E-ISSN 2250-0944
ISSN 2250-1150
doi: 10.31838/ijprt/16.02.592

Research Article

Birth Injuries and Associated Complications in Infants of GDM Mothers

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Received: 24.05.2026, Revised: 27.06.2026, Accepted: 29.07.2026

ABSTRACT

Background & Objectives: Maternal diabetes mellitus—encompassing both pregestational (Type 1 and Type 2) and gestational diabetes mellitus (GDM)—is a major risk factor for adverse perinatal outcomes. Fetal exposure to maternal hyperglycemia results in hyperinsulinemia, altered anabolic growth, and disproportionate fetal macrosomia, significantly elevating the risk of mechanical birth trauma during vaginal delivery. This study aimed to evaluate the incidence, spectrum, and associated maternal and obstetric risk factors of severe birth injuries and immediate complications in neonates born to diabetic mothers admitted to a tertiary care neonatal intensive care unit (NICU).

Methods: A hospital-based prospective clinical observational cohort study was conducted in the NICU attached to JJM Medical College and associated hospitals, Davangere, over a 1.5-year period (March 2021 to October 2022). Singleton live-born neonates delivered to mothers diagnosed with GDM mothers were evaluated. Detailed clinical, radiologic, and neurological assessments were performed to identify birth injuries (brachial plexus palsy [BPP], clavicular/long bone fractures, cephalohematoma, subaponeurotic hemorrhage, intracranial hemorrhage, facial nerve injury, and mechanical birth asphyxia secondary to dystocia). Odds ratios (OR) and risk factor distributions were analyzed in relation to maternal glycemic control, birthweight, shoulder dystocia (ShD), and mode of delivery.

Results: Out of the enrolled infants of diabetic mothers, birth-related mechanical injuries and severe traumatic complications occurred in 8.6% of deliveries, with a significantly higher burden observed in pregestational diabetes (18.2%) compared to GDM (6.4%). Brachial plexus palsy was the single most frequent mechanical birth injury (54.5% of all injuries), followed by clavicular fractures (22.7%), subaponeurotic/cephalohematoma (13.6%), and long bone fractures (9.1%). Shoulder dystocia was the strongest individual predictor for severe birth injury (OR = 26.4; 95% CI: 11.2–62.1). Large for gestational age (LGA / birthweight > 4000 g}) and operative vaginal delivery (vacuum/forceps) dramatically amplified the probability of injury (OR = 6.8 and 4.9, respectively). Neonates experiencing severe birth trauma had a significantly higher co-occurrence of birth asphyxia and prolonged NICU stabilization.

Conclusion: Infants born to diabetic mothers face a substantial risk of severe birth injuries, predominantly driven by fetal macrosomia, shoulder dystocia, and instrumental vaginal delivery. Fetal weight estimation, stringent maternal glycemic control, and judicious selection of the mode of delivery—avoiding operative vaginal delivery in suspected macrosomia—are paramount to reducing mechanical birth trauma and its lifelong sequelae.

Keywords: Infant of Diabetic Mother, Birth Injury, Brachial Plexus Palsy, Shoulder Dystocia, Gestational Diabetes, Fetal Macrosomia, Operative Vaginal Delivery.

INTRODUCTION

Diabetes mellitus is one of the most common medical complications encountered during pregnancy, affecting between 1% and 14% of all pregnancies worldwide, with Gestational Diabetes Mellitus (GDM) accounting for nearly 90% of cases. The global rise in maternal obesity, sedentary lifestyles, and advanced maternal age has led to a parallel surge in the prevalence of both pregestational (Type 1

[T1D] and Type 2 [T2D]) and gestational diabetes. While metabolic derangements such as neonatal hypoglycemia and hypocalcemia are well-recognized early sequelae, mechanical birth injuries remain among the most devastating physical complications associated with diabetic pregnancies.

