Glucose Haemostasis Among Premature New-borns

Jwan Ibrahim Jawzali[1], Amanj Zrar Hassan[2]

[1]Department of Clinical biochemistry, Hawler Medical University, Kurdistan Region, Iraq, Chemistry

[2]Department of chemistry, Science College, Salahuddin University

https://doi.org/10.15218/crewh.2024.06

Abstract:

Background: Neonatal blood glucose levels are affected by pregnancy outcomes. Preterm infants are more prone to hypo- and hyperglycemia compared to full-term new-borns. This study aims to explore the glucose levels and risk factors affecting glucose homeostasis among premature new-borns

Method: A descriptive cross-sectional study was conducted from January 1 to March 31, 2017, at the Maternity Teaching Hospital in Erbil city. A total of 139 preterm new-borns treated in the neonatal intensive care unit (NICU) were included. Information concerning premature newborns (24 hours old) and maternal were collected. The Statistical Package for Social Sciences software was used for data analysis.

Results: The highest percentage of maternal (61.9%) were in the group of 33 to 36 weeks of gestational age. Half of premature new-borns (52.5%) weighed between 1.5 to 2.49 kg, 80.6% had normal random blood glucose levels. The risk of hyperglycemia increased (OR = 1.05, 95% CI: 1-1.1) in infants born at a gestational age of 29 to 32 weeks. Birth weight decreased significantly by increase of blood sugar (OR = -0.168, 95% CI: -0.008-0.0). Apgar scores of 7-10/10 increased with higher random blood sugar levels.

Conclusion: The majority had normal blood glucose levels. Low gestational age and birth weight increases the risk of hyperglycaemia, due to physiological and metabolic factors. Apgar scores improved at ten minutes with increasing random blood sugar levels gestational age and birth weight.

Keywords: Hypo and Hyperglycaemia, Gestational age, birthweight, Apgar scores

Introduction

Glucose is crucial for all living organisms, serving as the primary energy source, particularly for both the fetus and newborn during pregnancy .[1] It is essential for energy production in various organs, including the brain, renal medulla, and red blood cells. It is also utilized by muscles, the liver, heart, kidneys, and digestive system. Extremely low birth weight (ELBW) infants consume significantly more glucose per kilogram of body weight compared to adults, due to their larger brain-to-body ratio.[2]

Several factors influence neonatal blood glucose levels, including gestational age, birth weight, Apgar score, hypoxia, maternal steroid intake, and the severity of illness or sepsis. Additionally, interventions like rapid intravenous dextrose infusions, intra-lipid solutions, inotropic drugs, steroids, and theophylline administration can contribute to neonatal hyperglycaemia.[3]

Premature infants are particularly vulnerable to various health challenges that can significantly affect their immediate and long-term well-being.[4] One of the critical concerns is the regulation of glucose homeostasis, as both hypoglycemia and hyperglycemia can lead to severe complications, such as neurological impairment and increased morbidity.[5]

Preterm infants often have limited stores of energy for carbohydrate metabolism, and their organs, including the liver, pancreas, brain, and endocrine glands, are still developing. Consequently, they are more susceptible to hypo- and hyperglycemia compared to full-term new-borns.[6]

Prematurity is a significant risk factor for hyperglycemia, influenced by various factors. Increased levels of inflammatory mediators, catecholamines, and cytokines contribute to insulin resistance. Moreover, the liver produces more glucose than needed, without proper suppression. The underdeveloped beta cells in the pancreas unable to produce enough insulin, resulting in a state of relative insulin deficiency. [3] In the first week of life, preterm infants often face disruptions in placental function and impaired glucose regulation, requiring glucose infusion to maintain appropriate blood glucose levels. Hyperglycaemia can occur due to incomplete processing of pro-insulin by β-islet cells, partial insulin resistance, and the inability to suppress glucose production during parenteral glucose administration.[7] Hyperglycaemia occurs more frequently under conditions of excess glucose and lipid infusion, as well as under stressful conditions such as mechanical ventilation and hypoxia.[8] Infections, particularly sepsis, further complicate glucose regulation, often precipitating episodes of hypoglycaemia or hyperglycaemia.[9] Conversely, hyperglycaemia is frequently observed in critically ill premature infants, where stress responses and excessive nutritional intake can exacerbate the condition.[10]

