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Original Article	3500	350 (Structured)	40	6	6
Review Article	5000	350	50	6	10
Case Report	1500	200	15	No tables	5
Letter to the Editor	1000	No abstract	10	No tables	No media
Image	200	No abstract	3	No table	3

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CONTENTS

Zeynep Kamil Med J 2026;57(4):199–203
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ORIGINAL ARTICLE

A pilot study on the role of artificial intelligence in predicting preterm labor

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ABSTRACT

Objective: Preterm labor is a major obstetric challenge that contributes significantly to neonatal morbidity and mortality. This pilot study investigated the feasibility of machine learning techniques for predicting the risk of threatened preterm labor, rather than confirmed preterm birth, among first-time mothers using readily available sociodemographic and obstetric variables.

Material and Methods: This retrospective, single-center study included 102 nulliparous women with singleton pregnancies. Five machine learning models were developed using basic clinical parameters. Model performance was evaluated using an 80/20 training–test split and assessed based on accuracy, ROC-AUC, sensitivity, and specificity.

Results: The XGBoost classifier demonstrated the best performance, with an accuracy of 70% and a ROC-AUC of 0.64. Body mass index and a history of abortus imminens were the most influential predictors.

Conclusion: Machine learning models based on simple clinical data can modestly predict threatened preterm labor. Although these models are not intended for immediate clinical application, the findings demonstrate feasibility and support further large-scale, externally validated studies incorporating maternal and neonatal outcomes.

Keywords: Artificial intelligence, machine learning, nulliparous women, predictive modeling, preterm labor.

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INTRODUCTION

The presence of pain that may result in cervical changes before 37 weeks is known as preterm labor. Term and preterm births are distinguished according to the gestational week at birth.[1]

Not every threat of preterm labor culminates in preterm birth; however, even the possibility necessitates timely identification and intervention.[2] Early detection of threatened preterm labor provides critical opportunities to mitigate risks, prepare for potential preterm delivery, and implement preventive measures such as corticosteroids for fetal lung maturation, tocolytic therapy, or in utero transfer to facilities with neonatal intensive care units.[3] This underscores the importance of predictive approaches that identify threats before clinical progression occurs.

Despite advances in obstetric care, predicting and preventing preterm labor remains a formidable challenge. Notably, more than 50% of preterm labor cases occur without identifiable risk factors, underscoring the limitations of conventional predictive models.[4] Historically, methods for predicting preterm labor have relied on clinical assessments, obstetric history, and diagnostic tools. These include transvaginal ultrasonography for cervical length measurement and biochemical markers such as fetal fibronectin and placental alpha-microglobulin-1.[5] Although these methods provide valuable insights, they are often constrained by variability in interpretation, limited availability, and suboptimal predictive accuracy. The absence of a prior obstetric history in nulliparous women poses an additional challenge, leaving a substantial number of high-risk pregnancies undetected.[6]

The use of artificial intelligence models has begun in the healthcare sector and other domains.[7,8]

The number of published studies on this topic is very limited; however, existing research has employed various approaches to develop models for predicting preterm labor. These studies predominantly use electrohysterogram (EHG) signals, which record uterine electrical activity noninvasively from the abdominal surface.[9] Temporal, spectral, and nonlinear features of these signals are extracted and analyzed. In addition to EHG data, clinical parameters such as cervical length, gestational age, maternal age, and obstetric history are often incorporated. Furthermore, maternal sociodemographic characteristics, including education level, socioeconomic status, and access to healthcare, as well as obstetric features such as parity and a history of preterm birth, play a significant role in identifying the risk of preterm labor.[3,4]

One notable limitation of the existing studies is their predominant reliance on clinical variables collected during or near the onset of preterm labor. Although these data are valuable, their use primarily reflects a labor process that is already in progress rather than predicting the risk of preterm labor before the threat emerges. This approach limits the window for preventive interventions and preparation.

The aim of this study was to establish a novel approach for predicting the threat of preterm labor in primiparous women by leveraging simple and readily available sociodemographic characteristics and obstetric data through machine learning algorithms. By focusing on early and accessible risk assessment, this study aimed to identify potential threats of preterm labor before clinical signs emerged, thereby enabling timely interventions and improved preparation for at-risk pregnancies.

MATERIAL AND METHODS

This retrospective study was conducted among pregnant women admitted to the Department of Obstetrics at the hospital between January 1, 2022, and January 1, 2023, following approval from the Eskişehir City University Ethics Committee (October 17, 2024; Decision No. ESH/BAEK 2024/54). This study was conducted in accordance with the principles of the Declaration of Helsinki.

The inclusion criteria were as follows:

- Age between 18 and 40 years
- A healthy, singleton pregnancy conceived without *in vitro* fertilization
- Availability of complete sociodemographic and clinical data relevant to the study, including age, body mass index (BMI), smoking before pregnancy, and a history of threatened abortion during the pregnancy included in the study
- No history of chronic disease
- No history of previous pregnancy

The data collected from the participants included age, BMI, smoking status, and a history of threatened abortion. These variables were systematically collected to assess their potential contributions to the prediction of preterm labor in the study population.

Data Preparation

According to the guidelines, the presence of pain that could lead to cervical changes before the 37th week of gestation is defined as preterm labor. Specifically, it occurs between 20 and 36 weeks of gestation. Preterm labor may include regular contractions, changes in vaginal discharge, pelvic pressure, and pain resembling menstrual cramps.[10] According to the inclusion criteria, the study population was divided into two groups: participants who did not experience threatened preterm labor during pregnancy (Group 1) and those who did (Group 2).

Statistical Analysis

Statistical analysis was performed using SPSS. Categorical variables were expressed as frequencies and percentages (n [%]). Differences between the groups were assessed using the chi-square (χ^2) test. A p-value <0.05 was considered statistically significant.

Machine Learning Models

The study was designed according to the principles of machine learning (ML). The Extra Trees (Extremely Randomized Trees) Classifier is an ensemble learning method based on decision trees. It differs from Random Forest by using random splits for features instead of optimizing split points, thereby increasing diversity among the trees and potentially reducing overfitting. It is computationally efficient and performs well on large datasets.

Light Gradient Boosting Machine (LGBM) is a highly efficient gradient boosting framework optimized for speed and memory usage. LGBM performs well in classification tasks and is particularly effective in handling categorical variables and imbalanced datasets. Extreme Gradient Boosting (XGB) is a robust implementation of

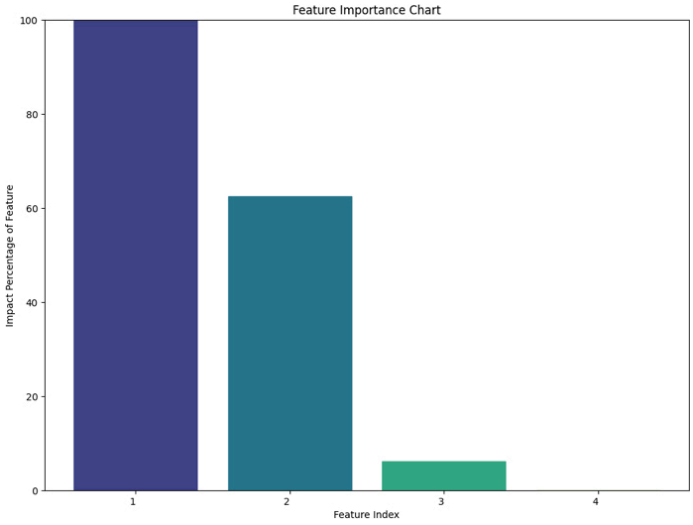

Figure 1: Charts of the variables.

1: BMI, 2: Smoking 3: History of abortion imminens in the pregnancy included in the study. BMI: Body mass index.

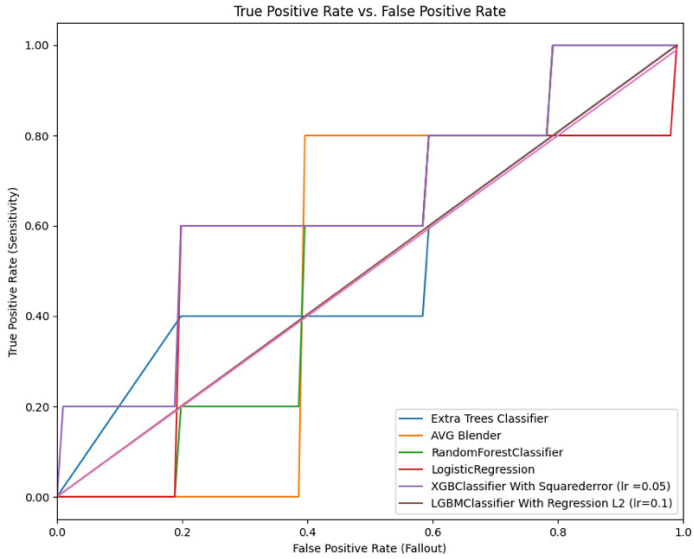

Figure 2: Operator curve graphics.

gradient boosting that focuses on speed and performance. XGB is known for its accuracy and is widely used in competitions and real-world applications.

Random Forest is another ensemble learning method based on decision trees. It constructs multiple decision trees during training and aggregates their outputs through majority voting for classification to improve accuracy and robustness. These models were selected because of their complementary strengths in handling structured data.

Performance Metrics

Eighty percent of the patient data was used to train the artificial intelligence (AI) models, while the remaining 20% was used for testing. The performance of the AI models was then evaluated based on the results obtained.

Feature Selection

The permutation feature importance method was used to identify variables affecting preterm birth. This technique evaluates the effect of each variable by measuring the decrease in the model's performance score when the values of a single variable are randomly shuffled. The permutation feature importance plot is presented in Figure 1.

Python software was used to conduct the ML algorithm analyses.

Due to the limited sample size, external validation and k-fold cross-validation were not feasible. Therefore, the dataset was randomly divided into training (80%) and testing (20%) sets to assess internal performance. The class distribution between the groups was nearly balanced, and no additional resampling techniques were applied.

RESULTS

A total of 102 pregnant women were included in the study. Of these, 52 women (50.98%) did not experience preterm labor (Group 1), whereas 50 women (49.02%) were diagnosed with preterm labor (Group 2). As shown in Table 1, BMI and a history of threatened abortion differed significantly between the two groups (p=0.004 and p=0.001, respectively). All three variables, except age, were included in the model, and BMI was identified as the most important predictor of preterm labor (Fig. 1).

The present study used five distinct machine learning algorithms to predict preterm labor. The results of the algorithms are summarized in Table 2 and Figure 2. The XGBoost Classifier was found to be the best-performing ML technique based on accuracy, ROC-AUC, sensitivity, and specificity (70.0%, 64.0%, 60%, and 80%, respectively).

DISCUSSION

It is important to emphasize that the outcome predicted in this study was threatened preterm labor, not confirmed preterm birth. Threatened preterm labor represents a clinically meaningful condition that frequently leads to hospitalization, closer surveillance, and preventive interventions. Although not all cases progress to preterm birth, early identification may influence maternal management and indirectly affect neonatal outcomes through timely intervention.

Preterm labor remains one of the most challenging topics in obstetric medicine because of its multifactorial nature and unpredictable onset. Its definition, risk factors, and prediction methods continue to be areas of active investigation, as traditional clinical approaches often fail to identify at-risk pregnancies early, particularly in nulliparous women. This condition poses significant risks to both maternal and neonatal health, highlighting the need for accurate and timely prediction to guide preventive measures and optimize outcomes.[2] It is important to emphasize that the outcome predicted in this study was threatened preterm labor, not confirmed preterm birth. Threatened preterm labor represents a clinically meaningful condition that frequently leads to hospitalization, closer surveillance, and preventive interventions. Although not all cases progress to preterm birth, early identification may influence maternal management and indirectly affect neonatal outcomes through timely intervention. Conventional predictive models, which rely heavily on linear statistical methods and clinical

Table 1: The demographic data of the patients

	Preterm labor		
	-	+	p
Age	29.15±4.37	29.0±4.68	0.904[a]
BMI	27.73±3.43	31.19±6.69	**0.004**[a]
Smoking			0.322[b]
-	2 (3.8%)	0 (0%)	
+	50 (96.2%)	50 (100%)	
History of abortion imminens in the pregnancy included in the study			**0.001**[b]
-	22 (42.3%)	2 (4%)	
+	30 (57.7%)	48 (96.0%)	

a: Student t test; b: Chi Square; BMI: Body mass index.

assessments obtained during or near the onset of labor, have shown limited success in addressing the complexity of preterm labor.[11] These models often fail to capture the intricate nonlinear interplay among maternal, fetal, and environmental factors.

Recent advances in machine learning offer promising alternatives by integrating diverse datasets and uncovering hidden patterns within complex data.[12] Unlike traditional methods, machine learning algorithms can process large volumes of diverse inputs, including sociodemographic and obstetric characteristics, to identify subtle risk factors that may precede clinical symptoms.[13] This capability has the potential to transform obstetric care by enabling early and accessible risk stratification, which is particularly crucial for preventing preterm labor in its earliest stages. By shifting the focus to preemptive identification and intervention, these innovative approaches pave the way for improved maternal and neonatal outcomes.[6]

Existing research on preterm labor prediction has predominantly focused on the use of electrohysterogram (EHG) signals combined with obstetric data. Mas-Cabo et al.[9] demonstrated the potential of artificial neural networks (ANNs) for predicting imminent labor within 7 and 14 days in women with threatened preterm labor (TPL), achieving AUC values of 87.1% and 76.2%, respectively. Similarly, Prats-Boluda et al.[3] optimized prediction models using computationally efficient algorithms, such as Random Forest and Extreme Learning Machines, achieving F1 scores of up to 90% for predicting labor within 7 days and highlighting the importance of sensitivity optimization. Mohammadi Far et al.[4] proposed a gestational age-specific approach using empirical mode decomposition (EMD) and AdaBoost classifiers, achieving accuracies of 95% and 93% for recordings obtained before and after the 26th week of pregnancy, respectively. Finally, Shahbakhti et al.[10] introduced a low-complexity algorithm using EMD and Support Vector Machines, achieving remarkable accuracy (99.56%) and sensitivity (98.95%) in distinguishing term from preterm labor. These studies predominantly focused on the use of EHG signals, often combined with obstetric data, to predict preterm labor. Most achieved high predictive accuracy but were limited by small datasets, reliance on complex features, and a lack of generalizability to broader clinical populations.

Table 2: Results of ML algorithms

Model name	ROC-AUC	Accuracy	Interval
Extra trees classifier	0.52	0.5	0.19–0.81
Random forest classifier	0.52	0.5	0.19–0.81
Logistic regression	0.56	0.5	0.19–0.81
XGB classifier	0.64	0.7	0.416–0.984
LGBM classifier	0.5	0.5	0.19–0.81

LGBM: Light gradient boosting machine; XGB: eXtreme gradient boosting.

In this study, we aimed to identify predictive factors for preterm labor by analyzing sociodemographic and obstetric data from a homogeneous population of pregnant women. The study included 102 singleton pregnancies without significant medical conditions. By focusing on variables such as BMI, smoking status, and a history of threatened abortion, we sought to determine their contributions to the risk of preterm labor and develop a predictive model using machine learning algorithms. For the first time in the literature, this study used these variables to predict threatened preterm labor. Data analysis incorporated machine learning algorithms, including the Extra Trees Classifier, Random Forest, Logistic Regression, XGBoost, and LightGBM. Among the variables examined, BMI and a history of threatened abortion emerged as significant predictors. XGBoost demonstrated the best performance, with an accuracy of 70%, sensitivity of 60%, and specificity of 80%, highlighting the potential of simple clinical data for early risk stratification of preterm labor.

Our study offers several advantages over existing research on preterm labor prediction. Unlike previous studies relying on electrohysterogram (EHG) signals and specialized equipment, we used basic sociodemographic and obstetric data, such as BMI, smoking status, and a history of threatened abortion, making our approach more accessible and practical for routine clinical use. By focusing on data available early in pregnancy, our model enables earlier risk stratification than EHG-based studies that primarily

predict imminent labor within a short time frame.[4,9] This is also the first study in the literature to use these simple variables to predict threatened preterm labor, addressing a significant gap in existing research. Additionally, we employed a diverse set of machine learning algorithms, with XGBoost demonstrating superior performance (accuracy: 70%, sensitivity: 60%, specificity: 80%), thereby providing a robust evaluation of different predictive models.

In a review summarizing machine learning studies on preterm birth prediction, it was noted that different algorithms perform optimally for different types of data: artificial neural networks, logistic regression, and random forests for numerical data; support vector machines for electrohysterogram data; recurrent neural networks for text data; and convolutional neural networks for image data. The reported performance measures ranged from 0.79–0.94 for accuracy, 0.22–0.97 for sensitivity, 0.86–1.00 for specificity, and 0.54–0.83 for the area under the receiver operating characteristic curve.[7] Compared with these benchmarks, our study demonstrates the potential of simple sociodemographic and obstetric data to achieve practical predictive performance in preterm labor risk stratification. Our methodology is both cost-effective and practical, avoids the need for complex physiological measurements, and is particularly suitable for resource-limited settings. Furthermore, the rigorous inclusion criteria ensured a homogeneous population, reducing confounding factors and enhancing the reliability and generalizability of our findings.

Limitations

This study has several important limitations. First, the small sample size limits the robustness and generalizability of the machine learning models and likely contributes to the modest predictive performance observed. Second, the retrospective, single-center design and homogeneous population restrict external validity. Third, the outcome of interest was threatened preterm labor rather than confirmed preterm birth, and no maternal or neonatal outcome data were available, limiting direct clinical interpretation. Fourth, external validation and cross-validation were not performed because of sample size constraints. Finally, although the class distribution was nearly balanced, predictive performance remained moderate, indicating that further feature expansion, model optimization, and prospective multicenter validation are required before clinical application.

CONCLUSION

This study demonstrates the feasibility of predicting preterm labor using simple sociodemographic and obstetric variables through machine learning algorithms. Among the variables analyzed, BMI and a history of threatened abortion emerged as significant predictors, with the XGBoost algorithm showing the highest predictive performance. Despite being a pilot study with limitations such as a small sample size, a single-center design, and a lack of external validation, the findings provide valuable insights into the potential of accessible clinical data for early risk stratification of preterm labor. Further research using larger and more diverse populations, together with external validation, is needed to enhance the generalizability and robustness of these models. This study lays the groundwork for cost-effective, scalable, and practical approaches to improving maternal and neonatal outcomes in obstetric care.

Statement

Ethics Committee Approval: The study was approved by Eskişehir City Hospital Ethics Committee (No: ESH/BAEK 2024/54, Date: 17.10.2024).

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ORIGINAL ARTICLE

Five-year trends in modes of delivery in Turkish public hospitals: Maternal age distribution of primary and primiparous cesarean sections

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ABSTRACT

Objective: This study aimed to examine temporal trends in vaginal and cesarean deliveries in public hospitals in Istanbul between 2020 and 2024, with a focus on primary and primiparous cesarean sections across maternal age groups.

Material and Methods: This retrospective, descriptive, multicenter study included delivery records from six public maternity hospitals affiliated with the Ministry of Health in Istanbul, Türkiye. All live births at ≥24 weeks of gestation with complete demographic and delivery data were analyzed. Primary cesarean was defined as the first cesarean delivery in a woman, and primiparous cesarean was defined as a cesarean delivery in a woman giving birth for the first time. Maternal age was categorized into four groups: 15–18, 19–35, 36–39, and ≥40 years. Data were extracted from electronic medical records, cross-verified against official statistics, and analyzed using descriptive statistics, chi-square tests, and the Cochran–Armitage trend test.

Results: A total of 78,998 deliveries were recorded, of which 40,427 (51.1%) were vaginal deliveries and 38,571 (48.9%) were cesarean sections. The annual cesarean rate increased from 45.8% in 2020 to 51.2% in 2023 before slightly declining to 50.9% in 2024 ($p<0.0001$). Primiparous cesareans accounted for 11.8% of births and showed a significant upward trend ($p<0.001$), while primary cesarean rates remained stable (13.1%, $p=0.412$). Most primary and primiparous cesareans occurred among women aged 19–35 years, with notable increases among adolescents.

Conclusion: Cesarean rates in Istanbul's public hospitals remain far above the thresholds recommended by the World Health Organization, with high proportions of primary and primiparous procedures. Targeted strategies addressing high-risk subgroups, standardization of classification systems, and strengthening care through greater involvement of midwives are urgently needed to reduce unnecessary cesarean deliveries.

Keywords: Cesarean rates, maternal age, primiparous.

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INTRODUCTION

Cesarean delivery is a major obstetric procedure performed to safeguard maternal and fetal health. Historically, it was reserved for life-threatening conditions affecting the mother or fetus; however, with advances in surgical techniques, anesthesia, and obstetric care, it has become a common mode of delivery in many countries.[1–3] Although cesarean section (CS) can be a lifesaving intervention when medically indicated, its unnecessary use carries increased risks for both the mother and newborn, including higher rates of maternal morbidity, neonatal respiratory complications, and longer recovery periods.[4–6]

The World Health Organization (WHO) recommends an optimal CS rate of between 10% and 15%.[7] Despite these recommendations, a steady upward trend has been observed globally over the past three decades, with rates surpassing optimal thresholds in many regions.[8,9] In Türkiye, the CS rate increased from approximately 7% in the late 1980s to 60.1% in 2022, representing one of the highest rates worldwide.[10,11] Several factors have been linked to this rise, including improved access to healthcare, changing maternal demographics, patient preferences, medicolegal concerns, and evolving obstetric practices.[12–14]

Among all cesarean deliveries, primary (first-time) and primiparous (first-birth) CSs are of particular concern. Primary cesarean delivery significantly increases the likelihood of repeat cesarean deliveries in subsequent pregnancies, thereby contributing to the long-term increase in national CS rates.[15,16] Primiparous women undergoing cesarean delivery are also at greater risk of complications in future pregnancies, including placenta accreta spectrum disorders and uterine rupture.[17,18] Understanding the distribution of these subgroups across different maternal age categories can inform targeted strategies to reduce unnecessary first-time cesarean deliveries.

Previous studies in Türkiye have investigated cesarean delivery trends, but few have focused specifically on public hospital settings with detailed breakdowns by parity and maternal age group.[19–22] Furthermore, updated local data are needed to evaluate the impact of recent national initiatives, such as the Ministry of Health's "Normal Birth Action Plan," launched in 2024, on delivery practices.[10]

This study aimed to examine the rates of vaginal and cesarean deliveries in public hospitals in Istanbul between 2020 and 2024 and to analyze the distribution of cesarean deliveries according to primary cesarean status, parity, and maternal age group. By identifying patterns in these subcategories, our findings may contribute to evidence-based policymaking and interventions to reduce unnecessary cesarean deliveries in Türkiye.

MATERIAL AND METHODS

This retrospective, descriptive, multicenter study was conducted in six public healthcare facilities located in Istanbul, Türkiye, all of which are secondary- or tertiary-level maternity units affiliated with the Ministry of Health. These hospitals were selected based on their annual delivery volume (>2000 births/year) and the availability of complete electronic medical records for the study period. The participating institutions serve a diverse patient population from different socioeconomic backgrounds, allowing for a representative assessment of delivery trends in the region. Delivery records from January 1, 2020, to December 31, 2024, were reviewed to evaluate temporal changes in vaginal and cesarean deliveries, with a particular focus on primary and primiparous cesarean deliveries.

The study population included all women who gave birth at the participating institutions during the specified period. All live births at ≥24 weeks of gestation with complete maternal demographic and delivery data were eligible for inclusion. Cases with missing information on maternal age, parity, or mode of delivery, as well as stillbirths, were excluded from the subgroup analyses to ensure data consistency.

A primary CS was defined as the first cesarean delivery performed in a woman, regardless of parity, whereas a primiparous CS was defined as a cesarean delivery in a woman giving birth for the first time. These definitions were based on the World Health Organization's recommendations and widely accepted obstetric classification systems.[2] Maternal age was stratified into four categories: 15–18 years, 19–35 years, 36–39 years, and ≥40 years.

Data were extracted from the hospitals' electronic medical record systems by trained research staff and cross-verified against annual birth statistics provided by the Ministry of Health. A double-check procedure was implemented to ensure data accuracy, and inconsistencies were resolved by reviewing the original patient charts. The variables collected included maternal age, parity, gestational age at delivery, mode of delivery (vaginal or cesarean), primary or repeat cesarean status, and parity at the time of cesarean delivery. Missing or incomplete records were documented, and such cases were excluded from the final analysis.

The study was conducted in accordance with the principles of the Declaration of Helsinki. Ethical approval was obtained from the Non-Interventional Clinical Research Ethics Committee of Istanbul Medipol University (Approval No: 902; Date: 31.07.2025). Given the retrospective design and the use of anonymized data, the requirement for informed consent was waived.

Statistical Analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS), version 23.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to summarize the data. Continuous variables were expressed as mean±standard deviation (SD), and categorical variables were expressed as frequencies (n) and percentages (%). Differences in categorical variables between years and maternal age groups were evaluated using the chi-square test or Fisher's exact test, as appropriate. Trends over time in the distribution of delivery modes and subgroup patterns (primary and primiparous CS rates) were assessed using the Cochran–Armitage trend test. When more than two proportions were compared, the Bonferroni correction was applied to adjust for multiple testing. A two-tailed p-value of <0.05 was considered statistically significant. The results were presented in both tabular and graphical formats.

RESULTS

A total of 78,998 deliveries were recorded in six public hospitals in Istanbul between 2020 and 2024. Of these, 40,427 (51.1%) were

Table 1: Distribution of vaginal and cesarean deliveries by year, 2020–2024

Year	Vaginal delivery n (%)	Cesarean section n (%)	Total births n
2020	9,869 (54.2)	8,337 (45.8)	18206
2021	8,714 (52.0)	8,030 (48.0)	16744
2022	8,075 (50.7)	7,849 (49.3)	15924
2023	7,031 (48.8)	7,377 (51.2)	14408
2024	6,738 (49.1)	6,978 (50.9)	13716

vaginal deliveries and 38,571 (48.9%) were CSs. The total annual number of deliveries decreased from 18,206 in 2020 to 13,716 in 2024, representing a 24.6% decline over the five-year period.

The annual CS rate increased steadily from 45.8% in 2020 to a peak of 51.2% in 2023, followed by a slight decline to 50.9% in 2024 (Table 1). Trend analysis confirmed a statistically significant increase in cesarean deliveries over the study period ($p<0.0001$). Despite the minor reduction in 2024, the proportion of cesarean deliveries remained above 50% during the last two years of observation.

During the same period, 7,748 deliveries (11.8% of all births) were primiparous CSs, and 8,523 (13.1%) were primary CSs. The proportion of primiparous cesarean deliveries increased from 11.6% in 2020 to 13.8% in 2023 (Fig. 1), representing a statistically significant upward trend ($p<0.001$).

In contrast, primary CS rates remained relatively stable across the years, ranging from 12.5% to 13.7%, with no statistically significant temporal trend ($p=0.412$). Primary cesarean rates varied by maternal age, with the lowest rates observed in the 15–18-year age group (1.3%) and the highest rates among women aged ≥40 years (6.8%) (Table 2).

When analyzed by maternal age group, the majority of both primiparous and primary cesarean deliveries occurred among women aged 19–35 years, accounting for 86.9% of primiparous CSs and 80.0% of primary CSs across the entire study period. The chi-square test indicated statistically significant differences in the distribution of primiparous and primary cesarean deliveries among age groups ($\chi^2=256.7$, df=3, $p<0.0001$) (Table 2). Notably, the proportion of primiparous CSs in the 15–18-year age group increased from 1.3% in 2020 to 2.6% in 2023, suggesting a concerning upward trend in cesarean deliveries among primiparous adolescents.

