–37.

20 Acker DB, Sachs BP, Friedman EA. Risk factors for shoulder dystocia. *Obstet Gynecol* 1985; **66**: 762–68.

21 Baskett TF, Allen AC. Perinatal implications of shoulder dystocia. *Obstet Gynecol* 1995; **86**: 14–17.

22 Gross SJ, Shime J, Farine D. Shoulder dystocia: predictors and outcome. A five-year review. *Am J Obstet Gynecol* 1987; **156**: 334–36.

23 Nocon JJ, McKenzie DK, Thomas LJ, Hansell RS. Shoulder dystocia: an analysis of risks and obstetric maneuvers. *Am J Obstet Gynecol* 1993; **168**: 1732–37.

24 Sandmire HF, O'Halloin TJ. Shoulder dystocia: its incidence and associated risk factors. *Int J Gynaecol Obstet* 1988; **26**: 65–73.

25 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.

26 Gherman RB, Ouzounian JG, Satin AJ, Goodwin TM, Phelan JP. A comparison of shoulder dystocia-associated transient and permanent brachial plexus palsies. *Obstet Gynecol* 2003; **102**: 544–48.

27 Chauhan SP, Cole J, Laye MR, Choi K, Sanderson M, Moore RC *et al.* Shoulder dystocia with and without BPI: experience from three centers. *Am J Perinatol* 2007; **24**: 365–71.

28 Chauhan SP, Christian B, Gherman RB, Magann EF, Kaluser CK, Morrison JC. Shoulder dystocia without versus with brachial plexus injury: a case-control study. *J Matern Fetal Neonatal Med* 2007; **20**: 313–17.

29 MacKenzie IZ, Shah M, Lean K, Dutton S, Newdick H, Tucker DE. Management of shoulder dystocia: trends in incidence and maternal and neonatal morbidity. *Obstet Gynecol* 2007: **110**: 1059–68.

30 Poggi SH, Stallings SP, Ghidini A, Spong CY, Deering SH, Allen RH. Intrapartum risk factors for permanent brachial plexus injury. *Am J Obstet Gynecol* 2003; **189**: 725–29.

31 Mazouni C, Porcu G, Cohen-Solal E, Heckenroth H, Guidicelli B, Bonnier P *et al.* Maternal and anthropomorphic risk factors for shoulder dystocia. *Acta Obstet Gynecol Scand* 2006; **85**: 567–70.

32 Gudmundsson S, Henningsson AC, Lindqvist P. Correlation of birth injury with maternal height and birthweight. *BJOG* 2005; **112**: 764–67.

33 Dyachenko A, Ciampi A, Fahey J, Mighty H, Oppenheimer L, Hamilton EF. Prediction of risk for shoulder dystocia with neonatal injury. *Am J Obstet Gynecol* 2006; **195**: 1544–49.

34 Rouse DJ, Owen J, Goldenberg RL, Cliver SP. The effectiveness and costs of elective caesarean delivery for fetal macrosomia diagnosed by ultrasound. *JAMA* 1996; **276**: 1480–86.

35 Lee W, Deter RL, Ebersole JD, Huang R, Blanckaert K, Romero R. Birth weight prediction by three-dimensional ultrasonography: fractional limb volume. *J Ultrasound Med* 2001; **20**: 1283–92.

36 Schild RL, Fimmers R, Hansmann M. Fetal weight estimation by three-dimensional ultrasound. *Ultrasound Obstet Gynecol* 2000; **16**: 445–52.

37 Uotila J, Dastidar P, Heinonen T, Ryymin P, Punnonen R, Laasonen E. Magnetic resonance imaging compared to ultrasonography in fetal weight and volume estimation in diabetic and normal pregnancy. Acta *Obstet Gynecol Scand* 2000; **79**: 255–59.

38 Mehta SH, Blackwell SC, Hendler I, Bujold E, Sorokin Y, Ager J *et al.* Accuracy of estimated fetal weight in shoulder dystocia and neonatal birth injury. *Am J Obstet Gynecol* 2005; **192**: 1877–80.