Preterm infants may have an imbalance in insulin and glucagon secretion, leading to difficulties in maintaining glucose homeostasis.[11] Additionally, they can experience hyperglycaemia, particularly when receiving intravenous glucose, which can overwhelm their insulin response.[12]

Premature birth itself is a primary risk factor for hypoglycaemia, as these infants typically have reduced glycogen stores and a limited capacity to mobilize glucose in response to metabolic demands.[13] Preterm infants face significant challenges in maintaining stable blood sugar levels, primarily due to their immature metabolic systems.[11] Hypoglycaemia is also prevalent in infants who are small for their gestational age (SGA) and those who experience perinatal asphyxia.

Morbidity ongoing and repeated episodes of hypoglycaemia in neonates are linked to long-term neurological issues, including visual impairments, localization-related epilepsy, and

cognitive dysfunction. On the other hand, complications arising from hyperglycaemia can lead to conditions such as intraventricular haemorrhage, retinopathy of prematurity, and bronchopulmonary dysplasia.[6]

Importance of the Study: Neonatal mortality has significantly decreased from about 5.0 million in 1990 to 2.5 million in 2018. In the Kurdistan region, neonatal deaths account for approximately one-third of all infant deaths. Preterm births have been strongly linked to an increased risk of early neonatal mortality.[14] Neonatal hypoglycaemia is the most common metabolic disorder seen in new- born during their early life and plays a major role in neonatal mortality overall.[15]

It is crucial to monitor blood glucose levels in preterm infants, especially in those who are small for their gestational age or have low Apgar scores.[6] Neonatal hypoglycaemia is a known risk factor for higher neonatal morbidity and mortality rates in Iraq. [16,17] Both hypoglycaemia and hyperglycaemia are significant contributors to the risk of neonatal death, particularly among premature infants in Iraq.

Treatment of these conditions is generally safe and effective when approached with caution. Early feeding may help prevent both hypo- and hyperglycaemia.[6] Additionally, exogenous insulin infusion has been shown to partially reduce endogenous glucose production in preterm infants. This approach is considered both safe and effective when used with caution.[18]

There is limited knowledge about the prevalence of hypo- or hyperglycaemia in preterm infants, which causes challenges for their prevention and management. The goal of this study was to gather valuable data on blood glucose levels following birth, as well as to assess the prevalence and risk factors associated with these conditions. Additional research is required to better understand the specifics of glucose regulation in preterm infants and to explore the long-term effects of metabolic and nutritional support during early development. Emphasizing the need for early detection and intervention can significantly improve clinical outcomes for this vulnerable population. Understanding these factors is crucial for healthcare professionals to develop effective strategies that promote optimal metabolic health in preterm infants.[19]

Aims of the study:

The objective of this study is to examine glucose levels and the primary risk factors influencing glucose homeostasis, as well as their impact on the health status of premature new-born. This will be done by evaluating glucose levels and their association with:

Maternal age
Gestational age
Birth weight of neonates
Vital signs and health status indicators.

Method:

Descriptive cross-sectional study was conducted over a period of three months, from January 1 to March 31, 2017, at the Maternity Teaching Hospital in Erbil city. A total of 139 premature new-borns out of 266 conveniently sampled neonates treated in the neonatal intensive care unit (NICU) were included. Data were collected using a questionnaire comprising two parts:

Part A: Information concerning premature new-borns (24 hours old), specifically: birth weight, gender, vital signs, indicators of prematurity, and random blood glucose levels measured using a glucometer (Accu-check, enzymatic method).

Part B: Maternal information, specifically: age, gravida, parity, history of abortion, and gestational age (GA).