DISCUSSION

This multicenter retrospective analysis, encompassing 78,998 deliveries over a five-year period, demonstrates persistently high CS rates in six public maternity hospitals in Istanbul, Türkiye. Although the total number of deliveries declined by 24.6% between 2020 and 2024, the proportion of cesarean deliveries remained close to 50%, exceeding the rate of 10–15% recommended by the WHO as optimal for maternal and neonatal outcomes.[1,2] These findings mirror the rising global trend reported in recent decades, with worldwide CS rates increasing from 6.7% in 1990 to 19.1% in 2014 and some regions, including Latin America and Eastern Europe, surpassing 40%.[7]

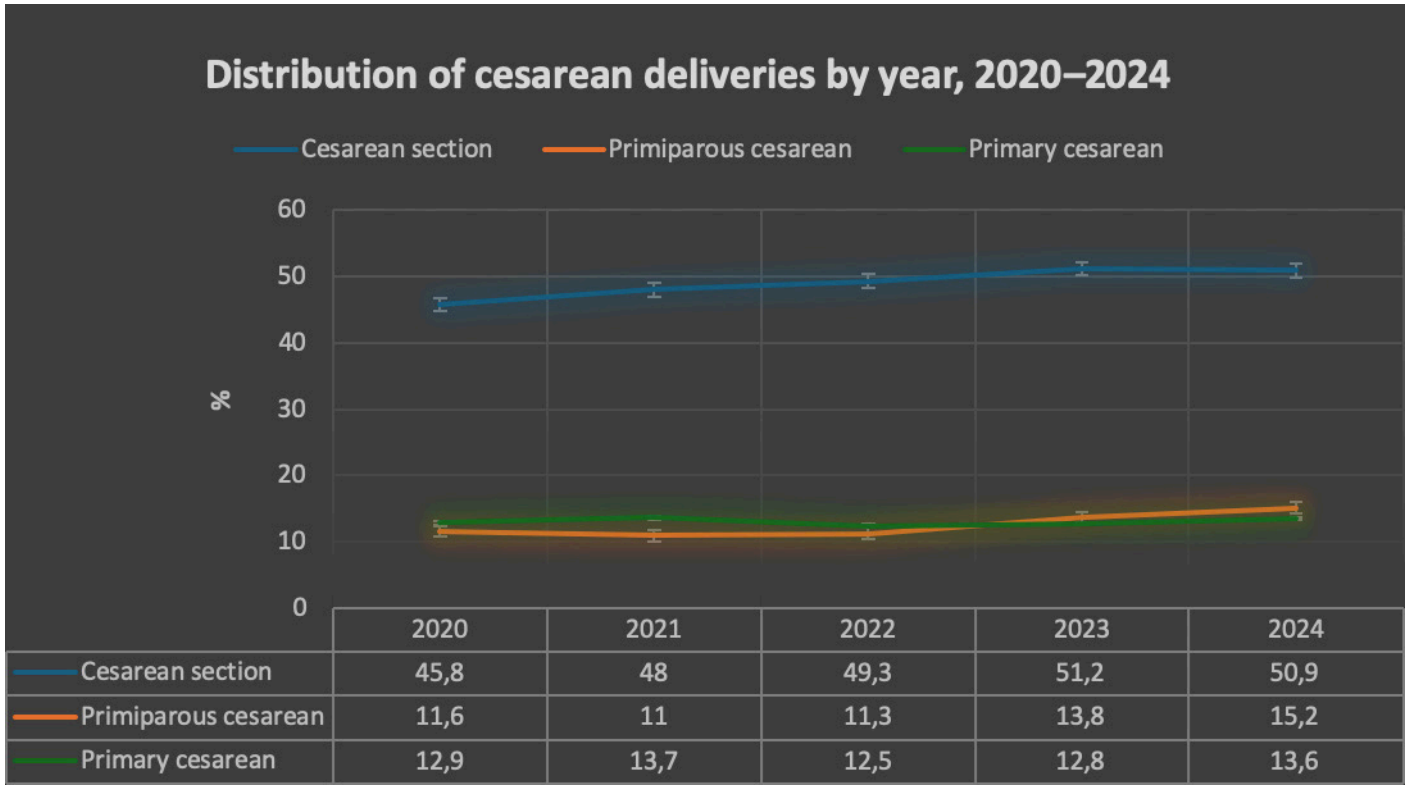

Figure 1: Distribution of cesarean deliveres by year, 2020–2024, %.

Table 2: Distribution of primiparous and primary cesarean deliveries by maternal age group, total for 2020–2024

Years	2020		2021		2022		2023		2024	
Maternal age group	Primiparous cesarean n (%)	Primary cesarean n (%)	Primiparous cesarean n (%)	Primary cesarean n (%)	Primiparous cesarean n (%)	Primary cesarean n (%)	Primiparous cesarean n (%)	Primary cesarean n (%)	Primiparous cesarean n (%)	Primary cesarean n (%)
15–18 years	28 (1.3)	26 (1.1)	46 (2.5)	26 (1.1)	40 (2.2)	26 (1.3)	51 (2.6)	26 (1.4)	45 (2.1)	27 (1.4)
19–35 years	1.796 (85.2)	1.879 (80)	1.620 (87.9)	1.870 (81)	1.565 (87)	1.592 (79.6)	1.730 (86.6)	1.481 (79.8)	1.842 (88.0)	1.485 (80)
36–39 years	196 (9.3)	277 (11.7)	129 (7)	277 (12)	114 (6.4)	247 (12.4)	143 (7.1)	207 (11.2)	131 (6.2)	231 (12.4)
≥40 years	88 (4.2)	178 (7.5)	47 (2.6)	136 (5.9)	80 (4.4)	134 (6.7)	75 (3.7)	141 (7.6)	76 (3.7)	116 (6.2)
Total	**2,108**	**2,360**	**1,842**	**2,309**	**1,799**	**1,999**	**1,999**	**1,855**	**2,094**	**1,859**
Percentage in total births	**11.6%**	**12.9%**	**11.0%**	**13.7%**	**11.3%**	**12.5%**	**13.8%**	**12.8%**	**15.2%**	**13.6%**

Values are presented as n (%), Chi-square test was applied (χ^2=256.7, df=3, p<0.001).

National data from Türkiye similarly indicate a sharp rise in CS rates over the past three decades, increasing from 21.0% in 2002 to 57.5% in 2023.[18,23] This pattern has persisted despite the Ministry of Health's "Normal Doğum Eylem Planı" and other policy initiatives aimed at promoting vaginal delivery.[10,20,21] Our results, showing an increase in the CS rate from 45.8% in 2020 to 51.2% in 2023, underscore the limited effectiveness of current interventions in curbing the overuse of cesarean delivery in public hospitals.

When examined according to parity and maternal age, primiparous CSs accounted for 11.8% and primary CSs for 13.1% of all births during the study period. According to the Türkiye Health Statistics Report 2019, the primary cesarean section rate was 26.5%, while it was reported to be 30.0% in 2020, 30.3% in 2021, 32.5% in 2022, and 32.4% in the 2023 report.[20,21] When primary cesarean section rates in healthcare facilities affiliated with the Ministry of Health were examined, they were found to be 16.8% in 2020, 17.5% in 2021, and 18.5% in 2022. The Ministry of Health's Normal Birth Action Plan states that the primary cesarean section rate between 2018 and 2023 was 28.8%.[10] According to the Health Statistics Yearbook 2023 NUTS-1 data, the primary cesarean section rate in Istanbul was reported to be 36.5%.[21] Our study found that primary cesarean section rates ranged from 12.9% to 13.6% between 2020 and 2024 and that 26.9% of the 38,571 cesarean deliveries performed over the five-year period were primary cesarean sections. Our study data indicate that the primary cesarean section rates in public healthcare facilities between 2020 and 2022 were higher than those reported in the Ministry of Health's Normal Birth Action Plan and the 2020–2023 Türkiye Health Statistics Reports.[10]

According to 2023 Turkish Statistical Institute data, the highest age-specific fertility rate in 2001 was 144 per thousand in the 20–24-year age group, whereas in 2023, it was 101 per thousand in the 25–29-year age group.[18] The mean age of mothers giving birth for the first time in 2023 was 27.0 years, and 40.6% of births were primiparous. According to data from the 2018 Türkiye Demographic and Health Survey, the median maternal age at the first birth was 23.3 years, and the highest age-specific fertility rate was observed in the 25–29-year age group. Furthermore, approximately 3% of women aged 15–19 years had given birth.[16] Our study data indicated that primiparous cesarean rates among women aged 15–18 years ranged from 1.3% to 2.6% between 2020 and 2023. Primiparous cesarean rates among women aged 19–35 years were also significantly higher than those in the other age groups over the four-year period. Our study found that adolescent primiparous cesarean rates are increasing, with the highest number of cesarean sections occurring among women aged 19–35 years. The majority of cases occurred among women aged 19–35 years, consistent with previous studies reporting that reproductive-aged women without prior deliveries are particularly vulnerable to undergoing their first CS.[4,6,24] Robson's Ten-Group Classification System (TGCS), which is widely recommended for the standardized auditing of CS practices, identifies Group 2—nulliparous women with a term, singleton, cephalic pregnancy who undergo induction of labor or prelabor CS—as a key contributor to rising rates.[4,8] Although TGCS data were not available for this study, our findings strongly suggest that nulliparous term pregnancies represent a major target group for intervention in Türkiye.

Several factors likely contribute to the persistently high CS rates observed. Medically, the increased use of elective CS for non-reassuring fetal status, suspected macrosomia, or previous uterine surgery is well documented.[8,25] Demographic trends, such as advanced maternal age and higher rates of assisted reproduction, may also play a role.[7,19] Sociocultural drivers, including maternal requests for CS due to fear of labor pain, perceptions of safety, or convenience, are particularly influential in Türkiye, where studies have shown that both patient preference and provider convenience influence the mode of delivery.[15,26] Moreover, medicolegal concerns among obstetricians, financial incentives within certain healthcare system structures, and insufficient midwifery-led care models further perpetuate high CS rates.[13,14,16]

Ethical considerations also warrant discussion. Although maternal autonomy should be respected, professional guidelines emphasize the importance of fully informed decision-making, particularly when maternal requests for CS are not supported by clinical indications.[12,15] In Türkiye, the ethical debate is ongoing, with recent nursing and midwifery literature calling for more comprehensive counseling and shared decision-making practices.[14,15]

From a health policy perspective, our findings reinforce the urgent need to strengthen evidence-based interventions to reduce unnecessary CSs. The "Normal Doğum Eylem Planı," initiated by the Ministry of Health in 2024, aimed to promote vaginal delivery through standardized labor protocols, training of obstetric staff, and public education campaigns. However, variability in its adoption across institutions and insufficient monitoring likely limited its overall impact on reducing cesarean rates. Additional policy initiatives, such as hospital-based incentives for vaginal births and national campaigns encouraging midwife-led care, have also been implemented. Nevertheless, persistently high cesarean rates suggest that sociocultural factors, patient preferences, and medicolegal concerns continue to undermine policy effectiveness. International experience suggests that continuous labor support, promotion of midwife-led models, use of standardized labor management protocols, and public education campaigns can effectively lower primary CS rates.[1,13] Integrating the TGCS into routine hospital reporting could facilitate more targeted strategies by identifying the groups contributing most to CS rates.[4] Moreover, combining policy interventions with TGCS-based audits and targeted strategies for high-contributing groups, such as nulliparous women with term pregnancies, could enhance the effectiveness of national policies in Türkiye.

The strengths of this study include its large sample size, multicenter design, and standardized data collection across six secondary- and tertiary-level public hospitals. These features enhance the generalizability of the findings to similar urban healthcare settings in Türkiye. However, the retrospective nature of the study limits causal inference, and the lack of data on CS indications, Robson classification groups, and maternal and neonatal outcomes constrains more granular analyses. Additionally, potential interhospital variability in clinical protocols and patient populations could not be fully accounted for.

Future research should adopt prospective, multicenter designs incorporating TGCS classification and detailed analyses of indications to better identify modifiable drivers of primary and primiparous CSs. Qualitative studies exploring patient and provider perspectives may also elucidate sociocultural influences unique to the Turkish healthcare context.

CONCLUSION

In conclusion, this multicenter analysis reveals that cesarean section rates in public hospitals in Istanbul remain well above WHO-recommended thresholds, with persistently high proportions of primary and primiparous procedures, particularly among women aged 19–35 years. These findings highlight the limited impact of current national initiatives to promote vaginal birth and underscore the need for targeted, evidence-based interventions. The adoption of standardized classification systems, strengthening of midwifery-led care, and expansion of public education efforts are essential to reduce unnecessary CS rates and improve maternal and neonatal health outcomes in Türkiye.

Statement

Ethics Committee Approval: The study was approved by Istanbul Medipol University Ethics Committee (No: 902, Date: 31.07.2025).

Informed Consent: Given the retrospective design and the use of anonymized data, the requirement for informed consent was waived.

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ORIGINAL ARTICLE

Perinatal and neonatal outcomes of multiple pregnancies in the middle black sea region: The role of assisted reproductive technology

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ABSTRACT

Objective: Due to the increased frequency of multiple pregnancies associated with the growing use of assisted reproductive technologies (ART), babies born from multiple pregnancies continue to attract global attention. Whether conceived through ART or spontaneously, newborns from multiple pregnancies require neonatal intensive care services much more frequently than singletons and have increased morbidity and mortality rates. Furthermore, some researchers argue that ART alone, regardless of the number of fetuses, may contribute to increased morbidity and mortality. In this study, we aimed to determine the morbidity and mortality rates in multiple pregnancies and identify the factors influencing these outcomes.

Material and Methods: Data on babies born or miscarried from multiple pregnancies between January 2008 and June 2013 at a single university hospital were investigated. Data on the patients and their mothers were collected retrospectively. Data on gestational age, birth weight, ART use, plurality, and sex were evaluated in relation to morbidity and mortality.

Results: A total of 488 babies were born from multiple pregnancies during the study period, and 49.6% of them were conceived through ART. The number of ART-related multiple pregnancies decreased over the years. Of the babies, 60.9% were born between 32 and 37 weeks of gestation, and 53.9% had birth weights between 1500 and 2500 g. Prematurity and its severity were found to be higher in infants born from ART-related multiple pregnancies (p=0.00). Newborns conceived via ART had a significantly lower gestational age at birth (32.59±3.57 vs. 34.17±3.36 weeks) and significantly lower birth weights (1953±672 vs. 2088±621 g).

Conclusion: In conclusion, we observed an increased frequency and severity of prematurity among newborns from ART-related multiple pregnancies. Mortality rates demonstrated a declining trend over time, in parallel with the reduced use of ART. These findings, highlighting prematurity as a major risk factor in multiple births, emphasize the critical importance of implementing strategies aimed at preventing multiple pregnancies in ART practices.

Keywords: Assisted reproductive technology, multiple pregnancy, preterm, triplet, twin.

This article is based on Emine Genç's master's thesis, which is a retrospective study. Some parts of this study were previously presented at the "10th Marmara Pediatrics Congress 2023." The title of the oral presentation (SS-005) was: "Retrospective Evaluation of 5-Year Single-Center Follow-up Data for Infants Born from Multiple Pregnancies and Results of the Denver-2 Screening Test."

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INTRODUCTION

Multiple-pregnancy births account for 3–4.5% of all births.[1–3] Twin births account for most multiple pregnancies (80–97.3%).[2] Half of pregnancies conceived through assisted reproductive technology (ART) result in multiple pregnancies.[2–4] The incidence of multiple pregnancies has increased with the use of ART; consequently, the frequency of complications related to multiple pregnancies has also increased.[2,4] In addition, the use of ART independently increases maternal and neonatal morbidity and mortality.[5–10]

Newborns from multiple-pregnancy births have increased rates of prematurity, preterm premature rupture of membranes (PPROM), low birth weight (LBW), growth discordance, respiratory distress syndrome (RDS), twin-to-twin transfusion syndrome (TTTS), cerebral palsy (CP), intracranial hemorrhage (ICH), bronchopulmonary dysplasia (BPD), retinopathy of prematurity (ROP), prolonged hospital stays, and mortality.[1,2,11] Multiple pregnancies account for 15–20% of preterm births.[12] The risk of prematurity among newborns from multiple pregnancies increases because the duration of pregnancy decreases as the number of fetuses in utero increases.[1] Furthermore, compared with preterm singletons, premature multiples have a 3–8-fold higher mortality rate. Therefore, multiple pregnancy represents an independent risk factor, regardless of gestational age.[1,11,13] Multiple pregnancies have increased rates of LBW, intrauterine growth restriction (IUGR), and small for gestational age (SGA). During the first and second trimesters, the intrauterine growth pattern is similar between multiples and singletons. However, during the third trimester, the growth of multiples is markedly impaired. Intrauterine growth restriction begins at approximately 30 weeks for twins and between 26 and 30 weeks for triplets. Thus, IUGR occurs in 25–30% of twins.[14] The incidence of LBW is 63% among all multiples, whereas it is 22% among all live births.[15] LBW and prematurity are the most important risk factors that increase the morbidity and mortality of multiples.[2]

In our study, we aimed to identify mortality rates and problems occurring during the antenatal, perinatal, and postnatal periods of multiple-pregnancy births, as well as the contributing factors, particularly ART.

MATERIAL AND METHODS

This study was conducted at Ondokuz Mayıs University Faculty of Medicine Hospital and included all multiple-pregnancy births (stillbirths, live births, or abortions) between January 1, 2008, and June 30, 2013. Retrospective data from 488 multiple-pregnancy births included antenatal follow-up, birth records, neonatal intensive care unit (NICU) admissions, diagnoses, treatments, and post-discharge complications. The inclusion criteria were as follows: 1) being born from a multiple pregnancy at Ondokuz Mayıs University, even if any of the babies were stillborn or aborted; and 2) being born from a multiple pregnancy but transferred to a different NICU. The families of these transferred babies were contacted by telephone to collect information. The exclusion criterion was being born from a multiple pregnancy at a different hospital and subsequently transferred to our NICU.

The ICD-10 criteria were applied to define fetal and perinatal deaths.[16] Death rates were calculated according to World Health Organization (WHO) formulas.[16] Abortions were not included in the calculation of perinatal deaths because they all occurred before 20 weeks of gestation. Newborns born before 32 weeks of gestation were defined as very preterm. The Lubchenco birth weight curve was used to define small for gestational age (SGA), appropriate for gestational age (AGA), and large for gestational age (LGA). The American Academy of Pediatrics criteria were used for ROP grading, the Volpe grading criteria and ultrasonography were used to define and grade ICH, and the Bell criteria were used to diagnose and grade NEC.

Ethics committee approval was obtained for this study from the Ondokuz Mayıs University Clinical Research Ethics Committee (Decision No: 2014/634). This study was conducted in accordance with the Declaration of Helsinki.

Statistical Analysis

SPSS version 15.0 for Windows was used for data analysis. The chi-square test was used to compare categorical data, and the Kolmogorov–Smirnov test was used to assess the normality of continuous variables. Student's t-test was used to compare normally distributed continuous variables, and the Mann–Whitney U test was used to compare non-normally distributed continuous variables. For comparisons among three groups, one-way analysis of variance (ANOVA) was used for normally distributed data, and the Kruskal–Wallis test was used for non-normally distributed data. When a significant difference was detected among the three groups using ANOVA or the Kruskal–Wallis test, the source of the difference was determined using the Bonferroni-corrected Mann–Whitney U test. Logistic regression analysis was applied to parameters that differed between the spontaneous and ART groups to adjust for the confounding effects of interrelated parameters.

RESULTS

In this study, we collected data from 488 newborns from multiple pregnancies and their mothers: 470 (96.3%) live-born newborns, 13 (2.7%) stillborn newborns, and 5 (1%) aborted fetuses. The stillbirth rate among multiple pregnancies was 26.9‰. Twins accounted for 89.8% (n=438) of the babies, triplets for 8.7% (n=42), and quadruplets for 1.5% (n=8). Of the multiples, 50.4% (n=246) were born from spontaneous pregnancies, and 49.6% (n=242) were born from ART pregnancies. Of the ART-conceived babies, 93.4% (n=226) were conceived through IVF, and 6.6% (n=16) were conceived through intrauterine insemination (IUI). Of the 18 fetuses that were stillborn or aborted, 50% were from ART pregnancies and 50% were from spontaneous pregnancies (p=0.59). The normal vaginal delivery rate was 10.6% (n=52), and the cesarean section rate was 89.4% (n=436). The male-to-female ratio was 0.99.

The mean maternal age was 29.55±4.97 years (range, 18–46 years), and the mean gestational age at birth was 33.4±3.5 weeks (range, 23–40 weeks). A total of 71 babies (14.5%) were born at term, whereas 417 (85.5%) were born preterm. Of the preterm infants, 119 (28.5%) were born before 32 weeks of gestation. The mean gestational age was 33.6±3.49 weeks (range, 23–40 weeks) for twins, 32.68±2.56 weeks (range, 26.2–37 weeks) for triplets, and 25.5±0.53 weeks (range, 25–26 weeks) for quadruplets. Term

Table 1: Comparison of multiple pregnancies conceived via ART versus spontaneous

	Spontaneous (n=246)	ART (n=242)	p
Mean maternal age (years) (min–max)	28.61±5.51 (18–42)	30.5±4.11 (21–46)	<0.001
Mean birth weight (gram) (min–max)	2088 ±621 (520–3040)	1953±672 (550–3000)	0.011
Mean gestational age (week) (min–max)	34.17±3.36 (23–40)	32.59±3.57 (23–38)	<0.001
Number of term babies (n=71)	48 (19.5%)	23 (9.5%)	0.002
Prematurity rate (%) %85.4 (n=417)	80.5%, 198	90.4%, 219	<0.001
Term /preterm ratio	24.2%	10.4%	<0.001
Very preterm (<32 weeks) babies (n=119) (48.3%)	38, 15.4%	81, 33.4%	<0.001

ART: Assisted reproductive technologies; Min: Minimum; Max: Maximum. Fisher Chi-Square; Student T-test.

Table 2: Perinatal, neonatal, and infant mortality rates of infants from multiple pregnancies

	Stillbirth baby	Exitus in delivery room	Exitus at 0–7. days	Exitus at 8-28. days	Exıtus after 28th day.	Exitus after discharge before 1 year	Total
Patient count	13	1	28	1	1	2	46
	Perinatal death: 42 (86‰)						
		Neonatal death: 30 (61‰)					
			Infant death: 33 (70‰)				

delivery occurred in 3 triplets (7.1%) and 68 twins (15.6%). Of the 71 term babies, 48 (67%) were born from spontaneous pregnancies (Table 1). In both groups, the majority of babies were born between 32 and 37 weeks of gestation (spontaneous group: 160 babies [65%] vs. ART group: 137 babies [56.6%]). The mean maternal age was 28.61±5.51 years (range, 18–42 years) in the spontaneous pregnancy group and 30.5±4.11 years (range, 21–46 years) in the ART group, and the difference was statistically significant (p<0.001).

In our study, the mean birth weight was 2021±649 g (range, 520–4040 g); 74.2% of the babies weighed less than 2500 g at birth, and 21.3% weighed less than 1500 g. The mean birth weights of twins, triplets, and quadruplets were 2067±649 g, 1787±354 g, and 748±82 g, respectively. The birth weights of all quadruplets were below 1000 g. The differences in mean birth weight were statistically significant both between twins and triplets and between triplets and quadruplets (p=0.01 and p<0.001, respectively). Newborns conceived spontaneously had a higher mean birth weight (2088±621 g) than those conceived through ART (1953±672 g) (Table 1).

Of the 470 live-born newborns, 56 (11.9%) did not require NICU admission. One baby (0.2%), born at 24 weeks of gestation and weighing 550 g, died in the delivery room. Of the 413 babies (87.9%) requiring neonatal intensive care, 3 (0.6%) were referred to other centers, and 410 (87.3%) were admitted to our hospital's NICU. Of the 410 babies followed in our hospital's NICU, 9 (3.1%) were transferred to other departments and/or centers, and 30 (7.3%) died. A total of 371 babies (90.3%) were discharged (Table 2). The perinatal and neonatal mortality rates were 86‰ and 61‰, respectively (Table 2). Of the 371 discharged infants, 2 died after discharge before reaching 1 year of age. Of these 2 infants, 1 died at home due to sudden infant death, and the other died due to sepsis resulting from gastrostomy leakage. The infant mortality rate was 70 per 1000 live-born babies from multiple pregnancies (n=470, 96.3%) (Table 2).

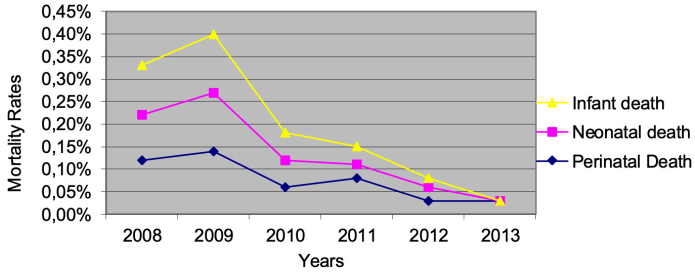


Figure 1: Mortality rates by years.

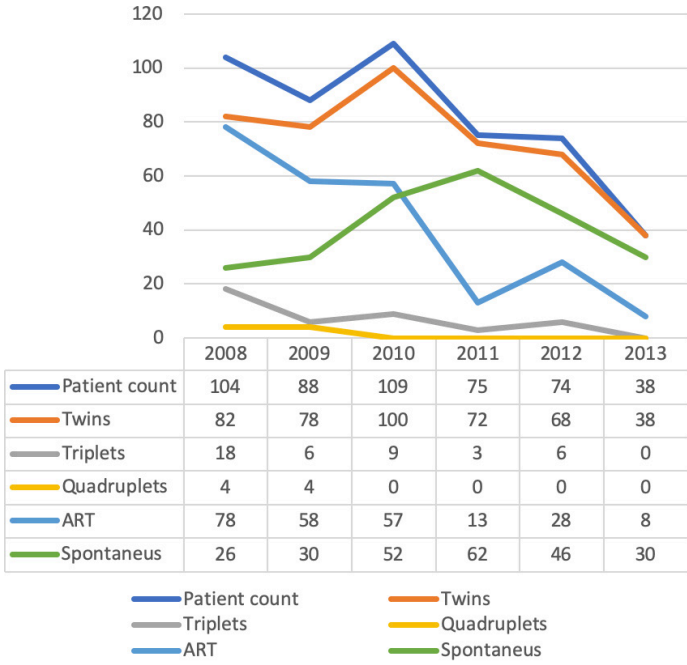
Of the 8 quadruplet infants, 2 (25%) were stillborn, and the remaining 6 (75%) died in the NICU. The neonatal, perinatal, and infant mortality rates for quadruplet pregnancies were 1000 per 1000. Among the 42 triplets, 1 (2.4%) was stillborn, and 1 (2.4%) died on the day of delivery in the NICU. The perinatal, neonatal, and infant mortality rates among triplets were 47‰, 24‰, and 24‰, respectively. For twins (n=438), the neonatal, perinatal, and infant mortality rates were 49‰, 69‰, and 54‰, respectively. Over the years, the perinatal, neonatal, and infant mortality rates showed a declining trend (Fig. 1). In addition, the numbers of twins, triplets, quadruplets, and infants from ART-related multiple pregnancies also decreased over the years (Fig. 2).

The mean length of stay in the NICU was 11.7±14.8 days (range, 1–85 days). Among newborns requiring intensive care, 38% had a 5-minute Apgar score below 8 (p<0.001). Newborns

with a 5-minute Apgar score <8 had a longer mean NICU stay (18.29±18.96 days) than those with a score ≥8 (7.75±8.89 days), and this difference was statistically significant (p<0.001). Prematurity was the most frequent indication (76%) for NICU admission. A total of 152 newborns (32.4%) were admitted to the NICU solely because of prematurity, and 215 (43.8%) were admitted because of prematurity plus another diagnosis (Table 3). Among the 410 NICU patients, 373 (90%) had prematurity listed as one of their admission diagnoses. Among the 71 term infants, 35 (49.2%) required NICU care, and in 24 of these infants (68.5%), at least one of the admission diagnoses was SGA. Notably, 20 term newborns (57.1%) were admitted to the NICU for SGA alone. Among term newborns, the primary diagnosis for NICU admission was SGA (68.5%), and the second most common diagnosis was transient tachypnea of the newborn (TTN) (n=7, 9.8%). Analysis of variance (ANOVA) and logistic regression analysis indicated that conception through ART in multiple pregnancies was associated with higher rates of prematurity and very preterm birth but did not increase the risk of other morbidities (Table 3).

