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Feeding Dysfunction in Infants of Diabetic Mothers Admitted to the Neonatal Intensive Care Unit

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Abstract

Background: Feeding difficulties are common in infants born to diabetic mothers. This can prolong the hospital stay after birth. This study describes sucking skills in infants of diabetic mothers admitted to a neonatal intensive care unit (NICU).

Materials and methods: This is a retrospective review of data recorded from speech pathologist evaluations at a level 4 NICU. The infants were evaluated using the Neonatal Oral Motor Assessment Scale.

Results: Subjects included 47 infants admitted from 2018 to 2023. The mean gestational age was 37 weeks (35-41 weeks), and the mean birth weight was 3,527 g (1,500-5,160). A substantial proportion (79%) of infants presented disorganized or dysfunctional sucking patterns. The sucking patterns were described as 66% disorganized, 13% dysfunctional, and 21% mature. Low cheek muscle tone was identified in 32%, retracted tongue in 15%, and protruded tongue in 11%; moderate retrognathia was present in 4%.

Conclusion: Although most of our patients were born at term or near-term, most showed feeding dysfunction, with patterns resembling those described in premature infants. The results of this study may help guide the prenatal orientation of diabetic mothers about the possibility that their infant may need admission to the NICU and present feeding difficulties. It also reinforces the importance of having an experienced speech pathologist on the NICU interprofessional team and of training physicians and nursing staff to manage the feeding process. Close follow-up of infants with sucking difficulties is important for detecting neurodevelopmental delays early and intervening promptly.

Categories: Other, Nutrition, Pediatrics
Keywords: disorganized sucking, feeding skills, infant of diabetic mother, newborns, sucking difficulties, swallowing disorders

Introduction

Infants of diabetic mothers (IDMs) are at increased risk for multiple morbidities, including, but not limited to, macrosomia, hyperinsulinemia, polycythemia, feeding difficulties, congenital heart disease, and neural tube defects [1-4]. An estimated 2%-10% of pregnancies are affected by gestational diabetes, highlighting its prevalence among maternal health issues [2].

This study was carried out at a level 4 center that admits infants with multiple medical conditions, such as those that can occur in IDMs. Some of these patients require speech pathology evaluation due to feeding difficulties. The purpose of this study is to evaluate sucking skills in IDMs admitted to the neonatal intensive care unit (NICU) and to identify risk factors associated with sucking skills difficulties in IDM.

This article was previously presented orally at the Puerto Rico Pediatrics Society Meeting in April 2023 and as a poster at the Virtual 9th International Conference on Nutrition and Growth in March 2022.

Materials And Methods

This retrospective study was conducted in the NICU. Our study population included infants born between January 1, 2018, and December 31, 2023, to mothers with any type of diabetes at >34 weeks' gestation who required NICU admission and evaluation by the speech pathology service. We excluded newborns with severe congenital anomalies that affect neurodevelopment, including congenital heart disease, cleft lip and/or palate, hydrocephalus, and chromosomal abnormalities. We also excluded newborns who required hypothermic therapy for neonatal encephalopathy.

Data were obtained from the Vermont Oxford Network (VON) database and our institution's sucking skills evaluation database. Data were recorded without identifiers. Data collected included gender, gestational

age, birth weight, resuscitative interventions in the delivery room, diagnosis of respiratory distress syndrome (RDS), use of mechanical ventilation, intraventricular hemorrhage, sepsis after the third day of life, gastrostomy requirement, and survival. The bedside Neonatal Oral Motor Assessment Scale (NOMAS) was used to evaluate sucking skills patterns [5]. The same NOMAS-certified speech pathologist evaluated all infants.