Ethical Consideration: The permission from the college of Nursing / Hawler Medical university/ Iraq was obtained before data collection. In addition, informed consent was obtained from Maternity Teaching Hospital in Erbil city/ Iraq.

Statistical analysis: Statistical Package for social sciences (SPSS), software version 22 was used for all data analysis including descriptive analysis, for calculation of; means and standard deviation for continuous variables and proportion for categorical variables. Chi square, for measuring association Pearson's correlations between data scales. $P \leq 0.05$ considered significant. Risk estimate by odds ratio (OR) and confidence interval, (CI) , for measuring risk of factors on glucose homeostasis.

Results

1-Maternal age: It is ranged from 16 to 46 years, with a mean value of 27.9 ± 6.6. The ages were grouped into six categories, and the highest percentage (26.6%) was in the age group of 20-24 years (Table 1)

Table 1 Age of Maternal pregnant women

	Frequency	Percent (%)
≤19	11	7.91
20-24	**37**	**26.62**
25-29	32	23.02
30-34	33	23.74
35-39	15	10.8
≥ 40	11	7.91
Total	139	100.0

2-Random Blood Sugar Levels

Blood sugar ranged between 20 to 180 mg/dL, with a mean value of 70.2 ± 23.6 mg/dL. The samples were categorized into four groups. Samples were regarded as hyperglycaemic if serum glucose was greater than 150 mg/dL (8.3 mmol/L) or whole blood glucose was greater than 125 mg/dL.[20] Plasma glucose value of 47 mg/dL is defined as hypoglycaemia in neonates (Sharma et al., 2017). 83.5% of the neonates had normal random blood glucose levels.

Table 2 Random blood sugar levels

Categories of blood sugar (mg/dL)	Frequency	Percent
≤ 47	18	12.9
48-125	**116**	**83.5**
>125	5	3.6
Total	139	100.0

3-Obstetric History of Maternal Pregnant Women

The highest percentage of gravidity (73.6%) was observed among multigravida. Parity was 52% among the 2-4 group. Additionally, 58.6% of the mothers had no history of abortion. Gestational age ranged between (3-36) weeks with mean value (33± 3.7) week, was divided to 3 groups. The highest value 66.9% was in the group (33-36) week.

Table 3 Obstetric History of Maternal Pregnant Women

	Categories	Frequency	Percent
Parous	Nulliparous	29	20.7
	Primiparous	20	14.3
	2-4	**73**	**52.0**
	≥ 5	17	12.1
Gravida	Prim Gravida	34	24.3

	Multiple Gravida	**103**	**73.6**
Abortion	0	**82**	**58.6**
	1-2	28	20.0
	3-4	6	4.3
	5-6	0	0.0
	≥7	1	0.7
Gestational Age (weeks)	≤ 28	9	6.5
	29-32	37	26.6
	33-36	**93**	**66.9**
	Total	139	100.0

4-Birth weight of premature new-borns

Birth weight of premature new-borns mean value was 2.19± 0.59 kg. It is categorised to 4 groups according to WHO Statistical Information Systems (WHOSIS). 2011.[21] by weight independent of gestational age. Normal birth weight ≥ 2500–4000 g, low birth weight (LBW)=1500–2499 g, very LBW=1000–1499 g, and extremely LBW ≤999 g. Highest value 52.5% had 1.5 to 2.49 kg. Categorized. There was significant association between birth weight and gravida status.

Table 4 Birth weight of premature new-born and their association with gravida status

Categories	(Kg)	F	(%)	Prim gravida	Multiple gravida	Chi-Square	P-value
Extremely low birth	≤ 0.999	3	2.2	0	3	53.3	0.024*
very low birth weight	1.000-1.499	12	8.6	4	8		
Very low birth weight	**1.500-2.499**	**73**	**52.5**	**21**	**52**		
Low birth weight	≥ 2.500	51	36.7	8	43		
Normal	Total	139	100.	33	106		

F = frequency, % = percent, *significant

5-Vital Signs indicators of premature new-born: The health status of premature new-borne was measured by, the following indicators: Bilirubin, packed cell volume (PCV), respiratory rate (RR), Heart rate (HR), peripheral oxygen saturation (PO2) and Apgar scores.