DISCUSSION

In this study, we examined 246 babies from spontaneous multiple pregnancies and 242 from the ART group. Thus, the frequency of ART use among multiple pregnancies was 49.6%. The rate of ART use in our study (49.6%) was higher than that reported by Sezer, who found a rate of 25.3% among twins in a study conducted in our country.[2] The sample sizes of the ART and spontaneous pregnancy groups were similar. Having similar sample sizes in the ART and spontaneous pregnancy groups contributed to the statistical power of the study.



	2008	2009	2010	2011	2012	2013
Patient count	104	88	109	75	74	38
Twins	82	78	100	72	68	38
Triplets	18	6	9	3	6	0
Quadruplets	4	4	0	0	0	0
ART	78	58	57	13	28	8
Spontaneus	26	30	52	62	46	30

Figure 2: Numbers of multiples and use of reproductive technologies by years.

The number of ART-associated multiple pregnancies progressively declined over the years in our study (Fig. 2). This finding supports the effectiveness of the legal regulations enacted in our country in 2010 in achieving their intended aim of reducing ART-related multiple pregnancies.[2,17] In our country, the first regulation concerning assisted reproductive technologies was published in 1987. Amendments introduced in 2005 stipulated that more than three embryos should

Table 3: Morbidities in newborns via spontaneous conception versus assisted reproductive technologies*

Clinical features and comorbidities	Pregnancy type		Odds ratio (ART/spontaneous)	95% CI
	ART	Spontaneous		
Frequency of prematurity (%)	90.5	80.5	2.298*	1.348–3.915
Frequency of very premature (<32 weeks) (%)	37.2	19.2	2.489*	1.591–3.896
PROM (%)	19.5	20.7	0.926	0.595–1.443
LBW (%)	76.9	73.4	1.208	0.799–1.828
NICU admission (%)	86.4	82.9	0.767	0.467–1.258
Ventilator requirement (%)	38.0	30.1	0.701	0.481–1.022
RDS (%)	11.6	9.8	0.826	0.464–1.471
BPD (%)	3.3	1.2	0.361	0.095–1.378
ROP (%)	15.3	10.2	0.627	0.365–1.708
TTTS (%)	1.7	4.1	0.397	0.123–1.282
ICH (%)	5.8	3.7	0.618	0.263–1.457

*: P<0.05, Logistic regression analysis was applied to spontaneous and ART groups for every single parameters which are different according to comparement and variance analysis. ART: Assisted reproductive technologies; BPD: Bronchopulmonary dysplasia; CI: Confidence interval; LBW: Low birth weight; PROM: Premature rupture of membranes; ICH: Intracranial hemorrhage; RDS: Respiratory distress syndrome; ROP: Retinopathy of prematurity; TTTS: Twin-to-twin transfusion syndrome.

not be transferred.[18] The regulations issued in 2010 and 2014 further stipulated that the development of more than two follicles should be avoided in conventional ovulation induction cycles and that no more than one embryo should be transferred.[19,20] In our study, following the implementation of these legal regulations, we observed a reduction not only in the number of infants born from ART-related multiple pregnancies but also in perinatal and neonatal mortality rates (Fig. 1). We considered that the reduction in ART-related multiple pregnancies achieved through restrictions on the number of embryos transferred was an important contributing factor to the observed decline in mortality rates.

In our study, the fetal mortality rate was 26.9‰, and there was no significant difference in the fetal mortality rate between the spontaneous pregnancy and ART groups. In Sezer's study, the fetal mortality rate among twins was reported as 12‰, irrespective of the reproductive technique used.[2] We considered that the inclusion of triplet and quadruplet pregnancies in our study contributed to the higher fetal mortality rate (26.9‰). When mortality rates were examined according to the number of fetuses, mortality increased as the number of fetuses increased. This finding is consistent with the literature, which indicates that an increase in the number of fetuses is closely associated with higher mortality.[1,21,22] In parallel with the declining number of ART pregnancies over the years, the incidence of triplet and quadruplet pregnancies and the associated mortality rates also decreased (Fig. 2). This finding suggests that limiting the number of embryos transferred may have had a beneficial effect on mortality. However, the experience gained in maternal and fetal care and improvements in neonatal intensive care services may also have contributed to the observed reduction in mortality.

Multiple pregnancies, whether spontaneous or resulting from ART, tend to increase with advanced maternal age.[4] In our study, the mean maternal age in the ART group was higher than that in the spontaneous pregnancy group (Table 1). The higher mean maternal age in our study may have contributed to increased morbidity and mortality. In spontaneous conceptions, the mean maternal age and the frequencies of preterm and very preterm birth were lower, whereas gestational age and term delivery rates were higher (Table 1).

The cesarean section rate observed in our study (84.9%) was higher than that reported in the literature (41%).[23] The elevated mean maternal age may also have contributed to this outcome. Furthermore, in our country, particularly for pregnancies achieved through ART, both obstetricians and families often prefer cesarean delivery because they may be unwilling to accept the inherent risks associated with vaginal birth. Although high cesarean section rates have been reported in multiple pregnancies in the literature for similar reasons, the rate observed in our study was even higher than the previously reported rate of 41%.[23] This may be because the hospital in which we conducted the study is a tertiary care hospital.

The higher the number of fetuses in utero, the lower the gestational age at delivery; all quadruplet pregnancies were delivered before 32 weeks of gestation. The rate of full-term delivery among newborns conceived via ART (9.5%) was markedly lower than that in the spontaneous pregnancy group (19.5%). Newborns conceived via ART exhibited both a higher incidence and greater severity of prematurity (Table 1, 3). Among newborns from spontaneous multiple pregnancies, the frequencies of full-term delivery and birth weight over 2500 g were higher than those in the ART group. These findings were consistent with studies supporting the view that ART use increases the risk of prematurity.[4] Conversely, there are also studies in the literature suggesting that prematurity is the most important cause of morbidity in multiple pregnancies and that ART does not constitute an additional risk factor.[11] In a multicenter study conducted in our country on newborns conceived via ART, high rates of morbidity, including LBW, RDS, and NEC, were attributed to the high number of multiple pregnancies, emphasizing that reducing the number of multiple pregnancies could decrease neonatal morbidity and mortality.[11] In other words, the authors stated that ART use itself did not constitute a risk factor.[11] Conversely, in our study, we found that ART use contributed to morbidity and mortality by increasing the rate and severity of prematurity.

Along with prematurity, LBW is also an important factor influencing morbidity and mortality.[1] Consistent with this, we found that the frequency of LBW was 74.2% (n=362) and that an increase in the number of fetuses was associated with a decrease in mean birth weight. The LBW rate was higher in the ART group. However, we could not support the hypothesis that ART increases the risk of LBW (Table 3). Mean birth weight was similar between the ART and spontaneous pregnancy groups, but the frequency of LBW was higher in the ART group (Table 1). SGA was also the reason for NICU admission in 57.1% of term multiples. This finding supports the view that multiple pregnancies are independent risk factors for SGA and LBW. In contrast to our findings, a study of very low birth weight (VLBW) infants in South Korea suggested that ART was associated with better neonatal outcomes.[24] That study also recommended the use of ART because of the high incidence of infertility in the country.[24] Although the authors argued that LBW, ART use, and multiple pregnancy did not constitute risk factors for neonatal outcomes, they also found an increased risk of intraventricular hemorrhage (IVH) in the ART group.[24]

However, we could not support the hypothesis that ART increases the risk of LBW (Table 3). Mean birth weight was similar between the ART and spontaneous pregnancy groups, but the frequency of LBW was higher in the ART group (Table 1). SGA was also the reason for NICU admission in 57.1% of term multiples. This finding supports the view that multiple pregnancies are independent risk factors for SGA and LBW. In contrast to our findings, a study of very low birth weight (VLBW) infants in South Korea suggested that ART was associated with better neonatal outcomes.[24] That study also recommended the use of ART because of the high incidence of infertility in the country.[24] Although the authors argued that LBW, ART use, and multiple pregnancy did not constitute risk factors for neonatal outcomes, they also found an increased risk of intraventricular hemorrhage (IVH) in the ART group.[24]

We found higher frequencies of prematurity, SGA, LBW, and morbidity. However, statistically, ART was associated only with an increased frequency and severity of prematurity. Prematurity and LBW/SGA are known to be important risk factors for neonatal outcomes, regardless of the mode of conception.[25] In our study, logistic regression analysis showed that the risk of LBW was not higher in the ART group because other comorbidities were associated with prematurity. Factors other than prematurity lost their statistical significance after logistic regression analysis. However, considering that 87.9% of the multiples required hospitalization, with a mean length of stay of 11.7±4.8 days, the burden associated with multiple pregnancy becomes evident. The Apgar score still appears to be an effective method for predicting the need for NICU admission because we found that low Apgar scores were associated with both an increased need for NICU admission and a longer mean hospital stay.

The inclusion of higher-order multiple pregnancies and detailed neonatal outcome data are notable strengths of our study. The retrospective design, single-center setting, and lack of data on long-term neurodevelopmental outcomes, chorionicity, and ART indications are limitations of the study.

CONCLUSION

In conclusion, although ART use alone could not be shown to be associated with increased morbidity and mortality, both the frequency and severity of prematurity were higher in the ART group. As the number of fetuses increased, the incidence of prematurity and LBW, as well as mortality rates, also increased. Based on these findings, limiting the number of embryos transferred during ART appears to be an appropriate approach. Furthermore, preventing prematurity is the most crucial factor in reducing morbidity and mortality associated with multiple pregnancy. ART may function as a proxy for advanced maternal age, infertility diagnosis, or obstetric management practices rather than as an independent biological risk factor. Additional analyses are needed to adjust for independent factors influencing the mode of conception.

Statement

Ethics Committee Approval: The study was approved by Ondokuz Mayıs University Clinical Research Ethics Committee (No: 2014/634, Date: 24.04.2014).

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ORIGINAL ARTICLE

Evaluation of nutritional anemia as a risk factor for childhood allergic diseases

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ABSTRACT

Objective: This prospective observational study aimed to evaluate the prevalence of allergic diseases in children with nutritional anemia caused by iron, vitamin B12, or folate deficiencies using clinical assessment tools, including the ISAAC questionnaires, skin prick testing, and laboratory markers.

Material and Methods: Between July 2013 and February 2014, a total of 123 children aged 3–18 years, including 77 children with anemia and 46 controls, were prospectively evaluated at Zeynep Kamil Women and Children's Health Training and Research Hospital. The ISAAC questionnaires were administered to determine the frequency of asthma, allergic rhinitis, and atopic dermatitis. Complete blood count, ferritin, serum iron, folic acid, vitamin B12, total IgE, and eosinophil levels were analyzed, and skin prick testing was performed.

Results: Allergic disease was detected in 24.7% of the patient group and 30.4% of the control group. No significant differences were found between the groups in the rates of physician-diagnosed asthma (1.3% vs. 4.3%), allergic rhinitis (22.1% vs. 26.1%), or atopic dermatitis (1.3% vs. 0%) ($p>0.05$). The frequency of atopy was 15.8% in the patient group and 14.2% in the control group. No differences were found in total IgE or eosinophil levels.

Conclusion: Nutritional anemias, including iron deficiency anemia and vitamin B12 and folate deficiencies, were not found to increase the frequency of allergic diseases in children. In line with the current literature, it was concluded that this relationship may be bidirectional (allergic disease → anemia or anemia → atopic severity) and that larger prospective studies are needed.

Keywords: Allergic diseases, atopy, folic acid, iron deficiency anemia, ISAAC, nutritional anemia, skin prick test, vitamin B12.

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INTRODUCTION

Nutritional anemias are disorders characterized by impaired erythropoiesis and decreased hemoglobin concentrations due to inadequate intake of essential micronutrients such as iron, folic acid, and vitamin B12. This condition is particularly important for growth and development, regulation of the immune response, and maintenance of cognitive functions in childhood.[1] According to the World Health Organization, approximately two billion people are anemic worldwide, and more than 80% of them live in developing countries. The regional prevalence of anemia in preschool children has been reported as approximately 74.6% in Africa, 76.7% in the Americas, 85.1% in Southeast Asia, 26.5% in Europe, 67.4% in the Eastern Mediterranean, and 90.4% in the Western Pacific.[2] These high rates indicate that anemia remains a significant health problem in early life.

National studies and field surveys from Türkiye show that the prevalence of anemia differs across age groups and geographical regions and that iron deficiency anemia affects approximately 15%–62% of children.[3–7] Iron plays a central role in oxygen transport, energy production, DNA synthesis, and immune system function. Its deficiency may lead to impaired growth, reduced cognitive performance, and increased susceptibility to infections. Folic acid and vitamin B12 deficiencies also contribute to clinical morbidity by impairing hematopoietic and nervous system functions.[8,9] Therefore, nutritional anemias should be considered not only in terms of hematological indicators but also because of their potential adverse effects on growth and development, immune response, neurodevelopment, and cognitive function.

Allergic diseases, including asthma, allergic rhinitis, and atopic dermatitis, are among the most common chronic health problems in childhood, and their prevalence has increased over the last three decades, particularly in developed countries. For example, according to 2021 data from the United States, approximately 27.2% of children have at least one allergic disease, including seasonal allergy in 18.9%, eczema in 10.8%, and food allergy in 5.8%.[10] In addition, global meta-analyses have reported the prevalence of asthma in school-aged children as approximately 7.7%, allergic rhinitis as approximately 23.7%, and eczema as approximately 15.8%.[11] Risk factors include genetic predisposition, environmental factors such as air pollution, cigarette smoke, and infections, and socioeconomic status.[12] In recent years, it has been suggested that nutritional deficiencies may also trigger the “allergic march.” Iron deficiency, in particular, has been suggested to influence mast cell activity and Th2 responses, thereby facilitating atopy.[13]

The aim of this study was to evaluate the prevalence of allergic diseases in children with nutritional anemia caused by iron, vitamin B12, and folic acid deficiencies at the clinical level using ISAAC modules, skin prick testing, total IgE, and peripheral eosinophil measurements and to interpret the obtained data in the context of the current literature.

MATERIAL AND METHODS

This study was conducted between July 1, 2013, and February 1, 2014, at the Department of Pediatrics, Zeynep Kamil Women’s and Children’s Health Training and Research Hospital, and included children aged 3–18 years. The study was designed as a prospective, observational, nonrandomized study. Patients with nutritional anemia were consecutively recruited, and the control group consisted of age- and sex-matched children without anemia. Patients with nutritional anemia constituted the patient group, whereas the control group consisted of children without anemia and with a similar age and sex distribution. The nutritional anemia group comprised a total of 77 patients: 60 with iron deficiency anemia alone, 10 with iron deficiency and vitamin B12 deficiency, and 7 with iron deficiency and folic acid deficiency. The control group consisted of 46 healthy children without nutritional anemia and without a history of regular medication use. Children receiving treatment for allergic diseases and those who declined to complete the questionnaire were excluded.

All children and/or their parents were interviewed face-to-face. Complete blood count, serum iron, total iron-binding capacity (TIBC), transferrin saturation, ferritin, folic acid, vitamin B12, total IgE, and absolute eosinophil counts were measured. The Turkish version of the ISAAC (International Study of Asthma and Allergies in Childhood) questionnaire was used to assess symptoms of allergic diseases.[14] In addition to allergic symptoms, the questionnaire included questions regarding a family history of atopy, duration of breastfeeding, household tobacco exposure, and environmental factors such as pet ownership. Skin prick tests were performed in patients diagnosed with allergic diseases; a positive reaction to at least one aeroallergen was considered indicative of atopy.

The study was approved by the Ethics Committee of the Ministry of Health Zeynep Kamil Women’s and Children’s Diseases Training and Research Hospital (date: August 2, 2013; number: 079) and was conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from all patients and their parents.

Statistical Analysis

Statistical analyses were performed using SPSS version 15.0 (SPSS Inc., Chicago, IL, USA). Categorical variables were analyzed using Pearson’s chi-square test, and comparisons between two independent groups were performed using the independent-samples t-test. A p value of <0.05 was considered statistically significant.

RESULTS

A total of 123 children aged 3–18 years were included in the study; 77 comprised the nutritional anemia group, and 46 comprised the nonanemic control group. Overall, 41.4% of the participants were male (n=51), and 58.6% were female (n=72). There was no statistically significant difference between the patient and control groups with respect to sex distribution (p=0.165). The mean age was 98.48±52.9 months in the patient group and 97.8±43.1 months in the control group, with no significant difference between the groups (p=0.942) (Table 1).

Within the nutritional anemia group, iron deficiency anemia was the most prevalent subtype, identified in 60 patients (77.9%), followed by combined iron and vitamin B12 deficiency anemia in 10 patients (13.0%) and combined iron and folate deficiency anemia in 7 patients (9.1%) (Table 1).

Table 1: Demographic characteristics and anemia subtypes in the patient and control groups

	Patient group (n=77, 54.5%)	Control group (n=46, 65.2%)	p
Male, n (%)	35 (45.5)	16 (34.8)	0.165
Female, n (%)	42 (54.5)	30 (65.2)	0.165
Mean age (months), mean±SD	98.5±52.9	97.8±43.1	0.942
Iron deficiency anemia (IDA), n (%)	60 (77.9)	–	–
IDA + vitamin B12 deficiency, n (%)	10 (13.0)	–	–
IDA + folate deficiency, n (%)	7 (9.1)	–	–

IDA: Iron deficiency anemia; SD: Standard deviation. p values were calculated using Pearson's chi-square test for categorical variables and the independent samples t-test for continuous variables.

Table 2: Prevalence of allergic diseases and atopy-related laboratory parameters in the patient and control groups

	Patient group (n=77, 54.5%)	Control group (n=46, 65.2%)	p
Physician-diagnosed asthma, n (%)	1 (1.3)	2 (4.3)	0.314
Physician-diagnosed allergic rhinitis, n (%)	17 (22.1)	12 (26.1)	0.384
Physician-diagnosed atopic dermatitis, n (%)	1 (1.3)	0	0.626
Atopic sensitization (positive skin prick test), n (%)	3 (15.8)	2 (14.3)	0.683
Total IgE (IU/mL), mean±SD	80±62.3	72±53.2	0.451
Eosinophil percentage (%), mean±SD	2.6±1.46	2.38±1.79	0.698

IgE: Immunoglobulin E; SD: Standard deviation. p values were calculated using Pearson's chi-square test for categorical variables and the independent samples t-test for continuous variables.

Assessment based on the ISAAC questionnaires demonstrated comparable prevalences of allergic disease manifestations between the groups. The lifetime prevalence of wheezing was 7.8% in the patient group and 4.3% in the control group (p=0.366). Wheezing within the preceding 12 months was reported in 2.6% of anemic patients and in none of the controls (p=0.390). Physician-diagnosed asthma was recorded in 1.3% of the patient group and 4.3% of the control group, with no statistically significant difference (p=0.314). Similarly, asthma-related symptoms, including exercise-induced wheezing and nocturnal cough, did not differ significantly between the groups (all p>0.05).

Regarding allergic rhinitis, the lifetime prevalence and prevalence within the previous 12 months were 23.4% in the patient group and 28.3% in the control group (p=0.346 for both). Seasonal distribution patterns were comparable between the groups (p=0.060). Physician-diagnosed allergic rhinitis was identified in 22.1% of anemic children and 26.1% of controls, with no significant between-group difference (p=0.384).

Eczema-related symptoms were infrequent in both groups. Lifetime chronic pruritic lesions were observed in 2.6% of the patient group, and chronic pruritic lesions within the previous 12 months were observed in 1.3%; no eczema-related symptoms were reported in the control group. Physician-diagnosed atopic dermatitis was present in 1.3% of anemic patients and in none of the controls (p=0.626). Indicators of symptom severity, such as nocturnal pruritus, did not differ significantly between the groups (Table 2).

Among participants with allergic disease symptoms who underwent skin prick testing, atopic sensitization was detected in 15.8% of the patient group and 14.2% of the control group, with no statistically significant difference (p=0.683). In these individuals, the mean total IgE level was 80±62.3 IU/mL in the nutritional anemia group and 72±53.2 IU/mL in the control group, whereas the mean eosinophil percentages were 2.6±1.46 and 2.38±1.79, respectively. No significant between-group differences were observed for these inflammatory markers (Table 2).

DISCUSSION

In this study, the frequency of allergic diseases in children aged 3–18 years with nutritional anemia caused by iron, vitamin B12, or folate deficiency was compared with that in controls, and no significant difference was detected. The rate of allergic disease was 24.7% in the anemic group and 30.4% in the control group, and there was no significant difference in atopic sensitization. These findings suggest that nutritional anemia does not appear to increase the prevalence of allergic diseases during childhood.

Mendelian randomization meta-analyses and population-based studies also support our results. Skaaby et al.[15] reported no causal relationship between serum vitamin B12 and folate levels and asthma or allergic rhinitis. In addition, large Mendelian randomization analyses examining the association between serum iron status

and asthma risk found no significant causal effect.[16] A prospective mother–child cohort assessing impaired folate metabolism also found no increase in the risk of atopy.[17] Similarly, Bédard et al.[18] demonstrated that maternal iron status during pregnancy was not causally associated with asthma or atopic dermatitis in offspring, and a Japanese cohort reported that maternal anemia was not associated with eczema in early childhood.[19] Consequently, these large-scale genetic and cohort data suggest that nutritional micronutrient deficiencies do not meaningfully influence the prevalence of allergic diseases.

There are also studies in the literature reporting an association between anemia and allergic diseases. For example, Ramakrishnan et al.[20] reported that children with iron deficiency anemia may have an increased risk of asthma. However, this study was cross-sectional, did not establish causality, and, unlike our study, focused only on the relationship between asthma and iron deficiency anemia. Studies using animal models or specific iron-transporting micronutrients, such as an iron, zinc, and vitamin A complex with a beta-lactoglobulin carrier (holo-BLG), have shown that iron supplementation reduces airway hyperreactivity and eosinophil infiltration.[13,21] Large cross-sectional studies of Korean and Japanese populations have also reported findings suggesting a higher risk of anemia in children with allergic diseases.[22,23]

The differences between these studies and our findings may be partly explained by methodological variations, including differences in study design, the relatively modest sample size of our cohort, and the limited statistical power to detect small or subgroup-specific effects.

Therefore, the conflicting data in the literature largely point to two different axes. First, some large human cohorts have reported an increased risk of allergic disease → anemia, whereas animal models and micronutrient intervention studies have discussed the anemia → severity of allergic inflammation axis.[21] From a clinical perspective, it has been suggested that nutritional anemia is associated with immune dysfunction, particularly that iron deficiency increases mast cell degranulation and macrophage activation, and that lipocalins in aeroallergens bind local iron, creating a "micro-iron deficiency" in the mucosa and triggering an IgE-mediated response.[13,21] From this perspective, some animal model and supplementation studies are consistent with reductions in airway hyperreactivity and eosinophil infiltration following iron supplementation. However, most of these studies evaluated inflammatory parameters and clinical severity rather than disease prevalence. In our study, ISAAC modules and atopy tests were evaluated together, and no difference in prevalence was observed.

A strength of our study is that it evaluated nutritional anemia across all components of iron, vitamin B12, and folic acid deficiency. There is no prospective publication in the literature that has simultaneously assessed all nutritional anemias in the pediatric age group together with asthma, rhinitis, atopic dermatitis, skin prick testing, and IgE and eosinophil parameters in the same individuals. In this respect, our study reflects the actual patient spectrum encountered in clinical practice. Therefore, our current data do not support the "iron deficiency → increased allergy prevalence" hypothesis; however, they do not clearly exclude associations at the level of disease severity or immunological phenotype.

Limitations

Several limitations should also be acknowledged. Because of the relatively modest sample size, the statistical power of subgroup analyses may have been insufficient to detect small or subtype-specific effects, particularly when evaluating different categories of nutritional anemia. In addition, because of the study design, potential confounding factors such as socioeconomic status, detailed dietary intake, and the presence of chronic infections or parasitic infestations were not systematically assessed or controlled for and may have influenced the observed associations. Furthermore, disease severity was not evaluated beyond the presence or absence of allergic conditions, which limits interpretation regarding clinical activity, symptom burden, and phenotypic heterogeneity. The data were collected between 2013 and 2014, which may affect the generalizability of the findings to current populations. Additional limitations include the restricted skin prick test allergen panel and the lack of re-evaluation after iron replacement. In particular, assessment of changes in the immune phenotype before and after replacement therapy may contribute to future mechanism-oriented analyses.

CONCLUSION

Based on our findings, nutritional anemia did not significantly affect the prevalence of allergic diseases in childhood. Although data in the literature suggest that anemia may exert modulatory effects on the immune system, there is no robust evidence that these effects translate into an increased prevalence of allergic diseases. Further prospective studies with larger sample sizes that measure immunometabolic parameters, including hepcidin, ferritin subfractions, and oxidative stress markers, and account for geographic, socioeconomic, and environmental factors are needed to clarify the role of nutritional anemia in the development of allergic diseases.

Statement

Ethics Committee Approval: The study was approved by Ministry of Health Zeynep Kamil Women's and Children's Diseases Training and Research Hospital Ethics Committee (No: 079, Date: 02.08.2013).

Informed Consent: Written informed consent was obtained from all patients and their parents.

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ORIGINAL ARTICLE

Conventional and remote intraoperative NRT measurements

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ABSTRACT

Objective: The aim of this study was to establish the reliability of evoked compound action potential (ECAP) thresholds obtained using the conventional AutoNRT programming system and the CR220 Intraoperative Remote Assistant. Another objective was to compare intraoperative NRT thresholds with postoperative thresholds.

Material and Methods: Nineteen patients who received a Nucleus CI24RE or CI422 cochlear implant for severe-to-profound hearing loss were included in the study. The patients' ages ranged from 13 months to 15 years, with a mean age of 4 years. Intraoperative NRT thresholds were measured on all functioning electrodes using both the conventional AutoNRT programming system and the CR220 Intraoperative Remote Assistant. Postoperative ECAP thresholds were obtained 4–6 weeks after surgery using the conventional AutoNRT system and were compared with the intraoperative measurements.

Results: NRT thresholds showed no statistically significant differences between the conventional and remote conditions for any electrode, except E20 (p=0.027). Intraoperative NRT thresholds were also compared with postoperative AutoNRT thresholds for five representative electrodes (E1, E6, E11, E16, and E22); a statistically significant difference was observed only for E22 (p=0.015), while no significant differences were found for the remaining electrodes.

Conclusion: The CR220 Intraoperative Remote Assistant provides reliable NRT thresholds. There were no statistically significant differences between the NRT thresholds obtained using the CR220 and those obtained using the conventional AutoNRT method. Although newer intraoperative platforms, such as SmartNav, have recently emerged, the CR220 Remote Assistant is still used in many centers worldwide and remains an essential tool in clinical settings where newer systems are not yet accessible. Therefore, establishing its reliability relative to AutoNRT continues to have clinical value, particularly for pediatric cochlear implant candidates and institutions interpreting large volumes of historical intraoperative NRT data.

Keywords: AutoNRT, cochlear implant, CR220 Remote Assistant, ECAP.