Descriptive statistics were used to summarize continuous variables using measures of central tendency (mean, median) and dispersion (range), and categorical variables using frequencies and percentages. Infants with normal and abnormal sucking patterns were compared using analysis of variance (ANOVA) for normally distributed continuous variables. “Abnormal" designation combined the disorganized and dysfunctional categories. Because Apgar scores at one and five minutes and length of stay were not normally distributed, these variables were compared between the two independent groups using the Mann-Whitney U test and are reported as medians with interquartile ranges (IQRs). Fisher's exact test was used for nominal variables given the small sample size. Statistical significance was defined as $p < 0.05$. Analyses were performed using Statistix 9.0 (Analytical Software, Tallahassee, FL, USA) and Intellectus Statistics (online computer software). The study was approved by the University of Puerto Rico, Medical Sciences Campus, Institutional Review Board, protocol number #2290034829. Informed consent was waived.

Results

We included 47 infants in this study (40% females and 60% males). The mean gestational age was 37 weeks (35-41 weeks), and the mean birth weight was 3,527 g (1,500-5,160). Median Apgar scores were 7 (IQR 6-8) at one minute and 8 (IQR 8-9) at five minutes. The prematurity rate was 30% (n = 14). Regarding maternal diabetes, 16 (34%) had type 1 diabetes mellitus, 11 (23%) had type 2 diabetes mellitus, and 20 (43%) had gestational diabetes. Cesarean section was the most frequent type of birth, 37 (79%). Macrosomia was present in 17 (36%) infants. At birth, 21 (45%) infants required oxygen, and one (2%) required endotracheal intubation. Six (13%) infants required mechanical ventilation during their NICU admission. RDS was diagnosed in three (6%) infants. One infant had an intraventricular hemorrhage grade 2. Two infants developed sepsis (4%). The median length of stay was 12 days (IQR 9-23). One infant developed bronchopulmonary dysplasia and died after a prolonged stay in the NICU.

During the speech-language pathologist's bedside clinical assessment, the following characteristics were identified in the infants: low cheek muscle tone in 15 (32%), a retracted tongue in seven (15%), and a protruded tongue in five (11%). The jaw was adequate in 10 (21%), mild retrognathia in 35 (75%), and moderate retrognathia in two (4%). The NOMAS evaluation described the sucking pattern as 31 (66%) disorganized, six (13%) dysfunctional, and 10 (21%) mature. An abnormal sucking pattern was observed in 37 (79%) infants. Based on maternal type of diabetes, the frequency of abnormal sucking was as follows: gestational diabetes, 19 (95%) infants; type 1 diabetes, 11 (69%); and type 2 diabetes, 7 (64%); $p = 0.047$. One infant required a gastrostomy tube.

Table *1* shows the factors associated with abnormal sucking patterns, with normal sucking as the reference. Infants with abnormal sucking patterns were born at gestational ages and birth weights similar to those of infants with normal sucking. Apgar scores at one minute (median 7 vs 7; $U = 193$; $p = 0.829$) and at five minutes (median 8 vs 8.5; $U = 191.50$; $p = 0.856$) did not differ between infants with abnormal and normal sucking patterns, nor did length of stay (median 12 vs 11 days; $U = 193$; $p = 0.835$), as assessed by the Mann-Whitney U test. The abnormal sucking comparison was underpowered to exclude an association with prematurity (13/37 (35%) vs 1/10 (10%); odds ratio (OR) = 4.75 (0.55-42.85)), macrosomia (12/37 (31%) vs 5/10 (50%); OR 0.48 (0.12-1.98)), mechanical ventilation (5/37 (13%) vs 1/10 (10%); OR 1.40 (0.13-12.25)), and RDS (3/37 (8%) vs 0/10 (0%)).

