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REVIEW

Prevention of shoulder dystocia related birth injuries: Myths and facts

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Abstract

Traditionally, brachial plexus damage was attributed to excessive traction applied on the fetal head at delivery. Recently, it was proposed that most injuries occur spontaneously *in utero*. The author has studied the mechanism of neurological birth injuries based on 338 actual cases with special attention to (1) fetal macrosomia; (2) maternal diabetes; and (3) methods of delivery. There was a high coincidence between use of traction and brachial plexus injuries. Instrumental extractions increased the risk exponentially. Erb's palsy following cesarean section was exceedingly rare. These facts imply that spontaneous neurological injury *in utero* is extremely rare phenomenon. Literary reports show that shoulder dystocia and its associated injuries increased in the United States several-fold since the introduction of active management of delivery in the 1970's. Such a dramatic change in a stable population is unlikely to be caused by incidental spontaneous events unrelated to external factors. The cited investigations indicate that brachial plexus damage typically is traction related. The traditional technique which precludes traction is the optimal method for avoiding arrest of the shoulders and its associated neurological birth injuries. Effective prevention also requires meticulous prenatal care and elective abdominal delivery of macrosomic fetuses in carefully selected cases.

Key words: Shoulder dystocia; Erb's palsy; Fetal macrosomia; Brachial plexus injury; Two-step delivery; Birth injury

Core tip: Traditionally, brachial plexus injury at birth has been considered traction related. Recently, several authors proposed that one-half or more of these injuries occur spontaneously "*in utero*" resulting from myometrial activity. Study of 338 birth injuries found close association with deliveries that had involved manual and instrumental extractions. Only one Erb's palsy occurred following cesarean section. These findings indicate that spontaneous intrauterine brachial plexus damage is extremely rare. Meticulous antenatal care, elective abdominal delivery of grossly macrosomic fetuses and non-interference with the natural birthing process are recommended for preventing shoulder dystocia and its dire consequences.

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INTRODUCTION

Since the 19th century double blind, controlled, prospective investigation has been the hallmark of scientific pedantry. However, not all medical puzzles yield themselves for evaluation by this important but costly and time consuming research approach. Injuries associated with arrest of the shoulders of the fetus at birth are eminent examples. Untold numbers of neonates are left with neurological damage following this complication every year, yet in any single service its incidence is low. Many newborn babies would need to be sacrificed at the altar

of pure science if investigators insisted on resolving this problem through this revered gold standard of research. Not since the Aztecs had offered the hearts of forty-thousand slaves to their gods have human lives been considered freely expendable for causes that contemporary society found noble and worthwhile.

Medical history shows that sophisticated methodology, whatever valuable is no substitute for intuition and deductive logic. The latter qualities made it possible for open minded scientists, such as Jenner, Lind, Holmes, Semmelweis, Pasteur, Koch, Sanger, M and P Curie, Fleming, Gregg, McBride, Friedman, Clarke and others to promote the progress of medicine. Rigid demand for experimental evidence delayed for four decades clinical implementation of "asepsis" for the prevention of childbed fever at the cost of tens if not hundreds of thousands of lives.

Not unlike in ancient Egypt, physicians face court action in the United States if their treatment entails bad outcome. Mercifully, monetary compensation has replaced death penalty that had been favored in the valley of the Nile 3000 years ago. As a result, medical documentation of incidents of birth injuries that are scattered in hundreds of hospitals can be found in abundance in the files of malpractice attorneys and insurance companies. The author's group gained access to these sources and collected 338 medical records which described shoulder dystocia related fetal injuries or deaths in detail. As explained in previous publications[1,2], in many cases the attorney's preliminary review was not followed by litigation. In those instances when court action ensued the records were only attached to the data base after the legal proceedings had been concluded. Eventually, cases were collected on the ground of the following criteria: (1) Neonatal brachial plexus damage that persisted for at least 6 mo with or without clinical diagnosis of shoulder dystocia; (2) Damage-other than brachial plexus palsy-that persisted at least six months with clinical diagnosis of arrest of the shoulders at birth; and (3) Perinatal death against the background of documented shoulder dystocia at birth.

The diagnosis of shoulder dystocia was mentioned in over 90% of the records. The remaining ones only referred to brachial plexus injury. Absence of documented diagnosis is considered by some investigators evidence to indicate that the brachial plexus palsy occurred without arrest of the shoulders[3]. This distinction is only relevant in the medico-legal context, since the injury has never been attributed to the arrest of the shoulders but to traction used by the physician or midwife in charge. Therefore, for the purpose of their studies the participants of this research included those cases in their material where brachial plexus injury occurred but the diagnosis of shoulder dystocia was not documented.

DEFINITION OF SHOULDER DYSTOCIA

Paradoxically, this important clinical complication has no generally accepted criteria. According to current American interpretation the diagnosis is applicable when in the absence of spontaneous expulsion of the fetus the "standard delivery procedure of gentle downward traction" of the fetal head fails to accomplish delivery. This definition ignores the fact that routine use of traction is disapproved in some European countries[4,5] and was discouraged in the United States also until the mid-1970's[6-9]. Non-interference with the birthing process is still practiced by British obstetricians[4,10], whose proverbial "cold blooded" detachment much impressed this writer during the years of his training in England. It has also been favored in the Perinatal Center of the UMDNJ in Newark throughout the last 40 years[11] in spite of the contrary advice of standard textbooks and of the American College of Obstetricians and Gynecologists (ACOG). By traditional interpretation interruption of the delivery process following expulsion of the fetal head is a physiological phenomenon which does not warrant intervention. It occurs at least in one-half of the deliveries of primiparous women and in about one-fourth of all multiparas. The next uterine contraction which seldom is delayed more than 2-3 min expels the body of the child spontaneously. The time interval can be shortened by administering slow intravenous infusion of oxytocin in low concentration.

Conservative interpretation of normal birthing process affects the criteria of shoulder dystocia since only when the next contraction fails to expel the body becomes this definition applicable. Therefore, with this technique the diagnosis is objective and does not depend on the judgment of the accoucheur. It is a matter of note that in the practices of physicians who embrace this approach the incidence of shoulder dystocia tends to be low[12,13].