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INTRODUCTION

Cochlear implants (CIs) are devices designed to restore auditory perception through electrical stimulation, mimicking the natural function of the cochlea in transmitting sound to the auditory nerve in individuals with hearing loss.[1] The effectiveness of these devices is typically assessed by improvements in speech perception after implantation. However, speech perception is influenced by various factors, such as the individual's educational level, duration of hearing loss, and age, in addition to CI performance. Therefore, evaluating CI performance solely on the basis of speech perception may be insufficient and may complicate a comprehensive understanding of the interface between the implant and the nerve.[2] Cochlear implants provide an effective solution for individuals with severe-to-profound hearing loss by enhancing auditory perception and communication skills. However, the accuracy and reliability of the measurement methods used during implant surgery play a critical role in the success of the procedure.[3] In this context, electrophysiological measurements have emerged as an essential method for more accurately assessing the interaction between the implant and the auditory nerve. Specifically, electrically evoked compound action potentials (ECAPs) are frequently used to evaluate neural interactions in cochlear implant users. Measurement of ECAP thresholds provides valuable insights into auditory nerve activity and neuronal density within the cochlea. Systems such as the conventional AutoNRT™ programming system (Custom Sound™, CS) and the CR220 provide crucial data during the surgical process.

Neural response telemetry (NRT) measures the electrical responses generated by the cochlear implant in the auditory nerve, thereby helping to assess implant performance and the interaction between the implant and the auditory nerve. The Nucleus CI system includes AutoNRT, which features automatic threshold determination and allows clinicians to measure thresholds using both conventional programming tools and the CR220 Intraoperative Remote Assistant. The CR220 enhances the speed and efficiency of the clinical process by providing rapid and reliable measurements during surgery, thereby contributing to more efficient use of resources. The reliability of these measurements is critical in clinical practice because inaccurate intraoperative thresholds may affect postoperative programming and clinical outcomes.[3,4]

The CR220 is a remote measurement device used for intraoperative measurements in the Cochlear™ Nucleus® implant series. This device rapidly and reliably determines electrode impedance and ECAP thresholds using the AutoNRT® algorithm. Its simple user interface allows efficient intraoperative testing. However, the device requires a computer and additional cable connections, which may prolong setup time during surgery.[5,6]

In routine clinical use, the CR220 communicates with the sound processor via radiofrequency transmission; however, during intraoperative measurements, the system still requires a physical cable connection between the sound processor interface and the surgical computer to run the AutoNRT software and transfer measurement data. This additional computer–interface cable is the primary factor contributing to increased setup time in the operating room.

SmartNav™, a new platform that uses electrode voltage telemetry (EVT) technology, allows rapid and accurate assessment of electrode placement. It serves as an alternative to X-ray imaging methods and shortens the intraoperative process.[7] In earlier studies, SmartNav™ was not yet available, and researchers relied on the CR220 for intraoperative ECAP and electrode status assessments.[5–7] Studies investigating the reliability of intraoperative measurements obtained using the conventional AutoNRT programming system and the CR220 Remote Assistant have shown that these systems provide valuable information about implant performance. In addition, comparing intraoperative and postoperative NRT thresholds may provide a useful approach for evaluating long-term implant performance.[3] Moreover, differences between intraoperative and postoperative ECAP thresholds have been reported in the literature and attributed to postoperative physiological changes.[8–10]

The present study aims not only to compare ECAP thresholds obtained using the CR220 and conventional AutoNRT systems during the same intraoperative session but also to examine how these intraoperative measurements relate to postoperative thresholds, an approach that provides a more comprehensive evaluation than previous studies.

MATERIAL AND METHODS

Ethical approval for this study was obtained from the Clinical Research Ethics Committee of Marmara University Faculty of Medicine (Protocol No.: 09.2016.577). All procedures were conducted in accordance with the ethical standards of the institutional and/or national research committee and the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

Subjects

The study sample size was determined using G*Power version 3.1.9.4 (Universität Düsseldorf) with a repeated-measures ANOVA (within-subject design), assuming 80% statistical power, a 0.05 margin of error, an effect size of 0.3, and a repeated-measures correlation of 0.5. Based on this analysis, the minimum required sample size was calculated as 18 participants. Therefore, the inclusion of 19 participants in the present study was considered sufficient to ensure adequate statistical power. The study included 19 patients aged between 13 months and 15 years who were candidates for cochlear implantation. The cochlear implants used in the study were the Nucleus CI24RE in 16 patients and the CI422 in 3 patients. Neural response telemetry (NRT) thresholds were measured intraoperatively and postoperatively, and the results obtained using the conventional AutoNRT programming system and the CR220 Intraoperative Remote Assistant were compared. Demographic data and implant details are summarized in Table 1.

Testing Procedure

All patients underwent cochlear implantation using either the Nucleus CI24RE or CI422 model. The CI24RE implants featured the Contour Advance perimodiolar array, whereas the CI422 implants featured a straight lateral wall array. Neural response telemetry (NRT) thresholds were measured intraoperatively using both the conventional AutoNRT programming system and the CR220 Remote Assistant.

Table 1: Demographics of the participants	
Gender	
Male	11
Female	8
Age (months)	
Range	13–180
Mean	48
Electrode type	
CI24RE	16
CI422	3

CI: Cochlear implant.

Intraoperative NRT thresholds were recorded for all functional electrodes during surgery and were subsequently compared with postoperative thresholds obtained 4–6 weeks later.

Intraoperative NRT Measurement

Following cochlear implant insertion, intraoperative NRT thresholds were recorded using the conventional AutoNRT programming system (Custom Sound™) and the CR220 Remote Assistant. Electrical stimuli were applied to all functional electrodes (E1–E22) to record evoked compound action potential (ECAP) thresholds and assess implant functionality and cochlear nerve integrity. Both systems were used during the same session for direct comparison, and thresholds were recorded in clinical units (CU) for analysis.

Postoperative NRT Measurement

Postoperative NRT measurements were also obtained to evaluate consistency and reliability between the two phases. Postoperative NRT thresholds were measured 4–6 weeks after surgery at the initial device activation appointment using the conventional AutoNRT system. Intraoperatively, ECAP thresholds were measured using both the conventional AutoNRT programming system and the CR220 system across all available electrodes (E1–E22). In the postoperative phase, measurements were limited to five electrodes (E22, E16, E11, E6, and E1), which represent key regions of the cochlear electrode array. Electrode 1 (E1) corresponds to the apical region, electrode 22 (E22) to the basal region, and electrode 11 (E11) to the mid-cochlear region, whereas electrodes 6 (E6) and 16 (E16) provide additional data points for assessing neural response variability across the cochlea. This targeted electrode selection reflects the default clinical protocol unless measurements from all electrodes are explicitly requested. It was particularly advantageous in pediatric patients because it allowed faster and more efficient testing while minimizing discomfort and facilitating cooperation. The selected electrodes enabled a comprehensive evaluation of neural response thresholds across the apical, mid-cochlear, and basal regions, thereby allowing a robust comparison between intraoperative and postoperative measurements to assess changes in cochlear implant function and neural responses over time.

Statistical Analysis

Data collection and management were performed using Microsoft Excel version 16.3 (Microsoft, Seattle, WA, USA). Statistical analyses were performed using SPSS version 22.0 (IBM SPSS Inc., Chicago, IL, USA). Descriptive statistics were used to summarize the demographic and clinical characteristics of the participants.

A one-way repeated-measures analysis of variance (ANOVA) was used to compare the mean ECAP threshold values obtained using the CR220 system, the conventional AutoNRT programming system, and postoperative measurements because all measurements were collected from the same participants. Measurement condition (CR220, conventional AutoNRT, and postoperative) was treated as a within-subject factor with three levels, and the ECAP threshold level was the dependent variable.

Repeated-measures ANOVA was first performed for all electrodes to compare CR220 and conventional AutoNRT measurements. In addition, a focused repeated-measures analysis was performed on five representative electrodes (E1, E6, E11, E16, and E22), selected to represent low-, mid-, and high-frequency regions of the electrode array. Before the analysis, the assumptions of normality and sphericity were evaluated. When a statistically significant main effect was detected, post hoc pairwise comparisons were performed using the Bonferroni correction to adjust for multiple comparisons. A p value of <0.05 was considered statistically significant. Graphical representations of the data were generated using Microsoft Excel based on the mean values and standard deviations.

RESULTS

Statistical analyses were conducted on NRT threshold values measured across different electrodes. To determine whether significant differences existed between the measurement conditions, one-way repeated-measures analyses of variance (ANOVA) were performed.

Intraoperative ECAP thresholds obtained using the CR220 Remote Assistant and the conventional AutoNRT programming system were compared using one-way repeated-measures ANOVA for each electrode (E1–E22). Measurement method (CR220 vs. conventional AutoNRT) was treated as a within-subject factor. Statistical significance was set at $p<0.05$. The results of these analyses, including the F and p values for each electrode, are presented in Table 2.

As shown in Table 2, no statistically significant differences were observed between the measurement methods for any electrode except E20 ($p>0.05$). For electrode E20, a statistically significant difference was detected ($p=0.027$). Overall, these findings indicate that ECAP threshold measurements obtained using the CR220 Remote Assistant and the conventional AutoNRT programming system were comparable across electrodes, with the exception of a single electrode.

ECAP thresholds obtained intraoperatively using the CR220 Remote Assistant and the conventional AutoNRT programming system and postoperatively using the AutoNRT system were further compared using one-way repeated-measures ANOVA for selected electrodes (E1, E6, E11, E16, and E22). Measurement condition

Table 2: Intraoperative comparisons of CR220 and conventional AutoNRT thresholds

Factor	df	Mean Square (between groups)	Mean Square (within groups)	F	p
E1	1	12.368	828.008	0.015	0.903
E2	1	6.149	635.928	0.010	0.922
E3	1	83.333	517.876	0.161	0.691
E4	1	284.546	566.032	0.503	0.484
E5	1	157.315	640.047	0.246	0.624
E6	1	52.737	726.975	0.073	0.790
E7	1	1275.377	792.850	1.609	0.214
E8	1	2684.047	854.077	3.143	0.088
E9	1	1072.002	769.034	1.394	0.248
E10	1	2270.700	675.981	3.359	0.077
E11	1	469.334	568.855	0.825	0.370
E12	1	957.038	886.069	1.080	0.308
E13	1	862.550	902.239	0.956	0.336
E14	1	1320.844	1125.529	1.174	0.287
E15	1	1724.560	898.212	1.920	0.176
E16	1	1052.259	702.189	1.499	0.231
E17	1	1398.393	747.516	1.871	0.182
E18	1	2133.368	676.952	3.151	0.086
E19	1	2047.284	729.924	2.805	0.106
E20	**1**	**2686.807**	**496.789**	**5.408**	**0.027**
E21	1	1453.968	422.030	3.445	0.074
E22	1	77.298	600.967	0.129	0.722

ECAP: Evoked compound action potential; CR220: Remote assistant; AutoNRT: Automated neural response telemetry. df: Degrees of freedom. Measurement method was treated as a within-subject factor. Statistical significance was set at $p<0.05$.

(CR220, conventional AutoNRT, and postoperative) was treated as a within-subject factor. When a significant main effect was observed, Bonferroni-adjusted post hoc pairwise comparisons were performed. Statistical significance was set at $p<0.05$. The results are presented in Table 3.

Postoperative measurements were obtained 4–6 weeks after surgery and included thresholds from electrodes E22, E16, E11, E6, and E1, in accordance with the standard clinical protocol. According to the results presented in Table 3, a statistically significant difference was observed only for electrode E22 ($p=0.015$). No significant differences were found for the remaining electrodes ($p>0.05$). These findings suggest that ECAP threshold measurements obtained under different measurement conditions were generally consistent, although electrode-specific variations may occur.

The distribution of mean ECAP threshold values for the same group of participants across the Remote Assistant (RA), conventional AutoNRT programming system (CS), and postoperative (POST) conditions for the five selected electrodes is illustrated in Figure 1. A noticeable decrease in mean threshold values was observed in

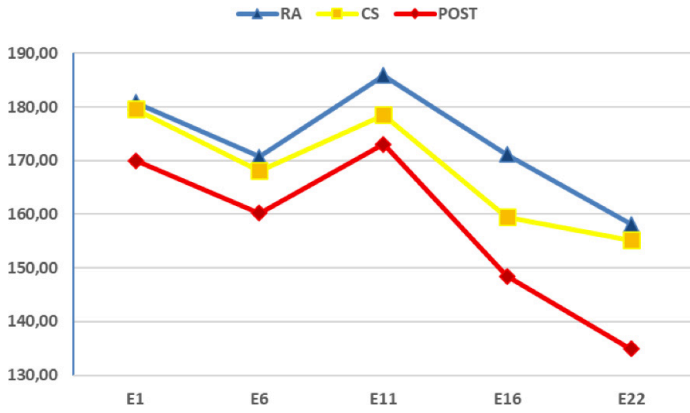

Figure 1: Comparisons of Remote Assistant (RA), Conventional AutoNRT programming system (CS), and POST groups for the selected five electrodes' thresholds.

Mean ECAP thresholds for intraoperative measurements obtained with the CR220 Remote Assistant (RA) and the conventional AutoNRT system (CS), compared with postoperative AutoNRT thresholds. Postoperative measurements were collected 4–6 weeks after surgery and were limited to electrodes E22, E16, E11, E6, and E1.

Table 3: Comparison of ECAP thresholds between RA, CS, and POST conditions

Electrode	RA Mean	RA SD	CS Mean	CS SD	POST Mean	POST SD	p
E1	180.83	25.99	179.63	31.63	170.00	23.65	0.500
E6	170.71	23.11	168.13	30.78	160.22	22.44	0.452
E11	185.88	12.36	178.56	30.99	173.06	16.26	0.246
E16	171.13	14.53	159.47	35.05	148.47	34.27	0.099
E22	158.19	19.79	155.17	28.03	134.94	24.78	0.015

ECAP: Evoked compound action potential; RA: Remote Assistant (CR220); CS: Conventional AutoNRT programming system; POST: Postoperative measurements obtained 4–6 weeks after surgery.

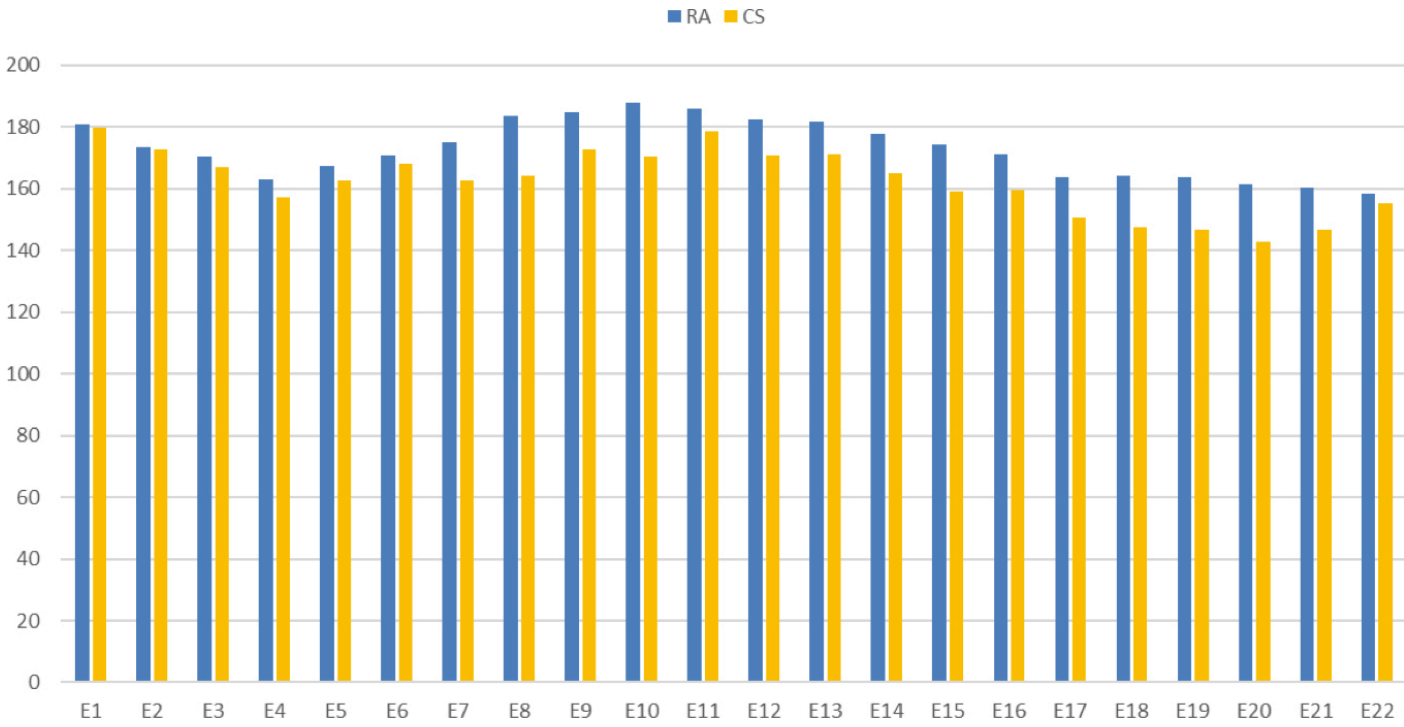

Figure 2: Mean ECAP threshold values for the Remote Assistant (RA) and conventional AutoNRT programming system (CS).

RA: Remote assistant; CS: Custom sound (conventional AutoNRT programming system).

the POST condition at electrode E22 compared with the RA and CS conditions. Overall, similar trends were observed between the RA and CS conditions, with the RA condition showing slightly higher mean values across all five electrodes (E1, E6, E11, E16, and E22).

Mean ECAP threshold values for the RA and CS conditions across all electrodes are presented in Figure 2. The distribution of values was generally similar between the two conditions. Although minor differences were observed across the electrodes, the RA condition showed slightly higher mean values than the CS condition for several electrodes; however, these differences were not statistically significant.

DISCUSSION

Cochlear implant surgery involves neural telemetry and impedance testing, which traditionally require audiologists to be present in the operating room. The CR220 Remote Assistant streamlines these processes while maintaining accuracy.[2,3] Tanamati et al.[3] reported that the CR220 device demonstrated high agreement with the conventional AutoNRT method, providing comparable impedance and neural response threshold measurements. Similarly, in our study, no significant differences were found between the CR220 and conventional AutoNRT measurements, indicating that both systems provide reliable and accurate results in cochlear implant assessments. Consistent with the findings of Hajr and Almuhawas,[4] the present study demonstrated no clinically relevant differences between intraoperative measurements obtained using the CR220 Remote Assistant and the conventional AutoNRT system, supporting the reliability of CR220-derived ECAP data. While Hajr and Almuhawas primarily focused on clinical efficiency and workflow optimization, the present study extends these findings by quantitatively comparing

ECAP threshold values obtained intraoperatively and postoperatively, thereby providing additional insight into the physiological stability of CR220 measurements over time.

Our findings indicate that no significant differences were observed between measurements obtained using the Remote Assistant (CR220) and the conventional method; however, a significant difference between intraoperative and postoperative measurements was observed only for electrode 22 (E22), consistent with previous research. This difference may be attributed to factors such as tissue healing, electrode stabilization, and neural adaptation, as reported in the literature.[8–10] Although previous studies have demonstrated the clinical efficiency of the CR220, evidence regarding the comparability of intraoperative CR220-derived ECAP thresholds with postoperative measurements remains limited. By addressing this gap, the present study provides clinically relevant data for interpreting historical and longitudinal NRT measurements, particularly in pediatric cochlear implant users.

A limitation of this study is the use of the CR220 system, which was the available technology at the time. Newer systems, such as SmartNav, may yield different outcomes and warrant further investigation.[7] Nevertheless, the CR220 has demonstrated reliable intraoperative and postoperative measurements, whereas SmartNav offers advantages such as faster assessment of electrode placement, potentially improving surgical efficiency and reducing procedural risks.[11] Future studies using newer technologies may validate and expand upon the present findings and help clarify their effects on auditory rehabilitation and patient satisfaction.[4,7]

The findings obtained using the CR220 are expected to be replicable with SmartNav, which provides comparable reliability and accuracy using more advanced technology. In resource-limited settings, the adoption of such technologies may help standardize cochlear implant care and improve access for a broader range of patients. Further research should focus on evaluating long-term outcomes across diverse patient populations, including pediatric patients and individuals with complex cochlear anatomies, as well as assessing the effects of emerging technologies on rehabilitation outcomes and clinical workflow efficiency. Another limitation of this study is the lack of detailed demographic information, which may have provided additional insight into the observed outcomes. Future studies should include more comprehensive demographic data.

CONCLUSION

The CR220 Intraoperative Remote Assistant provides reliable NRT thresholds. There were no statistically significant differences between the NRT thresholds obtained using the CR220 and those obtained using the conventional AutoNRT method. Although newer intraoperative platforms, such as SmartNav, have recently emerged, the CR220 Remote Assistant is still used in many centers worldwide and remains an essential tool in clinical settings where newer systems are not yet accessible. Therefore, establishing its reliability relative to AutoNRT continues to have clinical value, particularly for pediatric cochlear implant candidates and institutions interpreting large volumes of historical intraoperative NRT data.

Statement

Ethics Committee Approval: The study was approved by Marmara University Faculty of Medicine Ethics Committee (No: 09.2016.577, Date: 04.11.2016).

Informed Consent: Informed consent was obtained from all individual participants included in the study.

Conflict of Interest: The authors declare that there is no conflict of interest.

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ORIGINAL ARTICLE

Transforming pediatric surgery education: A technical note on creating advanced medical content using ChatGPT and InVideo AI

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ABSTRACT

Objective: Artificial intelligence (AI) significantly impacts medical education by enhancing learning methods and educational materials. Advanced AI platforms, such as ChatGPT and InVideo AI, offer promising tools for creating interactive and detailed content for medical training. This study evaluates their feasibility and limitations in generating pediatric surgery–focused videos, specifically content on newborn physical examinations, within an innovative methodological framework rather than an original research design.

Material and Methods: Scripts were initially created using ChatGPT and subsequently converted into educational videos using the InVideo AI platform (https://ai.invideo.io/). We produced four distinct videos: two based on brief scripts (12 words) and two based on detailed scripts (405 words), formatted for YouTube and YouTube Shorts. Video creation times, file sizes, content accuracy, formats, and durations were analyzed to assess effectiveness.

Results: Videos generated from detailed ChatGPT scripts required longer creation times (~10 minutes) and had larger file sizes (~700 MB) than those generated from brief scripts (~3 minutes and ~180 MB). Although video generation was efficient, notable limitations emerged regarding the accuracy and availability of specialized pediatric surgical content, primarily due to the limited medical databases available to AI-driven platforms.

Conclusion: The integration of ChatGPT and InVideo AI demonstrated significant potential for enhancing pediatric surgery education by streamlining educational video production. However, substantial challenges regarding content accuracy and the comprehensiveness of medical data remain. Addressing these issues through continued technological advancements will be crucial for fully leveraging the educational potential of AI. Future improvements in AI databases and algorithms may profoundly enhance medical training, benefiting both educational outcomes and patient care in pediatric surgery.

Keywords: AI, ChatGPT, video, medical education, pediatric surgery.

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INTRODUCTION

The active integration of innovative technologies into both medicine and medical education is crucial. These approaches not only enhance the quality of content but also significantly accelerate the dissemination of information.[1] Technologies currently referred to as disruptive technologies include augmented reality, virtual reality, blockchain, and artificial intelligence. Although these technologies may initially be limited in terms of content and usability, their importance in the medical field increases significantly as new content is produced and infrastructure is developed.[2] AI-based tools can be effective in various areas, ranging from anatomy and surgical skills training to feedback mechanisms; however, some technical and ethical challenges still need to be addressed.[3] AI platforms enhance productivity and efficiency across industries through advanced machine learning, enabling businesses to automate processes, gain insights from data, and make informed decisions. Their adaptability allows customization for various applications, ranging from customer service to data analysis. Emerging text-to-video models, such as SORA AI, may further advance educational content generation in the future. However, this study focuses on currently accessible platforms, such as InVideo AI, and evaluates their practical applicability in pediatric surgery education.[4]

The AI-driven process ensures consistent and comprehensive educational content, enhancing training for medical students and professionals. It can play a significant role in the acquisition and reinforcement of medical knowledge relevant to preparation for examinations, such as board certification examinations in medical specialties.[5]

Despite their shortcomings and incomplete development, these AI-supported videos may serve as reliable resources for continuous learning by streamlining content creation and reducing development time.[6] This efficiency enables the production of diverse instructional videos, thereby broadening the range of learning resources. In a recent report, incorporating ChatGPT-generated texts into OpenAI-based text-to-video platforms was shown to improve clinical skills and provide a comprehensive educational tool for pediatric surgeons, thereby enhancing diagnostic and training processes.[7] However, previous studies have not provided a step-by-step, reproducible workflow for specific video creation. Despite the growing literature on AI in medical education, practical and reproducible guidance on how readily available AI tools can be applied step by step to generate specialty-specific educational content remains limited. This study addresses this gap by presenting an applicable workflow tailored to pediatric surgery. High educational standards can be maintained across platforms such as Instagram Reels, YouTube Shorts, Instagram, and LinkedIn, making specialized knowledge widely accessible and ensuring that training materials remain current with medical practices.

This manuscript primarily presents a novel workflow describing how AI tools can be used to generate educational content rather than testing a formal hypothesis using new empirical data. Therefore, the study aligns more closely with the structure of a "Technical Note" or "Innovative Method" paper than with that of an "Original Research" article. The contribution of this work lies in providing a step-by-step, reproducible protocol that can guide educators and clinicians in applying readily available AI tools to medical content creation. Within this framework, the aim of the manuscript is to demonstrate the feasibility, limitations, and practical considerations of this AI-based workflow. Future studies should focus on systematically evaluating the educational impact of this method. The techniques and details discussed below focus on evaluating the workflow while considering the potential capabilities and limitations of platforms similar to emerging text-to-video models, such as SORA AI, using scripts prepared with ChatGPT.

This study tested only the free version of InVideo AI in detail. Other advanced platforms, including SORA AI, Adobe Firefly, Midjourney, DALL-E, and Leonardo AI, were reviewed only at the literature level without direct comparative testing. This limits the generalizability of the study findings.

MATERIAL AND METHODS

ChatGPT, developed by OpenAI and based on GPT-4, engages in natural conversations by providing information, answering questions, and assisting with writing tasks. Its versatility makes it useful for applications such as customer support and creative writing.[8] In this study, we used the free version of GPT-3.5, with limited use of GPT-4.[9]

AI platforms resembling SORA AI are available on various websites, and we tested three of them before the study: Artguru.ai,[10] Canva.com,[11] and InVideo AI. We excluded Canva.com because it generated highly irrelevant content due to the insufficient medical content available in its AI library. We also excluded Artguru.ai because it generated only short, animated GIFs lasting 1–2 seconds. Therefore, we decided to use InVideo AI. The InVideo AI platform enables the creation of video edits tailored to social media platforms by using text prompts and AI-generated stock videos. This functionality makes InVideo AI a suitable option for generating AI-driven videos from diverse textual inputs, in line with the objectives of this study. We used a video-editing AI platform similar to SORA AI through the InVideo AI website (https://ai.invideo.io/) to create the videos.[12] The free version of the website was used, and only free versions of the platforms were used throughout the study; features available in paid versions were beyond the scope of this research.

This project aimed to produce content based on a topic covered in pediatric surgery education. We created a 12-word main text related to our medical topic: "How we do detail physical examination on a newborn in pediatric surgery," and converted it into both short and long videos using InVideo AI.

