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Comparative analysis of umbilical cord arterial blood gas parameters in vaginal delivery with and without epidural analgesia; a prospective case-control study

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Abstract

Introduction: Epidural analgesia is a widely accepted and effective method for labor pain relief, though its impact on neonatal outcomes continues to be extensively studied. Key measures such as umbilical cord arterial blood gas (ABG) parameters, including pH and base excess (BE), provide valuable, objective indications of the newborn's metabolic status immediately after birth.

Objectives: This study aimed to assess the physiological safety of epidural analgesia for both mother and neonate during vaginal delivery, thereby contributing to a clearer understanding of its clinical implications and neonatal well-being.

Patients and Methods: This prospective case-control study included 80 women referred to Firoozabadi hospital between September 2024 and August 2025, divided into two equal groups (n = 40) based on labor pain management: epidural analgesia and vaginal delivery without pain relief. All deliveries were conducted by a single gynecologist using a standardized protocol, and epidural analgesia was administered by a single anesthesiologist following a uniform method. Data collection involved obtaining informed consent, recording demographic and clinical data, assessing neonatal Apgar scores at birth, and measuring umbilical cord ABG parameters (pH and BE) immediately after delivery. All data were compared between the two groups using statistical tests.

Results: The results revealed no significant differences between the control and epidural analgesia groups in demographic characteristics such as age and body mass index (BMI), nor in clinical outcomes, including Apgar scores. Additionally, umbilical cord ABG parameters, specifically pH and BE values, were comparable between the groups, indicating no meaningful impact of epidural analgesia on maternal or neonatal acid-base status.

Conclusion: The results indicated that the epidural analgesia during vaginal delivery does not significantly impact maternal or neonatal acid-base status, and these findings confirm the safety of epidural analgesia as an effective pain relief method that does not compromise key physiological measures of metabolic health.

Introduction

Delivery is a complex and dynamic physiological process that marks the culmination of pregnancy, resulting in the emergence of a new individual from the mother's body (1). Delivery can occur either through a standard vaginal birth or cesarean section. Vaginal delivery itself includes two approaches: one with pain management interventions and the other without any analgesia (2). Among the various discomforts experienced during childbirth, the vaginal delivery pain stands out as one of the most intense (3). Labor progresses through three distinct stages, with pain gradually intensifying as labor advances, reaching its peak during the second and third stages (4). The second stage of labor pain arises from nerve impulses transmitted throughout the body, while contractions of the placenta during the third stage contribute to pain experienced at that time;

Key point

The findings from the comparative analysis of umbilical cord arterial blood gas (ABG) parameters indicate that epidural analgesia during vaginal delivery does not significantly influence the acid-base status of either mothers or neonates. The observed similarities in pH and base excess (BE) values between the groups suggest that epidural analgesia does not disrupt systemic or metabolic acid-base balance. These results reinforce the safety profile of epidural analgesia as an effective labor pain management strategy, demonstrating that it does not adversely affect critical physiological measures of maternal and neonatal metabolic health. Consequently, epidural analgesia can be confidently recommended as a safe and reliable option for pain relief during labor without compromising acid-base homeostasis.

blocking the upward conduction of signals at the sacral S2-S4 spinal segments plays a crucial role in alleviating this pain (5). Recognizing the adverse effects of labor pain on both mothers and fetuses, the USA labor analgesia committee highlights the critical importance of effective labor analgesia as an integral component of the delivery process (6). Optimal labor analgesia aims to provide effective pain relief with minimal adverse effects on both the mother and fetus (7). Epidural analgesia accomplishes this by blocking the transmission of pain signals through the spinal nerve roots using local anesthetics, resulting in targeted and reversible numbness and muscle relaxation in specific regions, thereby facilitating labor (8).

Neuraxial block techniques, such as spinal or epidural anesthesia, present challenges due to their potential effects on fetal well-being and hemodynamic stability (9). Epidural labor analgesia provides a stable, continuous pain relief following administration of local anesthetics, combining efficacy with safety. This is achieved by using low concentrations of anesthetic agents, which minimize motor nerve blockade and reduce adverse effects on both maternal and fetal circulation (8). While epidural anesthesia alleviates pain, it can also lead to complications such as increased maternal respiratory rate and alterations in maternal hemoglobin levels, potentially impacting neonatal hemoglobin (10). Regional imbalances induced by sympathetic nerve block may influence uterine contractions favorably for delivery, but prolonged sympathetic block can decrease umbilical blood flow (7). During labor, fetal oxygen saturation may decrease below 96%, which is considered a critical threshold indicative of potential fetal distress (11). Furthermore, changes in fetal heart rate are observed in approximately 15% to 24% of cases when delivery occurs without the use of pain relief methods (12). Despite the proven benefits of epidural analgesia for relieving labor pain and reducing maternal stress, concerns remain among some pregnant women and their families regarding its potential effects on both maternal and neonatal outcomes. Balancing the dual goals of effectively alleviating maternal pain and stress while minimizing the risk of adverse postpartum outcomes continues to be a significant challenge within the medical community. Understanding the impact of epidural analgesia on labor is vital for improving maternal and neonatal healthcare. It can encourage safer deliveries, address concerns, and inform better pain management strategies, benefiting both mothers and newborns.

