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ORIGINAL RESEARCH

The Impact of Prolonged Deceleration During the Second Stage of Labor on Umbilical Artery Blood Gas Analysis

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Objective: To investigate the association between prolonged deceleration during the second stage of labor and umbilical artery acid-base status.

Methods: This retrospective study analyzed 122 singleton deliveries at Second Nanning People's Hospital (2022–2024). Participants were stratified into low pH (umbilical artery pH <7.20, n=64) and normal pH (pH ≥7.20, n=58) groups. Variables included demographics, labor characteristics (delivery mode, deceleration-to-delivery interval), fetal heart rate (FHR) parameters (prolonged deceleration duration, FHR nadir, non-periodic accelerations, baseline variability), complications, and neonatal outcomes.

Results: The low pH group exhibited longer prolonged deceleration periods ($p<0.05$), greater FHR declines ($p<0.05$), and fewer non-periodic accelerations ($p<0.05$). Multivariate analysis identified prolonged deceleration duration and FHR decline magnitude as independent predictors of low pH. No significant intergroup differences existed in maternal BMI, gestational age, or delivery mode.

Conclusion: Our findings indicate that prolonged deceleration and fetal heart rate decrease are risk factors for low pH, underscoring the critical pH threshold of 7.2, below which the risk of neonatal asphyxia increases. These results highlight the importance of timely intervention during prolonged deceleration in labor to reduce adverse outcomes.

Keywords: second stage of labor, prolonged deceleration, blood gas analysis

Introduction

The second stage of labor is a critical phase in the delivery process, making it essential to monitor the fetal condition within the uterus.[1] The duration of this stage and changes in fetal heart rate significantly impact maternal and neonatal health. Therefore, management during the second stage should not only focus on maternal support and monitoring but also ensure that healthcare providers are equipped to handle emergencies.[2] During this phase, the fetal physiological status is assessed through fetal heart monitoring, particularly through patterns of heart rate changes such as prolonged deceleration (PD), which often indicate potential fetal distress. Prolonged deceleration is defined as a significant decrease in fetal heart rate below baseline, with a deceleration depth of ≥15 beats/min, and a duration from onset to recovery to baseline of ≥2 minutes but <10 minutes. If the deceleration lasts longer than 10 minutes, it may indicate a change in baseline.[3,4] Prolonged deceleration is classified as a Category II fetal heart monitoring pattern and may be closely related to fetal hypoxia and adverse outcomes. Therefore, timely recognition and management of these changes are crucial for improving delivery outcomes. Previous studies have shown that the occurrence of prolonged deceleration during the second stage is closely associated with the risk of fetal acidosis and adverse neonatal outcomes.[5,6] The presence of prolonged deceleration should prompt clinicians to consider expedited delivery interventions. Any acute fetal hypoxia

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that manifests as persistent deceleration on fetal heart monitoring should be treated as an obstetric emergency, requiring immediate intervention to optimize perinatal outcomes.[7] Research has also indicated a correlation between the number of persistent decelerations and the overall area of deceleration with fetal acidosis.[8] The risk of neonatal acidosis has a positive correlation with the duration of fetal heart rate deceleration during the second stage, significantly increasing as time prolongs.[9] In cases of prolonged deceleration during the second stage, despite active intrauterine resuscitation, there are currently no unified guidelines to determine when to conclude delivery or which delivery method to choose if fetal monitoring shows no improvement. Umbilical artery blood gas analysis has become an important tool for assessing fetal hypoxia, particularly as changes in pH are widely used to determine fetal acid-base status and overall health. This study aims to explore the relationship between prolonged deceleration and umbilical artery blood gas analysis (especially pH), focusing on influencing factors including the duration of a single prolonged deceleration, degree of fetal heart rate decrease, non-periodic accelerations, and other related complications. Through this study, we hope to provide valuable insights for clinical practice to effectively manage prolonged deceleration phenomena during the second stage of labor, thereby reducing the occurrence of adverse outcomes and ensuring maternal and neonatal health.

Given this context, this study explores the relationship between prolonged deceleration and umbilical artery blood gas analysis (especially pH), focusing on influencing factors such as the duration of a single prolonged deceleration, heart rate decrease amplitude, non-periodic accelerations, and other related complications. Through this study, we hope to provide valuable insights for clinical practice to effectively manage prolonged deceleration phenomena during the second stage of labor, thereby reducing the occurrence of adverse outcomes and ensuring maternal and neonatal health.