Interpretation of the so called "turtle sign" differs for those who accept the conservative concept of shoulder dystocia from that of others. Retraction of the head from the perineum following relaxation of the uterus is considered a physiological phenomenon which requires no intervention. The fetal body is likely to be delivered spontaneously with the next contraction. It is true however, that "real" shoulder dystocia relatively often is preceded by turtle sign. It should be regarded therefore a warning about possible forthcoming arrest of the shoulders rather than a diagnostic sign of it. Most importantly, its occurrence should be considered a relative contraindication for any attempt at delivery before the next uterine contraction.

There has been some dispute about the question of whether even a short waiting for the spontaneous expulsion the fetal body is warranted before the use of traction[14]. For reason to be discussed later, the idea of prompt traction reflects unawareness of the normal mechanism of the birthing process. Because the author considers any interference at this stage of the delivery ill-advised, this subject is outside the scope of discussion at this point.

FETAL EFFECTS OF ARREST OF THE SHOULDERS

In the absence of consensus about the diagnostic criteria

Table 1 Predisposing factors for shoulder dystocia

Preconceptional	Prenatal	Intrapartum
Small maternal stature	Low glucose tolerance	Protracted latent phase
Obesity	Preeclampsia	Protracted labor (1st stage)
Diabetes (or family history)	Gestational diabetes	Protracted labor (2nd stage)
High maternal birth weight	Large for gestational age fetus	Conduction anesthesia
Past birth of LGA child	Excessive weight gain (> 18 kg)	Use of oxytocin
Narrow pelvis	Postdatism	Arrest of labor
Past incidence of shoulder dystocia	Postmaturity	Vacuum extraction
"Elderly" primigravida	Induction of labor	Forceps delivery

LGA: Large for gestational age.

of arrest of the shoulders the rate of fetal damage associated with it cannot be determined. In the Perinatal Center in Newark head and body have been delivered during separate uterine contractions in about 1 out of 3 instances. Such cases were described in the records as normal spontaneous vaginal births. Obviously, some of these deliveries would have been labeled as shoulder dystocia elsewhere. Thus, the statistics of those doctors who "pull" routinely differ from those who "do not pull". Like apples and oranges, the results of these groups cannot be compared. Therefore, the impression deriving from the literature, namely that about 1 out of 10 cases of shoulder dystocia entails lasting fetal damage is an educated guess at best.

The characteristic damages associated with arrest of the shoulders are Erb's and-less often-Klumpke's palsies. Neurologists generally endorse the opinion that these are traction related injuries[15]. Rarely, the lesion may be bilateral. Fractures of the scull, clavicle and humerus are relatively frequent and so are intracranial hemorrhage and hypoxic brain damage[16]. The latter ones can be life threatening and may occur with or without brachial plexus affliction. Injuries of the spinal cord and the phrenic nerve are rare. Minor brachial plexus lesions that are apparent at birth usually disappear after a few weeks or months. These are probably pressure rather than traction related injuries. Afflictions that persevere for more than six months are likely to remain permanent.

PREDISPOSING FACTORS FOR ARREST OF THE SHOULDERS

Factors listed in Table 1 have been found conducive to arrest of the shoulders at delivery. Because their significance varies on a broad range, only those considered of major clinical importance require discussion in some detail.

Pelvic contraction

The importance of feto-pelvic relations is obvious even for the uninitiated. The expediency that a large head cannot pass through a small opening was already taken into account by medieval architects when they built the dungeons of Castel Sant' Angelo in Rome, the Bastille in Paris and the Tower of London. Manufacturers of kings' crowns and men's hats used this knowledge even earlier. Unfortunately, physicians failed to take notice of this information until the 17th century. Consequently, "midwifery" practiced by granny midwives only turned into "obstetrics" after Mauriceau[17] had recognized the importance of the relationship between the size of the fetal head and the capacity of the mother's pelvis. Considering this background and the information that even a low for gestational age infant may encounter severe shoulder dystocia in case the pelvis is inadequate[18], the fact that some current texts describe not only antepartum but even intrapartum pelvic assessment unnecessary represents a romantic and adventurous but ill-conceived return to the Middle Ages. Also surprising is the fact that in spite of the well-recognized role of diabetes in the causation of fetal macrosomia, shoulder dystocia and other serious complications, antenatal diabetic screening in the absence of predisposing factors was still labeled unnecessary relatively recently[19].

Obesity

It is a widespread misconception that danger of postoperative complications makes abdominal delivery in morbidly obese women undesirable. Since their risks increase when cesarean section is performed after protracted labor and also because arrest of the shoulders may be as much as 10-times more frequent in this group than in the general population, gross obesity frequently makes cesarean delivery the preferable choice[20]. While reviewing cases of arrest of the shoulders at delivery it became apparent that far too often little attention had been paid to maternal weight increase during pregnancy. Insofar as obesity is conducive to diabetes and thus to excessive fetal size, the importance of preventing undue maternal weight gain by restricting its gestational increase to 10-12 kg with appropriate diet is readily apparent.

Past history of shoulder dystocia

Previous shoulder dystocia is widely considered an indication for cesarean section. While a desirable choice in most instances, trial of labor may be a reasonable alternative when predisposing factors that prevailed in the preceding pregnancy (such as gestational diabetes, fetal macrosomia, protracted labor and difficult forceps extraction)

Figure 1 The picture illustrates a "2-step delivery" complicated by umbilical cord around the fetal neck. External rotation occurred shortly after the expulsion of the head and the delivery process stopped at that point. The cord was loosened but no attempt was made to extract the body. The picture taken at the onset of the next uterine contraction depicts its effect, namely expulsion of amniotic fluid from the respiratory tract (arrow). Since external electronic monitoring had demonstrated variable fetal heart rate decelerations at the end of the 2nd stage of labor, the cord complication was anticipated. Courtesy of Dr. Vivic Johnson.

are not present or appear avoidable.