We generated a video from the main text using a web-based platform that utilizes AI (Fig. 1). First, we processed the main text with InVideo AI to create two videos: one for YouTube and one for YouTube Shorts. The videos were created within the InVideo AI platform by entering the text and selecting each platform option individually. We then elaborated on the text using ChatGPT and subsequently created two additional videos with AI (Fig. 2). The main text was expanded into a more detailed explanation using ChatGPT (Table 1). We converted the resulting 405-word text into both short and long videos. We compared the production times, technical formats (portrait and landscape), video durations, unique narratives, and accuracy of the video content in a comparative table. The main challenges encountered during the workflow were related to the platform's limited pediatric surgery visual database, which

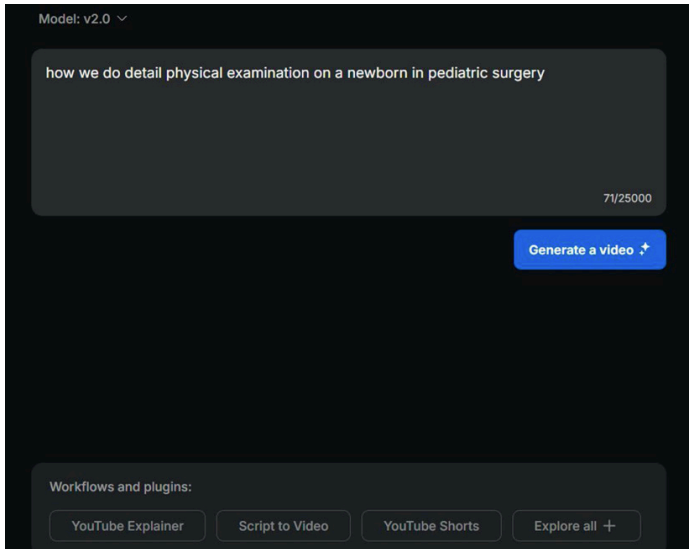

Figure 1: The website interface where text is entered on the AI screen.

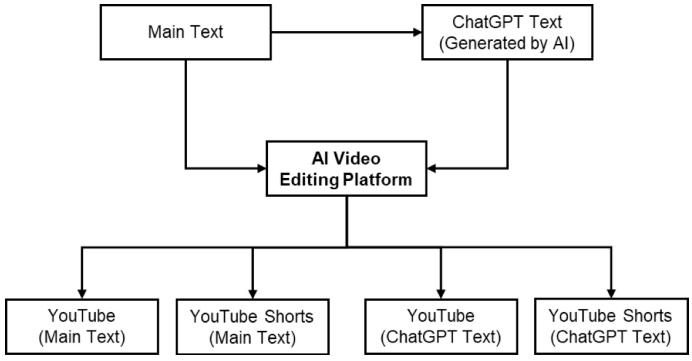

Figure 2: Workflow diagram of the performed processes.

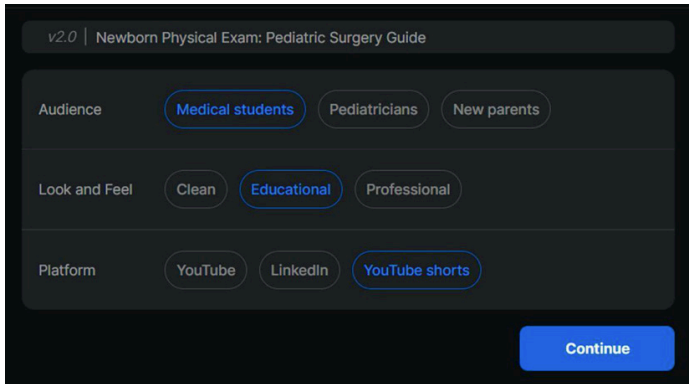

Figure 3: The interface where the criteria for creating the video are selected.

occasionally led to misinterpretation of specific terms or scenes. This required script revisions or multiple generation attempts.

We proceeded by selecting “Medical Students,” “Educational,” and “YouTube/YouTube Shorts” as the video creation settings (Fig. 3). The video had a duration of 1 minute. It included paid and free stock videos and photographs, contained subtitles, and was formatted vertically. The video creation time was 2 minutes and 50 seconds, and the file size was 104 MB (Fig. 4). Using the same main text and

Figure 4: A YouTube Shorts video created using AI with this main text.

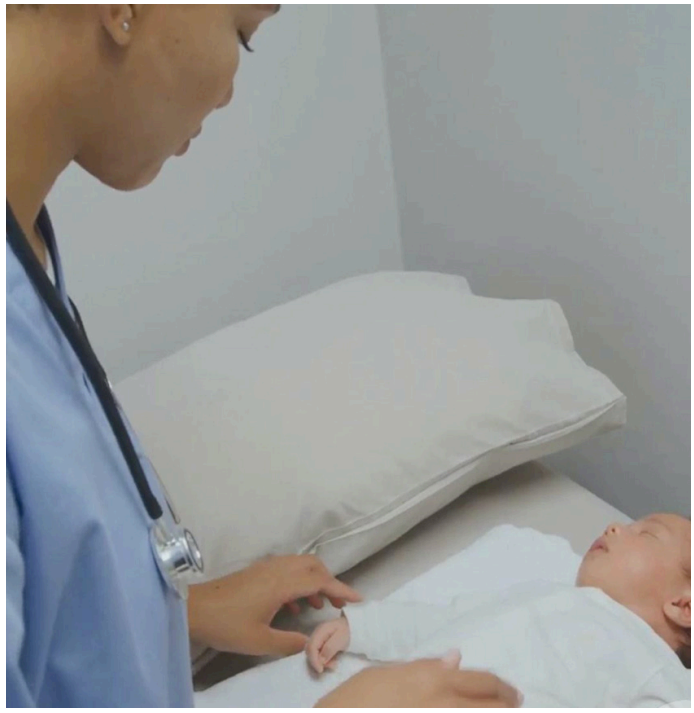

Figure 5: A YouTube Shorts video created using AI with this main text.

keeping all other settings unchanged, we repeated the process by selecting YouTube instead of YouTube Shorts. The resulting video was 2 minutes and 36 seconds long. This landscape-format video had a file size of 249 MB (Fig. 5). In the second round, we generated the main text using ChatGPT and then used the OpenAI text-to-video platform to create YouTube Shorts and YouTube videos demonstrating how pediatric surgeons perform various examinations in newborns.

Table 1: The content included in this table was obtained by entering the prompt "How we do detail physical examination on a newborn in pediatric surgery". The table outlines the examination process in 11 steps

ChatGPT Prompt: How we do detail physical examination on a newborn in pediatric surgery	
Performing a detailed physical examination on a newborn in pediatric surgery is a methodical process aimed at assessing the infant's overall health and detecting any abnormalities or concerns. The examination typically follows a structured approach:"	
Step	**Actions**
1.General assessment	**Observation:** Begin by observing the newborn's general appearance, behavior, and level of alertness. **Skin:** Note skin color, texture, and any abnormalities such as rashes or lesions. **Cry:** Evaluate the quality of cry, which can indicate respiratory or neurological issues. **Activity:** Assess spontaneous movements and muscle tone.
2.Vital signs	**Temperature:** Measure using a calibrated thermometer, ensuring warmth and comfort. **Heart Rate:** Palpate the radial pulse or use a stethoscope to auscultate heart sounds. **Respiratory Rate:** Count breaths per minute and observe for any signs of respiratory distress. **Oxygen Saturation:** Monitor using pulse oximetry to assess oxygenation status.
3.Head and neck examination	**Fontanelles:** Palpate anterior and posterior fontanelles for size, tension, and symmetry. **Eyes:** Inspect for symmetry, red reflex, and ability to open and close. **Ears:** Examine for shape, position, and patency of external auditory canals. **Mouth and Throat:** Check for cleft palate, tongue-tie, and normal suck reflex.
4.Cardiovascular examination	**Heart Sounds:** Auscultate at various points (aortic, pulmonic, tricuspid, mitral) for heart murmurs and normal sounds. **Peripheral Pulses:** Palpate radial and femoral pulses to assess circulation and perfusion.
5.Respiratory examination	**Lung Fields:** Auscultate both lungs to detect normal breath sounds, crackles, or wheezes. **Chest Wall:** Inspect for symmetry and movement abnormalities.
6.Abdominal examination	**Inspection:** Look for distention, scars, or abdominal masses. **Palpation:** Gently palpate to assess liver, spleen, and kidneys for size, tenderness, or masses. **Bowel Sounds:** Listen for active bowel sounds in all quadrants.
7.Genitourinary examination	**External Genitalia:** Assess for normal development and any abnormalities. **Urinary Output:** Evaluate diaper for adequate urine output as a sign of renal function.
8.Musculoskeletal examination	**Extremities:** Inspect for symmetry, deformities, or abnormalities in limb length. **Spine:** Check for midline defects such as spina bifida or abnormalities in curvature.
9.Neurological examination	**Reflexes:** Test primitive reflexes (e.g., Moro reflex) and muscle tone. **Cranial Nerves:** Assess facial movements and suck reflex. **Level of Consciousness:** Evaluate responsiveness and alertness.
10.Skin and extremities examination	**Skin Integrity:** Note any birthmarks, petechiae, or areas of bruising. **Nails and Hair:** Inspect nails and hair for anomalies or signs of congenital conditions.
11.Documentatio n and follow-up	**Recording Findings:** Document all examination findings systematically, noting any abnormalities or concerns. **Communication:** Clearly communicate findings with caregivers and healthcare team members for appropriate management and follow-up.

The platform also allows users to edit the final video in up to three components: the video, script, and voice or music, when used (Fig. 6). We produced four distinct videos on the physical examination of newborns in pediatric surgery. The total text length, including the description and subtitles, was measured in words. The consistency and educational value of the AI-generated videos were evaluated.

RESULTS

The outputs presented in this section should be interpreted not as hypothesis-driven findings but as practical results generated through the described workflow.

We created a total of four videos. The word counts and video

Table 2: Comparative table of videos created using the main text and ChatGPT-generated text. These videos were created with invideo AI, a video editing platform

Video	Text	The contents	The targeted population	Type of video	Text Word count	Time to create (minutes)	Video duration (minutes)	File size (mb)	Subtitle
1	Main text	Educational	Medical students	YouTube	12	4:35	2:36	249	No
2	Main text	Educational	Medical students	YouTube Shorts	12	2:50	1:00	104	Yes
3	ChatGPT text	Educational	Medical students	YouTube	405	12:20	9:50	966	No
4	ChatGPT text	Educational	Medical students	YouTube Shorts	405	6:45	4:24	442	Yes

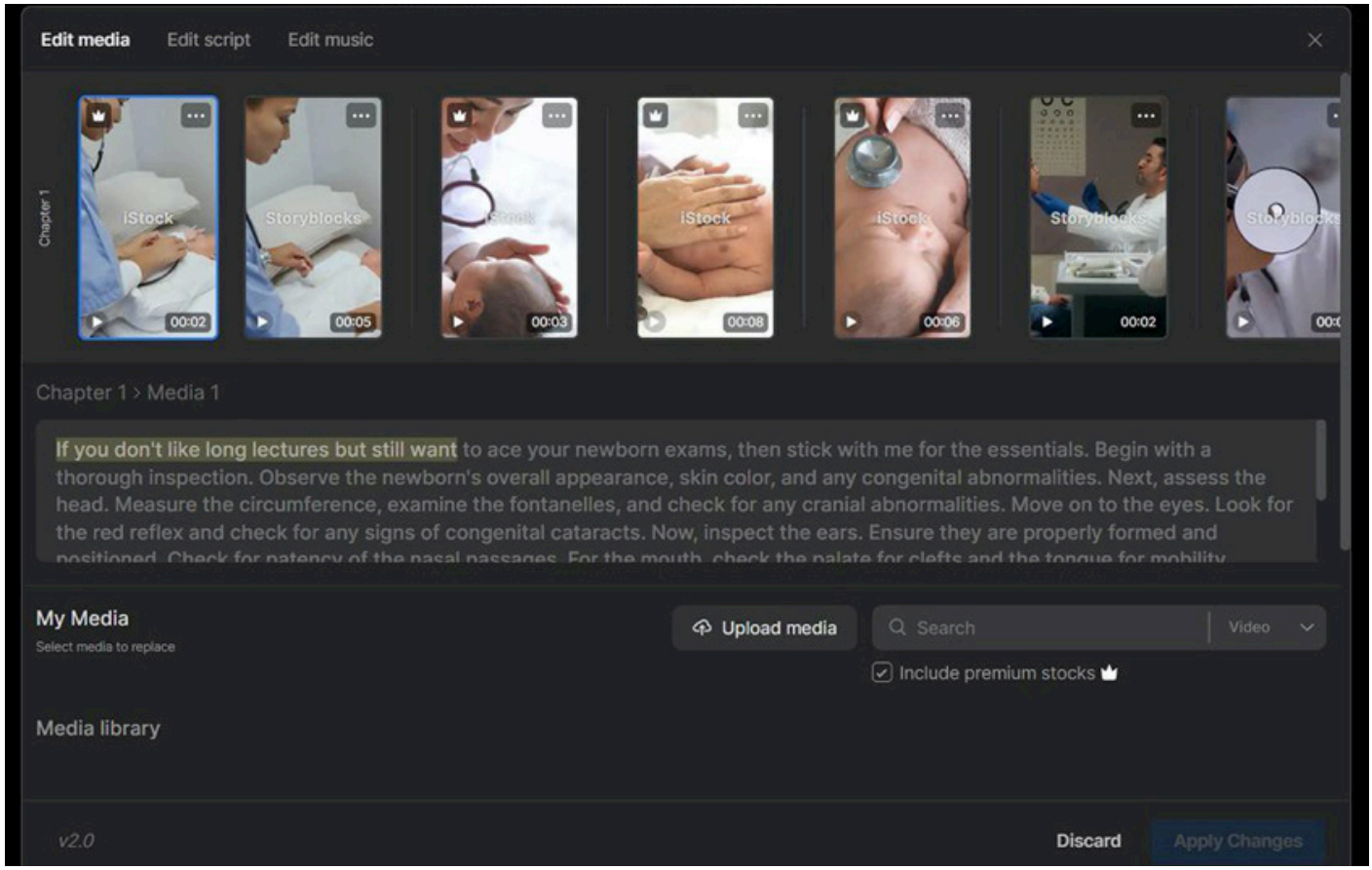

Figure 6: The interface where you can edit text, video, and audio.

durations are summarized in Table 2. The main text for the topic selected in the field of pediatric surgery was as follows: "How do we perform a detailed physical examination of a newborn in pediatric surgery?" A detailed text was then generated using ChatGPT and is presented in Table 1. The main text consisted of 12 words and was written as a question. The text generated by ChatGPT consisted of 405 words in total, including the description. ChatGPT divided the text into 11 subchapters, which are summarized in detail in Table 1. The duration of each video depended on the length of the text and the selected video format; YouTube videos were longer, whereas YouTube Shorts videos were shorter (Table 2).

All videos can be accessed via the Drive link below or through the following YouTube links:

Main Text YouTube: https://youtu.be/OTa5WxjujU4

Main Text YouTube Shorts: https://www.youtube.com/shorts/v32LcrZsQ1o

ChatGPT Text YouTube: https://youtu.be/HqRCatboMUk

ChatGPT Text YouTube Shorts: https://youtu.be/ykdmN8_6Lgs

Drive link

DISCUSSION

This discussion section aims to evaluate the technical innovation, practical applicability, and educational potential of the proposed workflow.

The findings of this study indicate that videos generated from short scripts required shorter production times and resulted in smaller file sizes, whereas detailed scripts produced longer videos and larger files. A major limitation was the scarcity of pediatric surgery–specific medical visuals within AI databases. ChatGPT may support medical education by providing rapid explanations and simulated interactions; however, expert oversight is essential to ensure clinical accuracy.

AI offers significant potential to enhance the understanding of complex clinical concepts in medical education. AI-based platforms can analyze large datasets to generate personalized learning materials, simulate clinical scenarios, and provide a risk-free environment for skill development. However, appropriate contextual use, expert validation of content accuracy, and adherence to ethical standards remain essential for safe and effective integration.

Long Videos and Repetition

One of the primary challenges in creating medical educational videos using AI is managing video length and content repetition. Long videos tend to include more repetitive content, which may reduce viewer engagement and educational effectiveness. AI-based video-editing platforms can mitigate this issue through the following approaches:

Content Summarization: Advanced algorithms can be used to summarize lengthy explanations and procedures into concise segments without omitting essential information.

Adaptive Learning: Video content can be tailored to users' learning pace and preferences, thereby reducing unnecessary repetition and making the learning process more efficient.

However, developing and refining these algorithms to ensure their effectiveness in the context of complex medical education remains a significant challenge.

Insufficient Medical Databases

Creating high-quality medical educational content requires access to extensive and accurate medical databases. A common limitation is the scarcity of medical videos and images suitable for educational purposes. The reasons for this scarcity include the following:

Copyright Restrictions: Many medical images and videos are protected by copyright, limiting their use in the creation of new educational content. AI-based video-editing platforms need to address these restrictions through the following approaches:

Creating Original Content: High-quality AI-generated images and animations can be produced to accurately represent medical conditions and procedures.

Partnerships and Licensing: Collaboration with medical institutions and content creators may enable the licensing of copyrighted materials for use in educational videos.

Quality Assurance: AI-generated content must meet the high standards required for medical education. This requires the continuous updating and validation of the medical databases used by AI-based video-editing platforms.

Legal and Ethical Issues

The use of medical data for educational purposes presents legal and ethical challenges, particularly regarding patient privacy and content appropriateness. Key issues include the following:

Privacy Laws: Strict regulations, such as the Health Insurance Portability and Accountability Act (HIPAA) in the United States, prohibit the use of identifiable patient information without consent. AI-based video-editing platforms must address these requirements through the following measures:

Data Anonymization: All personal information should be removed from medical data before it is used in educational content.

Compliance: Relevant privacy laws and regulations must be followed to avoid legal consequences. International data protection frameworks, such as the European Union's General Data Protection Regulation (GDPR) and Türkiye's Personal Data Protection Law (KVKK), also impose strict requirements on the processing of personal health information. These regulations must be observed to ensure full legal compliance when producing AI-generated medical educational materials.

Content Appropriateness: Medical videos may sometimes be misinterpreted or misclassified as inappropriate content, including pornography. AI-based video-editing platforms can address this issue through the following approaches:

Contextual Analysis: Advanced AI techniques can be used to ensure that medical content is accurately categorized and presented within an educational context.

Content Moderation: Robust content moderation systems should be implemented to review and approve videos before they are made publicly available.

Interpretation of the Study Results and Recommendations for Optimizing Text-to-Video AI

a. Select Appropriate Text: Revise the text when the AI platform fails to recognize it, particularly when it includes specific medical terms, techniques, or syndromes.
b. Keep Videos Short: Shorter videos may help reduce noticeable errors, which tend to become more apparent in longer videos.
c. Perform Multiple Attempts: Video creation may require multiple attempts because of potential limitations in the AI platform's video and image databases.
d. Edit Final Videos: If the AI-generated content is inappropriate or inaccurate, the final video should be edited manually.

The integration of ChatGPT-generated texts into OpenAI-based text-to-video platforms may improve several components of medical education. By using AI to produce detailed scripts that can be converted into high-quality instructional videos, this method may facilitate the creation of consistent and comprehensive educational content, thereby enriching the training of pediatric surgeons under optimal conditions.

This study focused exclusively on technical production processes and did not include pilot testing to evaluate educational impact. Future studies should incorporate educational metrics, such as learning outcomes, blinded expert evaluations, and student performance scores.

The medical accuracy, clinical relevance, and narrative consistency of the AI-generated videos were not assessed using a systematic rubric. Therefore, the evaluation of content accuracy was limited to the researchers' observations.

Although AI-generated content offers substantial benefits in terms of accessibility and efficiency, it also presents several challenges. Ensuring accuracy, maintaining contextual relevance, and addressing potential biases in content creation are critical considerations. Despite these challenges, the integration of AI into medical education holds considerable promise for enhancing learning experiences and ultimately advancing clinical proficiency and patient care in pediatric surgery.

Weaknesses of the Study

1. This study tested only the free version of InVideo AI, and no direct comparisons were performed with other advanced platforms, such as SORA AI, Midjourney, DALL-E, Adobe Firefly, Leonardo AI, or Playground AI, which limits the generalizability of the findings.
2. No pilot testing, blinded expert review, or educational outcome measurements were performed, limiting the study's ability to determine the pedagogical effectiveness of the generated videos.
3. No objective scoring rubric was applied to evaluate medical accuracy, clinical relevance, or visual coherence; therefore, the accuracy assessment remained limited to the researchers' observations.
4. Potential losses in visual detail and consistency between YouTube and YouTube Shorts formats were not systematically assessed.
5. The number of pediatric surgery topics was limited to one, and this scope should be expanded to allow for a more comprehensive analysis.
6. Time requirements and variations in video creation may be influenced by the type and model of the computer, the quality of the internet connection, and the video software used.
7. AI capabilities may improve over time, making it difficult to establish a consistent standard because of ongoing developments in machine learning.

CONCLUSION

The use of AI-based video-editing platforms to create medical educational videos has significant potential to enhance learning and improve the accessibility of medical education. However, careful consideration must be given to issues related to video length and repetition, access to comprehensive and legally permissible medical databases, and compliance with legal and ethical standards. By addressing these challenges through advanced AI techniques, partnerships, and compliance measures, SORA AI and similar AI-based video-editing platforms may contribute effectively to medical education.

When platforms such as SORA AI enable the creation of entirely original medical videos from text, content production may become more feasible. At present, however, these platforms have not progressed beyond video editing. Moreover, at the time of this study, despite their promising capabilities, AI-based video-editing platforms lacked sufficiently comprehensive medical databases, indicating that further development is required to achieve optimal performance. In its current form, this study is best classified as a "Technical Note." With the inclusion of objective evaluation metrics in future studies, it may be expanded into an original research format.

Statement

Ethics Committee Approval: This study did not involve human participants, animals, identifiable patient data, or clinical interventions. Therefore, ethics committee approval was not required.

Informed Consent: This study did not involve human participants or the use of identifiable patient data or images; therefore, informed consent was not required.

Conflict of Interest: The authors declare that there is no conflict of interest.

Funding: The authors declare that they did not receive any funding, grants, or other support during the course of this study.

Use of AI for Writing Assistance: In this study, the ChatGPT and Invideo AI platforms were utilized to evaluate an AI-supported workflow for the production of educational content. In addition, AI-powered tools were used during the preparation of the article for language editing and text refinement. The scientific content, interpretation, critical evaluation, and final approval of the study were carried out entirely by the authors, who are solely responsible for the entire content of the article.

Authorship Contributions: Concept – MBY, SC; Design – MBY, SC; Supervision – SC; Results – SC, AC; Materials – SC; Data Collection and/or Processing – SC; Analysis and/or Interpretation – MBY, SC; Literature Search – SC, AC; Writing – MBY, SC; Critical Reviews – SC.

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ORIGINAL ARTICLE

Distribution of children with imperforate hymen between pediatric surgery and gynecology outpatient clinics in a maternity and children's hospital: A 10-year retrospective study

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ABSTRACT

Objective: Imperforate hymen is the most prevalent congenital obstructive abnormality of the female genital tract. This study was conducted to determine which department children who underwent surgery for imperforate hymen first presented to or were referred to at a maternity and children's hospital. The primary aim was to emphasize the importance of a comprehensive physical examination in reducing the age at diagnosis because of the serious complications associated with delayed diagnosis.

Material and Methods: The medical records of children who underwent surgery for imperforate hymen between January 2014 and 2024 were retrospectively reviewed.

Results: Of the 32 patients who underwent surgery for imperforate hymen at our hospital over a 10-year period, the mean age at surgery was 116±69 months (minimum: 1 month, maximum: 192 months). Thirteen of the 32 patients (40.6%) underwent surgery in the Department of Pediatric Surgery; six of these 13 patients (46%) were neonates. Among the patients presenting to pediatric surgery, four had prenatally diagnosed hydrocolpos, and five were diagnosed during the first postnatal physical examination. Four adolescents presented directly to pediatric surgery with primary amenorrhea, abdominal pain, and an abdominal cystic mass. Nineteen of the 32 patients (59.4%) underwent surgery in the Department of Gynecology and Obstetrics. The primary reason for referral to the Department of Gynecology and Obstetrics was primary amenorrhea, followed by pelvic pain.

Conclusion: A comprehensive physical examination can facilitate the diagnosis of imperforate hymen at an earlier age, particularly when a cystic structure suggestive of hydrometrocolpos is detected on prenatal or postnatal ultrasonography.

Keywords: Adolescent, imperforate hymen, neonate.

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INTRODUCTION

The most common obstructive anomaly of the female genital tract is imperforate hymen, with an incidence ranging from 0.01% to 0.05%.[1] The vaginal opening is normally partially covered by the hymen, which consists of a thin layer of squamous epithelium. In imperforate hymen (IH), the vaginal opening is completely closed, and there is no entrance to the vaginal lumen.[2]

In a fetus with an imperforate hymen, increased uterovaginal secretions caused by maternal estrogen stimulation can lead to hydrocolpos. Symptomatic hydrocolpos can be diagnosed by prenatal ultrasonography, whereas imperforate hymen can be diagnosed by postnatal perineal examination.

Imperforate hymen may present as hydrocolpos during the fetal and neonatal periods because maternal estrogen stimulation increases uterovaginal secretions. Cases presenting with hydrocolpos with or without hydronephrosis can be diagnosed prenatally.[3]

In adolescents, an imperforate hymen appears as a bulging, bluish membrane, indicating the accumulation of blood in the vagina. This appearance is highly characteristic of imperforate hymen and is also diagnostic.[4] If fetal or neonatal hydrocolpos does not develop and the condition remains asymptomatic, the absence of routine gynecological examinations in this age group or an inadequate perineal examination may delay the diagnosis of imperforate hymen.[5]

This study was conducted to determine which department children who underwent surgery for imperforate hymen first presented to or were referred to at a maternity and children's hospital. The primary aim was to emphasize the importance of a careful and comprehensive perineal examination in the early diagnosis of imperforate hymen, as delayed diagnosis can lead to significant complications and morbidity.

MATERIAL AND METHODS

The medical records of children who underwent surgery for imperforate hymen between January 2014 and January 2024 were retrospectively reviewed. Patients with vaginal atresia were excluded from the study. All data, including the department to which the patients first presented, the referring department, the department in which the diagnosis was made, the department in which surgery was performed, age at presentation, presence of a prenatal diagnosis, presenting complaints, physical examination findings, and radiological imaging findings, were obtained from the hospital records.

The surgical techniques differed between the two clinics. The Department of Obstetrics and Gynecology performed incisions at the 6 and 12 o'clock positions and removed a portion of the hymen, whereas the Department of Pediatric Surgery performed incisions at the 3, 6, 9, and 12 o'clock positions and secured the edges to the four quadrants with sutures.

Approval was obtained from the Clinical Research Ethics Committee of Zeynep Kamil Maternity and Children's Diseases Health Training and Research Center (07.08.2024/50). The study was conducted in accordance with the principles of the Declaration of Helsinki, and informed consent was obtained from the patients' parents.

Table 1: Distribution of descriptive characteristics

	n (%)*
Age (months) (the age at presentation/surgery)	
Mean±SD	116±69
Median (min–max)	108 (1–192)
Initial department of presentation	
Department of perinatology	4 (12.5)
Department of pediatrics	10 (31.3)
Department of pediatric surgery	4 (12.5)
Department of the gyneocology & obstetrics	14 (43.8)
Referred department	
Department of pediatric surgery	9 (28.1)
Department of the gyneocology & obstetrics	5 (15.6)
Diagnosed department	
Department of pediatric surgery	8 (25)
Department of the gyneocology & obstetrics	14 (43.8)
Performed department	
Department of pediatric surgery	13 (40.6)
Department of the gyneocology & obstetrics	19 (59.4)
The presence of prenatal diagnosis	
Hydrocolpos	4 (12.5)
Complaints*	
No complaint (the first postnatal physical examination)	5 (15.6)
Primary amenorrhea	17 (53.1)
Abdominal pain	16 (50)
Abdominal cystic mass	11 (34.4)
Palpable mass in the abdomen	
With Hydrocolpos	11 (34.4)

SD: Standard deviation; *: Patients had more than one complain.

Statistical Analysis

Data were analyzed using SPSS Statistics version 20 (IBM Corp., Armonk, NY, USA). Quantitative variables were presented as the mean, standard deviation, and range (minimum and maximum values), whereas qualitative variables were presented as frequencies and percentages.