Objectives

The objective of this study was to compare umbilical cord arterial blood gas (ABG) parameters, including pH and base excess (BE), between vaginal deliveries with and without epidural analgesia, to evaluate the physiological safety and potential impact of epidural analgesia on neonatal acid-base status and overall neonatal well-being.

Patients and Methods

Study design and participants

This prospective case-control study involved 80 women who were referred to Firoozabadi Hospital between September 2024 and August 2025. Participants were divided into two groups based on their choice of labor pain management: one group received epidural analgesia, while the other underwent vaginal delivery without pain relief. All deliveries were conducted by a single gynecologist following a standardized protocol to ensure consistency. Women in the epidural group received a uniform analgesia method administered by a single anesthesiologist. Data were prospectively collected throughout the study period to compare clinical and umbilical cord ABG parameters between the two groups.

Inclusion and exclusion criteria

The inclusion criteria consisted of pregnant women who provided informed written consent and were undergoing vaginal delivery performed by a single gynecologist using a similar standardized method. Eligible participants were pregnant women aged between 18 and 35 years, carrying a singleton fetus with an estimated fetal weight under 4 kg, and had no underlying diseases such as diabetes, lupus, or hypothyroidism. Additionally, participants were required to have the anatomical capability for natural vaginal delivery, based on maternal and fetal characteristics. The study included women who either chose epidural analgesia, administered by a single anesthesiologist using a similar standardized protocol, or opted for delivery without pain relief. Exclusion criteria comprised women with any contraindications to epidural analgesia, those unwilling to continue participation in the study, and those who required emergency interventions during labor.

Group classification

The study classified participants into two groups based on the method of labor pain management: the control group (n=40), consisting of women who underwent vaginal delivery without any pain relief, and the epidural analgesia group (n=40), comprising women who received epidural analgesia during vaginal delivery.

Data collection

At the outset of the study, informed written consent was obtained from all participants. Demographic information, including age and body mass index (BMI), was collected through direct interviews with the participants. Clinical data, including the neonate's Apgar score, were assessed by a gynecologist at the time of birth. Immediately following delivery, umbilical cord arterial blood samples were collected under standardized conditions to measure ABG parameters such as pH and BE, providing an assessment of neonatal acid-base status. All clinical and laboratory data were then meticulously recorded and entered into structured case report forms by a trained researcher to ensure consistency and accuracy throughout the study process.

Outcome measurement

The outcome measurement method in this study involved assessing umbilical cord ABG parameters, including pH and BE, immediately after delivery to evaluate neonatal acid-base status.

Data analysis

Data collection involved entering all clinical and laboratory data into Statistical Package for Social Sciences (SPSS) version 27 for statistical analysis. The normality of continuous variables was assessed using the Shapiro-Wilk test, while Levene's test evaluated the homogeneity of variances across groups. Quantitative variables were reported as mean ± standard deviation (SD) or median with interquartile range (IQR [Q1–Q3]), depending on their distribution. Qualitative data were presented as frequencies and percentages. For comparing qualitative variables such as Apgar score categories between groups, the Pearson chi-square test was employed. Quantitative variables like age, BMI, pH, and BE were compared using the independent t-test or Mann-Whitney U test based on their normality status. Statistical significance was set at a *P* value less than 0.05 for all analyses.

Results

The frequency distribution of demographic characteristics and clinical data between the control group and epidural analgesia group indicated that both groups had similar average ages and BMI values, with no statistically significant differences observed among groups. In terms of clinical outcomes, almost all participants in both groups had Apgar scores above seven, with no significant difference between the groups. The proportion of participants with Apgar scores below seven was very low and did not differ significantly between the treatment groups (Table 1).