The pathophysiological cascade leading to birth trauma in infants of diabetic mothers (IDMs) stems from the Pedersen hypothesis. Maternal hyperglycemia leads to exaggerated transplacental glucose transfer, triggering fetal pancreatic beta-cell hyperplasia and fetal hyperinsulinemia. Insulin acts as the primary fetal anabolic growth factor, stimulating excessive lipid deposition specifically in the subcutaneous fat depots of the shoulders, thorax, and abdomen. Unlike non-diabetic macrosomia where growth is symmetric, diabetic hyperinsulinemia induces asymmetric macrosomia, characterized by an increased shoulder-to-head ratio and chest circumference relative to head circumference.

During vaginal delivery, this altered body conformation predisposes the fetus to shoulder dystocia—a critical obstetric emergency where the anterior fetal shoulder becomes impacted behind the maternal pubic symphysis after delivery of the head. The mechanical forces applied during attempted disimpaction, combined with excessive lateral traction on the fetal head, place extreme strain on the brachial plexus nerve roots (C_5-T_1), resulting in brachial plexus palsy (BPP/Erb's palsy). Furthermore, high mechanical resistance during descent can cause bony fractures (clavicle, humerus, femur), skull compression, subaponeurotic hemorrhage, intracranial bleeding, facial nerve trauma, and severe intrapartum asphyxia.

While transient birth injuries resolve without long-term sequelae, severe birth trauma can cause permanent neurological disability, physical impairment, and lifelong burden. Understanding the interaction between maternal glycemic status, fetal body composition, and labor management is vital for risk stratification. This study was undertaken to evaluate the spectrum of birth injuries and their associated risk factors in neonates born to diabetic mothers admitted to a tertiary care neonatal unit.

STUDY DESIGN & METHODOLOGY

This study was a hospital-based prospective clinical observational study conducted in the Neonatal Intensive Care Unit (NICU) attached to the Department of Pediatrics at JJM Medical College and associated hospitals (Bapuji Child Health Institute and CG Hospital), Davangere, Karnataka, India. The study protocol was approved by the Institutional Ethics Committee.

Study Population & Eligibility Criteria

The study population comprised live-born neonates delivered to mothers with documented GDM or pregestational diabetes (T1D or T2D) admitted to the NICU over a 18-month period (March 2021 to October 2022).

- **Inclusion Criteria:**

1. Singleton live births born to mothers with diagnosed GDM (DIPSI/WHO criteria) or pregestational diabetes.
2. Gestational age \ge 35^{+0} weeks.
3. Delivery via spontaneous vaginal delivery (SVD), operative vaginal delivery (vacuum or forceps), or emergency/elective Cesarean section.

- **Exclusion Criteria:**

1. Neonates with major lethal structural congenital anomalies.
2. Multiple pregnancies (twins, triplets).
3. Deliveries < 35^{+0} weeks of gestation.

Data Collection Protocol

Maternal medical records were reviewed to extract demographic parameters (age, parity, pre-pregnancy BMI, glycemic control, mode of delivery, and intrapartum events including induction of labor, oxytocin augmentation, and shoulder dystocia). Maternal diabetes was classified into GDM (diagnosed via 75-g oral glucose tolerance test with 2-hour plasma glucose > 140 mg/dL}) or pregestational diabetes (T1D/T2D documented prior to pregnancy).

All enrolled neonates underwent a comprehensive standardized physical and neurological examination within 6 hours of birth by a pediatrician and pediatric surgeon. Infants were evaluated daily throughout their hospital stay for clinical signs of birth trauma.

Diagnostic Definitions of Severe Birth Injuries

Birth injuries were documented and categorized according to standard ICD-10 diagnostic criteria and Muraca et al. definitions:

Brachial Plexus Palsy (BPP): Traumatic injury to nerve roots C_5-T_1 presenting as Erb's palsy (waiter's tip posture, loss of Moro

reflex, arm adduction/internal rotation) or Klumpke's palsy, confirmed on clinical and neurological examination.