RESULTS

Of the 32 patients who underwent surgery for imperforate hymen at our hospital over a 10-year period, the mean age at surgery was 116±69 months (minimum: 1 month, maximum: 192 months). The distribution of the descriptive characteristics of the patients is summarized in Table 1.

Table 2: Departmental pathway from initial presentation to surgical management

Clinical step	Pediatric surgery n (%)	Gynecology & obstetrics n (%)
Initial department of presentation	4 (12.5)	14 (43.8)
Department establishing the diagnosis	8 (25.0)	14 (43.8)
Department performing the surgery	13 (40.6)	19 (59.4)

Table 3: Comparison of patients with and without prenatal diagnosis

Variables	Prenatal diagnosis(+) (n=4)	Prenatal diagnosis(-) (n=28)
Age at presentation (months)	Neonatal period	108 (1–192)*
Initial department of presentation	Department of perinatology (100%)	Pediatric surgery/ gynecology & obstetrics
Presenting symptoms	Hydrometrocolpos	Primer amenorrhea, abdominal pain, abdominal cystic mass
Palpable abdominal mass	Present	11 (39.3%)
Timing of diagnosis	Neonatal period	Adolescence
Department performing surgery	Pediatric surgery	Pediatric surgery/ gynecology & obstetrics

*: Median(min-max) values are shown for postnatally diagnosed patients.

Figure 1: Preoperative, intraoperative, and postoperative photographs of the neonatal patient are presented.

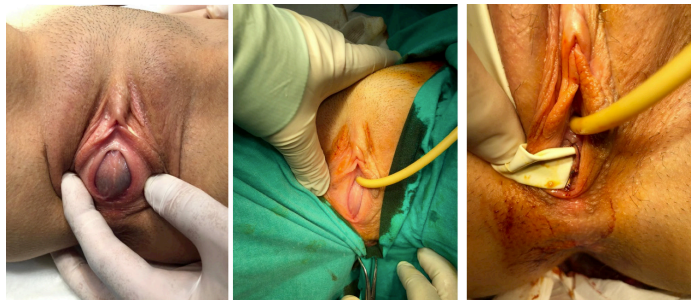

Figure 2: Preoperative, intraoperative, and postoperative photographs of the adolescent patient are presented.

Thirteen of the 32 patients (40.6%) underwent surgery in the Department of Pediatric Surgery. Six of these 13 patients (46%) were neonates, and the mean age at surgery of the remaining seven patients was 10.43±3.5 years (minimum: 3 years, maximum: 14 years). Among the patients presenting to pediatric surgery, four had prenatally diagnosed hydrocolpos, and five were diagnosed during the first postnatal physical examination. Four adolescents presented directly to pediatric surgery with primary amenorrhea, abdominal pain, and an abdominal cystic mass.

The clinical pathway from presentation to treatment and a summary of the departments involved at each stage are presented in Table 2.

Nineteen of the 32 patients (59.4%) underwent surgery in the Department of Gynecology and Obstetrics, and their mean age was 12.58±3.27 years (minimum: 1 year, maximum: 16 years). None of these 19 patients had been referred to the Department of Pediatric Surgery, whereas five were referred from the Department of Pediatrics. The primary reason for referral to the Department of Gynecology and Obstetrics was primary amenorrhea, followed by pelvic pain.

Patients diagnosed prenatally were managed during the neonatal period with minimal symptoms, whereas those without a prenatal diagnosis commonly presented during adolescence with abdominal pain or primary amenorrhea, as shown in Table 3.

Preoperative, intraoperative, and postoperative photographs of the neonatal and adolescent patients are presented in Figure 1 and Figure 2.

DISCUSSION

Imperforate hymen can present as hydrocolpos during the neonatal period due to the accumulation of mucoid secretions in the vagina or become symptomatic as hematocolpos during adolescence due to the accumulation of menstrual blood after menarche.[3]

Hydrocolpos or hematocolpos associated with congenital imperforate hymen is generally not a life-threatening condition, and outcomes are favorable. However, delayed diagnosis and intervention can lead to serious complications caused by compression of the surrounding structures, depending on the size of the hydrocolpos

or hematocolpos. These complications include infection, retrograde menstruation, ruptured hematosalpinx, endometriosis, pyocolpos, and infertility. In addition, imperforate hymen can lead to both physical and psychosocial complications if not diagnosed early.[1,6]

Patients more commonly become symptomatic and present during adolescence at the onset of menarche. The accumulation of menstrual blood in the vagina, cervix, and uterus usually manifests as abdominal pain, constipation, a pelvic mass, bowel obstruction, and urinary retention. Primary amenorrhea is also present. Hydronephrosis and renal failure may develop.[4,5] Surgical hymenectomy and evacuation of the hematocolpos are mandatory treatments for imperforate hymen and are associated with few long-term complications.[7,8]

During the neonatal period, the diagnosis can be easily made through careful genital inspection.[1] Given its rarity, imperforate hymen can be overlooked in both newborns and adolescents because of an inadequate examination of the perineum and vulva. A thorough physical examination is essential for the diagnosis of imperforate hymen.[1] Imperforate hymen accompanied by a characteristic bluish swelling caused by the accumulation of blood in the vagina is highly typical and diagnostic of hematocolpos.[1,4] Although rare, imperforate hymen may be detected during the neonatal period as a bulging, bluish hymenal membrane caused by mucocolpos.[9] Sakalkale et al.[10] reported that none of the four patients diagnosed during the neonatal period had symptoms and that the diagnosis was made solely by physical examination. Laasri et al.[11] emphasized the importance of obtaining a detailed gynecological history and performing a thorough physical examination of the vaginal introitus in adolescent girls presenting with abdominal pain and difficulty with defecation. In our study, the presence of patients who presented to the Department of Pediatric Surgery and were diagnosed during the neonatal period demonstrates the importance of routine examinations for early diagnosis. Five patients were identified during the first postnatal physical examination and referred for further management.

Radiological diagnosis can be achieved using ultrasonography, which usually demonstrates a cystic mass containing echogenic fluid. Magnetic resonance imaging can be used when a congenital malformation, such as vaginal agenesis, is suspected.[4] Imperforate hymen may be detected prenatally, manifesting as hydrocolpos, hydrometrocolpos, or hydronephrosis on fetal ultrasonography.[3] When the hymen remains intact, excessive intrauterine stimulation of the fetal cervical mucous glands by maternal estrogen results in hydrocolpos due to the accumulation of secretions in the uterus and vagina.[10,12] Prenatal diagnosis of imperforate hymen with hydrocolpos has been reported as early as 25 weeks of gestation.[13] In our study, four patients had prenatally diagnosed hydrocolpos, and all were diagnosed after 25 weeks of gestation.

Although complications are minimal in patients diagnosed early, serious complications such as hematocolpos, hematometra, and hydronephrosis may develop in patients diagnosed late.[14] Bakos et al.[15] reported a case of imperforate hymen associated with ruptured hematosalpinx. Alghanim et al.[16] also emphasized the importance of early diagnosis of imperforate hymen to preserve normal reproductive health and prevent long-term complications. Hematocolpos may also occur in uterovaginal malformations such as a complete transverse vaginal septum, distal vaginal atresia or obstruction, uterine didelphys, or cervical atresia.[17] In our study, patients with vaginal atresia were excluded. We included only patients with hydrocolpos or hematocolpos caused by imperforate hymen and excluded those with hematocolpos due to other causes. The diagnosis was most commonly made during adolescence in patients presenting with amenorrhea and pelvic pain. Four of the 13 patients evaluated in the Department of Pediatric Surgery presented with primary amenorrhea and abdominal pain. The primary reason for referral to the Department of Gynecology and Obstetrics was primary amenorrhea. None of the patients in our study had acute urinary retention or ruptured hematosalpinx.

Patients diagnosed prenatally were managed during the neonatal period with minimal symptoms, whereas those without a prenatal diagnosis commonly presented during adolescence with abdominal pain or primary amenorrhea, highlighting the clinical importance of early detection.

CONCLUSION

A comprehensive physical examination can facilitate the diagnosis of imperforate hymen at an earlier age. If a cystic structure suggestive of hydrometrocolpos is detected on prenatal or postnatal ultrasonography, careful examination of the genitalia and hymen can ensure early diagnosis before complications develop.

Particularly in adolescents presenting to the emergency department with abdominal pain who have not yet menstruated, including a hymenal examination as part of a comprehensive physical examination may provide the last opportunity for diagnosis and intervention before serious complications develop.

In addition, this study highlights that the diagnosis of imperforate hymen primarily relies on meticulous physical examination rather than advanced diagnostic techniques. Although prenatal and neonatal diagnosis is possible, the condition may be overlooked in the absence of routine genital examination. In adolescents presenting with primary amenorrhea and abdominal or pelvic pain, hymenal examination represents a critical step in achieving a timely diagnosis before preventable complications occur. Differences in referral patterns among clinical departments further emphasize the need for increased awareness and education regarding this condition.

Statement

Ethics Committee Approval: The study was approved by Zeynep Kamil Maternity and Children's Diseases Health Training and Research Hospital Ethics Committee (No: 50, Date: 07.08.2024).

Informed Consent: Informed consent was obtained from the patients' parents.

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ORIGINAL ARTICLE

Determination of maternal mortality and associated risk factors in the Jigawa North-East senatorial district, Jigawa State, Nigeria, 2018–2022

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ABSTRACT

Objective: This study examined maternal mortality rates and causes in three state hospitals—Hadejia General Hospital (HGH), Kafin Hausa General Hospital (KGH), and Birniwa General Hospital (BGH)—in the North-East Senatorial District of Jigawa State, Nigeria, between 2018 and 2022.

Material and Methods: This descriptive study retrospectively reviewed the hospital records of all maternal deaths, as defined by the World Health Organization International Classification of Diseases–Maternal Mortality (WHO ICD-MM). Maternal mortality ratios (MMRs) were calculated per 100,000 live births, and the causes were classified as direct or indirect. Trends over time and differences among the hospitals were analysed. Data are presented as numbers, percentages, and rates per 100,000 live births. SPSS version 22 was used for the analysis.

Results: A sharp increase was observed in 2020, coinciding with the COVID-19 pandemic. The MMR increased from 1,454 to 5,045 in BGH, from 3,578 to 9,627 in HGH, and from 0 to 1,709 in KGH. Rates declined slightly in 2021–2022 but remained far above national and global targets. In BGH, anaemia was the leading cause of maternal mortality (45.35%), followed by eclampsia (27.91%) and postpartum haemorrhage (8%). In HGH, eclampsia was the leading cause (27.89%), followed by placental abruption, pulmonary embolism, hypovolaemic shock, and transfusion reactions, which collectively accounted for 24% of deaths. In KGH, postpartum haemorrhage was the most common cause (36.59%), followed by eclampsia (17.07%), difficult delivery (14.63%), and anaemia (9.76%).

Conclusion: Maternal mortality in Jigawa State remains unacceptably high and is largely attributable to preventable direct obstetric causes and indirect factors. Reducing maternal mortality requires urgent improvements in obstetric care, stronger referral systems, greater consideration of indirect causes, continuity of services during crises, and sustained health education.

Keywords: Anaemia, COVID-19 pandemic, eclampsia, Jigawa state, maternal mortality rate, Nigeria.

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INTRODUCTION

Maternal deaths remain a critical global public health issue, particularly in low- and middle-income countries. In 2020, approximately 287,000 women worldwide lost their lives due to pregnancy- and childbirth-related causes. This figure equates to an average of 830 maternal deaths per day, with nearly all (99%) occurring in developing countries.[1] Sub-Saharan Africa bears the heaviest burden, accounting for approximately 70% of global maternal deaths; approximately one-quarter of these deaths occur in Nigeria alone.[2] Nigeria has the second-highest number of maternal deaths after India, accounting for approximately 59,000 maternal deaths per year, or 19.5% of the global burden.[3] Nigeria's national maternal mortality ratio (MMR) is reported to be 814 per 100,000 live births.[2] However, in some northern states, this ratio exceeds 1,000 per 100,000 live births. In Jigawa State, the maternal mortality ratio was estimated at 1,012 per 100,000 live births in 2017, with the lifetime risk of maternal death estimated to be as high as 1 in 15.8.[4] This clearly demonstrates the severity of the crisis in the region.

The burden of maternal deaths in Nigeria is not evenly distributed, with marked differences between regions. Northern states such as Jigawa, in particular, face disproportionately high rates due to a combination of structural, socioeconomic, and cultural factors. These factors include poor access to skilled birth attendants, delays in emergency obstetric care, low utilisation of antenatal care, and restrictive gender norms that limit women's autonomy in healthcare decision-making. For example, the proportion of primary healthcare centres (PHCs) staffed by specialised healthcare workers is only 41% in the northwest, whereas it exceeds 90% in the southwest and southeast. Similarly, the proportion of births attended by skilled personnel reaches 96.5% in the southern states but remains alarmingly low, at below 20%, in most north-western and north-eastern states.[5]

Most maternal deaths occur in sub-Saharan Africa and South Asia, which bear the greatest global burden. Regional patterns vary: haemorrhage is the leading cause of death in North Africa, hypertensive disorders are more prevalent in Latin America and the Caribbean, and sepsis is most commonly observed in low-income regions. Abortion- and embolism-related mortality rates also vary by region, while indirect causes, including HIV-related deaths, are most concentrated in sub-Saharan Africa and South Asia.[6] Structural factors such as poverty, limited health literacy, and persistent traditional practices create conditions that make many women susceptible to anaemia during pregnancy and related serious obstetric complications. In addition, malnutrition, which is particularly prevalent among girls and young women, contributes to risks such as pelvic narrowing, difficult labour, uterine rupture, and postpartum haemorrhage.[7] These conditions collectively perpetuate the high burden of preventable maternal morbidity and mortality in resource-limited settings. Placental abruption is a serious obstetric emergency affecting approximately 0.8–1% of pregnancies and posing significant risks to both the mother and the fetus. Single-centre studies, including those by Uluutku et al.,[8] have shown that hypertensive disorders, anaemia, placenta previa/accreta, and multiple pregnancies commonly increase the likelihood of this condition.

To implement effective measures for reducing maternal mortality, a strong healthcare infrastructure must be established, and maternal health services must be improved. With accurate data and effective planning, the goal should be to reduce the maternal mortality ratio to below 70 per 100,000 live births by 2030. Maternal health is critical to countries' progress toward achieving Sustainable Development Goal 3.1. Therefore, this study aimed to determine maternal mortality and its associated risk factors in the Jigawa North-East Senatorial District, Jigawa State, Nigeria, from 2018 to 2022. Specifically, the study was designed to describe the socioeconomic characteristics of the deceased mothers, describe their obstetric histories and characteristics, analyse maternal mortality trends across three selected general hospitals, and identify the causes of maternal mortality in the study area.

Hypotheses of the Study

The hypotheses regarding the trend in the maternal mortality ratio from 2018 to 2022 and the comparison among hospitals were formulated and tested using Pearson's chi-square test and the linear-by-linear association test. The hypotheses were as follows:

1. H_0: There was no linear trend in the maternal mortality ratio from 2018 to 2022; any apparent trend was due to chance.

   H_1: There was a linear trend in the maternal mortality ratio from 2018 to 2022.

2. H_0: There was no statistically significant difference in the maternal mortality ratio among BGH, HGH, and KGH.

   H_1: There was a statistically significant difference in the maternal mortality ratio between at least two of the three hospitals (BGH, HGH, and KGH).

MATERIAL AND METHODS

Study Area

The study was conducted in the North-East Senatorial District of Jigawa State, located in north-western Nigeria. With a population of over 8.1 million as of 2024, Jigawa is one of the country's most populous states, with an annual growth rate of 3.5%.[9] Covering an area of approximately 22,410 square kilometres, the state consists of three senatorial districts, 27 local government areas, and 288 political units. Approximately 80% of the population lives in rural areas, where access to quality healthcare remains a serious challenge. Although Jigawa has a three-tier healthcare system encompassing primary, secondary, and tertiary services, maternal health indicators remain poor. The state's MMR is 1,012 per 100,000 live births, and women's lifetime risk of dying from pregnancy-related causes is estimated at 15.8 per 100,000.[10] This rate is well above the national average and far exceeds the Sustainable Development Goal (SDG) target of fewer than 70 maternal deaths per 100,000 live births. Three general hospitals were selected for this study.

Research Ethics and Permissions

All relevant ethical procedures were completed before the initiation of this research. The necessary approvals were obtained from the Hamidiye Scientific Research Ethics Committee of the University

of Health Sciences (approval no.: 23/374; date: January 19, 2024) and the Jigawa Health Research Committee (approval no.: JGHREC/2024/0052; date: February 29, 2024). Additionally, administrative and institutional approvals were obtained from the management of the three participating hospitals: Birniwa General Hospital (BGH), Hadejia General Hospital (HGH), and Kafin Hausa General Hospital (KGH). After the purpose and scope of the study had been discussed with the chief physicians and relevant department heads, formal approval was obtained. The study was conducted in accordance with the Declaration of Helsinki. The research team took all necessary measures to ensure patient confidentiality and comply with the institutions' data protection regulations.

Study Design and Population

The study employed a retrospective research design to collect data from the hospital records of three general hospitals selected within the study area. The study population included all maternal deaths resulting from pregnancy-related complications between 2018 and 2022.

Data Collection

In April 2024, maternal death records from 2018 to 2022 were retrospectively reviewed at HGH, KGH, and BGH. All maternal deaths were identified through a comprehensive examination of records from key service points, including the emergency department, delivery room, operating theatre, antenatal and postnatal wards, intensive care unit, and morgue. For each case, patient files relating to deaths occurring during the antenatal, intrapartum, or postpartum periods were retrieved from the hospitals' medical records departments. Because none of the hospitals maintained electronic medical record systems, data were manually extracted from physical registers and case files. A standardised data extraction form was used to ensure uniformity across the facilities. Each extracted entry was cross-checked against additional record sources, such as operating theatre logs, emergency registers, and ward summary books, to confirm accuracy and minimise inconsistencies.

To further ensure completeness, a five-year maternal mortality dataset for the entire state was obtained from the Medical Registration Services of the Jigawa State Ministry of Health. These state-level records, which included the numbers and causes of maternal deaths reported across all general hospitals and primary healthcare centres, were used to validate and reconcile the data collected from the hospital files. This multisource verification process ensured that the manually extracted data were comprehensive, consistent, and reliable for analysis.

Definitions

According to the World Health Organization, maternal death is defined as the death of a woman during pregnancy or within 42 days of the termination of pregnancy from any cause directly related to or aggravated by the pregnancy or its management, but not from accidental or incidental causes.[1] The maternal mortality ratio (MMR) is a measure indicating the number of maternal deaths per 100,000 live births. The MMR is calculated by dividing the total number of maternal deaths by the total number of live births and multiplying the result by 100,000.[2]

Statistical Analysis

The collected data were carefully checked, cleaned, and coded for accuracy and consistency before analysis. All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS), version 22. Given the descriptive nature of the dataset, descriptive statistical methods, such as frequency distributions and percentages, were used to summarise and present the characteristics of the study variables. The maternal mortality ratio (MMR) formula was applied to quantitatively estimate maternal mortality within the study population, as follows:

$$MMR = \frac{Number\ of\ maternal\ deaths}{Number\ of\ live\ births} \times 100{,}000$$

This formula provided a standardised measure for comparing maternal mortality across hospitals and over time. Based on the calculated MMR values, graphs and trend lines were generated to visualise temporal changes and fluctuations in maternal mortality over the five-year study period.

To complement the descriptive analysis, inferential statistical techniques were also employed to determine whether the observed variations in maternal mortality were statistically significant. Specifically, the chi-square (χ^2) test was used to examine variations in the maternal mortality ratio across the selected general hospitals (BGH, HGH, and KGH) and to determine whether institutional differences significantly influenced maternal mortality outcomes.

Additionally, the linear-by-linear association test, an extension of the chi-square test for ordinal data, was applied to determine whether there were significant temporal trends or linear relationships in the maternal mortality ratio over the five-year period under review. All statistical tests were conducted at a 95% confidence level ($p<0.05$). This combination of descriptive and inferential analyses enabled both a quantitative understanding of maternal mortality patterns and an assessment of their statistical significance across hospitals and over time.

RESULTS

Socioeconomic Characteristics of the Deceased Mothers

Table 1 presents the socioeconomic characteristics of the mothers who died from maternal causes. The age distributions of the mothers showed similar patterns across the three hospitals. In BGH, the largest proportion (46.5%) were aged 18–24 years, followed by those aged 25–34 years (27.9%). In HGH, most mothers (40.6%) were aged 25–35 years, while those aged 18–24 years accounted for 36.9%. Similarly, in KGH, 39.0% of the mothers were aged 18–24 years, and 34.2% were aged 25–34 years. The mean ages were 24.86±7.14, 28.07±8.50, and 25.63±8.12 years for BGH, HGH, and KGH, respectively.

Educational attainment among the mothers varied across the three hospitals. In BGH, half of the cases (50.0%) involved mothers with no formal education, while 30.2% had primary education, 15.1% had secondary education, and only 4.7% had tertiary education. In HGH, a higher educational profile was observed, with 42.8% of the mothers having secondary education, 25.9% having primary education, and 10.4% having tertiary education, while 20.9% had no formal education. At KGH, most mothers had primary education (39.0%), while only 7.3% had tertiary education.

Table 1: Socioeconomic characteristics of the deceased mothers in the study area

Variables	BGH (n=86)		HGH (n=502)		KGH (n=41)	
	Fre.	Per.	Fre.	Per.	Fre.	Per.
Age						
13–17 (under 18)	10	11.6	26	5.18	5	12.20
18–24	40	46.51	185	36.85	16	39
25–34	24	27.91	204	40.64	14	34.20
35 and above	12	13.95	87	17.33	6	14.60
Mean						
BGH (24.86±7.14)						
HGH (28.07±8.50)						
KGH (25.63±8.12)						
Education level						
No formal education	43	50	105	20	14	34.15
Primary	26	30.20	130	25.9	16	39.02
Secondary	13	15.10	215	42.8	8	19.51
Third	4	4.70	52	10.4	3	7.32
Place of residence						
Rural	70	81.4	351	69.9	28	68.29
Urban	16	18.60	151	30.1	13	31.71
Employment status						
Not working	69	80.23	344	68.5	32	78.05
Working outside the scope of social/health insurance	10	11.63	121	24.1	3	7.32
Work with social/health insurance	7	8.14	37	7.4	6	14.63
Household welfare level						
Lowest	27	31.40	85	16.9	19	46.34
Low	44	51.16	240	47.8	17	41.46
Medium	10	11.63	152	30.3	3	7.32
High	2	4.88	20	4	2	4.88
Highest	3	7.32	5	1	0	0

Fre: Frequency; Per: Percentage; BGH: Birniwa General Hospital; HGH: Hadejia General Hospital; KGH: Kafin Hausa General Hospital.

The results regarding maternal deaths according to place of residence revealed a consistent predominance of rural residence across all hospitals. In BGH, the majority of cases (81.4%) involved mothers from rural areas. Similarly, in HGH, 69.9% of the mothers resided in rural areas, compared with 30.1% from urban areas. A comparable pattern was observed in KGH, where the majority of the mothers (68.3%) were rural residents.

With respect to employment status, the majority of mothers who died from maternal complications across the three hospitals were unemployed housewives. Specifically, 80.2% in BGH, 68.5% in HGH, and 78.1% in KGH were not engaged in formal employment. Among those who were employed, 11.6%, 24.1%, and 7.3% in BGH, HGH, and KGH, respectively, worked without social or health insurance coverage.

Lastly, the results regarding maternal deaths according to household welfare level revealed that the majority of the affected mothers belonged to the lowest and low welfare groups across all hospitals. In BGH, the low welfare group accounted for 51.2% and the lowest welfare group for 31.4%, together representing 82.6% of all maternal deaths. Only 11.6% were from medium-welfare households, while 4.9% and 7.3% were from high- and highest-welfare households, respectively. In HGH, similar patterns were observed, with 47.8% of maternal deaths occurring in the low welfare group and 16.9% in the lowest welfare group. The medium welfare category constituted 30.3%, whereas the high and highest welfare groups accounted for only 4% and 1%, respectively. In KGH, maternal deaths were most concentrated in the lowest (46.3%) and low (41.5%) welfare groups,

Table 2: Distribution of mothers according to obstetric characteristics

Variables	BGH (n=86)		HGH (n=502)		KGH (n=41)	
	Fre.	Per.	Fre.	Per.	Fre.	Per.
Pregnancies						
1	10	11.63	65	12.95	6	14.63
2–4	46	53.49	220	43.82	19	46.34
5–9	23	26.74	162	32.27	11	26.83
≥10	7	8.14	55	10.96	5	12.20
Number of births						
0–1	8	9.30	59	11.75	4	9.76
2–4	44	51.16	225	44.82	21	51.22
5–9	24	27.91	158	31.47	10	24.39
≥10	10	11.63	64	12.75	6	14.63
Birth interval						
First birth	23	26.74	171	34.06	11	26.83
Less than 24 months	45	52.33	173	34.46	25	60.98
24 months and over	18	20.93	158	31.47	5	12.20
Prenatal care visit						
0–1	72	84.88	275	54.78	32	78.05
2–3	11	12.79	191	38.05	5	12.20
4 or more	3	3.49	36	7.17	4	9.76
Adequacy of prenatal care						
No prenatal care	68	79.07	264	52.59	27	65.85
Inadequate prenatal care	15	17.44	202	40.24	10	24.39
Adequate prenatal care	3	3.49	36	7.17	4	9.76
Gestational age in the last pregnancy (weeks)						
Less than 37 (premature birth)	40	46.51	239	47.61	21	51.22
37–41 (period)	31	36.05	170	33.87	17	41.46
42 and above (late birth date)	4	4.65	8	1.59	1	2.44
Unknown	11	12.79	85	16.93	2	4.88
Adequacy of care during intrapartum						
Inadequate care	48	55.81	213	42.43	22	53.66
Adequate care	26	30.23	159	31.67	14	34.14
Birth not reached	12	13.95	130	25.90	5	12.20
Adequacy of postpartum care						
Inadequate	21	24.42	137	27.29	10	24.39
Adequate	4	4.65	21	4.18	3	7.32
No postpartum period	61	70.93	344	68.53	28	68.29

Fre: Frequency; Per: Percentage; BGH: Birniwa General Hospital; HGH: Hadejia General Hospital; KGH: Kafin Hausa General Hospital.

jointly accounting for 87.8% of the total. Only 7.3% of the cases were from medium-welfare households and 4.9% were from high-welfare households.

Obstetric Characteristics and Histories of the Deceased Mothers

Table 2 presents the obstetric characteristics of the mothers who

Table 3: Maternal mortality trends by year (from 2018 to 2022)

Year	Total pregnancies*	Live births n (%)	Maternal deaths n (%)	MMR (per 100,000 births)
2018	4213	4113 (97.7)	95 (2.3)	2310
2019	5694	5579 (98.0)	115 (2.0)	2061
2020	2746	2595 (94.5)	151 (5.5)	5819
2021	7205	7066 (98.1)	139 (1.9)	1967
2022	7029	6900 (98.2)	129 (1.8)	1870
Total	26,882	26,253 (97.7)	629 (2.3)	2396

*: Total pregnancies = (maternal deaths + live births); MMR: Maternal mortality ratio.

died from maternal complications. The results regarding the number of pregnancies revealed that most mothers who died from maternal causes had moderate pregnancy histories. In BGH, more than half (53.5%) had experienced 2–4 pregnancies, followed by 26.7% who had experienced 5–9 pregnancies, while 11.6% and 8.1% had experienced one and 10 or more pregnancies, respectively. Similarly, in HGH, most mothers (43.8%) had experienced 2–4 pregnancies, 32.3% had experienced 5–9 pregnancies, and smaller proportions had experienced one (13.0%) or 10 or more pregnancies (11.0%). A comparable pattern was observed in KGH, where 46.3% had experienced 2–4 pregnancies, 26.8% had experienced 5–9 pregnancies, 14.6% had experienced one pregnancy, and 12.2% had experienced 10 or more pregnancies.

