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Shoulder dystocia related fetal neurological injuries: the role of diabetic control

Research Article

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Abstract: The study explores the roles of routine prenatal diabetic screening and control in the occurrence of neurological birth injuries associated with shoulder dystocia. The investigation involved retrospective review of 226 medical records that contained information about the antenatal events in cases that resulted in permanent neonatal injuries following arrest of the shoulders at delivery. Close attention was paid to diabetic screening and management of mothers with evidence of glucose intolerance. Analysis of the records revealed that one-third of all women, including those with predisposing factors, received no diabetic screening during pregnancy. The majority of confirmed diabetic patients were not treated adequately. Among babies of diabetic women, birth weights exceeding 4500 g were about 30-fold more frequent than among those with normal glucose tolerance. The data suggest that universal screening and rigid diabetic control, including mothers with borderline glucose tolerance, are effective measures for the prevention of excessive fetal growth and intrapartum complications deriving from it. If ignored, impaired maternal glucose tolerance may become a major predisposing factor for neurological birth injuries. It appears therefore that with routine screening for diabetic predisposition and effective control of gestational diabetes the risk of fetal damage can be reduced substantially.

Keywords: *Diabetes • Diabetic screening • Shoulder dystocia • Brachial plexus injury • Erb's palsy*

1. Introduction

In most instances the emergence of the fetal head from the birth canal is followed by that of the body during the same uterine contraction, or in response to gentle traction by the obstetrician. On some occasions the shoulders become arrested by the bony pelvis, a complication called shoulder dystocia [1,2]. If the entrapment of the body remains unresolved for a prolonged period of time, the fetus may die [3] or may suffer brain damage [4]. Far more often the brachial plexus of one of the upper extremities suffers traumatic damage during the delivery process. Such injuries frequently remain permanent and manifest as Erb's or Klumpke's palsy later in life [5]. The incidence of shoulder dystocia increased markedly in recent decades [6]. Paradoxically this development coincided in time with impressive advances in the fields of obstetrics and neonatology that led to precipitous reduction in perinatal (*i.e.* fetal and neonatal) mortality rates [7].

The mysterious "shoulder dystocia epidemic" has caused much controversy in the medical literature and led to the formulation of imaginative but disputable hypotheses concerning the pathological mechanism

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of associated neonatal neurological injuries [8]. There has been little disagreement about those factors that predispose some mothers for shoulder dystocia and its dire sequelae. Unduly large fetal size [9], usually secondary to maternal obesity and/or diabetes [10], protracted labor process, utilization of oxytocin for induction or augmentation of labor [11], inadequate maternal pelvic capacity [12], use of forceps or ventouse for the extraction of an unduly large arrested fetus [4,11] and certain fetal developmental defects [13] have been long known to increase the risk. On the other hand the magnitude of danger attributable to the various predisposing factors is difficult to determine. Clinical research has been hindered by the fact that shoulder dystocia has no generally agreed upon definition. Thus the diagnosis much depends upon the perception of the physician in charge [2]. Besides, different delivery techniques set different diagnostic criteria for arrest of the shoulders [2,12,14]. These circumstances make it difficult to compare clinical data.

Concluding that "in the absence of fetal injury shoulder dystocia is only a passing nuisance", in their initial publication some of the authors suggested that, in order to create an objective denominator for comparison, relevant investigations should focus on cases that involved damage to the neonate [4]. It was further proposed subsequently that major predisposing factors for arrest of the shoulders should be studied in isolation, detached –as far as possible– from others, in order to eliminate confounding factors. Implementation of these principles opened the way to some new observations [15,16]:

a) Macrosomia (interpreted as ≥4000 g fetal body weight) was shown to carry higher fetal risk than what influential professional organizations attributed to it [8,17].
b) Although previous research had found that the majority of arrests of the shoulders involved <4000 g fetuses [18], it was demonstrated that ≥4000 g neonates sustained most of the associated injuries [15].
c) Growth standards utilized for the interpretation of ultrasound findings tend to underrate the weights of large fetuses. Attention was drawn therefore to the fact that, contrary to prevailing belief, underestimation of the fetal weight is more perilous than overestimation, insofar as with increasing size the risk of birth injuries rises on a logarithmic rather than geometric scale [15].
d) Forceps and vacuum extractions proved to be independent risk factors. They were found to increase the danger of fetal damage exponentially in all birth weight groups [16], rather than selectively for very large babies as previously thought [19].