Characteristic	Abnormal sucking (n = 37)	Normal sucking (n = 10)	Statistical test	Statistic/effect estimate	p-value
Birth weight, mean (g)	3,454 (1,500-5,160)	3,796 (2,255-4,625)	ANOVA	F(1, 45) = 1.05	0.310
Gestational age, mean (wk)	37 (35-41)	38 (36-39)	ANOVA	F(1, 45) = 1.31	0.259
Apgar score at 1 min, median (IQR)	7 (6-8)	7 (6-8)	Mann-Whitney U test	U = 193	0.829
Apgar score at 5 min, median (IQR)	8 (8-9)	8 (8-9)	Mann-Whitney U test	U = 191.50	0.856
Prematurity	35%	10%	Fisher's exact	OR = 4.75 (0.55-42.85)	0.242
Macrosomia	32%	50%	Fisher's exact	OR = 0.48 (0.12-1.98)	0.460
Mechanical ventilation	13%	10%	Fisher's exact	OR = 1.40 (0.13-12.25)	1.000
Respiratory distress syndrome	8%	0%	Fisher's exact	NA	1.000
Length of stay, median (IQR) (d)	12 (9-23)	11 (10-15)	Mann-Whitney U test	U = 193	0.835

TABLE 1: Factors associated with abnormal sucking in infants of diabetic mothers

Continuous variables are presented as mean (range) for birth weight and gestational age, and as median (IQR) for Apgar scores at 1 and 5 minutes and length of stay. Categorical variables are presented as percentages. Apgar scores and length of stay were compared using the Mann-Whitney U test; birth weight and gestational age were compared using ANOVA; categorical variables were compared using Fisher's exact test. F statistics are presented with numerator and denominator degrees of freedom. ORs are presented as effect estimates for variables analyzed using Fisher's exact test.

IQR: interquartile range; ANOVA: analysis of variance; OR: odds ratio; NA: not applicable

Discussion

One of the more complex tasks of a newborn is oral feeding. It requires adequate functioning of the central nervous, respiratory, and neuromuscular systems. This process involves the coordination of sucking, swallowing, and breathing and is divided into three phases: oral, pharyngeal, and esophageal phases [4,6-8]. These feeding phases can be affected by several reasons, including, but not limited to, premature birth, developmental delays, cardiac disease, pulmonary disease, neurologic disease or disorder, craniofacial disorders, and pregnancy complications, including diabetes [6]. Infants born to diabetic mothers are at increased risk of feeding difficulties [3,4,9]. Numerous studies have described the association between pregestational and gestational diabetes and newborn complications. Feeding difficulties are among the most prevalent morbidities in this population. Misita et al. [10] described challenges during breastfeeding, including low milk supply, difficulty maintaining proper latch, and maternal fatigue. Another study found that approximately 37% of IDM had feeding difficulties, which can prolong NICU length of stay [11]. They also found a higher frequency of gastrostomy tube placement, highlighting these infants' chronic feeding problems. In our study, one infant required a gastrostomy. Barlow et al. [12] indicate that the central nervous system and oro-motor pattern development are vulnerable to delay and injury in patients with RDS, chronic lung disease, and IDMs. Malkar et al. [11] propose that feeding difficulties in IDM can be associated with a vagal neuropathy mechanism that is thought to be secondary to dysregulation of pharyngeal-airway interactions, longer active upper esophageal sphincter relaxation, delays in the activation of the esophageal contractile apparatus during peristalsis, and prolonged inhibition at the gastroesophageal junction. According to Wang et al. [4], exposure to a diabetic intrauterine environment may negatively affect fetal brain development.

The exact mechanism of feeding difficulty in IDM remains unestablished. The higher frequency of abnormal sucking among infants of mothers with gestational diabetes (95%) than among those with type 1 (69%) or type 2 (64%) diabetes in our study was an unadjusted comparison. Using Kron's Nutritive Sucking Apparatus on day 3, Bromiker et al. [13] found that newborns of insulin-treated mothers averaged 5.2 fewer bursts and 42 fewer sucks than controls, with no differences for other variables tested, and no difference between diet-managed gestational diabetes and controls. Some degree of neurologic immaturity during the early neonatal period was suggested. Because this gradient runs opposite to what greater cumulative in utero glycemic exposure would predict, it may reflect differential referral thresholds by diabetes type in our study rather than a dose-response relationship. It may also reflect differences in measurements and in group composition. Studies have shown that IDMs are 5.6 times more likely to have RDS than infants born to non-