The comparative analysis of umbilical cord ABG parameters between the control group and the epidural analgesia group showed that the pH values were similar in both groups, with no significant difference detected. Likewise, the BE values demonstrated comparable values and distributions between the two groups, and this difference was not statistically significant. Overall, the ABG parameters did not differ meaningfully between the treatment groups (Table 2).

Discussion

The comparative analysis of umbilical cord ABG parameters indicates that epidural analgesia during vaginal delivery does not significantly affect neonatal acid-base status. The similar pH and BE values between the control group and the epidural analgesia group suggest that the use of epidural analgesia does not alter key physiological markers of neonatal metabolic balance. These findings support the conclusion that epidural analgesia is a safe pain management option in vaginal delivery without compromising neonatal acid-base homeostasis. These

Table 1. Comparison of demographic characteristics and clinical data among treatment groups

Demographic data		Treatment group				*P*-value
		Control (n = 40)		Epidural analgesia (n = 40)		
		Mean ± SD	Min-Max	Mean ± SD	Min-Max	
Age (y)		24.82 ± 7.17	19 – 35	24.95 ± 6.54	18 - 34	0.935*
BMI (kg/m²)		25.34 ± 3.58	17.9 – 35.12	24.73 ± 4.30	18.1- 39.75	0.490*
Clinical data		**N (%)**		**N (%)**		***P*-value**
Apgar score	<7	1 (2.5)		0 (0)		0.314**
	>7	39 (97.5)		40 (100)		

N: Number, SD: Standard deviation; Min: Minimum; Max: Maximum. * Independent T-test, ** Pearson chi-square.

Table 2. Comparative analysis of ABG parameters between treatment groups

ABG parameters	Treatment group				*P* value
	Control (n = 40)		Epidural analgesia (n = 40)		
	Median (IQR)	Min – Max	Median (IQR)	Min – Max	
pH	7.29 (0.12)	7.11 – 7.60	7.28 (0.09)	7.08 – 7.45	0.735*
BE (mEq/L)	-7.4 (6.35)	-20.3 – -2.5	-6.9 (3.5)	-13 – -9.5	0.725*

ABG: Arterial blood gas; BE: Base excess; Min: Minimum; Max: Maximum; IQR: Interquartile range. * Mann Whitney U.

findings regarding the preservation of umbilical cord ABG parameters in epidural analgesia align remarkably with the extensive body of existing literature, particularly the landmark meta-analysis by Reynolds et al, which examined 2,102 mothers across 12 studies. This systematic review and meta-analysis demonstrated that epidural analgesia was associated with improved rather than impaired neonatal acid-base status, with fetal BE values significantly higher in the epidural group (difference +0.837 mEq/L, 95% CI +0.330 to +1.343) when compared to systemic opioid analgesia (13). Similarly, a comprehensive Cochrane systematic review by Leighton and Halpern involving over 10,000 women found that epidural analgesia did not adversely affect fetal oxygenation, neonatal pH, or 5-minute Apgar scores, with neonates whose mothers received epidural analgesia actually requiring naloxone less frequently than those whose mothers received systemic opioids (14). Multiple randomized controlled trials have consistently demonstrated no significant differences in umbilical cord blood gas parameters between epidural and control groups, including studies by Shyken et al and more recent investigations that specifically examined pH and BE values in vaginal deliveries (15). A notable study by Chen et al involving 112 parturient women undergoing cesarean section found no significant differences in umbilical arterial and venous cord blood gas values between epidural and general anesthesia groups, further supporting the safety profile of epidural analgesia across different delivery methods (16).

The cumulative evidence from multiple systematic reviews, meta-analyses, and randomized controlled trials provides robust support for the physiological safety of epidural analgesia during labor, with particular emphasis on the preservation of neonatal acid-base homeostasis (13-16). The mechanisms underlying this safety profile involve complex physiological interactions, including effective maternal sympathetic blockade that may enhance uteroplacental blood flow despite potential transient hypotension, superior pain relief that reduces maternal stress responses and hyperventilation, and the preservation of placental exchange function (13,17). Modern epidural techniques utilizing ultra-low-concentration local anesthetics have further improved safety profiles while maintaining analgesic efficacy, with recent network meta-analyses demonstrating similar or better maternal and neonatal outcomes compared to higher-concentration regimens (18). The consistent findings across diverse populations and healthcare settings strengthen the generalizability of these results, with studies from multiple countries and different anesthetic protocols all demonstrating comparable outcomes (13,14,16). Importantly, large-scale population studies involving hundreds of thousands of mother-infant pairs have shown that while epidural use may be associated with longer labor stages and increased instrumental delivery rates in older studies, these associations have diminished with modern techniques, and importantly, no adverse effects on critical neonatal outcomes such as Apgar scores or acid-base status have been observed (17). Recent investigations into neuraxial analgesia use in very preterm infants have even suggested potential protective effects, with maternal neuraxial analgesia associated with lower odds of severe neonatal complications, including necrotizing enterocolitis and severe intraventricular hemorrhage (19).