Conduct of delivery

Interference with the physiological birthing process has been so widespread in recent decades that probably few obstetricians have witnessed a normal spontaneous labor and delivery during their career. In the course of its passage through the pelvic inlet the sagittal suture of the skull is in or close to the transverse diameter. As the head enters the mid-pelvis the caput rotates 90 degrees. In 96% of the instances the small fontanel moves anteriorly. It is under the symphysis when the caput reaches the outlet. These turns and the descent itself are brought about by uterine contractions and represent passive accommodation to the available space. After the emergence of the head expulsion of the fetal body is preceded by another 90 degree rotation around its axis, since the chest cannot pass between the sciatic spines unless the shoulders occupy the antero-posterior diameter of the pelvis. This process brings about "external rotation of the head" on the maternal perineum. In a considerable minority of deliveries the contraction stops after the emergence of the head but before its external rotation. It only occurs 2-3 min later. This process called "2-step delivery"[11] is a physiological phenomenon and carries no inherent risk[4-13,21-23]. Evidence of fetal compromise on electronic monitoring rarely justifies extraction of the body since the associated stress exacerbates preexisting hypoxia and may lead to meconium aspiration. Use of traction before external rotation of the head is futile and stressful for the fetus because the shoulders cannot traverse the pelvis in transverse rotation. It follows therefore that traction immediately after the delivery of the head invites arrest of the shoulders and may lead to Erb's palsy. For this reason, apart from major degree of abruption of the placenta or uterine rupture almost no situation calls for manual traction within the 3-4 min time frame of spontaneous vaginal delivery.

Tight umbilical cord around the fetal neck should be slackened but the temptation to extract the fetus must be resisted. While delivering the body the uterus compresses the chest and expels amniotic fluid and meconium from the respiratory tree (Figure 1). Cutting the nuchal umbilical cord prior to delivery of the shoulders is a dangerous polypragmasy which has no place in obstetrical practice[22,24].

In medicine as much as in everyday life to prevent a mishap one must know what brings it about. With regard to prevention of brachial plexus injuries, for reasons that go beyond the boundaries of medical science this question has become a battle ground of conflicting opinions: (1) Almost one-half of obstetrical malpractice claims relate to shoulder dystocia in America; (2) Skyrocketing malpractice premiums have forced capable doctors into early retirement; (3) Prodigious expenses of legal procedures have augmented the costs of maternity care; (4) The high costs of malpractice actions hindered the introduction of a national health care system; (5) Escalating brachial palsy cases required opening of neurosurgical units specializing in Erb's palsies; (6) Contradictory opinions have left doctors without guidance about the conduct of labor and delivery; (7) Obstetricians' obvious confusion has undercut patients' confidence in their knowledge and integrity; (8) The prevailing state of affairs turns capable medical students away from the specialty of obstetrics; and (9) Search for quick remedy obscures the fact that preventing birth injuries is the only long-term solution. Although contradictory views in medical publications dealing with this subject tend to confuse the picture, the basic issues are not particularly complex.

According to traditional thinking Erb's and Klumpke's palsies are physical injuries caused by use of excessive force during the extraction of the child from the birth canal. This concept is still favored by obstetricians in some foreign countries and probably everywhere by neurologists[15,21]. In contrast, among American obstetricians the idea that most injuries develop "*in utero*" spontaneously has gained wide acceptance[25-29]. It is understandable, that it struck a favorable cord in the hearts of practitioners. If Erb's palsies are spontaneous "*in utero*" injuries then there is no cause for self-doubt or self-reproach. Besides, this idea offers a firm ground for defending malpractice claims. If most injuries occur spontaneously, physicians are immune against litigations because it can never be alleged that "more likely than not" the damage derived from medical error. Formal acceptance of this concept would promptly end many obstetrical malpractice claims and could reduce insurance premiums by 40% or more. It is hardly surprising therefore that the arguments about the merits of the respective points of view have gone beyond the limits of disciplined academic dispute. Therefore, it amounted to an impressive example of professional integrity that a prominent protagonist of the "*in utero*" injury concept withdrew his initial claim when he recognized that the results of his animal experiments

Table 2 Birthweight distribution in 316 cases of fetal damage associated with shoulder dystocia[1]

Birth weights	Number of cases	Percentage of total
2500-2999 g	6	2%
3000-3499 g	20	6.0%
3500-3999 g	68	21.5%
=	=	=
4000-4499 g	107	34%
-	-	-
4500-4999 g	72	22%
5000-5499 g	32	10.5%
5500-5999 g	9	3%
⩾ 6000 g	2	0.5%

=: Traditional borderline for macrosomia; -: New American borderline for macrosomia. Based on traditional standards, less than 10% of all fetuses qualify for the definition of macrosomia. In this material 70% of all birth injuries were sustained by neonates belonging to this group. [1]Tables 2-4 show the results of mathematical calculations presented in previous publications. Copies of original articles containing details of the data analysis by the group's biostatistician can be obtained from the author.

Table 3 Birth weight associated risk of shoulder dystocia related fetal injury at delivery

Birth weight	National average	Sample	Estimated risk of damage
Under 3000 g	24%	2%	1:12000
3000-3249 g	17%	2%	1:8500
3250-3499 g	20%	4.5%	1:4444
3500-3749 g	16%	12%	1:3333
3750-3999 g	13%	9.5%	1:3368
4000-4249 g	5.5%	20%	1:275
4250-4499 g	3%	14%	1:214
4500-4749 g	0.8%	14%	1:57
4750-4999 g	0.3%	8%	1:37
5000-5249 g	0.2%	8%	1:25
⩾ 5250 g	0.2%	6%	1:33

In previous publications the author arbitrarily defined "acceptable" risk for fetal injury as 1% noting that the maternal risk of permanent injury in case of cesarean section is much lower. The table shows that the limit of acceptable risk is already exceeded at the 4500 g level and increases to 3%-4% when the fetal weight is 5000 g or more.

had been misinterpreted[27].

Conduction anesthesia during labor

Since it was recognized during the early days of spinal and epidural anesthesia that it had significant side effects, concern was expressed about the desirability of its routine use[30]. The untoward effects of conduction anesthesia fall into four major categories[31]: (1) Cardiovascular toxicity; (2) Maternal and fetal central nervous system toxicity; (3) Reduced uterine blood flow; and (4) Decreased uterine contractility.

Clinically, these effects manifest in convulsions, hypotensive episodes, cardiac arrhythmias leading to cardiac arrest and lasting neurological damage by injection into the spinal canal rather than into the epidural space. Eventually, in the absence of medical consensus it was women's demand that turned epidural anesthesia into a routine procedure[32].