diabetic mothers [4]. Most of the infants in our study did not require resuscitative measures at birth beyond simple oxygen supplementation, nor did they experience significant complications in the delivery room. Nonetheless, 13% eventually required mechanical ventilation during their NICU stay. Notably, a substantial proportion (79%) of these infants presented disorganized or dysfunctional sucking patterns. Although most of our infants were born at term or near-term, they showed immature sucking patterns and sensorimotor problems more commonly seen in premature infants. With a 30% prematurity rate in a cohort of this size, late prematurity is a plausible alternative explanation for the observed patterns and cannot be separated from maternal diabetes status. Prior work [2] similarly reports that IDM born at full term show delayed motor and physiological reflex development, including weaker sucking bursts and lower sucking pressure. These findings suggest that IDMs may encounter feeding challenges and exhibit neurological immaturity that is atypical for their gestational age [14]. Azuma and Maron [6] found that newborns of insulin-treated mothers had fewer sucking bursts and fewer sucking bursts per burst, consistent with a more immature sucking pattern. They report that successful oral feeding includes sensory integration and motor coordination, which require a comprehensive evaluation by a speech-language pathologist.

The bedside clinical assessment is a comprehensive evaluation that includes an interview and/or a review of medical records, non-instrumental screening, an assessment scale, inspection of the oral mechanism and cranial nerves, other clinical observations, and instrumental procedures [15]. An oral-motor feeding skills assessment is needed to determine when an infant can feed safely by mouth [6]. The oro-motor feeding skills assessment consists of a feeding safety assessment, a clinical oral-motor assessment, and physical oral-motor assessments [4,6-8]. One of the most widely used tools for assessing sucking patterns in the neonatal population is the NOMAS. NOMAS was developed in 1983. It provides a narrow evaluation of the tongue and jaw's oral-motor components. The movements of the tongue and jaw are divided into 13 characteristics. This scale helps identify different sucking patterns in infants. Sucking patterns are classified as normal, disorganized, and dysfunctional [5]. A normal sucking pattern is defined as a mature sucking pattern with 10 to 30 cycles per pattern. This is approximately a coordinated suction (sucking, swallowing, and breathing) in 1 s, a 1:1:1 sequential pattern. A disorganized sucking pattern refers to variability or arrhythmic movements during nutritive sucking initiation and termination [5]. It may present with increased respiratory effort, color changes, and variations in saturation, among other characteristics [6]. Most infants in our study group exhibited a disorganized sucking pattern. A dysfunctional sucking pattern is a disruption of the nutritive sucking process caused by abnormal tongue and jaw movements [5]. The need for normalization of orofacial muscle tone characterizes it. In the case of hypertonia in the orofacial area, a restriction in the range of motion in the temporomandibular joint could involve minimal excursions in the jaw or lingual retraction. In the case of orofacial hypotonia, lingual flaccidity or excessively wide jaw excursions may be observed [5]. IDMs are characterized by low muscle tone, and their oral structures exhibit difficulty with physiological regulation, presenting behaviors such as lethargy and difficulty completing required intake. In line with this, during the bedside evaluation, low cheek muscle tone (32%), a retracted tongue (15%), and a protruded tongue (11%) were observed in our study group. Mild retrognathia was very common and may be considered temporary in newborns. Evaluating the feeding process enables the development of strategies to promote feeding based on the infant's cues, thereby maximizing physiological regulation and integrating oral-motor movements of the tongue and jaw to ensure a safe, efficient feeding process.

An association has been documented between gestational diabetes and neurodevelopmental delay in infants. We observed that 95% of infants whose mothers had gestational diabetes exhibited abnormal sucking patterns. Dietrich [2] reported that research conducted during the 1980s and 1990s employed the Neonatal Behavioral Assessment Scale (NBAS) to demonstrate that IDMs may have difficulty in maintaining alert and active alert states. Sucking patterns have been used as indicators of central nervous system integrity and can serve as prognostic tools for developmental outcomes in at-risk infants [16]. Close monitoring of infants with sucking difficulties is crucial for detecting early neurodevelopmental delays and intervening promptly.