Patients and Methods

General Information

This medical study is a retrospective observational study. According to the Declaration of Helsinki (World Medical Association Inc, 2009), this research requires ethical review and approval. The study received ethical approval from the Ethics Committee of the Second Nanning People's Hospital, which agreed to waive the requirement for informed consent from the participants.

Data analysis will be conducted using coded information, ensuring that no personal details (such as contact information, addresses, etc.) of the participants will be collected. All samples will be de-identified to fully protect the privacy rights of the participants. Furthermore, the data selected for this study will only be used for research purposes and will not be utilized for any other purposes. The public reporting of research results will not disclose any personal identities of the participants.

Patients

The study subjects were pregnant women with singleton pregnancies who delivered in the head-down position at the Second Nanning People's Hospital from January 2022 to December 2024. All emergency interventions occurred during the second stage of labor, with fetal station ≥S+2 in vaginal operative deliveries and ≤S+2 in cesarean deliveries. Continuous electronic fetal heart rate (FHR) monitoring was maintained from the onset of the second stage until fetal delivery. Arterial blood gas analysis was performed within 20 minutes after birth; however, the assessment was limited to umbilical artery samples without concurrent venous sampling. This methodological constraint precludes comparative analysis of arterial-venous (A-V) gradients, thereby impeding precise differentiation between acute and chronic hypoxic insults. Although FHR tracing interpretation lacked independent blinded expert review, all recordings underwent serial assessments, potentially introducing interpretation bias. Upon detection of prolonged decelerations, standardized intrauterine resuscitation protocols were activated, including maternal repositioning, supplemental oxygen administration (10 L/min via non-rebreather mask), rapid intravenous crystalloid bolus, and immediate discontinuation of oxytocin infusion in augmented labors. Despite these interventions, no appreciable FHR recovery was observed, with all parturients maintaining normotensive status throughout deceleration episodes. Our institutional thresholds for second stage duration were: 3 hours for nulliparous women without neuraxial analgesia, 2 hours for multiparous women without analgesia; 4 hours for nulliparous women with neuraxial analgesia, and 3 hours for multiparous women with analgesia.[1,10–13]