The above findings necessitated an unattractive conclusion, namely that protection of babies from injuries required expansion of indications for elective abdominal delivery. Since effective diabetic control is known to reduce the risk of excessive fetal growth [20-22], and because the latter is widely considered a very important predisposing factor for shoulder dystocia [1,2,9,12], evaluation of the potential role of antenatal care in the prevention of neurological birth damage appeared a logical next step in the authors' research program.

2. Material and Methods

Permanent fetal damage, as an end point for studying predisposing factors for shoulder dystocia, sets major limitations for data collection. Even if such injuries have been increasing, their incidence is still low in any particular institution. This circumstance practically precludes prospective hospital based research and seriously hinders even retrospective investigations. In contrast, since birth injuries frequently lead to litigations in the United States, records providing documentation of events surrounding shoulder dystocia related birth injuries can be found in large numbers in the files of malpractice attorneys and insurance companies. Utilizing the latter sources, the authors collected 226 records of cases involving neurological birth injuries that occurred between January 1, 1987 and December 31, 2006.

In the absence of universally recognized definition for shoulder dystocia [2,12,14,23], the criteria for the data collection had to be arbitrary. Therefore, for the purpose of this study cases were selected that fulfilled the following requirements:

A. Persistent brachial plexus injury diagnosed >6 months following birth with or without documented history of arrest of the shoulders at birth. (More than 90% of the records in the data base contained reference to this diagnosis.) [4,24].
B. Central nervous system injury, still demonstrable >6 months after birth, in a child whose delivery records referred to the diagnosis of shoulder dystocia.
C. Neonatal death following complicated delivery, characterized as shoulder dystocia in the medical records.

The selected time frame of the investigation rested upon the knowledge that basic principles of currently prevailing management patterns for the diagnosis and treatment of diabetes in pregnancy had been well established in America by the mid-1980's [20-22]. It was felt feasible therefore to define minimum standards of practice that could reasonably be considered applicable

for all study years. The records that satisfied the above mentioned criteria were scrutinized individually in order to determine whether the respective mother had received adequate diabetic screening and, when circumstances warranted, appropriate treatment.

Although favored by most authorities [20,22,25], influential medical organizations in the United States still encourage omission of routine antenatal diabetic screening in the absence of predisposing factors [26,27]. Therefore the prenatal management was only considered inadequate in case of one or more of the following findings:

A) When a mother with predisposing factor for diabetes received no screening, involving glucose loading, sometime between the 24th and 30th gestational weeks.

B) If the physician failed to perform or repeat diabetic screening in response to recurrent episodes of glucosuria or if urinalyses were omitted during the majority of prenatal visits.

C) If a positive screening result, typically a blood glucose level of ≥140 mg/dl (≥ 7.8 mmol/L) one hour after drinking 50 g sugar solution, was not followed by a diagnostic 3 hour glucose tolerance test within three weeks.

D) When a confirmed diabetic mother received no medication and/or dietary instruction.

E) If repeated blood glucose levels of ≥180 mg/dl (≥ 9.8 mmol/L) were tolerated without hospitalization or by adjusting the medication in the course of at least weekly visits. This criterion rested on the information that hyperglycemia of such degree is conducive to fetal compromise demonstrable on electronic monitoring [28].

The following predisposing factors were considered indications for diabetic screening at the end of the 2nd trimester of gestation [26,27]:

a) Maternal age of 30 or above; b) obesity as defined by the Metropolitan Insurance Company [29]; c) diabetes in a first degree relative or two grandparents; d) gestational diabetes in a preceding pregnancy; e) previous birth of a macrosomic child; f) past history of stillbirth; g) history of birth of a child with congenital defect; h) repeated episodes of glucosuria; i) past history or documented evidence of hypertension; j) personal history of previous shoulder dystocia.

Interpretation of the 3 hour glucose tolerance test rested upon the definition of the 2nd International Workshop Conference [27]. It was considered positive if two blood glucose levels reached or exceeded the following limits: Fasting level of 105 mg/dl (5.8 mmol/L); 1, 2 and 3 hour levels of 190 mg/dl (10.6 mmol/L); 165 mg/dl (9.2 mmol/L); and 145 mg/dl (8.1 mmol/L) following oral consumption of 100 g sugar solution.

Blood glucose level determination one hour after drinking 50 gm glucose solution for screening and 3 hour tolerance test with 100 gm glucose loading for women with positive screening results were generally accepted standards in America during the two decades covered by this investigation [23]. These tests were used almost invariably for women included in this study. However those few physicians who utilized some alternative screening method in a timely manner were considered compliant with prevailing standards for the purpose of this study.