Fetal macrosomia

Large fetal size plays a major role in arrest of the shoulders at birth[16,33-38]. However, it has been problematic to quantitate the magnitude of the risk[39]. Therefore, concern about increasing cesarean section rates induced professional organizations to encourage practitioners to deliver markedly large for gestational age (LGA) fetuses vaginally[40]. Apparently reassured by the claim that 50% or more of all brachial plexus injuries are spontaneous "*in utero*" events, as recently as 2002 and 2005 the ACOG[41] and the Royal College of Obstetricians and Gynaecologists (RCOG)[42] advised physicians to deliver fetuses of diabetic mothers weighing as much as 4500 g and those of non-diabetic women up to 5000 g vaginally and to use traction if the body does not soon follow the head.

In the course of a review of cases of shoulder dystocia related birth injuries that had occurred between 1960 and 2007 the author's group evaluated the distribution of birth weights of affected neonates[16]. The findings summarized in Table 2 show that a relatively small group of macrosomic babies suffered the overwhelming majority of injuries. The weight related increase of permanent damage showed a logarithmic curve rather than a geometric line. This finding implies that danger of underestimating fetal weight exceeds that deriving from overestimation.

Based on the above mentioned evidence the risks of damage for individual fetuses belonging to various weight groups were evaluated next. The calculation took into account the birth weight distribution in the United States[43] along with the information that about 1 out of 100 deliveries involve shoulder dystocia[44] and 1 out of 10 such newborn babies sustain permanent injury[45]. The results of this calculation are indicated in Table 3.

The investigated cases derived from 40 states or districts of the Union. The mothers' parity ranged from zero (112 cases) to more than six (4 cases). Maternal ages ranged from 13 to 45 years with the majority of them falling into the middle range. The ratio of male *vs* female neonates was 51:49.

Birth injures included 259 incidents of brachial plexus damage, 32 cerebral palsies, 6 cases of mental retardations, 16 developmental delays, 12 traumatic cerebral bleedings, one spinal cord dissection, and 8 perinatal deaths. The method of delivery was spontaneous on 200 occasions. Forceps were used for delivery 61-times, vacuum extraction on 41 occasions and both instruments (ventouse followed by forceps) 14-times. Several babies suffered multiple injuries. Three childbirths concluded by the Zavanelli maneuver[11] and cesarean section were included in the spontaneous vaginal delivery group.

According to reliable statistics[19], "in all series there is a two or threefold increase in the rate of cesarean delivery with high birthweight". This being the case, the gradually increasing frequency of fetal injuries in the LGA and macrosomic categories derived from a gradually diminishing number of vaginal deliveries of large fetuses. Obviously this circumstance biased the above presented results. When based on this knowledge the calculation

Table 4 Risks of shoulder dystocia related fetal damage in spontaneous and instrument assisted deliveries

Birth weights	Spontaneous deliveries	Instrumental extractions
Under 3500 g	1:5660	1:900
3500-3999 g	1:1740	1:110
4000-4499 g	1:204	1:24
4500-4999 g	1:41	1:6
⩾ 5000 g	1:25	1:3

Birth weight related fetal risks for damage in cases of spontaneous *vs* instrument assisted deliveries. Note that use of extraction instruments increases the chance for fetal damage almost 10-fold.

was adjusted, it transpired that the actual risks for lasting damage in these groups were more than 2.5% when the weight exceeded 4500 g and 5% when the child weighed more than 5000 g. Evaluation of these findings even on the ground of high school mathematics permitted the conclusion that widely quoted and relied on statistics[39,40] had grossly overestimated the number of cesarean sections needed for preventing of one fetal injury.

Arguments against elective abdominal delivery on the basis of estimated fetal weight have often included the warning that sonography was likely to overestimate the fetal size. Review of the literature clarified however, that in the 5000 g danger zone ultrasound examinations underestimated the fetal weight in 80% of the instances[46-48]. This fact indicates that the real danger associated with reliance on sonography is failure of identifying some excessively large fetuses rather than overestimating those who are not unduly large.

Because maternal risks associated with abdominal delivery are substantially less, in the writer's opinion a chance of 1% for permanent fetal damage is the acceptable maximum in contemporary practice. Even this liberal view incorporates obstetricians' traditional prejudice, namely that the mother's life is more precious than that of her unborn child. Consequently, the final arbiter of any relevant decision has to be the pregnant woman whose tolerance concerning maternal and fetal risks may differ from that of her obstetrician or of the consensus of medical opinion.

Instrumental deliveries

Observant obstetricians drew attention to the fact several years ago that mid-forceps extractions had markedly increased the incidence of shoulder dystocia[49]. By the same token, in the authors' material shoulder dystocia related fetal injuries had often been preceded by forceps or ventouse extractions. Between 1973 and 2006 not less than 117 records referred to instrumental deliveries[50]. When the material was distributed into weight groups (less than 3750 g/3750-4499 g/4500 g or more), it was learned that extraction instruments were frequently used in each of them (37%/40%/27%).

Comparison between the various technical procedures was hindered by two circumstances: (1) The ACOG elected to change the criteria of mid and low forceps operations in the 1980's. Since some physicians continued adhering to the old definitions, the documentations with regard to the actual types of the operations were often inconclusive; and (2) Whereas a statement pertaining to the nature of forceps operations usually appeared in the records, the majority of ventouse users provided no explanation.

Among those forceps procedures where the nature of the operation was stated 2 were performed at the outlet, 27 were low forceps and 29 mid-pelvic operations. Three forceps, one ventouse and one ventouse-forceps procedures were marked as "high".

Although in the entire material about two-thirds of the deliveries were spontaneous, the incidents of central nervous system (CNS) damage in the spontaneous and instrumental delivery groups were close to equal (37 *vs* 33). Thus, the use of instrument almost doubled the risk of CNS damage.

The data permitted a comparison between spontaneous deliveries on the one hand and extractions by instrument on the other. The result of this calculation is shown in Table 4. The tabulation indicates that in most categories the risk of major injury was more than 10-times higher when forceps or vacuum extractor was used than when unassisted delivery of the child was allowed.