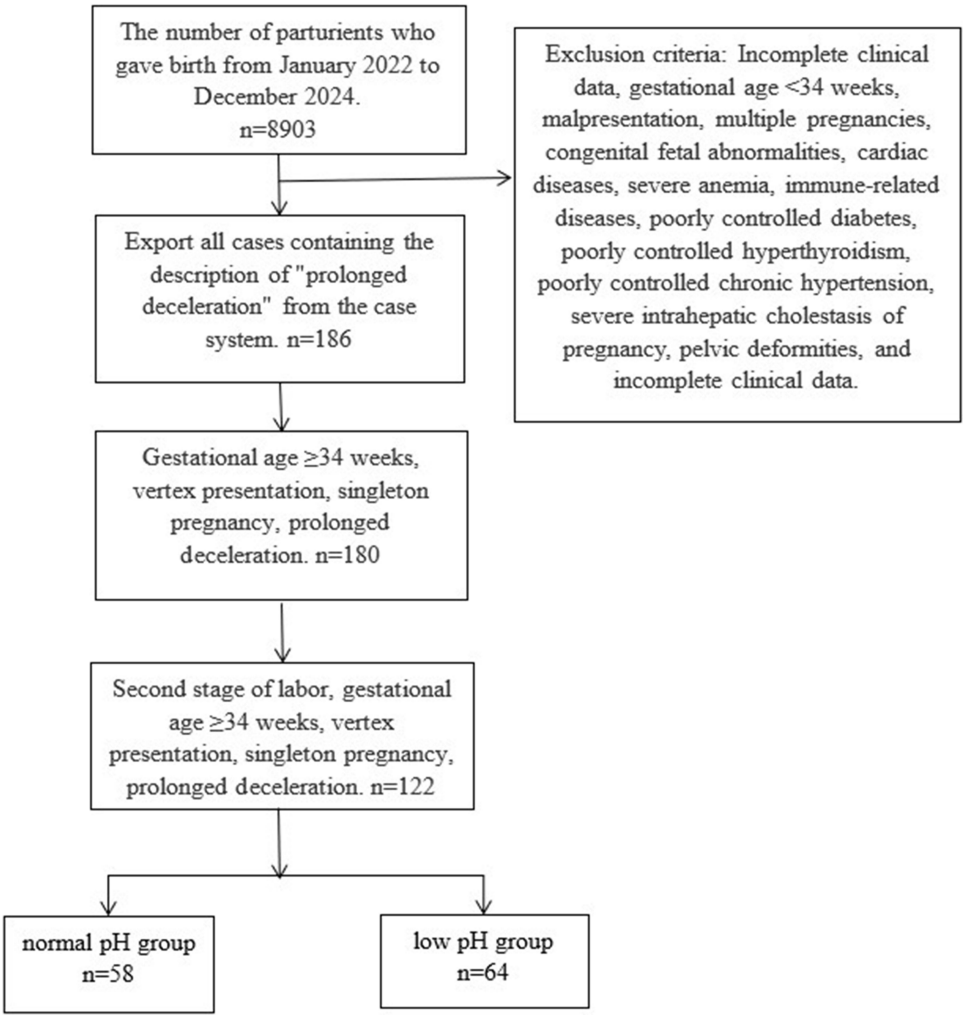

Figure 1 Flowchart of Study Population Selection.

A total of 122 cases were included, with 64 in the low pH group (umbilical artery blood gas analysis pH <7.2) and 58 in the normal pH group (pH 7.2–7.45). The pH value of <7.2 is defined as low pH, as a pH <7.2 in umbilical artery blood gas analysis is an essential criterion for the diagnosis of neonatal asphyxia,[14,15] experts suggest using a threshold of umbilical artery blood pH > 7.00 but < 7.20 to identify abnormal fetal heart rates. If intervention is performed at this point, the fetus may be spared from pathological acidosis and fetal injury.[16] Flowchart of Study Population Selection (Figure 1).

Sample Size: Although we did not perform a formal sample size calculation for this study, we included all eligible cases that met our inclusion criteria. This approach was taken to maximize the data available for analysis and ensure the robustness of our findings.

In order to minimize potential confounding, we implemented several strategies, including careful selection of control and experimental groups and standardization of data collection procedures.

Inclusion and Exclusion Criteria

Inclusion criteria: Gestational age ≥34 weeks (Vacuum-assisted delivery is contraindicated before 34 weeks,[17] with a focus on labor management disparities between late-preterm and term infants), vertex presentation, singleton pregnancy.

Exclusion criteria: Incomplete clinical data, gestational age <34 weeks, malpresentation, multiple pregnancies, congenital fetal abnormalities, cardiac diseases, severe anemia, immune-related diseases, poorly controlled diabetes, poorly controlled hyperthyroidism, poorly controlled chronic hypertension, severe intrahepatic cholestasis of pregnancy, pelvic deformities.

Methods and Observational Indicators

Based on pH values, eligible pregnant women were divided into the low pH group (pH <7.2) and the normal pH group (pH 7.2–7.45). We compared the following variables: maternal age, body mass index (BMI) (pre-pregnancy and pre-delivery), gravidity and parity, birth weight, gestational weeks at delivery, mode of delivery (vaginal birth, vacuum-assisted delivery, forceps-assisted delivery, cesarean section), duration from the onset of deceleration to fetal delivery, duration of prolonged deceleration, degree of fetal heart rate decrease, non-periodic accelerations (during deceleration/recovery), baseline variability (moderate variability: 6–25 bpm; non-moderate variability: 0–5 bpm/>26 bpm), complications (gestational diabetes, gestational hypertension, intrahepatic cholestasis of pregnancy), amniotic fluid characteristics (clear/cloudy), hemoglobin levels, umbilical artery blood gas analysis (pH), and 1-minute low Apgar scores (<7).