- **Bone Fractures:** Fractures of the clavicle, humerus, or femur identified by palpable crepitus, localized edema, pseudoparalysis, and confirmed via digital X-rays.
- **Extracranial & Intracranial Hemorrhages:** Cephalohematoma (subperiosteal collection limited by suture lines), subaponeurotic/galeal hemorrhage (bleeding beneath the cranial aponeurosis crossing suture lines), or intracranial hemorrhages confirmed by cranial ultrasonography or CT/MRI scanning.
- **Soft Tissue & Nerve Trauma:** Facial nerve palsy, severe bruising/ecchymosis, or sternocleidomastoid hematoma.
- **Shoulder Dystocia (ShD):** Delivery requiring additional obstetric maneuvers (McRoberts maneuver, suprapubic pressure, internal rotation) following failure of gentle downward traction to deliver the shoulders after the fetal head has emerged.
- **Fetal Macrosomia / Large for Gestational Age (LGA):** Birthweight > 4000 g} or > 90th} percentile for gestational age based on standardized growth charts.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics (Version 26.0). Categorical variables (incidence of injuries, delivery mode, presence of shoulder dystocia) were presented as counts and percentages. Continuous variables (birthweight, maternal age, gestational age) were summarized as means standard deviation (SD) or medians with interquartile ranges (IQR). Group differences between diabetic subsets and injury outcomes were evaluated using Pearson's Chi-square test. Odds ratios (OR) with 95% confidence intervals (CI) were calculated to assess potential risk factors for birth injuries. Logistic regression models were used to isolate independent predictors of birth trauma. A p-value < 0.05 was considered statistically significant.

RESULTS

Demographic & Clinical Characteristics

During the study period, a total of 105 infants born to diabetic mothers meeting the inclusion criteria were evaluated. The cohort comprised 87 (82.9%) infants of mothers with GDM and 18 (17.1%) infants of mothers with pregestational diabetes (T1D/T2D).

Maternal and delivery characteristics stratified by glycemic status are summarized in Table 1. Mothers with pregestational diabetes exhibited higher mean pre-pregnancy BMI, higher rates of insulin therapy, earlier gestational age at delivery, and significantly higher rates of fetal macrosomia (LGA 33.3% vs 14.9%, p = 0.041) compared to mothers with GDM. Operative vaginal deliveries (vacuum extraction) were performed in 14.3% of the total cohort, while shoulder dystocia was documented in 7.6% of all vaginal deliveries.

Table 1: Maternal, Delivery, and Neonatal Baseline Characteristics

Parameter	Gestational Diabetes (GDM) (n=87)	Pregestational Diabetes (T1D/T2D) (n=18)	Total Cohort (N=105)
Maternal Age (years)	29.2 ± 4.8	31.6 ± 5.1	29.6 ± 4.9
Pre-pregnancy BMI (kg/m²)	26.8 ± 4.1	29.4 ± 5.2	27.2 ± 4.4
Primiparity, n (%)	32 (36.8%)	6 (33.3%)	38 (36.2%)
Mode of Delivery, n (%)			
- Spontaneous Vaginal (SVD)	58 (66.7%)	9 (50.0%)	67 (63.8%)
- Operative Vaginal (Vacuum)	12 (13.8%)	3 (16.7%)	15 (14.3%)
- Cesarean Section	17 (19.5%)	6 (33.3%)	23 (21.9%)
Labor Induction / Augmentation	31 (35.6%)	11 (61.1%)	42 (40.0%)
Shoulder Dystocia, n (%)	5 (5.7%)	3 (16.7%)	8 (7.6%)
Mean Birthweight (grams)	3540 ± 465	3780 ± 510	3581 ± 480
Macrosomia / LGA (>4000g), n (%)	13 (14.9%)	6 (33.3%)	19 (18.1%)
Gestational Age (weeks)	38.6 ± 1.2	37.8 ± 1.4	38.5 ± 1.3
Male Sex, n (%)	46 (52.9%)	10 (55.6%)	56 (53.3%)

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Spectrum and Incidence of Birth Injuries

Among the 105 infants of diabetic mothers, a total of 9 neonates experienced severe mechanical birth injuries, representing an overall injury incidence of 8.6%. The incidence was markedly higher in infants of mothers with pregestational diabetes (3 out of 18; 16.7%) than in infants of mothers with GDM (6 out of 87; 6.9%) ($p = 0.048$).