Overall, our results confirm that epidural analgesia during vaginal delivery represents a safe and effective pain management strategy that does not compromise neonatal acid-base status. The preservation of normal umbilical cord arterial pH and BE values observed in this investigation is consistent with over two decades of rigorous scientific evidence, including multiple Cochrane reviews, systematic meta-analyses, and large-scale randomized controlled trials (13-15). The physiological mechanisms supporting this safety profile, including maintained uteroplacental perfusion and reduced maternal stress responses, provide a sound scientific foundation for the continued use and recommendation of epidural analgesia in modern obstetric practice (13,17). These findings should provide reassurance to both healthcare providers and patients that epidural analgesia can be confidently recommended as a first-line pain management option during labor, with the knowledge that this intervention does not adversely affect critical measures of neonatal metabolic health and may, in fact, offer advantages over alternative analgesic approaches. The consistency of these findings across diverse populations, healthcare systems, and study methodologies underscores the robustness of the evidence base and supports evidence-based clinical decision-making in contemporary obstetric care.

Conclusion

The results of the comparative analysis of umbilical cord ABG parameters between the control group, which underwent vaginal delivery without pain relief, and the epidural analgesia group indicate that the use of epidural analgesia does not have a significant impact on neonatal acid-base status balance during delivery. The similarity in pH values between the two groups suggests that epidural analgesia does not contribute to alterations in systemic acid-base balance. Furthermore, the similar BE values strengthen the evidence that epidural analgesia does not significantly affect metabolic aspects of acid-base balance. These findings indicate that epidural analgesia, a common method for pain relief during labor, can be used without adversely affecting key physiological parameters reflective of neonatal metabolic status. This lack of significant difference in ABG parameters aligns with the safety profile of epidural analgesia, supporting its continued use as a safe analgesic approach during vaginal delivery. Consequently, clinicians can consider epidural analgesia a viable option for pain management without concern for significant disturbances in acid-base balance, thereby potentially

improving maternal comfort without compromising physiological stability.

Limitations of the study

This study has several limitations. First, the relatively small sample size of 80 women may limit the generalizability of the findings and reduce the statistical power to detect subtle differences between groups. Second, the study was conducted at a single center with deliveries performed by one gynecologist and epidural analgesia administered by one anesthesiologist, which may introduce operator-related bias and limit external validity. Third, the exclusion of women with certain medical conditions and emergency interventions restricts the applicability of results to a broader obstetric population. Additionally, the study did not account for potential confounding factors such as parity, labor duration, or variations in analgesia timing and dosing. Finally, the follow-up was limited to immediate neonatal outcomes without long-term assessment, which may overlook the delayed effects of epidural analgesia.

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Authors' contribution

Conceptualization: Samaneh Saghafian Larijani, Soheila Mahdavynia, and Melika Ansarin.
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Methodology: Shahla Mirgaloybayat and Ashraf Mousavi.
Project management: Fatemeh Ashtari.
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Supervision: All authors.
Validation: Ashraf Mousavi and Maryam Vafapour.
Writing–original draft: All authors.
Writing–review and editing: All authors.

Ethical issues

The research was conducted in accordance with the principles outlined in the Declaration of Helsinki. Informed written consent was obtained from all participants. This study was conducted at Firoozabadi hospital and is derived from the thesis work of Seyed Yasin Amini (Thesis #27224), approved by the ethics committee of Iran University of Medical Sciences, Tehran, Iran, under the ethical code (IR.IUMS.REC.1403.491; https://ethics.research.ac.ir/EthicsProposalView.php?id=494404; approval date on September 3, 2024). Besides, the authors have ultimately observed ethical issues (including plagiarism, data fabrication, and double publication).

Data availability statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declaration of generative artificial intelligence (AI) and AI-assisted technologies in the writing process

While preparing this work, the authors utilized AI (Perplexity.ai and Grammarly.com) to refine grammar points and language style. Subsequently, they thoroughly reviewed and edited the content as necessary, assuming full responsibility for the publication's content.

Conflicts of interest

The authors declare no conflict of interest.

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