This study does not support the claim that ventouse is more accident prone than forceps[51]. In fact the opposite was the case in this material. It transpires however, that both instruments augment the risks and that gradually increasing fetal weight increases them exponentially. The findings imply that one percent chance for fetal injury already prevails when extraction instrument is used for the delivery of a 4000 g fetus. Therefore, the author considers such a fetal weight the uppermost limit for a relatively safe extraction procedure in virtually any clinical situation. Undoubtedly, mid-cavity operations carry even higher danger.

Impaired glucose tolerance and diabetes

Routine glucose screening was not a requirement during those years while the medical records utilized for the here cited study were generated[52]. On this account evaluation of the predisposing effect for shoulder dystocia of maternal glucose intolerance was hindered. Only about two-thirds of all records contained reference to diabetic screening and some of these were not standard tests. Therefore, the information they provided was often equivocal. This circumstance limits the validity of the investigators' calculation, namely that whereas only 10% of all neonates weigh more than 4000 g in the general population, the rate is about 50% for diabetic mothers and 20% for those women with "predisposition" for diabetes[53]. Typically, positive screening test followed by negative 3 h glucose tolerance test was considered indicative of predisposition. In the > 4000 g weight group the risk of birth damage was 5-times increased for infants of diabetic mothers and twice for those of pre-diabetics as compared to others. Birth weights exceeding 4500 g seem to be 10-times more likely to occur among babies of dia-

betic women than among those of non-diabetic ones[16].

In light of the data reviewed routine diabetic screening of all pregnant women and attentive treatment of the disease are considered absolutely necessary. Although good management must take into account many relevant factors, including pelvic dimensions, previous births, maternal diet and others, in most instances an estimated fetal weight of 4000-4200 g represents for the author the uppermost limit for vaginal delivery in case of confirmed maternal diabetes. Assessment of fetal weight and size by ultrasound should be considered an obligatory routine in case of suspicion of LGA fetal status.

EFFECTS OF PRACTICE PATTERNS

During the 50 years covered by the studies of the author's group, routine management of labor has changed in many respects. It is necessary therefore to consider the potential effects of new developments upon the birthing process and its complications.

Oxytocin

When the drug entered the market it often caused uterine hyper-stimulation. Later it was only administered in intravenous drip under electronic fetal monitoring. Therefore this side effect became substantially reduced. This being the case, although it is suspected to increase the chance for shoulder dystocia, the drug is unlikely to be a major predisposing factor for arrest of the shoulders since it did not affect its rate during its relatively liberal use in clinical practice between the 1950's and 1970's.

Electronic fetal heart rate monitoring

Dysfunctional labor predisposes for shoulder dystocia. Designed to register uterine activity and evaluate fetal condition, external monitoring combined with tokography is useful and innocuous. By allowing the obstetrician to eliminate abnormal labor patterns and thus avoid difficult deliveries, electronic monitoring substantially reduced the number of factors conducive to brachial plexus injuries.

Fetal scalp blood pH determination

The technique is difficult, costly, labor intensive, in untrained hands inaccurate and carries the risk of causing fetal infection. It enjoyed popularity initially and was used with relative frequency for three decades. The technique largely disappeared from clinical practice by the early 2000's. It is unlikely that it influenced the rate of shoulder dystocia.

The "labor curve"

During the first half of the 20th century dysfunctional labor was tolerated for long periods of time because a cesarean section rate of 5% was considered the acceptable maximum. Friedman's[54] research pointing out the dangers of protracted labor changed physicians' thinking. Introduction of fetal heart rate monitoring that allowed recognition of "fetal distress" had similar effect. As a result, by the 1970's cesarean section rates rose to 10%-15%. The bush fire no longer could be stopped. At the turn of the century the rate of abdominal deliveries reached 30% and then increased even further. While it's other effects are disputable, this development was bound to reduce the incidence of shoulder dystocia and the related fetal injuries for more than one reason: (1) The fact alone, that the number of vaginal deliveries decreased by almost one-third allowed the expectation that shoulder dystocia would be reduced by the same rate; and (2) Many abdominal deliveries are done for protracted labor predominantly due to large fetal size[19]. Thus a high proportion of difficult vaginal deliveries that were conducive to shoulder dystocia became replaced by cesarean sections. In effect, changes that turned "obstetrics" into "perinatology" were such in nature that they were bound to cut the prevailing rates of shoulder dystocia and its related fetal injuries markedly. Obviously, any theory addressing the subject of causation must explain why Erb's palsies have continued to increase in America despite a marked reduction of its predisposing factors.

MISCELLANEOUS FACTORS AFFECTING INCIDENCE OF SHOULDER DYSTOCIA

The above mentioned change in the management of the birthing process that had escaped critical evaluation for several decades diverted the investigations of the author's group to new directions.

Geographic variations

The rates of shoulder dystocia differ in various geographic areas and at various time periods. Examples are its increasing rate in the United States[55,56], a high proportion of brachial plexus injuries deriving from a moderate number of shoulder dystocia incidents in Sweden[57,58] and its infrequent occurrence in the British Islands[42,59,60], Hong Kong[61] and Israel[62,63]. High birth weights of Swedish babies and relatively low weights of Chinese ones probably played a role in the quoted trends. This circumstance underlines the rule that conclusions based on one particular racial group do not always apply to others.

Chronologic fluctuations in the rates of shoulder dystocia

Disputes in America about the causes of shoulder dystocia have involved the contention that its incidence had not changed for decades[64]. The data presented in support of this claim included statistics from foreign countries where this complication had been rare. This arbitrarily mixed material did not reflect the state of affairs in the United States. Therefore, a computer search was undertaken. It yielded 20 reports that included 26 separate studies for the years of 1949-2005. The periods of observation ranged in the various studies from 1 to 10 years. The results deriving from these statistics are shown in Table 5.

Table 5 Incidence of shoulder dystocia in the United States between 1949 and 2005

Time periods (yr)	Number of reports	Ref. numbers of reports[1]	Average incidence per 100 births[2]
1949-1974	5	[55,65-68]	0.26%
1975-1990	10	[49,55,56,69,70-74]	1.22%
1991-2005	11	[56,74-81]	1.65%

[1]Two authors presented multiple reports; [2]Some reports referred to number of cases per 100 vaginal births. These were adjusted under the premise that the rate of cesarean section was 20%. Note that the rate of shoulder dystocia increased almost 5-fold by the 2nd and more than 6-fold by the 3rd time period as compared to the 1949 to 1974 average.