The findings regarding parity distribution revealed that most mothers across all hospitals had moderate parity levels. Specifically, 51.2%, 44.8%, and 51.2% of the mothers in BGH, HGH, and KGH, respectively, had 2–4 previous births, indicating that the majority were multiparous women. Considerable proportions also fell within the category of 5–9 previous births: 27.9% in BGH, 31.5% in HGH, and 24.4% in KGH. Meanwhile, smaller but notable proportions of women—11.6% in BGH, 12.8% in HGH, and 14.6% in KGH—had 10 or more previous births. In contrast, only 9.3%, 11.8%, and 9.8% of the mothers in BGH, HGH, and KGH, respectively, had one or no previous births, representing the nulliparous or primiparous group.

Analysis of birth intervals revealed that the majority of mothers at BGH (52.3%) and KGH (61.0%) had short birth intervals of less than 24 months, while 34.5% of mothers at HGH also fell within this category. Additionally, 26.7%, 34.1%, and 26.8% of mothers at BGH, HGH, and KGH, respectively, were first-time mothers, while only 20.9%, 31.5%, and 12.2%, respectively, had birth intervals of 24 months or more.

The results regarding antenatal care (ANC) attendance revealed extremely low utilisation across all hospitals. In BGH, the majority of mothers (84.9%) attended only 0–1 ANC visit, compared with 54.8% in HGH and 78.1% in KGH. Moderate attendance (2–3 visits) was recorded among 12.8%, 38.1%, and 12.2% of mothers in BGH, HGH, and KGH, respectively, while only negligible proportions (3.5%, 7.2%, and 9.8%, respectively) completed the recommended four or more visits.

Findings regarding the adequacy of antenatal care revealed a high prevalence of non-attendance across all hospitals. Specifically, 79.1%, 52.6%, and 65.9% of mothers in BGH, HGH, and KGH, respectively, received no antenatal care, indicating significant gaps in maternal health service utilisation. Smaller proportions received inadequate ANC (17.4% in BGH, 40.2% in HGH, and 24.4% in KGH), meaning that they attended fewer than the recommended number of visits or did not receive comprehensive care. Only negligible proportions (3.5%, 7.2%, and 9.8%, respectively) received adequate ANC.

The results regarding gestational age among the deceased mothers revealed that nearly half of the cases involved preterm births (<37 weeks): 46.5% in BGH, 47.6% in HGH, and 51.2% in KGH, indicating a high prevalence of preterm delivery in the study area. Term births (37–41 weeks) accounted for 36.1%, 33.9%, and 41.5% of cases, respectively. In contrast, post-term births (≥42 weeks) were relatively rare, accounting for 4.7%, 1.6%, and 2.4% of cases across the three hospitals, respectively. Additionally, 12.8% of cases in BGH, 16.9% in HGH, and 4.9% in KGH had unknown gestational ages.

The findings regarding the adequacy of care during labour and delivery and the postnatal period are also presented in Table 2. More than half of the maternal deaths at BGH (55.81%) and KGH (53.66%), and 42.43% of those at HGH, occurred among women who received inadequate intrapartum care. In contrast, adequate intrapartum care was received by 30.23%, 31.67%, and 34.14% of mothers at BGH, HGH, and KGH, respectively. Regarding postnatal care, the majority of the deceased mothers (68.29%–70.93% across the hospitals) did not reach the postpartum period. Among those who did, inadequate postnatal care was prevalent, affecting 24.42% at BGH, 27.29% at HGH, and 24.39% at KGH, while only a small proportion (4.18%–7.32%) received adequate care.

Maternal Mortality Trends Across the Three Selected General Hospitals, 2018–2022

Temporal Trends in Maternal Mortality, 2018–2022

Table 3 presents maternal mortality trends over the five-year period from 2018 to 2022. The results revealed significant fluctuations characterised by a sharp crisis followed by a notable recovery. The aggregated data for the study period included 26,882 pregnancies, resulting in 26,253 live births and 629 maternal deaths, yielding an overall maternal mortality ratio (MMR) of 2,396 per 100,000 live births (Table 3).

The year 2020 represented a pronounced outlier. Despite having the lowest numbers of recorded pregnancies (2,746) and live births (2,595), this year had the highest absolute number of maternal deaths (151) and the highest proportion of maternal deaths relative to pregnancies (5.5%). Consequently, the MMR increased dramatically to 5,819 per 100,000 live births. In the subsequent years, a consistent positive trend was observed. The MMR declined substantially to 1,967 in 2021 and further to 1,870 in 2022, the lowest level recorded during the study period. This decline occurred alongside a return to higher numbers of pregnancies and live births, indicating stabilisation of healthcare services following the 2020 crisis.

Table 4: Results of Chi-Square analysis of maternal mortality trends across the years (2018–2022)

Test	Value	df	p
Pearson Chi-Square	135.753	4	<0.001
Likelihood ratio	104.292	4	<0.001
Linear-by-linear association	4.443	1	0.035

df: Degrees of freedom.

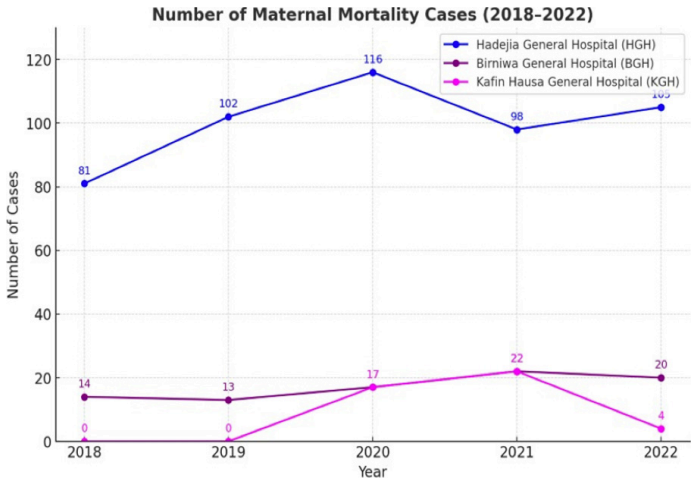

Figure 1: Summary of maternal death cases in three general hospitals (2018–2022).

A chi-square test of independence was performed to examine the relationship between the year and the distribution of maternal mortality outcomes. The results revealed a statistically significant association (Pearson's chi-square, χ^2=135.753; p<.001) (Table 4).

Furthermore, Figure 1 summarises the maternal deaths recorded across the three general hospitals—BGH, HGH, and KGH—between 2018 and 2022. During this five-year period, 86 maternal deaths were recorded at BGH, 502 at HGH, and 41 at KGH. The highest number of maternal deaths among the three hospitals was recorded at HGH, which has the largest capacity and the greatest number of healthcare personnel. Furthermore, HGH has the largest service area and is strategically located in the centre of Jigawa State's North-East Senatorial District. It therefore serves as a critical referral centre for the region and receives a large number of patients from other parts of the state and neighbouring states, such as Bauchi and Yobe (Fig. 1).

Variation in Maternal Mortality Across Hospitals

An analysis of the aggregated five-year data revealed substantial and statistically significant differences in maternal mortality outcomes across the three hospitals (Table 5). While the overall maternal mortality ratio (MMR) for the study period was 1,967 per 100,000 live births, this aggregate figure masked profound institutional variations. KGH recorded the lowest number of maternal deaths (41) and the lowest proportion of maternal deaths relative to total pregnancies (0.4%). However, it also had the highest MMR, at 5,819 per 100,000 live births. This paradox is explained by the much lower number of live births at KGH relative to the other facilities, which magnified the ratio.

Table 5: Five year maternal mortality ratio across the three general hospitals

Hos.	Total pregnancies	Live births n (%)	Maternal deaths n (%)	MMR (per 100,000 births)
BGH	4,418	4,332 (98.1)	86 (1.9)	2310
HGH	12,804	12,302 (96.1)	502 (3.9)	2061
KGH	9,660	9,619 (99.6)	41 (0.4)	5819
Total	26,882	26,253 (97.7)	629 (2.3)	1967

Hos: Hospital; BGH: Birniwa General Hospital; HGH: Hadejia General Hospital; KGH: Kafin Hausa General Hospital.

Table 6: Chi-square analysis of inter-hospital differences in maternal mortality

Test	Value	p
Pearson Chi-Square	298.106	<0.001
Likelihood ratio	353.570	<0.001

Conversely, HGH bore the greatest absolute burden of maternal mortality, accounting for 502 deaths, representing 79.8% (502/629) of all maternal deaths in the study. The proportion of maternal deaths relative to pregnancies at HGH was 3.9%, the highest among the three hospitals. Despite this high burden, its MMR (2,061 per 100,000 live births) was the lowest among the three hospitals because of its high number of live births (12,302). BGH presented intermediate figures, with 86 maternal deaths, a maternal death proportion of 1.9%, and an MMR of 2,310 per 100,000 live births. A chi-square test of independence was performed to determine whether the distribution of maternal deaths and live births was independent of the hospital. The result was statistically significant (Pearson's χ^2=298.106; p<.001) (Table 6).

Figure 2 presents the MMRs for BGH, HGH, and KGH between 2018 and 2022. The MMR represents the number of maternal deaths per 100,000 live births and is one of the most important indicators of maternal health status. At BGH, the MMR was 2,020 in 2018, which was lower than that at HGH but remained alarmingly high. In 2019, the ratio decreased to 1,454, indicating a possible improvement in maternal health services. However, in 2020, it increased sharply to 5,045. Following this increase, there was a marked decline in subsequent years, with the ratio decreasing to 1,799 in 2021 and 1,688 in 2022, demonstrating a sustained positive trend (Fig. 2).

At HGH, the MMR was 3,898 in 2018. Although the ratio decreased to 3,578 in 2019, indicating limited improvement, it remained critically high. In 2020, the MMR increased dramatically to 9,627, the highest value among all hospitals included in the study. In 2021, the ratio

Table 7: Distribution of maternal deaths by cause and hospital

Maternal death causes	Classification	BGH (%)	HGH (%)	KGH (%)
Anemia	Indirect	45.3	11.75	9.76
Eclampsia	Direct	27.91	27.89	17.07
PPH	Direct	8	11.55	36.59
Other causes (IUFD, placental abruption, pulmonary embolism, hypovolemic shock, transfusion reaction)	Direct/indirect	8.14	24	7.32
Sepsis	Direct	6.98	6.77	4.88
Malaria	Indirect	2.3	4.58	7.32
Obstructed delivery	Direct	1.16	10.36	14.63
Abortion	Direct	—	1.99	2.44
HIV	Indirect	—	0.20	—

BGH: Birniwa General Hospital; HGH: Hadejia General Hospital; KGH: Kafin Hausa General Hospital; PPH: Postpartum haemorrhage; IUFD: Intrauterine foetal death; HIV: Human immunodeficiency virus.

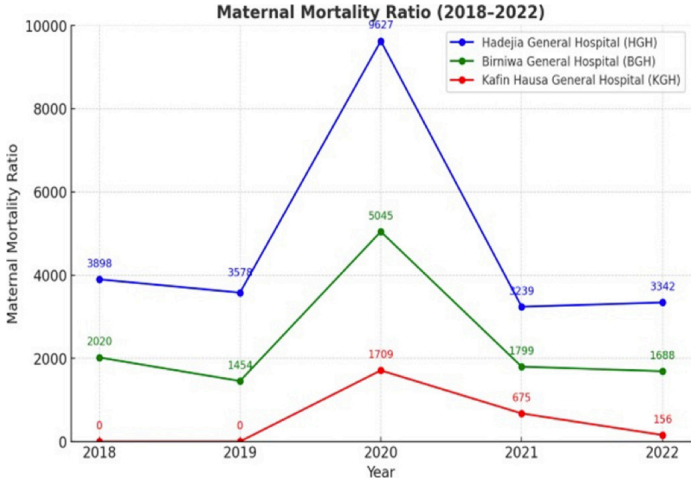

Figure 2: Maternal mortality ratio at three general hospitals (2018–2022).

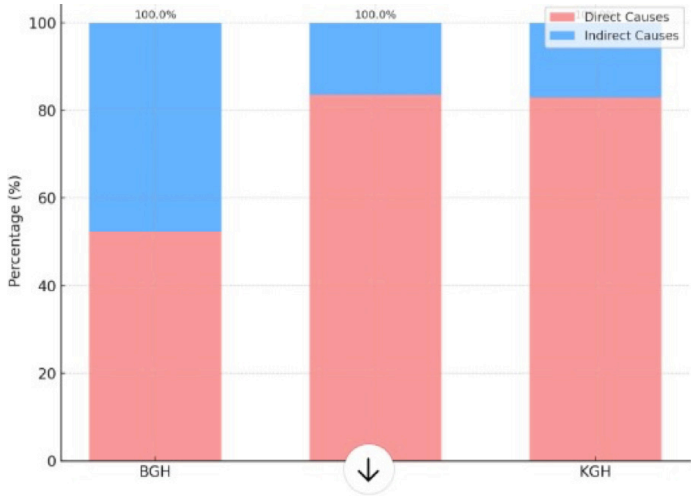

Figure 3: Proportion of direct and indirect causes of maternal deaths by hospital (2018–2022).

BGH: Birniwa General Hospital; HGH: Hadejia General Hospital; KGH: Kafin Hausa General Hospital.

decreased to 3,239, representing a substantial improvement from its peak, and increased slightly to 3,342 in 2022 (Fig. 2).

At KGH, the MMR was recorded as 0 in both 2018 and 2019, indicating that no maternal deaths occurred during those years. In 2020, the MMR increased to 1,709. It subsequently decreased to 675 in 2021 and 156 in 2022 (Fig. 2).

Causes of Maternal Deaths

This section presents the causes of maternal deaths recorded at the three general hospitals (BGH, HGH, and KGH) during the study period. The findings are summarised in Table 7 and Figure 3.

At BGH, anaemia was the leading cause, accounting for 45.35% of maternal deaths. This was followed by eclampsia (27.91%) and postpartum haemorrhage (8%). Other causes, including intrauterine fetal death (IUFD), placental abruption, and pulmonary embolism, collectively accounted for 8.14% of maternal deaths. Less common causes included sepsis (6.98%), malaria (2.33%), and obstructed labour (1.16%). Direct causes included eclampsia, postpartum haemorrhage, sepsis, obstructed labour, placental abruption, and pulmonary embolism. Indirect causes included anaemia, malaria, and, in some cases, IUFD, which was classified as an indirect cause.

At HGH, the most common cause was eclampsia (27.89%), followed by a group of causes comprising IUFD, placental abruption, pulmonary embolism, hypovolaemic shock, and blood transfusion reactions (24%). Less common causes included sepsis (6.77%), malaria (4.58%), unsafe abortion (1.99%), and HIV infection (0.20%). Direct causes included eclampsia, postpartum haemorrhage, obstructed labour, sepsis, unsafe abortion, placental abruption, pulmonary embolism, hypovolaemic shock, and transfusion reactions. Indirect causes included anaemia, malaria, HIV infection, and IUFD attributable to indirect factors.

At KGH, the most common cause was postpartum haemorrhage (36.59%). This was followed by eclampsia (17.07%), obstructed labour (14.63%), and anaemia (9.76%). Direct causes included postpartum haemorrhage, eclampsia, obstructed labour, sepsis, unsafe abortion, and placental abruption. Indirect causes included anaemia, malaria, and IUFD linked to indirect factors (Table 7).

Figure 3, a stacked bar chart, presents the proportions of direct and indirect causes of maternal deaths across the three hospitals from 2018 to 2022. Direct causes, such as eclampsia, postpartum haemorrhage, sepsis, and obstructed labour, accounted for the majority of maternal deaths at all three hospitals, whereas indirect causes, such as anaemia, malaria, and HIV infection, accounted for a smaller proportion. BGH had the highest proportion of deaths due to indirect causes, mainly anaemia, and showed the most balanced distribution between direct and indirect causes. At HGH and KGH, direct causes, particularly eclampsia and postpartum haemorrhage, accounted for the vast majority of maternal deaths (Fig. 3).

DISCUSSION

The study found that a significant proportion of maternal deaths occurred among young women, particularly those aged 18–24 years at BGH and KGH. This finding aligns with studies from northern Nigeria identifying younger women as being at the highest risk.[11–13] It also reflects the impact of early marriage and childbearing on maternal mortality, as similarly reported in other studies.[14,15] This pattern contrasts with the older mean age at death reported in a teaching hospital in Lagos, revealing marked urban–rural and socioeconomic disparities in maternal health outcomes.[16] While the population in Lagos is more urbanised, women in Jigawa are typically younger and reside in rural areas, demonstrating the inequalities that contribute to poor maternal health outcomes.

The study found an alarmingly low level of formal education among the deceased mothers, which is a major predictor of maternal mortality, consistent with previous studies.[17,18] Low literacy limits the recognition of danger signs and reduces antenatal care utilisation.[19] The educational gradient across hospitals, with the more urban HGH serving a more highly educated population, suggests that urban residence may improve both educational attainment and health-seeking behaviour, highlighting the need for health education strategies that do not depend on literacy.

The results showed a pronounced rural–urban disparity, with most deceased mothers residing in rural areas. This finding reflects national trends characterised by inadequate rural healthcare infrastructure, workforce shortages, and transportation delays.[18,20] Urban hospitals serving as referral centres also highlight the critical "third delay," namely, the delay in receiving adequate care at a healthcare facility. Most deceased mothers were housewives without formal employment or health insurance, which limited their financial autonomy and access to care.[17,20] Maternal deaths were concentrated among women in the lowest welfare groups, confirming poverty as a fundamental determinant of maternal mortality.[17,21] These findings demonstrate that substantial economic barriers prevent the most vulnerable women from using healthcare services and emphasise the interrelationship among poverty, low literacy, and poor maternal health outcomes.

Most maternal deaths occurred among multiparous women with 2–4 previous births, while a considerable proportion occurred among grand multiparous women with ≥10 births, who constitute a high-risk group.[13] However, the high number of deaths among unbooked patients suggests that the absence of antenatal care may be a stronger predictor of maternal mortality than parity.[16,17] Additionally, most mothers had short birth intervals of <24 months, contrary to World Health Organization recommendations, indicating limited access to family planning services and an increased risk of adverse maternal outcomes.

Extremely low antenatal care utilisation was observed, with most women attending no visits or only one visit and only a negligible proportion receiving adequate care in accordance with World Health Organization guidelines. This finding is consistent with studies reporting that most maternal deaths occurred among unbooked patients.[16,17] Consequently, opportunities to identify and manage pregnancy-related complications were missed.[12] This gap may be attributed to limited access to services, poor quality of care, and negative patient experiences.[22] Most deaths occurred during pregnancy or delivery, and among women who reached the postpartum period, very few received adequate postnatal care, leaving complications such as sepsis undetected.[21]

The analysis revealed significant fluctuations in the maternal mortality ratio over the five-year period, with a pronounced increase in 2020. This pattern indicates that periodic disruptions substantially affect maternal health outcomes. The increase observed in 2020 coincided with the COVID-19 pandemic, which may have contributed through mechanisms such as the reallocation of resources, disruption of healthcare services, and saturation of healthcare facilities. Similar global trends have been attributed to lockdowns, referral delays, and increased rates of home births.[17,18] The decrease in the maternal mortality ratio in 2021–2022 suggests adaptation within the healthcare system; however, the sharp increase in 2020 demonstrates the vulnerability of maternal health services to external shocks.

A statistically significant association was observed (χ^2=135.753; p<0.001), confirming that the fluctuations, particularly the peak in 2020, were unlikely to have occurred by chance. Although the maternal mortality ratio likely decreased in 2021–2022 because of partial recovery of the healthcare system and greater emphasis on community-based services, the persistently high rates indicate underlying structural deficiencies. These deficiencies include inadequate emergency preparedness, weak referral networks, and a shortage of qualified birth attendants. Addressing these problems is essential to reduce the current burden of maternal mortality and strengthen the resilience of maternal health services against future public health emergencies.

The study revealed statistically significant differences in the maternal mortality ratio across the three hospitals (Pearson's χ^2=298.106; p<0.001), indicating that these differences were systemic. The five-year average MMR was 2,404 per 100,000 live births, more than seven times Nigeria's national average of 196.6 per 100,000 live births.[20] HGH had the highest burden, with 502 deaths (MMR: 4,081 per 100,000 live births), followed by BGH, with 86 deaths (MMR: 1,985 per 100,000 live births), and KGH (MMR: 427 per 100,000 live births). These findings are consistent with reports showing that the MMR in

Nigerian secondary hospitals exceeds the national average.[17] They also align with the MMR of 1,791 per 100,000 live births reported for northern Nigeria.[12] The ratios at HGH and BGH also exceeded the MMR of 2,674 per 100,000 live births recorded at University College Hospital Lagos over a 12-year period.[16]

The high concentration of deaths at HGH, which accounted for 80% of the total, may be explained by its role as a referral centre for Jigawa and neighbouring states. This role results in a high number of late referrals and complicated cases; healthcare workers reported that many women arrived in critical condition after delayed or inadequate treatment elsewhere. Although HGH handled the largest volume of deliveries, this did not result in better outcomes, contradicting the commonly observed volume–outcome relationship.

Distinct hospital-specific patterns were evident regarding the causes of death. Anaemia was the leading cause at BGH, accounting for 45.35% of deaths. This finding may reflect chronic malnutrition, high malaria prevalence, and delayed access to blood transfusion, consistent with reports showing that chronic iron deficiency and late antenatal care increase the risk of fatal decompensation during childbirth.[23,24] These factors often interact: anaemia reduces tolerance to blood loss, hypertensive disorders increase the risk of placental abruption, and multiple pregnancies impose additional physiological stress. Although sepsis and malaria were less common, their presence indicates deficiencies in timely diagnosis and treatment. This pattern is consistent with regional reports and highlights the need for improved prevention and early management of obstetric risks.

The leading cause of death at HGH was eclampsia (27.89%), while IUFD, placental abruption, pulmonary embolism, hypovolaemic shock, and transfusion reactions collectively accounted for 24.9% of deaths. At KGH, postpartum haemorrhage was the leading cause (36.59%). Direct obstetric causes included eclampsia, haemorrhage, sepsis, obstructed labour, unsafe abortion, placental abruption, pulmonary embolism, hypovolaemic shock, and transfusion reactions, whereas indirect causes included anaemia, malaria, HIV infection, and IUFD. These findings are consistent with national and regional data. The prominence of hypertensive disorders, haemorrhage, and anaemia supports findings from other Nigerian and West African studies.[15,25] It also reflects previous reports identifying these conditions as major contributors to severe maternal morbidity and mortality.

As noted, these risks often overlap. Women with underlying anaemia or hypertension are more susceptible to complications such as placental abruption and severe bleeding.[8] The ranking of haemorrhage, hypertensive disorders, and sepsis among the leading direct causes is consistent with World Health Organization global estimates.[2] The prominence of anaemia at BGH aligns with findings from previous studies in northern Nigeria,[12] whereas the higher incidence of postpartum haemorrhage reported in tertiary hospitals in southern Nigeria highlights regional variation.[16]

In contrast to Jigawa State, Nigeria, the leading causes of maternal death in the United Kingdom are epilepsy, pulmonary embolism, and heart disease, which are predominantly indirect medical conditions.[26] This difference may be attributed to variations in healthcare system capacity, disease patterns, and socioeconomic conditions. In high-income countries such as the United Kingdom, established obstetric care, rapid access to emergency services, and effective antenatal screening have substantially reduced deaths from acute obstetric complications, with mortality increasingly resulting from chronic medical conditions. By contrast, in Jigawa State and much of sub-Saharan Africa, preventable causes such as haemorrhage, eclampsia, and sepsis remain prevalent because of weak healthcare systems, inadequate referral and transfusion services, and low rates of skilled birth attendance, compounded by the high prevalence of anaemia and malaria.

CONCLUSION

The study revealed substantial facility-level differences. The mortality profile at HGH was dominated by hypertensive disorders, that at KGH by haemorrhage, and that at BGH by anaemia. These differences may reflect variations in referral patterns, clinical expertise, and community-level health determinants. The considerable contribution of indirect causes also indicates deficiencies in antenatal screening, timely referral, and chronic disease management during pregnancy. Reducing maternal deaths therefore requires facility-level interventions targeting the predominant direct causes, including strengthened emergency care for haemorrhage and eclampsia, as well as community-level measures addressing indirect causes through malaria prevention, nutritional supplementation, anaemia control, and early antenatal care.

Statement

Ethics Committee Approval: The study was approved by the Hamidiye Scientific Research Ethics Committee of the University of Health Sciences (approval no.: 23/374; date: January 19, 2024) and the Jigawa Health Research Committee (approval no.: JGHREC/2024/0052; date: February 29, 2024).

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Authorship Contributions: Concept – HI; Design – HI; Supervision – HHE; Results – HI; Materials – HI; Data Collection and/or Processing – HI; Analysis and/or Interpretation – HI; Literature Search – HI; Writing – HI; Critical Reviews – HHE.

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CASE REPORT

Concurrent uterine inversion and postpartum seizure in a patient with epilepsy: A case report

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ABSTRACT

Timely diagnosis of uterine inversion is critical for favorable maternal outcomes. This article presents the case of a 26-year-old postpartum woman with a history of epilepsy who was diagnosed with uterine inversion during a seizure. A 26-year-old woman, gravida 3, with a history of two previous vaginal deliveries, presented at 38 weeks of gestation with contractions. She delivered a viable male infant vaginally but experienced postpartum complications, including an epileptic seizure, uterine atony, and uterine inversion. Postpartum hemorrhage occurred, requiring blood transfusion, surgical intervention, and subsequent admission to the intensive care unit. Hemostasis was successfully achieved through ligation of the ascending branches of both uterine arteries and insertion of a Bakri balloon. Uterine inversion is a life-threatening obstetric emergency that, if not promptly recognized and managed, can result in severe hemorrhage, shock, and maternal mortality. This case demonstrates the simultaneous occurrence of an epilepsy-related seizure and uterine inversion, highlighting the importance of close monitoring and timely, coordinated management of postpartum complications in women with epilepsy.

Keywords: Epilepsy, postpartum hemorrhage, seizure, uterine inversion.

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INTRODUCTION

Uterine inversion is a rare but life-threatening obstetric emergency characterized by the collapse of the uterine fundus into the endometrial cavity, resulting in partial or complete inversion. This complication can occur following both vaginal and cesarean deliveries, leading to severe postpartum hemorrhage and shock, with reported maternal mortality rates as high as 41%.[1] The incidence of uterine inversion varies between 1 in 3,500 and 1 in 20,000 deliveries, depending on differences in diagnostic criteria, postpartum uterine assessment methods, patient populations, and obstetric practices. The management of puerperal uterine inversion relies primarily on clinical experience and data from case reports and small retrospective case series.[2] The updated NICE guidelines (2024) define puerperal uterine inversion as one of the most important obstetric emergencies and emphasize the importance of rapid diagnosis, simultaneous resuscitation, and immediate manual reduction of the uterus as the cornerstones of management.[3]

Epilepsy is a common chronic neurological disorder affecting approximately 0.3%–0.5% of all pregnancies. While most pregnancies in women with epilepsy progress without complications, existing evidence suggests an increased risk of maternal mortality during childbirth, as well as a higher incidence of obstetric complications such as preeclampsia, antepartum hemorrhage, and postpartum hemorrhage due to uterine atony. Additionally, adverse fetal outcomes, including fetal growth restriction and stillbirth, have been reported. However, the underlying mechanisms contributing to these increased risks remain unclear.[4,5]

Delayed diagnosis of uterine inversion can further contribute to maternal morbidity and mortality. Therefore, maintaining a high index of clinical suspicion, particularly in patients with predisposing factors, is crucial for reducing adverse maternal outcomes. Although various risk factors for uterine inversion have been identified, to the best of our knowledge, no reports have established a direct association between epileptic seizures and uterine inversion. In this case report, we present a rare instance of uterine inversion following a postpartum seizure in a woman with epilepsy, highlighting the challenges in diagnosis and management.