The question of what proportion of unscreened women may have had gestational diabetes or borderline glucose tolerance conducive to fetal macrosomia [30] was analyzed based on the following information: a) Of all pregnant American women an estimated 2-5% had diabetes during the study years [26]. b) Among babies of diabetic mothers approximately 50% are born macrosomic [22], as compared to about 10% in the general population [15]. c) The rate of ≥4000 g birth weights has been estimated as 20% among borderline glucose intolerant mothers [20,21]. d) Birth weights of ≥4500 g are about 10-times more frequent among infants of diabetic than those of non-diabetic women [30]. e) As will be shown later, in the material utilized for this study, out of 40 women who had received a 3 hour glucose tolerance test after positive screening, 10 proved to be diabetic. Thus in this group of mothers, borderline glucose intolerance was 3-times as frequent as gestational diabetes.

3. Results

Among the mothers included in the data base five women were noncompliant with their instructions. Therefore they were excluded from the study. Five others had pregestational diabetes. Of the remaining 216 patients 155 had risk factor(s). Nonetheless, as Table 1 indicates, only 66% of them received diabetic screening. A comparable proportion of mothers (69%), underwent screening in the absence of any predisposing factor.

Table 2 demonstrates that 220 risk factors were identified in 216 women. Among these, obesity and advanced maternal age were particularly frequent.

Case by case analysis of the records identified frequent omissions in terms of diabetic screening and/or treatment (Table 3). Failure of implementing obligatory diabetic screening was a recurrent finding. With relative frequency, positive results of indicated or elective screening tests were not followed by further action.

Table 1. Prenatal screening for diabetes in 216 cases that resulted in Neurological birth injuries following shoulder dystocia.

61 patients with no risk factor for diabetes		155 patients with risk factor(s) for diabetes	
Screened for diabetes	Not screened for diabetes	Screened for diabetes	Not screened for diabetes
42* (69%)	19** (31%)	103*** (66%)	52**** (34%)

* *10 patients (24%) had positive screening test. Of these 2 had gestational diabetes based on further testing.*
** *1 patient had gestational diabetes according to late 3rd trimester testing.*
*** *36 patients (35%) had positive screening test, of these 19 had gestational diabetes.*
**** *8 patients had gestational diabetes based on testing in advanced gestation.*

Table 2. The nature and frequency of risk factors among 155 gravidas predisposed for gestational diabetes.

Obesity	66
Maternal age of 30 or more	63
Birth of ≥4000 g baby in the past	25
Repeated glucosuria	22
Family history of diabetes	19
Personal history of hypertension	8
Past delivery with shoulder dystocia	8
Gestational diabetes in previous pregnancy	7
History of stillbirth	2

Table 3. Inadequacies of diabetic screening and/or treatment in pregnancies that resulted in shoulder dystocia associated neurological damage in the neonate.

A. PATIENTS WITH RISK FACTOR(S) FOR DIABETES	
Indicated screening for diabetes omitted	52
Screening omitted or negative: glucosuria disregarded	6
Screening result positive: absent or inadequate follow-up	19
B. PATIENTS WITH NO RISK FACTOR FOR DIABETES	
Elective screening positive: absent or inadequate follow-up	3
Elective screening negative: subsequent glucosuria ignored	6
Elective screening negative: no subsequent urinalysis	1
C. PRE-GESTATIONAL DIABETES	
Inadequate diabetic control	5

The birth weights of babies, delivered by inadequately screened or treated mothers predisposed for diabetes, are shown in Table 4. Almost 90% of them were large for gestational age, over 80% were macrosomic and 45% weighed ≥4500 g. For comparison Table 5 demonstrates the birth weights of babies of 61 mothers who had no predisposing factor for diabetes. On this account the management of several of them legitimately excluded diabetic screening.

Taking into account the entire data base, including that used for the previous relevant publications [4,15,16,24], Table 6 uses relative risk to compare the rate of macrosomia in the sample with that in the general U.S. population, for cases of neonates who suffered shoulder dystocia related injury. The comparison shows that whereas only some 10% of all

Table 4. Birth weights in 76 cases of shoulder dystocia related fetal neurological injuries that followed omission of indicated screening for and/or inadequate treatment of diabetes.