The data reveal that arrest of the shoulders occurred rarely (about 2-3 out of 1000 births) prior to the mid-1970's. Its rates rose rapidly thereafter until and including the first decade of the current century. In some services the increase was as high as 10 to 15-fold. Thus, rather than having remained stable cases of arrest of the shoulders and its neonatal consequences increased exponentially in the United States since the 1970's. This development appeared mysterious for a variety of reasons: (1) Changes in practice patterns eliminated or markedly reduced the number of predisposing factors for shoulder dystocia since the 1950's; (2) While the incidence of arrest of the shoulders increased in America its rate remained stable in the British Islands; (3) Circulars from medical organizations inundated practitioners with instructions about the prevention and management of arrest of the shoulders in recent years; and (4) Few issues of obstetrical journals appeared without studies discussing shoulder dystocia related problems.

Because the turnaround happened in the 1970's, the author elected to study those changes that had taken place in the practice of obstetrics around that time. This inquiry brought into focus two articles published by Wood *at al*[82,83] in the leading British specialty journal in 1973. Utilizing the at that time novel scalp blood pH technic during normal deliveries, these investigators found that after the emergence of the head the pH of the capillary blood fell at a rate of 0.04 to 0.14 units per minute although the neonates had excellent Apgar scores. Presumably because the technique was as yet unreliable at that time, these papers generated little interest in Great Britain. In contrast, they caused concern in the United States. Without explaining why, new editions of textbooks announced that the fetus must be extracted from the birth canal following the expulsion of the head without delay[84,85].

Wood *at al*[82,83] inconclusive research certainly deserved rechecking in order to assess its clinical relevance. However, things went the opposite way. Practice patterns were modified overnight but only quarter of a century later were scalp capillary pH levels studied during the head-to-body delivery interval in well-equipped laboratories by investigators who had experience with the technique. Aware of the clinical implications of their research their attention focused on babies who encountered shoulder dystocia. They found that delayed delivery of the body did not alter capillary pH significantly[80,86,87]. Investigations by Gurewitsch[88] based on more than 200 cases revealed that delayed delivery of the body caused no clinically significant change in the fetal metabolic equilibrium for up to 8 min.

Perhaps the most persuasive contribution to this subject was the investigation of Locatelli *et al*[23]. These research workers undertook a prospective study involving 789 patients who gave birth by the conservative method. It was found that the mean head-to-body interval was 88 s and the decline of the umbilical artery pH was only 0.0078 units per minute. They concluded that spontaneous birth did not significantly increase the risk on neonatal acidemia. Obviously, Wood *et al*[82,83] grossly overrated the decline of the fetal scalp blood pH during the delivery process. Thus, the reason for the still ongoing effort directed at shortening the head-to-body delivery time is difficult to understand.

In the opinion of the writer of this review the abrupt change in the management of the delivery process introduced into practice in the mid-1970's has been and remains the most important single factor responsible for the rapid increase of arrests of the shoulders at birth and the associated fetal neurological injuries in the United States.

It should be a matter of great concern that a group of investigators who had attempted in earnest to reduce the head-to-body interval to a minimum ended up with unprecedented 13.8% and 10.8% rates of arrest of the shoulders[89,90]. News of this "shoulder dystocia tsunami" raised no eyebrows among "fetal rescue" advocates. They reiterated a few years later: "Shoulder dystocia is an unpreventable obstetric emergency"[64].

Indeed, arrest of the shoulders is unpreventable if one prefers to believe that brachial plexus palsy has little to do with the method of delivery. Investigators who refrained from using traction during the birthing process, reduced the rate of this dangerous complication to the range of 0.2% without even trying[12,13].

On account of its adverse effect upon the practice of medicine, the fact that in the long run prevention of catastrophic birth injuries is the most effective approach to avoiding costly malpractice litigations deserves a brief mention in the context of the ongoing controversy[91].

Methods of delivery and shoulder dystocia

In order to evaluate the fetal effect of delayed delivery of the body after arrest of the shoulders, the writer's group reviewed in their medico-legal material those births that had occurred after 1974. Only 103 records documented the head-to-body intervals. Table 6 shows the relevant findings.

Table 6 Head-to-body delivery times in 103 cases of shoulder dystocia related neonatal neurological damage

Head-to-body interval	Number of cases
0-1 min	32
1-2 min	38
2-3 min	12
3-4 min	5
4-5 min	8
5-6 min	2
6-7 min	2
7-8 min	2
8-9 min	0
9-10 min	2

Note that in 82 instances (80%) delivery involving neurological injury of the child was accomplished within 3 min. Before 1973 these cases would not have been classified as shoulder dystocia. Because delay of the next contraction by 5 min does not endanger the fetus, the use of traction was unnecessary in the majority of these cases.

In a high proportion of the cases (42%) the 5 min Apgar score was less than five. Clinical experience shows that babies who are born spontaneously are in good condition even if the body is expelled with 5 min delay[11,88]. Thus, the low scores in this group most likely derived from stress caused by the extraction efforts.

Although the United Kingdom remained unaffected by the American shoulder dystocia crisis, the RCOG in 2005 endorsed the idea that the fetus must be extracted from the birth canal after the delivery of the head[42]. The "Guidelines" of the College cited the so called CESDI report in support of this advice stating that the investigation had found that 47% of babies who perished following deliveries complicated with shoulder dystocia "died within 5 min of the head having been delivered". Actually, members of the CESDI Committee emphasized that the adverse outcomes were unrelated to the head-to-body delivery intervals. They explained that the neonatal deaths had resulted from substandard management of the labor and inadequate skills on the part of doctors in charge[92]. The misleading misinterpretation of the official report by the RCOG Guidelines was duly pointed out by this writer's group in a recent review article sponsored by the Royal Society of Medicine in London[93].