Related Work Disclosure

This study utilizes a cohort that overlaps with that of a related study by our group, which compared the outcomes of different urgent delivery modalities (vacuum, forceps, cesarean) following prolonged deceleration. The two manuscripts address distinct, sequential research questions (risk factors vs. management outcomes) and are reported separately to maintain analytical clarity.[18]

Statistical Analysis

Statistical analysis was performed using SPSS 29.0 software. Normally distributed or approximately normally distributed continuous data were expressed as mean ± standard deviation ($\overline{x} \pm s$). Comparisons between two groups were conducted using *t*-tests, with P<0.05 indicating statistical significance. Quantitative data that do not follow a normal distribution are expressed as median (interquartile range), and the comparison of indicators between two groups is conducted using the rank-sum test. A p-value of <0.05 is considered statistically significant. Categorical data were expressed as percentages (%), and comparisons were made using the χ^2-test; when the expected count was <5, Fisher's exact test was applied, with P<0.05 indicating statistical significance. The occurrence of low pH (0=no, 1=yes) was treated as the dependent variable for binary logistic regression analysis. Independent variables were initially screened through univariate analysis. Risk factors for low pH were determined based on P values, odds ratios (OR), and 95% confidence intervals (CI). In our analysis, we included only complete cases; notably, there were no missing data in our dataset. Furthermore, outliers were identified using the interquartile range method and were excluded from the analysis.

Results

Comparison of General Information

There were no statistically significant differences in maternal age, body mass index (BMI), gravidity, and parity between the two groups (P>0.05) (Table 1).

Comparison of Hemoglobin Levels and Fetal Monitoring Indicators During Pregnancy

No statistically significant differences were observed in hemoglobin levels, duration from the onset of deceleration to fetal delivery, number of decelerations, and baseline variability between the two groups (P>0.05). However, the duration of a single deceleration and heart rate decrease amplitude were significantly lower in the normal pH group compared to the low pH group, while non-periodic accelerations were significantly higher in the normal pH group (P<0.05) (Table 2).

Table 1 Comparison of General Information ($\bar{x} \pm s$), M (P25, P75)

General Information	Normal pH Group (n=58)	Low pH Group (n=64)	t/z	p
Age (years)	29.45 ± 5.49	29.18 ± 5.27	−0.533	0.595
BMI (kg/m^2)				
Pre-pregnancy	21.66 (18.82, 24.01)	20.81 (18.91, 22.89)	−0.895	0.390
Pre-delivery	26.64 (23.97, 28.80)	25.04 (23.62, 27.54)	−1.551	0.121
Gravidity	2.00 (1.00, 2.00)	1.00 (1.00, 2.00)	−1.895	0.058
Parity	1.00 (1.00, 2.00)	1.00 (1.00, 1.00)	−0.731	0.465

Abbreviation: BMI, Body Mass Index.

Table 2 Comparison of Hemoglobin Levels and Fetal Monitoring Indicators ($\bar{x} \pm s$), M (P25, P75), (N)%

Indicator	Normal pH Group (n=58)	Low pH Group (n=64)	t/z/χ^2	p
HB (g/L)	120.34 ± 13.12	121.69 ± 10.77	0.620	0.536
Duration from Deceleration Onset to Delivery (min)	20.50 (15.00, 30.50)	20.50 (16.00, 30.75)	−0.103	0.918
Single Deceleration Duration (min)	7.00 (5.00, 9.00)	10.00 (7.00, 14.75)	−4.550	<0.001
Number of Decelerations	1.00 (1.00, 2.00)	2.00 (1.00, 2.00)	−0.469	0.639
Heart Rate Decrease Amplitude (bpm)	50.00 (40.00, 60.00)	60.00 (50.00, 80.00)	−2.844	0.004
Baseline Variability (Moderate)	44.00 (75.86%)	45.00 (70.31%)	0.475	0.491
Non-Periodic Accelerations	32.00 (55.17%)	21.00 (32.81%)	6.191	0.013

Abbreviation: HB, Hemoglobin.

Comparison of Pregnancy Outcomes

There were no statistically significant differences in birth weight, gestational weeks at delivery, incidence of preterm birth, complications, amniotic fluid characteristics, and mode of delivery between the two groups (P>0.05). The pH value was significantly higher in the normal pH group compared to the low pH group, and the 1-minute low Apgar score was significantly lower in the normal pH group than in the low pH group (P<0.05) (Table 3).