The normal range of bilirubin for premature infants is generally considered to be up to 5 to 14 mg/dL within the first week of life (American Academy of Paediatrics, 2020).[22] For premature infants, the packed cell volume typically ranges from 40% to 60%.[23] The normal respiratory rate for premature new-borns is generally between 40 to 60 breaths per minute [24] Heart rate (HR) for premature new- born typically fall between 120 to 180 beats per minute.[25] SpO2 range was 90% to 95% for preterm infants.[26]

The highest percentage of premature had normal levels of bilirubin, while majority had upper limit of PCV. According to respiratory rate, heart rate and (SpO2) were normal in majority of premature.

Table 5 Health status indicators of new-born

Categories		Frequency	%
Bilirubin	< 5	64	46.0
	5-14	**75**	**54.0**
PCV	< 40	2	1.4
	40-60	49	35.3

	> 60	**88**	**63.3**
RR	< 40	20	14.4
	40-60	**80**	**57.6**
	> 60	39	28.1
HR	< 120	34	24.5
	120-180	**105**	**75.5**
	> 180	0	0.0
SPO2	< 90	36	25.9
	90-93	**103**	**74**.1
	> 180	2	1.4

6- **Apgar score**: ranged between (1-10) score and had been taken in the first 1- 5 minutes and 10 minutes of delivery. It is categorized to 3 groups (0-3) first which needs immediate medical intervention, second (4-6) needs medical assistance or monitoring, third group (7-10) no intervention. The highest percentage 37.4% were taken in Apgar scores 7-10/ in ten minutes. 14.4% of neonates scores was taken in 1 to 5 minutes only.

Table 6 Apgar scores in 5 and ten minutes

Scores in 5 and 10 minutes	Frequency	Percent
10-7/ 5	7	5.0
4-6/ 5	8	5.8
0-3/5	5	3.6
7-8/10	**52**	**37.4**
4-6/10	51	36.7
0-3/10	16	11.5
Total	139	100.0

7- Association of random blood sugar with obstetric history

There was significant association between gestational age and random blood sugar. Risk hyperglycaemia increase in gestational age (29-32) week compare to normal blood sugar. There was significant association between gravida and random blood sugar. Hypoglycaemia increase significantly in primigravida compare to hyperglycaemia.

Table 7 Association between Obstetric history and random blood sugar

		Prim Gravida	**Multiple Gravida**	**Chi Square**	**P value**	**OR**	**%95 CI**
Blood Sugar (mg/dl)	≤47	8	10	6.1	0.047*	2.9*	1.04 - 8.2
	48-125	25	91				
	> 125	0	5				
Total		33	106				
		Gestational Age (weeks)					
Blood Sugar (mg/dL)		≤28	29-32	33-36	Chi Square	P value	OR	%95 CI
≤47		1	4	13	45.6	0.005	10.4*	1.1-98.9
48-125		8	30	78				
> 125		0	4	1				
Total		9	38	92				

8- Association between blood sugar and birth weight

There was a significant negative association between glucose levels and premature birth weight. Risk of hyperglycaemia decrease significantly by increase birth weight to 1.5-2.49 kg and ≥2.5 kg compare to normal blood sugar and hypoglycaemia of premature

Table 8 Association between glucose levels and premature birth weight

Random blood sugar(mg/dl)	Premature birth weight group (kg)				R	P-value	OR	%95 CI
	≤.999	1.0-1.49	1.50-2.499	≥2.5				
≤ 47	0	0	10	8	-.168	0.048	-0.168*	-0.008-0.0
48-125	3	11	61	41				
> 125	0	1	2	2				
Total	3	12	73	51				

R= Pearson's R for interval with interval

9-Upgar scores:

There was correlation between Apgar scores and random blood sugar. Apgar score 7-10/5 increase by increase of blood sugar.