Research performed one century ago utilizing fetal cadavers showed that typical brachial plexus lesions could be induced by applying strong traction upon the fetal head against resistance[94]. More recent experimentation conducted by French neurologists confirmed the earlier findings[95]. Utilizing sophisticated methodology Allen produced evidence that supported a relationship between aggressive management of the birthing process and neurological birth injuries[96]. He concluded based on his experiments that brachial plexus lesions sustained at birth were traction injuries and demonstrated that when encountering strong resistance, physicians subconsciously double the effort that the extraction of a child under normal circumstances requires.

Based on an extensive review Gurewitsch *et al*[97] concluded that "the single greatest correlate with neonatal brachial plexus injury after shoulder dystocia is (the) degree of clinician-applied traction".

Brachial plexus injury and cesarean section

Disregarding the fact that the observed cases of brachial plexus "paresis" had been only transitory, it has been proposed that babies born without any traction suffered brachial plexus damage (*i.e.*, "paralysis"). It has also been claimed that Erb's palsies are frequent among babies born by cesarean sections.

In the material that included 338 fetal injuries typically related to shoulder dystocia, only one child sustained Erb's palsy during abdominal birth. The case in question was a term delivery by elective repeat cesarean section. During the operation the surgeon found extensive adhesions at the area of the previous lower segment transverse incision. He could not create adequate opening and it was with great difficulty that the child was extracted eventually through a small incision. This incident was rare enough to deserve publication. Based on the stated details the article presented the opinion that most likely this child sustained typical traction injury[98].

Ubachs *et al*[99] analyzed 130 brachial plexus injuries of which 28 were associated with breech extractions. The authors noted that all vertex deliveries involved extensive manipulation and concluded that none of the cases could be attributed to "intrauterine maladaptation". They emphatically pointed out that no injury in their material had been associated with cesarean delivery.

Most obstetricians have encountered cases where delivery of the shoulders across a small incision cut through an uneffaced cervix caused as much difficulty as arrest of the shoulders during a vaginal birth does. This being the case it seems likely that most of those extremely rare brachial plexus palsies that are associated with abdominal deliveries are traction related.

PREVENTION OF SHOULDER DYSTOCIA AND BRACHIAL PLEXUS INJURIES: CONTROVERSIAL ISSUES

Because education pertaining to its management has little if any effect upon the rate of fetal injuries associated with arrest of the shoulders[100], this complication needs to be avoided as far as possible. Since prevention requires understanding of the cause of the problem[101], any prevailing theory has to be consistent with established facts in order to prove its validity. Therefore, advocates of the respective concepts must be able to answer several relevant questions: (1) Why did the rate of shoulder dystocia increase exponentially in the United States during the last 40 years in spite of the fact that changing practice patterns eliminated many of its predisposing factors? (2) Why did the rate of shoulder dystocia remain stable in Great Britain while it escalated in America? (3) Why do instrumental extractions increase the rate of brachial plexus palsies exponentially? (4) Why is brachial plexus injury literary rarity among neonates delivered by cesarean section? (5) Why is

maternal diabetes a strong predisposing factor for neurological birth injuries? (6) Why do most Erb's palsies occur in association with documented diagnosis of shoulder dystocia? (7) What experimental model supports the validity of the respective etiological theories? and (8) Does lack of diagnosis of shoulder dystocia indicate that Erb's was sustained spontaneously "*in utero*"?

The following are the answers of the author to these questions:

Question 1: The population of, and the living conditions in the United States have been stable during the 20th century. No new circumstance has emerged that could conceivably have caused fetuses to suffer Erb's or Klumpke's palsies *in utero* six-times more often than 50 years ago. The cause of the damage has to be therefore extrinsic.

Question 2: Up to 2005 the method of delivery remained conservative in the British Islands whereas it has been changed to "active" management in the United States. As a result, up to recently the rate of shoulder dystocia had been low in the United Kingdom[59,60,102].

Question 3: Should neurological injuries occur spontaneously *in utero* the use of ventouse or forceps could not affect their incidence. The documented relationship underlines the role of traction in the causation of injuries. Following instrumental extraction of the caput the uterus seldom expels the body within 30 or even 60 s. As a result, doctors adhering to active management are compelled to apply manual traction after the instrumental delivery of the head virtually invariably.

Question 4: Because 15% to 35% of all births involved the abdominal route in recent decades, the extreme rarity of Erb's palsy among cesarean babies is noteworthy. Obstructed labor accompanied by strenuous uterine activity is a frequent indication for abdominal deliveries. If the activity of the uterus had caused a significant proportion of brachial plexus injuries, Erb's palsies should be frequent among babies delivered by cesarean section on account of obstructed labor. However, this is not the case.

Question 5: Diabetes causes fetal macrosomia and broadens the shoulders out of proportion to the diameters of the head[33]. These effects predispose for arrest of the shoulders at birth and explain why big fetuses of diabetic mothers are particularly prone to suffering damage[50,53].

Question 6: The records reviewed by the authors were unselected and had been generated by many doctors and nurses in almost as many hospitals. Their references to shoulder dystocia were not influenced therefore by policies, interpretations or biases that may have been prevalent in some institutions or certain geographical areas. Had a high proportion of injuries been spontaneous "*in utero*" accidents there would have been no reason for them to coincide in > 90% of all instances with a complication (*i.e.*, shoulder dystocia) which only occurs once out of 100 deliveries.

Question 7: Experimental evidence supports the role of traction in the causation of Erb's and Klumpke's palsies[94,95]. No comparable evidence has been presented on behalf of the spontaneous "*in utero*" injury mechanism.

Question 8: This question is irrelevant to the pathological mechanism for several reasons: (1) The cause of brachial plexus injury is traction. Whether excessive pulling is done during or in the absence of arrest of the shoulders does not influence the mechanism of the injury; (2) With traditional delivery the criteria of shoulder dystocia are unequivocal. With active management the diagnosis is subject to the judgment of the accoucheur. It has therefore no objective validity; and (3) If one believes that the absence of shoulder dystocia proves that brachial plexus injury has occurred spontaneously "*in utero*", his or her judgment may become biased, even if subconsciously against acknowledging this diagnosis. Uninfluenced by such specious interpretation, more than 90% of the records in the author's data base that came from hundreds of different geographic locations, indicated that shoulder dystocia and brachial plexus palsies had occurred coincidentally.