Table 3 Comparison of Pregnancy Outcomes ($\bar{x} \pm s$), M (P25, P75), (N)%

Indicator	Normal pH Group (n=58)	Low pH Group (n=64)	t/z/χ^2	p
Birth Weight (kg)	3101.55 ± 341.41	3023.13 ± 356.30	−1.238	0.218
Delivery (day)	273.00 (267.75, 278.50)	275.00 (268.25, 281.00)	−1.068	0.286
PTB	4.00 (6.90%)	3.00 (4.69%)	0.275	0.707
Complications	16.00 (27.59%)	17.00 (26.56%)	0.016	0.899
Amniotic Fluid Characteristics			0.282	0.595
Clear	45.00 (77.59%)	47.00 (73.44%)		
Cloudy	13.00 (22.41%)	17.00 (26.56%)		

(*Continued*)

Table 3 (Continued).

Indicator	Normal pH Group (n=58)	Low pH Group (n=64)	t/z/χ^2	p
Mode of Delivery			6.739	0.084
Vaginal Delivery	1.00 (1.72%)	4.00 (6.25%)		
Vacuum Extraction	27.00 (46.55%)	37.00 (57.81%)		
Forceps Delivery	14.00 (24.14%)	16.00 (25.00%)		
Cesarean Section	16.00 (27.59%)	7.00 (10.94%)		
pH Value	7.25 (7.23, 7.28)	7.13 (7.05, 7.16)	−9.524	<0.001
1-Minute Low Apgar Score	2.00 (3.45%)	13.00 (20.31%)	8.025	0.005

Abbreviation: PTB, Preterm Birth.

Table 4 Results of Binary Logistic Regression Analysis for Low pH Value

Indicator	B	SE	Wald χ^2	p-value	OR value	95% CI	VIF
Single Deceleration Duration (min)	0.243	0.067	13.356	<0.001	1.275	(1.119 - 1.543)	1.218
Heart Rate Decrease Amplitude (bpm)	0.031	0.013	5.420	0.02	1.031	(1.005 - 1.058)	1.053
Non-Periodic Accelerations	0.046	0.456	0.010	0.919	1.047	(0.429 - 2.560)	1.266

Binary Logistic Regression Analysis for Low pH

Using the occurrence of low pH as the dependent variable, with the assignment method: 0=no, 1=yes. Independent variables included the duration of a single deceleration duration, heart rate decrease amplitude, and non-periodic accelerations, all of which had a significant impact on the outcome. The results indicated that the duration of a single deceleration duration (95% CI [1.119, 1.543]) and heart rate decrease amplitude (95% CI [1.005, 1.058]) were risk factors for low pH during prolonged deceleration in the second stage of labor, with statistical significance (P<0.05) (Table 4).

Discussion

Principal Findings

In this study, we explored the relationship between prolonged deceleration during the second stage of labor and the results of umbilical artery blood gas analysis, particularly focusing on changes in pH and their clinical significance. Univariate analysis revealed significant differences in the duration of single prolonged deceleration, heart rate decrease amplitude, and non-periodic accelerations between the low pH group and the normal pH group. However, logistic regression analysis indicated that after adjusting for confounding factors, only the duration of single prolonged deceleration and heart rate decrease amplitude were identified as independent risk factors for low pH, with statistical significance (P<0.05). This result underscores the impact of prolonged deceleration duration and fetal heart rate decrease on the risk of fetal hypoxia. Low pH is typically regarded as a marker of fetal hypoxia, potentially leading to a range of adverse outcomes, including low Apgar scores and other perinatal complications. Our findings provide important references for clinical practice, suggesting that enhanced monitoring of fetal heart changes during the second stage of labor is crucial for timely intervention to improve maternal and neonatal outcomes. The occurrence of prolonged deceleration is closely linked to the risk of fetal hypoxia, and this finding provides a significant basis for understanding fetal monitoring during the delivery process. Our results indicate that the duration of prolonged deceleration and heart rate decrease amplitude significantly affect the pH values in umbilical artery blood gas analysis, suggesting that the fetus may face the risk of acidosis during these changes. Previous literature has indicated that prolonged deceleration is an

important sign of fetal distress, and timely identification and intervention of this phenomenon are essential for improving maternal and neonatal outcomes. Healthcare providers should be sensitive to fetal heart monitoring results during the second stage of labor to take swift action in the presence of prolonged deceleration. Moreover, umbilical artery blood gas analysis serves as a vital tool for assessing fetal hypoxia, providing strong support for clinical decision-making. Therefore, in clinical practice, paying attention to the occurrence of prolonged deceleration and its impact on umbilical artery blood gas analysis results will help optimize delivery management and reduce the incidence of adverse pregnancy outcomes. Our study emphasizes the importance of fetal monitoring during the second stage of labor, especially in the face of prolonged deceleration, necessitating proactive clinical interventions to safeguard maternal and neonatal health. Future research could further explore management strategies for prolonged deceleration to reduce the occurrence of low pH and its associated risks.