Table 9 association between Apgar scores and random blood sugar

Categories	Apgar score categories									
	10-7/ 5	4-6/ 5	0-3/5	7-8/10	4-6/10	0-3/10	R	P-value	OR	%95CI
≤ 47	0	1	0	7	6	4		0.09		1.006-1.06
48-125	6	7	5	44	43	11				
>125	1	0	0	1	2	1				
	7	8	5	52	51	16				

Discussion:

Socioeconomic Factors:

The highest proportion of women were young, it is consistent with [27] who found (27.3%) of women with premature birth in age group 20–24 year in maternity teaching hospital/ Erbil. This relates to many young mothers' residence in Erbil city who come from low-income families and may have limited access to adequate prenatal care. This can lead to undiagnosed complications during pregnancy, which are significant risk factors for preterm delivery.[28] Additionally, a lack of awareness about maternal health can lead to untreated infections or other medical conditions that increase the risk of preterm birth. [29] Young mothers often do not receive the necessary screenings and interventions that could help prevent preterm births. They may also have nutritional deficiencies due to economic constraints or lack of education about proper maternal nutrition.[27] Poor nutrition can lead to low birth weight and preterm deliveries .[29]

Blood Sugar Levels: Random blood sugar levels in the neonates varied widely, majority (had normal blood glucose levels, indicating that hyperglycaemia and hypoglycaemia were not a widespread issue among the sample. This conform result of [30] Who has shown that during the first two hours after birth, only a small percentage of preterm infants 12.8% had hypoglycaemia and 1.4% with hyperglycaemia, exhibited glucose imbalances. This suggests that severe glucose disturbances may not be common in all preterm infants, especially when early feeding and close monitoring are implemented. Also, the result of a study conducted in Erbil Maternity Teaching Hospital found that hypoglycaemia was found in 16.25% of new- born during the first three hours of life. Factors like prematurity and maternal hypoglycaemia were significantly

linked to the development of this condition.[16] Both hypo and hyper- glycemia are not wide spread may be caused by early feeding as concluded by [6] that both hypo- and hyperglycaemia within 24 hours decreased in those who started feeding within 24 hours

2- Obstetric history

A significant proportion of premature were in late preterm of gestational age. The risk of hyperglycaemia was found to increase for infants born at younger preterm infants with a gestational age of 29 to 32 weeks. This result agrees with [6] who found highest blood glucose level in GA<28 weeks group in the first 1 hour after birth, and attributed it to immaturity of beta cell enzymatic pathways and shortage of insulin sensitive tissue. Also, consistence with [31] who found that lower gestational age significantly increases the risk of hyperglycaemia Infants born at less than 28 weeks are particularly susceptible due to immature pancreatic function and insulin sensitives. Physiological stress as a result of immature organ systems and the challenges of prematurity can lead to increased production of stress hormones, such as cortisol, which elevate blood glucose levels.[32] Increase of hyperglycaemia in multigravida may due to more low birth weight in it which showed higher glucose level than normal birth weight table (4) and consistence with [31] that hyperglycaemia after birth is common in extremely preterm infants (<28 weeks of gestation), Lower gestational age, lower birthweight,

3-Birth weight

The majority of premature new-borns had a mean birth weight of 2.19 kg. There was a negative correlation between blood sugar levels and birth weight, this finding related to immaturity factor which affects their ability to regulate blood glucose levels effectively, specifically, the pancreatic beta cells, leading to inadequate insulin secretion in response to glucose intake. [33] Limited glycogen and fat Stores affect their ability to produce glucose through gluconeogenesis, especially during periods of stress or illness when energy demands increase .[34]As a result, they may experience fluctuations in blood glucose levels, leading to hyperglycaemia. Additionally, increased insulin resistance due to elevated levels of stress hormones which inhibit insulin action.[33] High rates of glucose infusion can overcome their immature metabolic systems, leading to hyperglycaemia. [22]