Predicting shoulder dystocia

Reflecting unawareness of medical history, the dictum: "arrest of the shoulders cannot be predicted" has been repeated incessantly in recent years. Advocates of this truism must have overlooked that Jenner had not proposed only to vaccinate those unidentifiable children who had been singled out by Fate to contract smallpox. By the same token, Lind did not try to find out which ones of the embarking sailors for a voyage overseas would need a supply of fresh fruits in order to avoid scurvy. Similarly, Semmelweis did not restrict his aseptic measures to women whose destiny had been to roll in fever within a few days. Had these scientists wasted their time trying to "predict" the next victims of smallpox, scurvy or childbed fever, the secrets of these diseases would have remained unresolved for many more decades. In the same spirit, brachial plexus palsies must be avoided by general precautionary measures rather than by trying to determine who may need such protection next time.

Considering the present state of knowledge one must accept the probability that shoulder dystocia even in the best hands will continue to complicate two or three out of 1000 births for some time unless gifted soothsayers figure it out how to predict the victims. Until then, American obstetricians must live with the thought that only 80%-90% of currently prevailing brachial plexus palsies are preventable even if the urge of rescuing healthy babies from the womb is successfully resisted.

The causes of shoulder dystocia and the mechanisms of brachial plexus injuries are well understood. This problem is no different from many others that medical research has already resolved.

Basic principles concerning use of traction for delivery

It is a strange aspect of the shoulder dystocia controversy that the management of delivery is usually discussed as if long established concepts of modern obstetrics were fairy tales. Ever since the vacuum extractor had been

introduced into clinical practice it has been a rule that traction should only be applied at the time of uterine contraction[103]. This requirement ensures that expulsive uterine force supplements traction, thus eliminating the need for using undue effort. In violation of this concept, instructions governing the management of normal delivery encourage doctors to apply traction 30 or 60 s after the emergence of the head; the time when the contraction has just ended. As a result, the physician is forced to use more effort than would be needed if he waited for the next uterine systole. Although the latter would expel the fetus without intervention anyway, the risk of stretch injury could be already reduced if the obstetrician waited for a contraction and used traction in synchrony with it. That the condition of the fetus does not deteriorate between the contractions has been proven beyond any doubt[12,13,28,80,88]. Therefore, it defies elementary logic that an obstetrician who may have to wait several minutes for a contraction before delivering a severely compromised fetus with the ventouse, must extract a perfectly normal child by sheer force right after the expulsion of the head.

Medical errors leading to shoulder dystocia

Because the subject had been disregarded in the past, the role of the method of delivery in the causation of birth injuries has been stressed in this review. However, the records used for this research also revealed numerous departures from good obstetrical practice (not necessarily in conflict with minimum contemporary requirements) that were common denominators of the described accidents: (1) Assessment of the pelvic dimensions was often omitted or not documented in any detail; (2) Small maternal stature was ignored even if the mother was primigravida or had diabetes; (3) Frequently diabetic screening was either not done or equivocal test results were disregarded; (4) Confirmed diabetes seldom was treated effectively and only rarely with the involvement of an expert; (5) Excessive maternal weight gain seldom received attention and dietary instruction was rarely offered; (6) Frequently, not even by manual palpation was fetal weight assessed at or near term gestation; (7) Suspected LGA fetal status was not always evaluated with ultrasound; (8) Even if fetal macrosomia was suspected preparation for a difficult delivery was seldom made; (9) Some instrumental extractions of LGA fetuses were done without clear indication; and (10) Often only McRoberts maneuver, suprapubic pressure and manual traction were used for the management of shoulder dystocia.

It was a thought provoking feature of these unfortunate accidents that with relatively few exceptions not one single misjudgment but a combination of errors had led to neonatal injury. Correction of any one of them could have avoided the bad outcome on many occasions.

EPILOGUE

For physicians who due to indoctrination, habituation or temperament are addicted to rescuing babies from the birth canal the above shown list offers "Ten Commandments of Avoiding Shoulder Dystocia". With just a little luck they will find them helpful. For others who can be persuaded to allow mothers give birth naturally, the 11th Commandment: "Use two-step delivery!" may be the compass that guides them to the Promised Land where the rate of arrest of the shoulders is only 2-3 out of 1000 births. The return voyage there should not take another forty years. Some clever doctors from the United Kingdom, Israel, Ireland and Hong Kong have already found their ways there. Yet, it may be a worrisome journey for one who decides to sail across the Ocean of Misgivings with doubts in his mind, not unlike the sailors of Santa Maria did in the 15th century when they were still not quite convinced that the earth was round.

Having been accepted by too many obstetricians in the New World, belief in the ritual of reducing head-to-body delivery time and in the myth of "*in utero*" acquired Erb's palsies has become a matter of faith. "Faith can move mountains". Actually, it has already moved one when the ancient fortress of sound obstetric practice in London opened its gate and invited the trans-Atlantic Trojan horse inside its walls.

Lack of supporting evidence does not automatically sink attractive new ideas back into oblivion. More comforting is to think that the missing evidence is hidden somewhere nearby. The alternative would be to admit that well-meaning doctors have deceived themselves when they announced the discovery of a magic formula, capable of solving a distressing medical problem and putting the evil jinn of malpractice claims back into the bottle from where he had escaped. Alas, facts do not always prevail over wishful thinking. It is difficult for doctors who have done what they considered best for their patients to acknowledge that some of their activities were counterproductive. Ignatz Semmelweis was tormented by this thought throughout his life. Some others found easier ways out.

Almost two centuries ago Oliver Wendell Holmes presented a thesis which was important enough to be remembered thousand years from now. He eloquently, logically and correctly explained the cause and patterns of spread of puerperal fever[104]. His lecture included the unwelcome news that doctors who provided care for women in labor unwittingly transferred a deadly disease from one mother to the next. Having given due consideration to his already famous colleague's discovery, Professor Meigs one of the foremost authorities in obstetrics at that time, declared his own opinion. With one single sentence he may have sealed the fate of more women than the number of those whom all obstetricians in America saved from death during his professional lifetime. He also demonstrated that men incapable of seeing the difference between "belief" and "knowledge" could achieve distinguished reputation in medicine: "I prefer to believe"-he said-"that childbed fever is brought about by the will of Providence, which I understand, than that it is caused by an unknown contagion, which I don't"[105].

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