CASE REPORT

A 26-year-old woman, gravida 3, para 2, at 38 weeks of gestation was admitted to the obstetric department during the first stage of labor. The pregnancy had progressed without complications. She had previously had two vaginal deliveries, but the second pregnancy had resulted in intrauterine fetal demise of unknown etiology. Her medical history was significant for juvenile myoclonic epilepsy, diagnosed at the age of 12 years. She had remained seizure-free on lamotrigine (LTG) monotherapy at a dose of 50 mg/day. This regimen was continued throughout the current pregnancy.

Upon admission, the patient was in stable general condition, with a blood pressure of 130/80 mmHg and a heart rate of 90 bpm. Laboratory test results were within normal limits. Due to insufficient uterine contractions, labor was augmented with intravenous oxytocin. Labor progressed normally, resulting in an uncomplicated vaginal delivery of a male neonate weighing 2,865 g. Following delivery, the placenta and membranes were expelled completely within 5 minutes through controlled cord traction. No perineal or birth canal injuries were noted, except for an episiotomy. Postdelivery abdominal examination revealed that the uterine fundus was positioned below the umbilicus and that the uterus was contracted. Ultrasonographic evaluation confirmed a normal uterine configuration with a midline stripe (Fig. 1). The mother received breastfeeding counseling, and breastfeeding was successfully initiated.

Figure 1: Postpartum US image: Normal configuration ofthe uterus with a midline stripe.

The patient experienced a generalized tonic-clonic seizure approximately 1 hour and 15 minutes after delivery. Postpartum eclampsia was excluded because of the absence of hypertension, proteinuria, edema, and other typical clinical signs. A neurology consultation was promptly obtained, and intravenous diazepam was administered. The seizure terminated spontaneously within 1–2 minutes.

Following this episode, she became hypotensive (80/50 mmHg) and tachycardic (144 bpm). Clinical examination revealed uterine atony, decreased consciousness, and cold extremities, with a shock index of 1.8. An intravenous crystalloid fluid bolus was initiated. Laboratory findings showed a hemoglobin level of 4.9 g/dL, a hematocrit level of 16.9%, a platelet count of 425,000/mm³, and an activated partial thromboplastin time (aPTT) of 34.9 seconds. The D-dimer level was 1.12, and the fibrinogen level was 290 mg/dL. Blood gas analysis showed a pH of 7.24 and a bicarbonate (HCO_3) level of 11.9 mmol/L. Liver and renal function test results were within normal limits.

In response to severe postpartum hemorrhage, blood component therapy was promptly initiated. The patient received 2 units of packed red blood cells, fresh frozen plasma, fibrinogen concentrate, and 1 g of intravenous tranexamic acid. Medical management also included a continuous infusion of 40 units of oxytocin and manual uterine

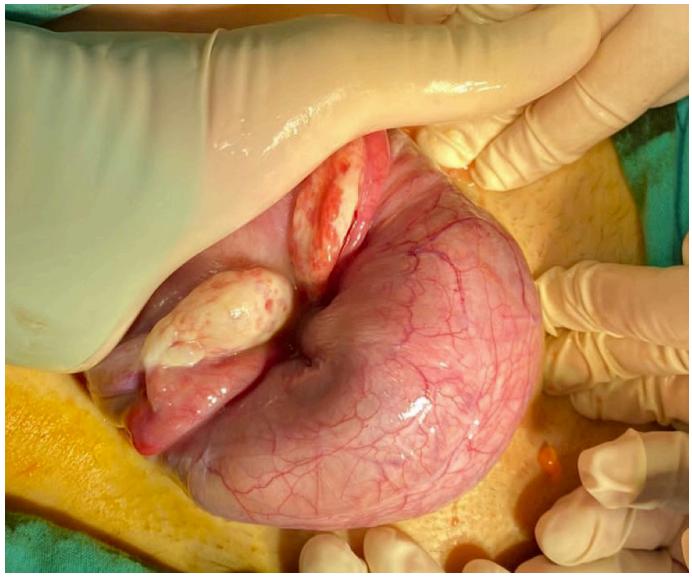

Figure 2: Intraoperative image: The ovaries, tubes, and round ligaments are pulled into the concavity of the inverted uterus.

massage. Despite these interventions, the hemorrhage persisted. Subsequently, the uterine fundus could not be palpated abdominally. Bedside ultrasonography showed a marked abnormality in the fundal contour, and vaginal examination revealed a soft mass protruding through the cervix. Based on these clinical and imaging findings, a senior obstetrician diagnosed uterine inversion.

Initial attempts at manual uterine replacement were unsuccessful. Due to the patient's hemodynamic instability, she was urgently transferred to the operating room. Under general anesthesia, an attempt at uterine repositioning was unsuccessful, necessitating an emergency laparotomy. Intraoperatively, the uterine fundus was found to have collapsed into the endometrial cavity, with the bilateral round ligaments and adnexa pulled inward, confirming uterine inversion (Fig. 2). Using the Huntington technique, the uterus was successfully repositioned with gentle upward traction.

Despite successful uterine repositioning, atony persisted. Uterotonics failed to restore adequate uterine tone. Bilateral ascending uterine artery ligation was performed. A Bakri balloon was then inserted into the uterine cavity and inflated with 360 mL of normal saline to achieve hemostasis. Bleeding was significantly reduced, and a Jackson-Pratt (JP) drain was placed in the pouch of Douglas. The intraoperative course was managed with aggressive fluid resuscitation, transfusion of 2 additional units of packed red blood cells and 2 units of fresh frozen plasma, and transient vasopressor therapy to stabilize hemodynamics.

Postoperatively, the patient was admitted to the intensive care unit for close monitoring and short-term ventilatory support, which was successfully discontinued. Minimal postoperative bleeding was observed. Prophylactic antibiotics, including cefuroxime and metronidazole, were administered to prevent endometritis. Enoxaparin sodium was also initiated for thromboembolism prophylaxis. The patient's condition stabilized within 24 hours. The Bakri balloon and JP drain were removed. She recovered uneventfully and was discharged in stable condition on postoperative day 5.

Figure 3: Six-month postoperative image showing normal configuration of the uterus with endometrial midline echo.

At 6 months postpartum, gynecological examination and pelvic ultrasonography showed a normal uterus with no abnormalities (Fig. 3).

Written informed consent was obtained from the patient for publication of this case report and accompanying images.

DISCUSSION

Acute uterine inversion is defined as uterine inversion occurring within the first 24 hours postpartum, with most cases developing during placental removal.[6] The literature identifies several maternal and obstetric risk factors for uterine inversion, including macrosomia, precipitous or prolonged labor, a short umbilical cord, severe preeclampsia, the use of tocolytics, uterine anomalies, tumors (leiomyomas), and placenta accreta spectrum. Additionally, iatrogenic factors, such as inappropriate fundal pressure, inadequate management of the third stage of labor, and manual placental removal, may contribute to the condition. However, large-scale studies have reported that no specific cause can be identified in approximately 50% of cases.[1,2,7] In our patient, uterine inversion, uterine atony, and a seizure occurred simultaneously approximately 1.5 hours after delivery. Although no direct causal relationship between seizures and uterine inversion has been established in the literature, generalized seizures may physiologically induce increased intra-abdominal pressure and hemodynamic fluctuations, which could act as facilitating factors for uterine inversion. Furthermore, aggressive manual uterine massage in this case may have contributed to the development of uterine inversion.

Epilepsy is associated with a significantly increased risk of maternal mortality, which is more than 10 times higher than that in the general obstetric population.[8] This elevated risk necessitates the prompt recognition and management of obstetric complications, such as postpartum hemorrhage and uterine inversion, in women with epilepsy. A substantial proportion of maternal morbidity in these patients is attributable to severe bleeding. A meta-analysis of 2,809,984 pregnancies found that women with epilepsy had increased odds of antepartum hemorrhage (OR: 1.49) and postpartum hemorrhage (OR: 1.29), with antiseizure medication use further increasing the risk.[5] Another study indicated that

women with epilepsy were more likely to experience postpartum hemorrhage due to both uterine atony (adjusted OR: 1.14) and nonatonic causes (adjusted OR: 1.38).[4]

Recent large-scale analyses have significantly advanced our understanding of the determinants of severe postpartum hemorrhage (PPH). A multicenter cohort study conducted in China identified parity ≥2, a history of ≥2 abortions, *in vitro* fertilization, abnormal fetal position, cesarean delivery, maternal anemia, and hypertensive disorders as independent predictors of severe PPH.[9] In patients with epilepsy, the exact pathophysiological mechanisms underlying uterine atony and hemorrhage remain incompletely understood; however, generalized seizures and the use of antiepileptic drugs (AEDs) appear to contribute to these complications.[10] The literature suggests that AED-induced folate deficiency and alterations in vitamin K-dependent coagulation factors may increase the risk of vaginal bleeding during late pregnancy.[11] In this context, the UK National Institute for Health and Care Excellence (NICE) guidelines recommend the administration of 1 mg of vitamin K to neonates at birth but do not advocate routine vitamin K supplementation in pregnant women.[12] These findings underscore the importance of considering both epilepsy-related and established obstetric risk factors in the peripartum management of women with epilepsy to minimize maternal morbidity associated with severe PPH.

The peripartum period is recognized as a vulnerable phase for women with epilepsy, during which they are more likely to encounter seizure triggers. One study reported that the risk of seizure relapse is highest during the 3 peripartum days: the day before delivery, the day of delivery, and the day after delivery.[13] Effective peripartum management strategies should focus on minimizing seizure triggers, ensuring adherence to AED therapy, and implementing supportive measures, such as epidural analgesia, to reduce pain-related stress. Additionally, environmental modifications, such as dimming the lights to promote rest and reducing sleep deprivation, may help reduce seizure risk in laboring patients.[14]

CONCLUSION

This case highlights that postpartum hemorrhage and uterine inversion can present as severe acute complications requiring prompt and systematic intervention. ACOG guidelines emphasize the early recognition and structured management of postpartum hemorrhage to reduce maternal morbidity and mortality and advocate for hospitals to establish organized, systematic protocols to coordinate the response and management.[15] Active management of the third stage of labor, timely administration of uterotonics, use of tranexamic acid, and minimally invasive interventions, integrated with multidisciplinary preparedness, can significantly improve outcomes in cases of rapid blood loss, as observed in this patient. In cases unresponsive to initial measures, escalation to more aggressive interventions and surgical options is critical to ensure maternal safety.

Statement

Ethics Committee Approval: This is a single case report, and therefore ethics committee approval was not required in accordance with institutional policies.

Informed Consent: Written informed consent was obtained from the patient for publication of this case report and accompanying images.

Conflict of Interest: The authors declare that there is no conflict of interest.

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CASE REPORT

Telescopic nail fixation of a femur fracture in a patient with osteogenesis imperfecta type 8: A rare case of homozygous c.446T>G mutation in the P3H1 gene

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ABSTRACT

Osteogenesis imperfecta (OI) type VIII is a rare genetic disorder characterized by brittle bones that are susceptible to fractures. This condition is associated with mutations in the LEPRE1 gene, which plays a key role in collagen synthesis and is critical for bone strength. The patient presented with a novel homozygous c.446TG mutation in the P3H1 gene that has not previously been reported in the literature. Individuals with OI type VIII commonly exhibit frequent fractures, skeletal deformities, short stature, blue sclerae, hearing loss, and dental abnormalities. Management focuses on symptom relief and fracture prevention through physical therapy, bracing, and surgical interventions. This report highlights the treatment of a patient with OI type VIII who sustained two femoral shaft fractures. The fractures were successfully managed with telescopic nailing, emphasizing the importance of tailored surgical approaches in the management of this rare condition. Given its rarity, further research is needed to deepen our understanding of OI type VIII and improve therapeutic options.

Keywords: Bracing, collagen, osteogenesis imperfecta type VIII, telescopic nail.

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INTRODUCTION

Osteogenesis imperfecta (OI) type VIII is a rare autosomal recessive subtype of OI characterized by bone fragility, recurrent long-bone fractures, progressive deformities, and short stature. It is caused by pathogenic variants in the P3H1 gene, historically referred to as LEPRE1, with P3H1 now being the official gene symbol. This gene encodes the prolyl 3-hydroxylase 1 (P3H1) enzyme. P3H1 functions as part of the prolyl 3-hydroxylation complex, together with CRTAP and cyclophilin B (CyPB, encoded by PPIB), and is essential for the proper post-translational modification and folding of type I collagen. Pathogenic variants in any of these three genes (CRTAP, P3H1, or PPIB) disrupt the complex and lead to recessive forms of OI. Loss of P3H1 function results in defective collagen 3-hydroxylation and diminished collagen stability, ultimately producing severe bone fragility and increased susceptibility to fractures.[1]

In this report, we describe a child with a homozygous P3H1 c.446T>G (NM_022356.4) variant that, to our knowledge, has not been previously reported. The presence of parental consanguinity supported the autosomal recessive inheritance pattern typical of OI type VIII. No other affected siblings were reported.

Clinically, OI type VIII may present with short stature, recurrent low-energy fractures beginning in infancy, progressive limb bowing, blue sclerae, dentinogenesis imperfecta, and hearing impairment.[2] In our case, the patient had experienced multiple previous fractures and had ambulated with support before the injury.

Radiographically, OI type VIII may demonstrate generalized osteopenia, gracile long bones, bowing deformities, and, in some cases, Wormian bones or coxa vara.[3,4] Our patient exhibited generalized osteopenia without Wormian bones or coxa vara, consistent with phenotypic variability. The fracture was treated with telescopic intramedullary nailing, which is considered the standard of care in growing children with OI to enhance stability, prevent deformity, and accommodate longitudinal growth. This case highlights a novel P3H1 mutation and the successful use of telescopic nailing for femoral fracture management in a patient with OI type VIII.

CASE REPORT

A 3-year-old boy presented to the emergency department following a low-energy fall. Clinical examination and radiographic assessment confirmed a right femoral shaft fracture (Fig. 1). Informed consent was obtained before evaluation and treatment. Initial stabilization was performed with a pelvic-pedal brace (Fig. 2), and the patient was admitted for surgical management.

The patient had a history of a right femoral fracture at the age of 1 year, which had previously been treated with pelvic-pedal bracing (Fig. 3). At presentation, physical examination revealed marked tenderness and swelling over the right thigh. Given the patient's known diagnosis of OI type VIII and history of recurrent long-bone fractures, operative fixation with a telescopic intramedullary rod system was planned to provide durable stabilization and minimize the risk of future refracture.

A 10-cm longitudinal incision was made over the greater trochanter, and the proximal femur was exposed with careful soft-tissue handling. A Kirschner wire was introduced under fluoroscopic guidance to establish the entry point. The canal was prepared using sequential reamers, and a guidewire was advanced across the fracture site.

Significant femoral bowing prevented straightforward rod passage; therefore, two controlled multiple drill-hole osteotomies were performed approximately 5 cm and 10 cm distal to the proximal femur to correct the deformity and facilitate nail insertion. This technique is well described for realignment and the prevention of progressive angulation in OI. After sequential reaming, a telescopic rod was inserted and advanced under fluoroscopic guidance to achieve stable fixation.

Figure 1: X-ray images of the patient at the time of arrival to our hospital. **(a)** Right femur ap view. **(b)** Right femur lateral view. **(c)** Pelvis ap view.

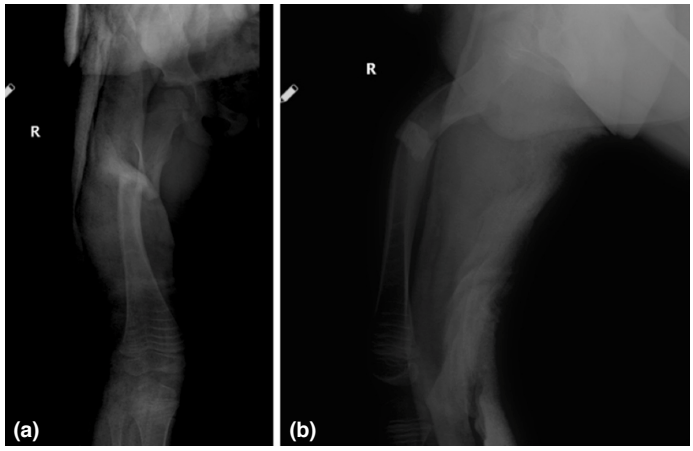

Figure 2: X-ray images of the patient with pelvipedal brace. **(a)** Right femur ap view. **(b)** Right femur lateral view.

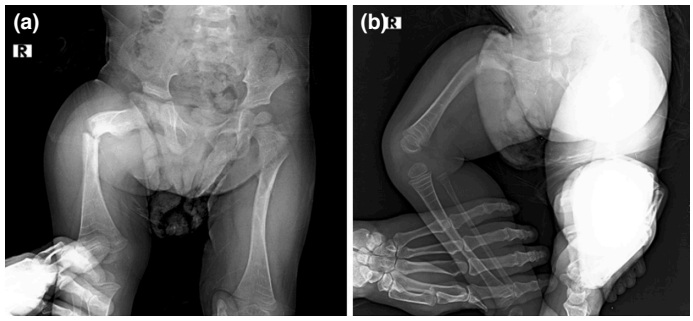

Figure 3: X-ray images of the patient 2 years ago after arrival to hospital **(a)** Right femur ap view. **(b)** Right femur lateral view.

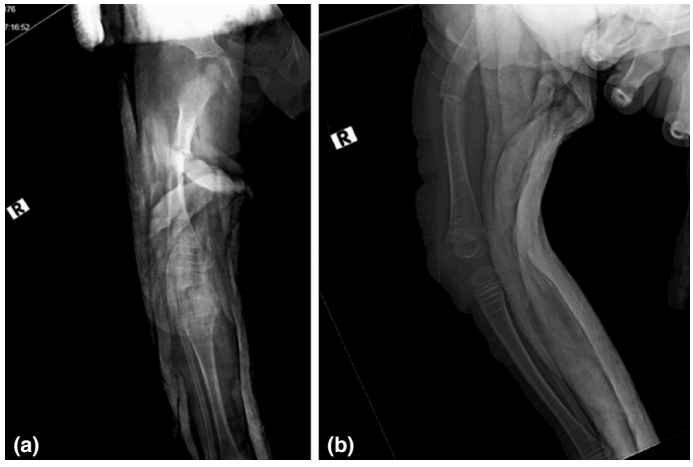

Figure 4: X-ray images of the patient 2 years ago after pelvipedal brace. **(a)** Right femur ap view. **(b)** Right femur lateral view.

The wound was irrigated and closed in layers. Postoperative radiographs demonstrated adequate alignment and implant positioning without complications (Fig. 4, 5). The patient was discharged after 2 days, mobilized with a brace, and scheduled for weekly outpatient follow-up.

Postoperative care included immobilization in a splint for 4 weeks with non-weight-bearing. Partial weight-bearing was allowed during weeks 5–6, followed by full weight-bearing thereafter.

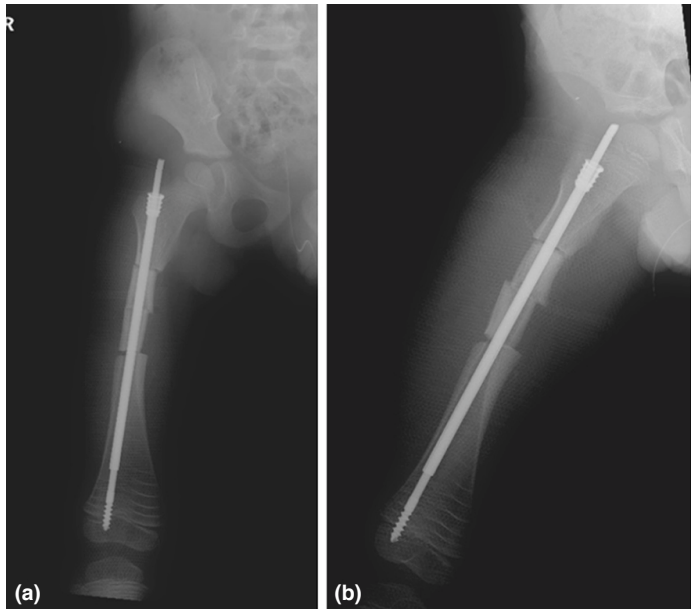

Figure 5: X-ray images of the patient after the telescopic nailing surgery. **(a)** Right femur ap view. **(b)** Right femur lateral view.

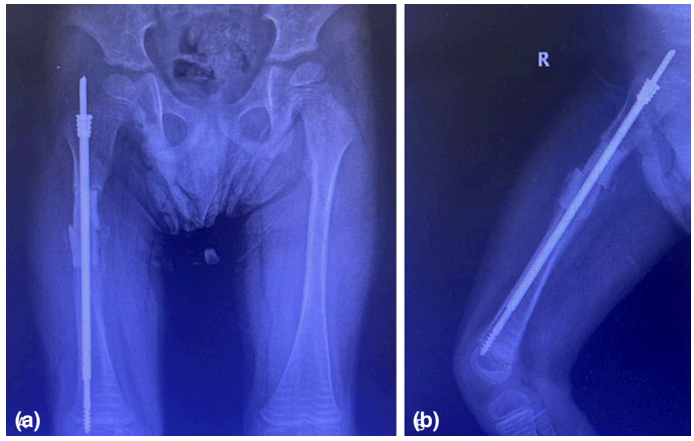

Figure 6: X-ray images of the patient after 2 months after the telescopic nailing surgery. **(a)** Right femur ap view. **(b)** Right femur lateral view.

Radiographs obtained at each follow-up demonstrated progressive callus formation and satisfactory telescopic elongation without implant migration or refracture (Fig. 6). At the 12-month follow-up, the patient was ambulatory with assistance and had no pain or functional limitations in daily activities. No recurrence of deformity or additional fractures was observed.

DISCUSSION

The management of femoral shaft fractures in children depends on fracture severity, stability, and patient-specific considerations. Nonsurgical approaches, such as pelvic-pedal bracing and Pavlik-type harnesses, are commonly used for stable fractures in infants and young children, promoting alignment and healing while minimizing complications.[5] However, in patients with osteogenesis imperfecta, nonoperative treatment carries a higher risk of malunion, progressive deformity, and refracture due to intrinsic bone fragility. Therefore, in

this patient, fracture instability and the underlying diagnosis of OI type VIII supported the decision to proceed with operative fixation rather than conservative management.

Surgical options for pediatric femoral fractures include plate fixation, external fixation, solid intramedullary rods, and telescopic systems. In OI, intramedullary fixation is preferred because it protects the entire length of the bone from deformation and future fractures.[5] Telescopic rods, first introduced by Fassier and Duval and later evaluated in outcome studies,[6,7] offer additional advantages over plating and solid nails. Unlike plates, which concentrate stress and are associated with high refracture rates after removal, or solid nails, which do not expand with growth and carry a risk of migration in osteoporotic bone, telescopic rods provide load-sharing fixation with dynamic micromotion that promotes callus formation, maintains alignment over time, and accommodates longitudinal bone growth. These benefits are especially important in OI, in which progressive bowing and the risk of refracture are high. In this case, controlled multilevel osteotomies using the Shish Kebab technique were performed to correct preexisting femoral bowing and facilitate safe rod passage,[8] consistent with established OI surgical protocols. Nevertheless, telescopic systems carry potential disadvantages, including the risk of rod migration, mechanical failure, and technical challenges in severely bowed bones, underscoring the need for careful preoperative planning.

The favorable early outcome in this case is consistent with published studies on OI demonstrating improved fracture healing, maintenance of alignment, and decreased refracture rates with telescopic rodding.[5] Previous studies have reported union times of approximately 10–14 weeks in patients with OI treated with telescopic devices and complication rates ranging from 10% to 30% related to telescoping failure or rod migration.[6,7]

Patients with OI type VIII may demonstrate delayed healing and greater deformity severity compared with those with classical COL1A1/COL1A2-related OI.[9–11] In this patient, progressive callus formation, maintained alignment, and effective telescoping were observed without early complications or hardware-related problems, representing a favorable outcome within the expected clinical range for telescopic fixation in OI.

Radiographically, OI classically demonstrates osteopenia, gracile long bones, and deformities such as coxa vara, saber-sheath tibia, and Wormian bones.[3,4] However, these findings may not be uniformly present, as demonstrated in this case, in which generalized osteopenia was the only notable radiographic abnormality. Such phenotypic variability highlights the importance of genetic analysis in confirming the diagnosis. In this patient, genetic testing identified a novel homozygous P3H1 c.446T>G variant predicted to impair prolyl 3-hydroxylase 1 function and disrupt collagen post-translational modification. Previous studies have described similar P3H1 variants associated with autosomal recessive OI type VIII, characterized by recurrent fractures, bone deformities, and short stature.[9–11] This case expands the mutational spectrum and provides additional clinical correlation for a previously unreported variant.

As a limitation, this report describes a single case with a relatively short follow-up period and without standardized functional outcome scoring. Continued follow-up is required to assess long-term telescoping behavior, refracture risk, rod durability, and functional mobility outcomes.

CONCLUSION

This case demonstrates the successful management of a femoral shaft fracture in a young child with OI type VIII using telescopic intramedullary nailing. The intervention provided stable fixation, supported growth, and prevented progressive deformity, aligning with established principles for long-bone stabilization in OI. Additionally, the identification of a novel homozygous c.446T>G variant in P3H1 expands the known genetic spectrum of OI type VIII and underscores the importance of molecular testing in diagnosis and treatment planning. Despite the short follow-up period, favorable clinical and radiographic outcomes support the role of telescopic nails as a preferred strategy for this rare and challenging condition.

Statement

Ethics Committee Approval: This is a single case report, and therefore ethics committee approval was not required in accordance with institutional policies.

Informed Consent: Informed consent was obtained before evaluation and treatment.

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LETTER TO THE EDITOR

Comment on "Prenatal isolated hydronephrosis: The value of UTD classification in assessing postnatal outcomes"

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To the Editor,

We read with interest the article by Gezer et al.[1] titled "Prenatal Isolated Hydronephrosis: The Value of UTD Classification in Assessing Postnatal Outcomes." The authors present an important single-center retrospective cohort study and clearly demonstrate that higher prenatal UTD grades correlate with disease progression and an increased need for postnatal surgical intervention. We congratulate the authors on a well-structured analysis that emphasizes a more comprehensive sonographic approach beyond the anteroposterior pelvic diameter alone.

We would like to offer several constructive comments to further strengthen the manuscript's interpretability and clinical applicability.

The authors appropriately acknowledged the retrospective and single-center nature of their study, as well as the lack of interobserver assessment. Building on this, future multicenter prospective research incorporating standardized sonographer training and interobserver reliability analyses could further validate the reproducibility and generalizability of the UTD classification.

Although postnatal surgery is a clinically relevant outcome, incorporating longitudinal renal function data, such as DMSA or MAG3 results obtained at 6–24 months, could provide a clearer link between prenatal UTD grades and long-term renal preservation rather than focusing solely on intervention rates.

Additionally, clarification of the postnatal imaging protocol, including the timing of ultrasonography, indications for VCUG and nuclear scans, and center-specific surgical thresholds, would facilitate the application of these findings in different clinical contexts.

Finally, recent reviews and consensus statements underscore the clinical value of the UTD system while emphasizing variability across studies. Consistent with the current literature, further multicenter validation and integration with long-term renal outcomes remain key priorities.[2–4]

In summary, Gezer et al.[1] provide valuable evidence supporting UTD-based prenatal risk stratification in isolated hydronephrosis. Addressing interobserver reliability and incorporating longer-term renal function outcomes would substantially increase the manuscript's impact and clinical relevance.

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