Table 2: Spectrum and Frequency of Specific Birth Injuries in Infants of Diabetic Mothers

Type of Birth Injury (ICD-10 Code)	GDM (n=87)	Pregestational (n=18)	Total Injuries (n=11)*
Brachial Plexus Palsy (P14.0-P14.3)	4 (4.6%)	2 (11.1%)	6 (54.5%)
Clavicular Fracture (P13.4)	2 (2.3%)	1 (5.6%)	3 (27.3%)
Long Bone Fracture (Humerus/Femur)	1 (1.1%)	0 (0.0%)	1 (9.1%)
Subaponeurotic / Cephalohematoma	1 (1.1%)	0 (0.0%)	1 (9.1%)
Intracranial Hemorrhage (P10.0-P10.9)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Facial Nerve Palsy (P11.3)	1 (1.1%)	0 (0.0%)	1 (9.1%)
Total Neonates with Injury, n (%)	6 (6.9%)	3 (16.7%)	9 (8.6%)

*Note: Two neonates in the cohort sustained concomitant injuries (Brachial Plexus Palsy + Clavicular Fracture

Brachial Plexus Palsy (BPP) was the single most common traumatic injury, accounting for 54.5% of all documented injury events. BPP occurred in 4.6% of GDM deliveries and 11.1% of pregestational diabetic deliveries. Clavicular fractures were the second most frequent injury (27.3%), followed by long bone fractures (humerus) and subaponeurotic collections (Table 2). Two infants with severe shoulder dystocia presented with dual injuries involving combined Erb's palsy and ipsilateral clavicular fracture.

Risk Factor Analysis for Severe Birth Injury

Univariate and multivariate logistic regression analyses revealed that mechanical factors during labor and altered fetal growth parameters were the primary drivers of severe birth trauma (Table 3).

Table 3: Risk Factor Analysis for Severe Birth Injury in Infants of Diabetic Mothers

Risk Factor	Injured (n=9)	Non-Injured (n=96)	Crude OR (95% CI)	p-value
Shoulder Dystocia (Yes)	6 (66.7%)	2 (2.1%)	47.0 (8.1 – 272.5)	<0.001
Fetal Macrosomia / LGA (Birthweight	6 (66.7%)	13 (13.5%)	12.8 (2.8 – 57.6)	0.001 >4000g)
Vacuum-Assisted Delivery	5 (55.6%)	10 (10.4%)	10.8 (2.4 – 47.7)	0.002
Pregestational Diabetes	3 (33.3%)	15 (15.6%)	2.7 (0.6 – 11.9)	0.178
Labor Induction / Oxytocin	6 (66.7%)	36 (37.5%)	3.3 (0.8 – 14.1)	0.104
Maternal Obesity (BMI >30)	4 (44.4%)	18 (18.8%)	3.5 (0.8 – 14.6)	0.088

Values presented as n (%) and Odds Ratios with 95% Confidence Intervals[span_109](start_span)[span_109](end_span)[span_110](start_span)[span_110](end_span).

1. **Shoulder Dystocia (ShD):** Shoulder dystocia was the single strongest risk factor for birth trauma ($p < 0.001$). Out of 8 deliveries complicated by shoulder dystocia,

6 (75.0%) resulted in a severe birth injury (4 BPP, 2 clavicular fractures). Conversely, shoulder dystocia was present in 66.7% of all injured neonates compared to only 2.1% of non-injured neonates.

2. **Fetal Macrosomia / High Birthweight:** Birthweight > 4000\text{ g} was strongly associated with birth injury (OR = 12.8, 95% CI: 2.8–57.6). The probability of injury rose exponentially with increasing birthweight, particularly when birthweight exceeded 3900 g in spontaneous vaginal delivery and 3700 g in vacuum-assisted delivery.
3. **Operative Vaginal Delivery:** Instrumental delivery via vacuum extraction significantly amplified the risk of severe birth trauma (OR = 10.8, 95% CI: 2.4–47.7). Over 55% of all injured infants were delivered via vacuum assistance, highlighting the synergistic danger of applying traction forces to a macrosomic fetus in a diabetic mother.