Results in the Context of What is Known

Our findings differ from previous studies in that we specifically identified the duration of prolonged deceleration and heart rate decrease amplitude as independent risk factors for low pH, whereas other studies have focused primarily on the overall presence of decelerations without quantifying their duration.

Hemoglobin Levels and Fetal Monitoring Indicators During Pregnancy

We found no statistically significant differences in hemoglobin levels, duration from the onset of deceleration to fetal delivery, number of decelerations, and baseline variability between the two groups ($P>0.05$). However, the comparison of single deceleration duration and heart rate decrease amplitude showed that the normal pH group had better indicators than the low pH group, with these differences being statistically significant ($P<0.05$). Additionally, the incidence of non-periodic accelerations was significantly higher in the normal pH group, further emphasizing the importance of fetal heart monitoring in assessing fetal health status. Univariate analysis indicated significant differences in single prolonged deceleration duration, fetal heart rate decrease, and non-periodic accelerations between the low pH and normal pH groups. This emphasizes the significant impact of prolonged deceleration duration and fetal heart rate decrease on fetal hypoxia risk. The diagnostic significance of single prolonged decelerations (SPDs) necessitates contextual integration with baseline fetal heart rate (FHR) characteristics. Recurrent SPDs may indicate progressive hypoxic-ischemic burden rather than isolated pathological events. According to existing literature, prolonged deceleration is considered a critical marker of fetal distress, necessitating timely exclusion of acute labor incidents and conservative measures to reverse reversible causes. Particularly, sustained deceleration lasting more than 10 minutes is regarded as terminal bradycardia, which may lead to severe neurological damage.[7] Our findings provide important references for clinical practice, suggesting that enhanced monitoring of fetal heart changes during the second stage of labor is essential for timely intervention to improve maternal and neonatal outcomes. The occurrence of prolonged deceleration is closely related to the risk of fetal hypoxia, especially significantly associated with pH values in umbilical artery blood gas analysis. In the low pH cohort, the maximum duration of single prolonged SPDs exceeded 10 minutes. However, institutional protocols mandated activation of emergency obstetric interventions (operative vaginal delivery or cesarean section preparation) when SPDs persisted beyond 5 minutes. Despite immediate escalation, the median decision-to-delivery interval extended to 10.0 minutes (IQR 7.0–14.75), leading to inclusion of these cases in prolonged deceleration analyses. This operational reality reflects the critical balance between intervention urgency and practical procedural constraints in acute fetal compromise scenarios. In our institution, vacuum extraction delivery (VED) was predominantly utilized over forceps-assisted or cesarean deliveries during acute fetal compromise. This operational preference likely reflects clinicians' greater technical familiarity with vacuum extraction techniques, coupled with perceived advantages in rapid device application during time-critical emergencies. Literature indicates that more than one episode of prolonged deceleration is significantly associated with abnormal umbilical artery pH values.[5] Therefore, healthcare providers should be sensitive to fetal heart monitoring results during the second stage of labor to promptly take action in the presence of prolonged deceleration, reducing potential fetal health risks.[19] Additionally, umbilical artery blood gas analysis serves as a crucial tool for assessing fetal hypoxia, providing strong support for clinical decision-making. Studies have shown that an increase in acceleration events during the last hour of labor significantly reduces the risk of adverse neonatal outcomes.[6]

Thus, in clinical practice, attention to the occurrence of prolonged deceleration and its impact on umbilical artery blood gas analysis results will help optimize delivery management and reduce the incidence of adverse pregnancy outcomes. Our study emphasizes the importance of fetal monitoring during the second stage of labor, particularly in the face of prolonged deceleration, necessitating proactive clinical interventions to ensure maternal and neonatal health. However, this study is limited by single-center data, and future research should incorporate multidimensional neonatal outcome indicators.