Average birth weight (8 cases)			Large for gestational age (7 cases)		Moderate macrosomia (27 cases)					Gross macrosomia (34 cases)								
Grams			Grams		Grams					Grams								
3100	3200 - 3600	3700	3800	3900	4000	4100	4200	4300	4400	4500	4600	4700	4800	4900	5000	5100	5200	5300
						X												
						X									X			
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						X									X			
						X									X			
				X		X					X				X			
				X		X	X	X		X	X				X	X		
	X			X		X	X	X	X	X	X			X	X	X		
	X			X		X	X	X	X	X	X			X	X	X		
X	X	X		X	X	X	X	X	X	X	X		X	X	X	X		
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X

Table 5. Birth weights in 61 shoulder dystocia related neurological injuries sustained by neonates whose mothers had no risk factor for diabetes.

Average birth weight	Large for gestational age	Moderate macrosomia	Gross macrosomia
(2500 – 3749 g)	(3750 – 3999 g)	(4000 – 4499 g)	(≥ 4500 g)
(16 cases)(26%)	(9 cases)(15%)	(15 cases)(25%)	(21 cases)(34%)

Table 6. Overall risk of macrosomia related fetal neurological injury from shoulder dystocia (n=333).

Birth weight	National %	Sample count	Sample %	C-Int %	RR	RR(L)	RR(U)	RRx X1000	RR(L) X1000	RR(U) X1000
<4,000g	90	105	31.5	27.0, 37.0	0.35	0.30	0.41	1:2860	1:3333	1:2430
≥4,000g	10	228	68.5	63.0, 73.0	6.85	6.3	7.3	1:150	1:160	1:140

Table 7. Maternal glucose intolerance related risk of fetal neurological injury for macrosomic (≥4000 g) fetuses.

	Percentage in population	Percentage of macrosomia	RR of injury	RR(L)	RR(U)
Diabetes	3.5%	50%	1:30	1:32	1:28
Borderline	10.5%	20%	1:75	1:80	1:70
Normal	86%	10%	1:150	1:160	1:140

newborns are macrosomic, they accounted for 68.5% of those neonates who suffered arrest of the shoulders associated injuries at birth. Based on these data, the risk of injury appears to be almost 20-fold higher for ≥4000 g than for <4000 g fetuses.

Table 7 adjusts the calculated relative risk of shoulder dystocia related neurological injury, associated with fetal macrosomia, for gestational diabetic and borderline glucose intolerant mothers. The estimation is based on the premise that 3.5% of all mothers are diabetic, 10.5% have borderline glucose tolerance and 86% are normal. It further assumes that about 50% of newborns of diabetic mothers weigh ≥4000 g. and that the applicable rates are about 20% for borderline glucose intolerant and 10% for non-diabetic patients. Based on these assumptions, the relative risk of shoulder dystocia associated birth injury is increased 5-fold for diabetic parturients (1:30) and by a factor of two for those with borderline glucose tolerance (1:75). While considered useful for demonstrating trends, it needs to be remembered that the presented calculations utilized mean estimates when the actual percentage values deriving from various sources differed on a broad scale, such as the reported of incidence of diabetes among pregnant women in America.

4. Discussion

In the general population about 1.5% of all babies weigh ≥4500 g [15]. Diabetic mothers give birth to such gigantic neonates up to 10-times more often. It can be roughly estimated from the earlier cited data that, among mothers of newborns belonging to this weight group, one-third are diabetic, one-third have borderline glucose tolerance and one-third are normal. Since almost one-half of all neonates who suffered shoulder dystocia related birth injuries belonged to the ≥4500 g weight group [4,24], the contribution of borderline glucose intolerance to such injuries may approach that of clinical diabetes itself. Thus, identification and attentive management of these by definition “non-diabetic” mothers is of considerable clinical importance.

In the United States a reported 96% of obstetricians consider diabetic screening a necessary prenatal routine [31]. In this material about one-third of those women whose babies suffered neurological birth injuries had not been screened. The implication is that those 4% of physicians who considered diabetic screening optional, encountered more than 30% of the documented fetal injuries. This circumstance contradicts the view that shoulder dystocia is usually an incidental phenomenon, unrelated to the antenatal care [19].

The frequent failure of screening for gestational diabetes even when indicated is a disconcerting finding. It may reflect misinterpretation of the policy that screening is subject to individual considerations. For this reason and because 1 out of 4 women without predisposing factor had positive screening test among the patients included in this study, one must question the policy that makes prenatal diabetic screening subject to a variety of predisposing factors.