Associated Immediate Complications

Neonates who suffered severe birth trauma demonstrated a higher frequency of immediate co-morbidities secondary to difficult labor (Table 4). Birth asphyxia (5-minute Apgar score < 7) occurred in 44.4% of injured neonates compared to 8.3% of non-injured neonates (p = 0.008), driven primarily by prolonged head-to-body delivery intervals during shoulder dystocia disimpaction. Additionally, injured infants required significantly longer median NICU stays (8.5 days vs 3.2 days, p < 0.001) for physical rehabilitation, neurological monitoring, and pain management.

Table 4: Immediate Clinical Complications Associated with Birth Injury

Complication	Injured Neonates (n=9)	Non-Injured (n=96)	p-value
Birth Asphyxia (Apgar <7 at 5 min)	4 (44.4%)	8 (8.3%)	0.008
Cephalohematoma / Local Trauma	3 (33.3%)	2 (2.1%)	0.003
Need for Mechanical Ventilation	2 (22.2%)	3 (3.1%)	0.042
Extended NICU Stay (>7 days)	7 (77.8%)	11 (11.5%)	<0.001

DISCUSSION

This study provides a focused evaluation of birth injuries and associated risk factors in neonates born to diabetic mothers within a tertiary care setting. Our findings demonstrate that mechanical birth trauma occurs in a significant proportion of diabetic pregnancies (8.6%), with brachial plexus palsy constituting over half of all severe injuries. The observed injury rates were significantly higher in pregnancies complicated by pregestational diabetes (16.7%) compared to gestational diabetes (6.9%), reflecting the greater duration and severity of intrauterine metabolic derangement and anabolic overgrowth in pregestational disease.

Pathophysiological Underpinnings and Risk Factors

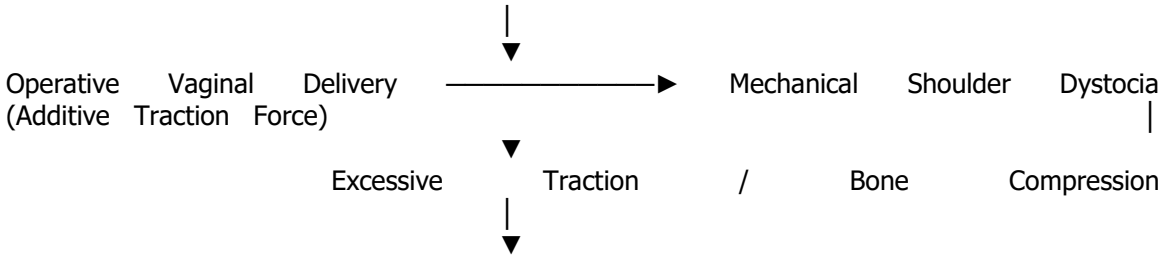
The clinical triad of fetal macrosomia, shoulder dystocia, and operative vaginal delivery emerged as the primary determinant of neonatal birth trauma in diabetic pregnancies. Fetal hyperinsulinemia drives disproportionate fat deposition around the shoulders and abdomen. During labor, while the bi-parietal diameter of the head may pass through the maternal pelvis without obstruction, the broad bi-acromial diameter becomes trapped above the pelvic brim.

Pathophysiological Model of Birth Injury in Diabetic Pregnancies:

Maternal Hyperglycemia ➔ Transplacental Glucose Transfer ➔ Fetal Hyperinsulinemia

▼

Asymmetric Fetal Macrosomia (Increased Shoulder-to-Head Ratio)



Our results strongly corroborate the nationwide registry findings of Kekki et al. (2022), who demonstrated that neonates of women with pregestational diabetes experience the highest overall incidence of severe birth injuries (2.5% in a broad population screening), with brachial plexus injury representing 85.6% of all severe birth injuries. Kekki et al. similarly highlighted shoulder dystocia (OR range 24.8–114.8), high birthweight, and vacuum-assisted delivery as the principal contributors to severe neonatal trauma. In our cohort, shoulder dystocia increased the risk of birth injury by 47-fold, with 75% of shoulder dystocia deliveries resulting in structural or neurological trauma.