Comparison of Pregnancy Outcomes

We found no statistically significant differences in birth weight, gestational weeks at delivery, incidence of preterm birth, complications, amniotic fluid characteristics, and mode of delivery between the two groups ($P>0.05$). We observed no inherent correlation between the mode of delivery and low pH values, which warrants further investigation into the differences among various delivery methods in the context of prolonged deceleration during the second stage of labor. However, the comparison of pH values revealed that the normal pH group was significantly higher than the low pH group, and the 1-minute low Apgar score in the normal pH group was significantly lower than that in the low pH group, with these differences being statistically significant ($P<0.05$). This finding suggests that the fetus may face a higher risk of hypoxia during prolonged deceleration, impacting its health at birth. Research indicates that low pH is typically regarded as a marker of fetal hypoxia, potentially resulting in a range of adverse pregnancy outcomes, including low Apgar scores and other perinatal complications. Literature has noted a significant association between abnormal fetal heart monitoring (FHT) and the need for neonatal resuscitation, and after adjusting for confounding factors, abnormal FHT and the 1-minute Apgar score were the only variables predicting the need for resuscitation at birth.[20] This further supports our findings, emphasizing the importance of fetal heart monitoring during the second stage of labor to timely identify the risk of fetal hypoxia. When prolonged deceleration occurs, we often administer oxygen via a mask; however, this measure seems not to improve outcomes. Some studies have found no evidence that maternal oxygen supplementation improves the characteristics of Category II fetal monitoring patterns, suggesting that clinicians should exercise caution when using oxygen supplementation in practice.[21] Prolonged exposure to oxygen may impair placental oxygen transfer.[22] Additionally, research has indicated that cases marked by recurrent deceleration in Category II monitoring may benefit from surgical intervention if sustained for more than 2 hours.[23] However, other studies have shown that when fetal heart sounds return to baseline in the operating room, the decision for cesarean section can be reconsidered. Nonetheless, many clinical factors must be taken into account, with the final decision resting at the discretion of the obstetrician.[24] Nearly two-thirds of Category II FHR monitoring patterns improve to Category I within 60 minutes of intervention, with a relatively low overall incidence of composite adverse neonatal outcomes.[25] This indicates that timely identification of prolonged deceleration and appropriate interventions are crucial for improving pregnancy outcomes. Our results show that the normal pH group had significantly better health status at birth than the low pH group, particularly in terms of Apgar scores, further emphasizing the importance of fetal monitoring in assessing pregnancy outcomes. Notably, literature indicates that up to 80% of women may exhibit Category II FHR monitoring patterns during labor, necessitating interventions for FHR deceleration and guiding clinicians on when to transition to vaginal delivery or cesarean section to ensure delivery is completed before the risk of fetal acidosis significantly increases.[26] Therefore, clinicians must possess sensitivity and judgment in the face of prolonged deceleration to timely implement interventions and reduce the incidence of adverse pregnancy outcomes. Finally, studies have also pointed out that fetal pH may normalize within 20 to 30 minutes after sustained deceleration, suggesting that this delay must be adhered to when collecting fetal blood samples to avoid unnecessary intervention decisions.[27] Our research corroborates the importance of fetal monitoring during the second stage of labor, particularly in the presence of prolonged deceleration, necessitating proactive clinical interventions to ensure maternal and neonatal health. This study employs a pH threshold of <7.2 to identify a broader risk of acidosis in neonates; however, it is important to note that this threshold may increase the risk of false positives, and future research should incorporate stratified analyses based on ACOG and other guideline standards.

Risk Factors for Low pH

The study results indicate that the duration of single deceleration duration (OR 1.275, 95% CI 1.119 - 1.543) and heart rate decrease amplitude (OR 1.031, 95% CI 1.005 - 1.058) were identified as independent risk factors for low pH, with statistical significance ($P<0.05$). This is consistent with previous studies that have linked the number of sustained decelerations and the overall area of deceleration to acidosis.[8] This finding emphasizes the importance of prolonged deceleration duration and fetal heart rate decrease concerning the risk of fetal hypoxia. Low pH is typically regarded as a marker of fetal hypoxia, which can lead to a range of adverse outcomes, including low Apgar scores and other perinatal complications. Literature indicates a significant association between persistent fetal heart rate decelerations and adverse fetal outcomes, with the duration of prolonged deceleration closely related to fetal health risks.[19] Our findings align with existing literature, further underscoring the importance of fetal heart monitoring during the second stage of labor. Notably, literature points out that the total area of deceleration in the abnormal umbilical artery pH group is significantly higher, with the strongest association between prolonged deceleration and abnormal fetal pH.[5] This suggests that monitoring changes in fetal heart rate and their duration is crucial for the timely identification of the risk of fetal hypoxia.