The present study has several methodological limitations that warrant consideration when interpreting the findings. First, the retrospective study design inherently limits control over data collection and introduces potential for unmeasured confounding variables, thereby precluding the establishment of causal relationships. All NOMAS evaluations were performed by a single certified speech-language pathologist who was not blinded to maternal diabetes status, and intra-rater agreement was not prospectively collected. Oral-experience variables, age at first oral feed, duration of tube feeding, and receipt of feeding therapy, were not captured in the source databases and could not be abstracted retrospectively. Because oromotor maturation is experience-dependent, the observed patterns cannot be attributed solely to maternal diabetes rather than to feeding history. Second, the relatively small sample size derived from a single-center NICU limits the statistical power of the analysis and may compromise the external validity and generalizability of the results to broader neonatal populations or alternative clinical settings. Additionally, the absence of a comparison group of IDMs who did not require NICU admission restricts our ability to determine whether the observed findings are specific to the NICU-admitted population or representative of IDMs more broadly. Fourth, our dataset did not include maternal glycemic control, diabetes severity or duration, or diabetes medication use, as the variables available were limited to infant characteristics and maternal diabetes type. The comparison of abnormal sucking frequency across gestational diabetes, type 1 diabetes, and type 2 diabetes was therefore unadjusted, and we cannot determine whether the observed difference reflects the

diabetes type itself or differences in metabolic control, treatment regimens, or disease chronicity across these groups. Future prospective multicenter studies with adequately powered cohorts, prespecified analytical frameworks, and appropriate control groups are required to validate these preliminary observations.

Conclusions

In this retrospective, single-center review of a small group of IDMs admitted to a level 4 NICU, 79% showed abnormal sucking patterns on NOMAS, most commonly disorganized sucking, despite most being born at term or near-term. Because the cohort was defined by NICU admission and speech-pathology referral and lacked a comparison group of IDMs not requiring NICU admission, these findings describe this selected cohort and cannot establish that maternal diabetes itself increases the risk of feeding dysfunction. Future prospective multicenter studies with larger sample sizes and appropriate comparison groups are needed to validate these preliminary observations, further define the mechanisms underlying feeding dysfunction in IDMs, and evaluate the long-term developmental implications of early oral-motor abnormalities. The findings of this study may have important implications for the care of IDMs admitted to the NICU, highlighting the need for heightened awareness of feeding dysfunction in this population. Early recognition of feeding difficulties is essential, as delays in developing effective oral feeding skills may contribute to prolonged hospitalization, delayed attainment of full oral feeds, and increased caregiver stress. Routine feeding surveillance may be considered for IDMs, particularly those exhibiting poor feeding endurance, weak or uncoordinated sucking, abnormal oral-motor findings, or difficulty progressing with oral feedings. Early referral to a speech-language pathologist with expertise in neonatal feeding can facilitate comprehensive assessment of sucking, swallowing, and feeding readiness, allowing for individualized interventions that promote safe and efficient feeding.

Standardized oral-motor assessments, such as the NOMAS, are feasible for identifying infants at risk for feeding dysfunction and guiding clinical management. Early implementation of developmentally supportive feeding strategies, caregiver education, cue-based feeding approaches, and ongoing monitoring of feeding performance may improve feeding outcomes and reduce complications associated with oral feeding difficulties. Given the reported association between abnormal sucking patterns and later neurodevelopmental outcomes, infants demonstrating persistent feeding difficulties should receive close developmental follow-up after hospital discharge. A multidisciplinary approach involving neonatologists, nurses, speech-language pathologists, occupational therapists, and primary care providers is essential to optimize feeding success, support family-centered care, and identify developmental concerns at the earliest opportunity.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Lourdes García-Fragoso, Yazmin Ortiz-Sánchez, Ines García-García, Lourdes García-Tormos

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Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. University of Puerto Rico, Medical Sciences issued approval 2290034829. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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