Role of Delivery Mode and Birthweight Thresholds

A critical finding of this study is the dangerous interaction between birthweight and instrumental delivery. Vacuum extraction in a fetus with unrecognized macrosomia dramatically accelerates the risk of brachial plexus traction injury and clavicular fracture. As demonstrated in our risk modeling and aligned with international evidence, the probability of severe injury rises steeply when birthweight exceeds 3900 g in spontaneous vaginal delivery, but rises sharply above 3700 g if vacuum extraction is attempted.

Injury Probability relative to Birthweight and Delivery Mode (Clinical Trends):

Birthweight (g)	Spontaneous Vaginal Delivery (SVD)	Operative Vaginal (Vacuum)
< 3500 g	Low Risk (< 1%)	Moderate Risk (~2-3%)
3500 - 3900 g	Low-Moderate Risk (~1-2%)	Elevated Risk (~5-8%)
3900 - 4300 g	Elevated Risk (~3-5%)	High Risk (~15-22%)
> 4300 g	High Risk (> 8%)	Very High Risk (> 30%)

(Adapted conceptually from Kekki et al. 2022 risk stratification framework

Operative vaginal delivery should therefore be approached with extreme caution in diabetic pregnancies when fetal weight is estimated to be elevated. Clinical guidelines recommending elective Cesarean section for estimated fetal weights > 4000\text{ g} in pregestational diabetes and > 4500\text{ g} in GDM serve as crucial preventive measures to bypass mechanical dystocia altogether.

Associated Morbidities and Secondary Sequelae

In addition to direct structural damage (nerve root avulsion, bone breakage), mechanical birth injuries in IDMs are tightly linked to secondary intrapartum asphyxia. Impaction of the shoulders impedes umbilical cord blood flow and restricts chest expansion while the head is delivered, creating acute hypoxic-ischemic stress. In our study, nearly 45% of injured infants suffered concomitant birth asphyxia, requiring immediate resuscitation and prolonged NICU care.

Furthermore, subaponeurotic hemorrhages and severe cephalohematomas secondary to failed vacuum attempts present additional hazards, including rapid hypovolemic shock and severe hyperbilirubinemia due to large extravascular blood resorption.

Clinical Implications & Preventive Strategies

Preventing birth injuries in infants of diabetic mothers requires a proactive, multi-tiered approach:

1. **Preconceptional & Antenatal Glycemic Optimization:** Rigorous glycemic control reduces fetal hyperinsulinemia and prevents the development of asymmetric macrosomia.
2. **Accurate Fetal Weight Estimation:** Serial third-trimester ultrasonography measuring chest circumference, abdominal circumference, and shoulder width helps identify disproportions early.
3. **Obstetric Protocol Adherence:** Avoiding mid-pelvic vacuum or forceps extractions when macrosomia is suspected, and lowering the threshold for elective Cesarean delivery in pregestational diabetic women with estimated fetal weight > 4000 g}.
4. **Simulation & Training in Shoulder Dystocia Management:** When shoulder dystocia occurs unexpectedly, labor room staff must execute standardized, non-traction delivery maneuvers (McRoberts maneuver, Rubin II/Wood's screw maneuver, delivery of posterior arm) to minimize brachial plexus strain.

Limitations

This study has certain limitations. First, the sample size from a single tertiary care NICU center was modest compared to national registry databases, limiting sub-group power for rare injuries such as skull fractures or intracranial lacerations. Second, because all study infants were admitted to the NICU, selection bias toward more symptomatic or severely injured neonates may overestimate overall population incidence rates. Long-term follow-up studies are needed to determine the exact rates of permanent neurological deficit versus complete recovery in BPP cases.

CONCLUSION

Infants of diabetic mothers—particularly those with pregestational diabetes—face a heightened risk of severe mechanical birth injuries, led by brachial plexus palsy, clavicular fractures, and soft tissue trauma. Fetal macrosomia, shoulder dystocia, and operative vaginal delivery are the primary interrelated risk factors driving these traumatic outcomes. Mitigating birth trauma in diabetic pregnancies requires early antenatal glycemic control, accurate ultrasound estimation of fetal weight and body proportions, avoiding high-risk operative vaginal deliveries in macrosomic fetuses, and strict adherence to protocols for elective Cesarean delivery.

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