The here reported findings do not support the view that, since many ≤4000 g fetuses encounter shoulder dystocia at birth, prospective assessment of fetal weight is an ineffective preventive measure [32]. Among those cases that involved omission of diabetic screening and/or treatment, 9 out of 10 neonates were large for

gestational age and 4 out of 5 were macrosomic. Large fetal size is the end result of a process which often can be controlled. Yet it is a prominent cause of shoulder dystocia and its dire sequelae [1,2,9,12,15,24]. It has been estimated that a 250 g fetal weight increase approximately doubles the risk of shoulder dystocia related fetal damage [15,16]. Close dietary and diabetic control during gestation can usually avoid weight accumulation of this degree [20,22].

Considering the method of case collection, the above presented findings rest upon a selected population, the exact characteristics of which are not easy to define. However, because birth injuries almost predictably lead to litigations in the United States, cases in the files of insurance companies and attorneys are not likely to differ very significantly from the general affected population. Nonetheless, they can only serve as a temporary substitute for national registries that need to be established on account of the relative rarity of such cases in the materials of obstetrical centers [15].

Positive diabetic screening implies predisposition for fetal macrosomia [20,30]. This being the case, impaired glucose tolerance, even if short of gestational diabetes, requires attention. Dietary control in this relatively large group could probably prevent many incidents of excessive weight gain. For this reason alone, universal screening is an important aspect of antenatal care.

Analysis of cases involving permanent fetal damage associated with shoulder dystocia does not support the pessimistic view that this complication and its consequences are generally unpredictable and thus unpreventable. The authors' presented data, past and present, along with much of the relevant literature project a different picture:

1) Well motivated investigators successfully cut the rate of macrosomia by one-half with rigid treatment of diabetic and borderline glucose intolerant gravidas [30].
2) About one-half of all birth injuries associated with shoulder dystocia affect ≥ 4250 g neonates. "Baby friendly" weight limits for vaginal deliveries, adjusted to the differing risk levels of diabetic and non-diabetic gravidas respectively, could prevent therefore many birth injuries [15].
3) According to some reports, in the ≥4000 g fetal weight range, instrumental extractions increase the risk of fetal injury close to 10-fold [11,16]. In the authors' material one-third of macrosomic fetuses who suffered permanent injuries were delivered by forceps or ventouse [16]. Therefore avoidance of their use for estimated ≥4000 g fetuses could decrease the risk of fetal injury substantially.
4) The presented data demonstrate a high rate of substandard diabetic control in the background of shoulder dystocia related fetal injuries. This finding implies that inadequate screening for glucose intolerance and superficial treatment of diabetes are conducive to these injuries. This being the case, implementation of the proposed measures could probably reduce the rate of shoulder dystocia markedly both in America and in other countries, where its rate has also increased in recent years [1,9,33-36].

The "CESDI Committee", having investigated shoulder dystocia related fetal deaths in England, Wales and Northern Ireland, found substandard intrapartum management the most frequent causative factor [3]. The present review supplements and expands the British study, demonstrating that inadequate antenatal care is equally prevalent in the background of fetal injuries associated with arrest of the shoulders at birth. Routine diabetic screening and attentive treatment of glucose intolerance are effective preventive measures, capable of reducing the rates of fetal injuries and, in the litigious environment of the New World, malpractice claims and insurance premiums along with them. Thus, there are good reasons for addressing the issues in earnest.

In conclusion, perceived by some as an act of God, fetal neurological damage deriving from arrest of the shoulders at delivery is in fact the final result of several well identifiable interdependent factors [1,2,12]. Maternal obesity and excessive weight gain during pregnancy often lead to diabetes. Diabetes is conducive to fetal macrosomia. In its turn, macrosomia hinders passage through the birth canal and slows down the process of labor. Protracted labor induces the obstetrician to use oxytocin and, when it occurs in the 2nd stage, to extract the child with forceps or ventouse. Instrumental extraction sets the scene for shoulder dystocia. Arrest of the shoulders compels the accoucheur to deliver the fetus with traction. Forceful traction causes damage to the brachial plexus and/or the central nervous system of the child [4,37-40]. At the end of the line, irreversible injury results in malpractice claim [15].

With only the last sequence excluded, the described chain of events can be cut at any point. Close to its end the cutting instrument is the scalpel used for cesarean section [16]. The presented observations suggest however that dietary control during pregnancy, combined with attention to pregnant mothers' glucose intolerance even at the borderline range [41], can turn abdominal delivery from a routine preventive measure into a relatively infrequent last ditch defense. All considered, there is reason to believe that physicians' instructions and prescriptions can be as effective for preventing neurological birth injuries as the knives of surgeons have

been. Routine glucose tolerance screening of pregnant women seems to be an essential first step on the road leading to prevention of birth injuries by medical rather than surgical intervention.

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