Moreover, studies have shown a significant negative correlation between an increase in acceleration events during fetal heart monitoring and adverse neonatal outcomes, while prolonged deceleration, late deceleration, tachycardia, and bradycardia are positively correlated with adverse neonatal outcomes.[6] This further supports our view that prolonged deceleration not only affects umbilical artery blood gas analysis results but is also closely related to fetal health status. However, after adjusting for confounding factors, we did not find that accelerations served as protective factors for low pH, which warrants further investigation. Healthcare providers during the second stage of labor should be sensitive to fetal heart monitoring results to promptly take action in the event of prolonged deceleration, thereby reducing potential risks to fetal health. Although persistent fetal heart rate deceleration is associated with adverse fetal outcomes, it does not always indicate the need for immediate cesarean delivery.[24] Therefore, clinicians must exercise sensitivity and judgment regarding the risk factors for low pH to implement necessary interventions promptly and optimize pregnancy outcomes. Our findings provide important references for clinical practice, emphasizing the need for careful fetal monitoring during the second stage of labor, especially when faced with prolonged deceleration, to ensure proactive clinical interventions that safeguard maternal and neonatal health.

Clinical Implications

Our study has significant implications for clinical practice. The identification of prolonged deceleration duration and fetal heart rate decrease as independent risk factors for low pH underscores the need for vigilant fetal heart rate monitoring during the second stage of labor. Timely recognition of prolonged deceleration can guide clinicians in implementing interventions to mitigate the risk of fetal hypoxia. Furthermore, prolonged deceleration may lead to decreased placental perfusion, resulting in fetal hypoxia and subsequent acidosis. This highlights the necessity for timely interventions to restore adequate fetal oxygenation.

Research Implications

While our study provides valuable insights, several unanswered questions remain. For instance, the role of non-periodic accelerations as a protective factor for low pH warrants further investigation. Additionally, the lack of a significant association between mode of delivery and low pH values suggests the need for more research into the impact of different delivery methods on fetal outcomes in the context of prolonged deceleration. Future studies should investigate the efficacy of specific interventions, such as maternal repositioning or oxygen supplementation, in mitigating the risks associated with prolonged deceleration.

Strengths

Our study contributes to the growing body of evidence on the clinical significance of prolonged deceleration during labor. By identifying specific risk factors for low pH, such as prolonged deceleration duration and fetal heart rate decrease, we

provide actionable insights for clinicians. The use of logistic regression to control for confounding factors strengthens the validity of our findings.

Limitations

As an observational study, our research cannot entirely eliminate the influence of confounding factors, and caution is warranted in inferring causal relationships. Additionally, we faced challenges related to data completeness, as some case data were missing, which may affect the accuracy of our results. Furthermore, the potential for selection bias exists, as the patients included in this study may not be representative of the broader population, limiting the external validity of our findings. Lastly, the single-center design of our study may restrict the generalizability of our conclusions, highlighting the need for future multicenter studies to validate our results and explore additional variables that may influence fetal outcomes. Future research should aim to include larger cohorts and more diverse populations to strengthen the conclusions drawn from our findings.

Conclusions

In summary, based on our research data, after controlling for confounding factors, we found that the duration of prolonged deceleration and heart rate decrease amplitude are risk factors for low pH. This suggests that when prolonged deceleration occurs during the second stage of labor, proactive measures should be taken to minimize adverse outcomes. Clinical practice should emphasize the importance of fetal monitoring, particularly in the context of prolonged deceleration during the second stage, necessitating active interventions to reduce the risk of low pH and its associated complications, thereby ensuring maternal and neonatal health.

Prospects

Future research should focus on effective management strategies for prolonged deceleration and explore the impact of different delivery methods on fetal outcomes.

Data Sharing Statement

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

Ethics Approval and Consent to Participate

This study received approval from the Ethics Committee of the Second Nanning People's Hospital [Y2024424].

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors have no conflict of interests to declare for this work.

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