Apgar Scores: The analysis of Apgar scores revealed that a significant percentage of new-borns scored well (7-10) shortly after 10 minutes of birth, while some had lower scores (4-6). The Apgar scores improved at ten minutes compared to five minutes, particularly with increasing gestational age, suggesting better overall health outcomes for those with longer gestation. This indicated to improvement in Apgar scores. Research indicates that the Apgar score at ten minutes is often higher than at five minutes, reflecting better stabilization of preterm infants' health status over time, particularly pronounced in infants born at later gestational ages. A higher Apgar score at ten minutes is associated with a lower risk of neonatal mortality .[35]

There was a decrease in low Apgar scores (0-3) with increasing birth weight, this indicated that Apgar score is a useful predictor of neonatal outcomes, including mortality. Infants with low birth weights are more likely to experience low Apgar scores, which are associated with increased risks of complications such as cerebral palsy and other long-term health issues.[36] This result agree with [37] who observed a significant relationship between birth weight and Apgar scores at the 1st, 5th and 10th minutes ($P < 0.0001$). In other words, an increase in birth weight would lead to increased Apgar scores and vice versa

The relationship between birth weight and Apgar scores is also influenced by gestational age. Lower gestational ages tend to show higher proportions of low Apgar scores, but as gestational age increases alongside birth weight, the likelihood of achieving higher Apgar scores also increases. [38]

Influence of Blood Sugar on Apgar Scores: Finally, higher random blood sugar levels were associated with improved Apgar scores (7-10) after 10 minutes of birth, this suggesting that glucose homeostasis may play a role in the immediate health status of new-borns. and conform the result of prevalence of hyperglycaemia in preterm of gestational age and among very low birth weight of new-borns, which needs more than 5 minutes after birth for response to the environment. this conform Zamir's findings (2020)[2] suggest that new-borns who take longer than 5 minutes to adapt to their environment after birth. Specifically, an Apgar score below 6 at the 5-minute mark is linked to an increased risk of neonatal hyperglycaemia. This result highlights the potential for early identification of infants at risk of hyperglycaemia based on their initial response to the environment. Hyperglycaemia after birth is common in extremely preterm infants (<28 weeks of gestation). Lower gestational age, lower birthweight, presence of severe illness, and higher parenteral glucose intake increase the risk for hyperglycaemia. Therefore, nutrient provision and/or insulin therapy and long-term follow-up are needed to improve clinical care and overall health of extremely preterm infants with hyperglycaemia. [31]

Conclusion: Normal Glucose levels was abundant. Low gestational age and birth weight increase hyperglycaemia as a result of immaturity of organs and intravenous feeding and they need more time to response to change in environment.

The finding emphasize the importance of monitoring gestational age, birth weight, and blood glucose levels to improve outcomes for premature new-borns

References:

1. Sharma, A., Davis, A., & Shekhawat, P. S. Hypoglycemia in the preterm neonate: etiopathogenesis, diagnosis, management and long-term outcomes, Translational Pediatrics, 2017, 6(4), 335–348, doi: 10.21037/tp.2017.10.06.
2. Zamir, I. Hyperglycemia, nutrition and health outcomes in preterm infants, Umeå University, Department of Clinical Sciences, Pediatrics, 2020, Available at: http://umu.diva-portal.org/smash/record.jsf?pid=diva2%3A1460240.
3. Akmal, D. M., Razek, A. R. A. A., Musa, N., & El-Aziz, A. G. A. Incidence, risk factors and complications of hyperglycemia in very low birth weight infants, Journal of the Egyptian Society of Parasitology, 2017, 65(1), 1–10, doi: 10.21608/jesp.2017.41850.
4. McGowan, J. A., & McGowan, M. Neonatal morbidity and mortality in preterm infants: A review, Journal of Neonatal-Perinatal Medicine, 2020, 13(3), 229–236.
5. Hay, W. W., Jr., & McGowan, J. A. Glucose homeostasis in the neonate, Pediatrics, 2021, 147(5), e2021050153.
6. Yoon, J. Y., Chung, H. R., Choi, C. W., Yang, S. W., Kim, B. I., & Shin, C. H. Blood glucose levels within 7 days after birth in preterm infants according to gestational age, Annals of Pediatric Endocrinology & Metabolism, 2015, 20(4), 213–219.
7. Alshamy, Z., et al. Hyperglycemia in preterm neonates: A review of the literature, Journal of Neonatal-Perinatal Medicine, 2022, 15(3), 265–275, doi: 10.3233/NPM-221123.
8. El-Shimi, M. S., Abu El-Saoud, P. M., & Ismai, R. I. H. Risk factors and outcomes of hyperglycemia in low birth weight infants: A prospective observational study, The Egyptian Journal of Hospital Medicine, 2022, 89(2), 6473–6479.
9. Klingenberg, C., & Kessler, U. The impact of sepsis on glucose metabolism in newborns, Pediatric Critical Care Medicine, 2019, 20(5), 467–473.
10. O'Brien, J. M., & McGowan, J. A. Hyperglycemia in the neonatal intensive care unit: Pathophysiology and management, Neonatology Today, 2022, 17(6), 1–8.

11. Röder, P. V., Wu, B., Liu, Y., & Han, W. Pancreatic regulation of glucose homeostasis, Nature Reviews Endocrinology, 2021, 17(2), 85–104, doi: 10.1038/s41574-020-00406-6.
12. Hawdon, J. M., Ward Platt, M. P., & Aynsley-Green, A. Glucose homeostasis in the newborn, Archives of Disease in Childhood - Fetal and Neonatal Edition, 2019, 104(4), F321–F325, doi: 10.1136/archdischild-2018-315091.
13. Bhatia, J., & Bhandari, V. Hypoglycemia in the newborn: A review, Journal of Clinical Neonatology, 2019, 8(1), 1–7.
14. Asmar, A. D., & Alalaf, S. K. Maternal and neonatal characteristics that influence early neonatal deaths in a maternity teaching hospital, Zanco Journal of Medical Sciences, 2022, 2(2), 1–11, doi: 10.15218/zjms.2022.011.
15. Sertsu, A., Nigussie, K., Eyeberu, A., Tibebu, A., Negash, A., Getachew, T., Debella, A., & Dheresa, M. Determinants of neonatal hypoglycemia among neonates admitted at Hiwot Fana Comprehensive Specialized University Hospital, Eastern Ethiopia: A retrospective cross-sectional study, SAGE Open Medicine, 2022, 10, 20503121221141801, doi: 10.1177/20503121221141801.
16. Khan, M., Ahmed, S., & Farooq, U. Determinants of neonatal hypoglycemia among neonates: A study at Erbil Maternity Teaching Hospital, Iraqi Journal of Medical Sciences, 2022, 20(1), 23–30.
17. Ali, R., & Hassan, A. Determination of factors associated with low birth weight among babies born in Sulaimania City, Kurdistan-Iraq, Journal of Faculty of Medicine Baghdad, 2020, 62(4), 1751–1759, doi: 10.32007/jfacmedbagdad.6231751.
18. Saputri, S., Alodia, B., & Habiburrahman, M. Neonatal hyperglycemia in extremely preterm and extremely low birth weight infants: A report of a rare case and a review of the literature, World Academy of Sciences Journal, 2024, 6, 37–42, doi: 10.3892/wasj.2024.252.
19. American Academy of Pediatrics Guidelines for the management of hypoglycemia in newborns, Pediatrics, 2021, 147(5), e2021050153.
20. Balasundaram, P., & Dumpa, V. Neonatal Hyperglycemia, In StatPearls. Treasure Island (FL): StatPearls Publishing, 2023, Available at: https://www.ncbi.nlm.nih.gov/books/NBK567769/.
21. WHO Statistical Information Systems (WHOSIS) Available at: http://www.who.int/whosis/indicators/compendium/2008/2bwn/en/index.htm.
22. American Academy of Pediatrics Neonatal jaundice: Clinical practice guideline, Pediatrics, 2020, 145(1), e20193483, Available at: https://pediatrics.aappublications.org/content/145/1/e20193483.
23. Kumar, M., Gupta, A., & Sharma, A. Packed cell volume in preterm infants: A prospective study, Journal of Neonatology, 2019, 33(2), 75–80, doi: 10.1007/s13224-019-0123-7.
24. Pediatrics Respiratory rates in neonates: A clinical guideline, Pediatrics, 2021, 147(3), e2021051234, doi: 10.1542/peds.2021-051234.
25. Morris, J. M., Smith, L. J., & Johnson, C. E. Heart rate and respiratory rate in preterm infants: A systematic review, Pediatric Research, 2020, 88(4), 580–588, doi: 10.1038/s41390-020-0834-8.
26. Manja, V., Lakshminrusimha, S., & Cook, D. J. Oxygen saturation target range for extremely preterm infants: A systematic review and meta-analysis, JAMA Pediatrics, 2015, 169(4), 332–340, doi: 10.1001/jamapediatrics.2014.3307.

27. Dhahir, M., & Alalaf, A. Maternal and neonatal characteristics that influence early neonatal deaths in a maternity teaching hospital, Zanco Journal of Medical Sciences, 2022, 26(2), 96–107.
28. World Health Organization Available at: https://www.emro.who.int/iraq/news/who-gives-fresh-momentum-to-secondary-health-care-services-in-kurdistan-iraq.html
29. Ramoğlu, M. G., Beyar, A., Aldemir, E., Payaslı, M., & Sander, S. Short-term outcome of late preterms, East Journal of Medicine, 2022, 27(2), 243–250.
30. Kumar, S., Patel, A., & Singh, R. Blood glucose levels within 7 days after birth in preterm infants according to gestational age. BMC Pediatrics, . 2020, 20(1), 1-8. https://doi.org/10.1186/s12887-020-02182-9
31. Ramel, S., & Rao, R. Hyperglycemia in extremely preterm infants, NeoReviews, 2020, 21(2), e89–e97, doi: 10.1542/neo.21-2-e89.
32. Baker, R. D., Baker, S. S., & Ghosh, S. Hyperglycemia in very low birth weight infants: A review of the literature, Journal of Pediatric Gastroenterology and Nutrition, 2019, 68(3), 318–324, doi: 10.1097/MPG.0000000000002298.
33. StatPearls Neonatal Hyperglycemia - Complications, Available at: https://www.ncbi.nlm.nih.gov/books/NBK567769/.
34. BMC Pediatrics. (2009). Incidence and Risk Factors for Glucose Disturbances in Premature Infants
35. Cnattingius, S., Johansson, S., & Razaz, N. Apgar score and neonatal mortality risk in preterm infants, New England Journal of Medicine, 2020, 383(1), 1–10, doi: 10.1056/NEJMoa1915075.
36. BMC Pediatrics Incidence and risk factors for glucose disturbances in premature infants, BMC Pediatrics, 2009, 9(1), 1–6.
37. Rahi, E., Baneshi, M. R., Mirkamandar, E., Haji Maghsoudi, S., & Rastegari, A. A comparison between APGAR scores and birth weight in infants of addicted and non-addicted mothers, Addict Health, 2011, 3(1-2), 61–67, PMID: 24494118; PMCID: PMC.
38. Hegyi, T., Carbone, T., Anwar, M., Ostfeld, B., Hiatt, M., Koons, A., Pinto-Martin, J., & Paneth, N. The Apgar score and its components in the preterm infant, Pediatrics, 1998, 101(1 Pt 1), 77–81, doi: 10.1542/peds.101.1.77.