Original Article

Does a longer second stage of labor worsen umbilical artery blood gas parameters in newborns?—a retrospective cohort study of 2,140 cases

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Background: With the application of the new labor management model in China, the normal length of the second stage of labor is significantly longer than that of the old model. It is unclear whether a longer stage of labor worsens umbilical artery blood gas analysis (UABGA) in newborns. The aim of this study was to investigate the correlation between the second stage of labor length, UABGA results, and neonatal intensive care unit (NICU) transfer rates under the new labor management model.

Methods: This is a retrospective cohort study including full-term, cephalic, vaginal deliveries. Exclusion criteria were preterm deliveries or deliveries by cesarean section during labor. The pH, base excess (BE), and lactate results of UABGA in newborns clearly reflect neonatal metabolic acidosis and intrauterine oxygenation of the fetus. The correlation between the length of the second stage of labor and the results of UABGA and NICU transfer rate was analyzed using linear or logistic regression and curve fitting.

Results: Of the total 2,140 cases, after adjusting for maternal age, gestational week, high-risk pregnancy factors, body mass index (BMI) before pregnancy, induced delivery, oxytocin during labor stage, labor analgesia, abnormal fetal position in labor stage, vaginal device delivery, length of first labor stage, and weight of the newborn, every 1 hour increase in the length of the second stage of labor decreased the UABGA pH by 0.01 [95% confidence interval (CI): −0.02 to −0.01, P<0.001], decreased the UABGA BE by 0.66 mmol/L (95% CI: −0.84 to −0.48, P<0.001), increased the UABGA lactate level by 0.39 mmol/L (95% CI: 0.29 to 0.50, P<0.001), and increased the NICU transfer rate by 26% (95% CI: 1.07 to 1.48, P=0.005). In the stratified analysis, when the length of the second stage of labor increased from 3 to 4 or more hours, there was no significant change in UABGA pH, BE, lactate, or NICU transfer rates.

Conclusions: Under the new criteria for the management of labor stage, the length of the second stage increasing from 3 to 4 or more hours did not negatively impact newborns. Therefore, clinician should not be too worried about the longer second stage of labor worsening adverse outcomes in newborns.

Keywords: Second stage of labor; umbilical artery blood gas analysis (UABGA); neonatal outcomes

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Introduction

Based on Zhang *et al.* (1) and Suzuki *et al.* (2) multicenter, large sample size study of labor in American and Japanese populations. In the "2018 WHO recommendations: intrapartum care for a positive childbirth experience" (3) and the Guidelines for Normal Birth (4), it is recommended that the normal length of the second stage of labor can be up to 4 hours with labor analgesia or 3 hours without labor analgesia in nulliparous women, while the maximum length of the second stage of labor in multiparous women can be up to 3 hours with labor analgesia or 2 hours without labor analgesia. Neonatal umbilical artery blood gas analysis (UABGA) combined with the Apgar score is currently an effective indicator for the diagnosis of fetal distress, neonatal metabolic acidosis, neonatal brain injury, and adverse neonatal outcomes. The pH, base excess (BE), and lactate parameters in UABGA are the most visual indicators of metabolic acidosis in newborns (5-7).

A previous study suggested that prolongation of the second stage of labor more than 45 minutes was associated with poor neonatal outcomes [UABGA pH <7.2, lactate >6 mmol/L, neonatal intensive care unit (NICU) transfer rate] (8), however, they were based on the old management model in which more than 3 hours was defined as prolonged second stage labor in nulliparous women. Lipschuetz *et al.* (9) concluded that a second stage of labor >3 hours in nulliparous women or >2 hours in multiparous women had little effect on UABGA pH <7.1, and they failed to use more effective indexes for UABGA such as BE and lactate to assess neonatal metabolic acidosis. Gimovsky *et al.* (10) riskily extended the length of second stage of labor observation to more than 5 hours and concluded that prolonged labor does not significantly increase neonatal risk, though neonatal risk was only assessed by morbidity. As the mainly difference between old and new standard of second stage of labor is the prolong of length from 3 to 4 hours in nulliparous women and 2 to 3 hours in multiparous women, the mainly target of this study is to assess the direct effect of the length of the second stage of labor on UABGA results and NICU transfer rate and to investigate whether it increased incidence of metabolic acidosis in neonates. We estimate the safety of prolong new labor stage will be proved as the UABGA and NICU transfer rate won't be worsen from 3 to 4 hours, which will give the clinicians strong confidence to not be worried about the longer second stage of labor worsening adverse outcomes in newborns. We present the following article in accordance with the STROBE reporting checklist (available at https://atm.amegroups.com/article/view/10.21037/atm-22-4604/rc).

Methods

Patient selection

This study is a retrospective cohort study in which we collected 2,140 cases of term, singleton, vaginal deliveries at the Third Affiliated Hospital of Sun Yat-sen University and Lingnan Hospital of Sun Yat-sen University from November 1st, 2020 to November 30th, 2021. The inclusion criteria were as follows: (I) full-term pregnancy; (II) live fetus, cephalic position, no contraindications of vaginal delivery such as significant cephalopelvic disproportion; (III) pregnancy complications such as gestational diabetes mellitus, gestational hypertension-related diseases, intrahepatic cholestasis during pregnancy, low amniotic fluid, fetal growth restriction were well controlled without significantly affecting the labor process; (IV) successful vaginal deliveries, including normal and vaginal device deliveries (all vaginal device deliveries in our hospital were low or exit device-assisted deliveries by forceps or vacuum devices). The exclusion criteria were as follows: (I) preterm delivery; (II) delivery by cesarean section during labor due to various medical and social factors; (III) delivery by cesarean section after the opening of the cervix. During spontaneous labor or induced labor, the timing of labor analgesia was started at any request after regular contractions with progressive shortening of the cervical canal, which marks the start of the first stage of labor. For all the cases included in the study, the general information [including age, gestational week of delivery, body mass index (BMI), parity, high-risk pregnancy factors, vaginal delivery after C-section], labor stage information (including whether it was an induced delivery, labor analgesia use, oxytocin use during labor stage, vaginal device delivery, length of first and second stage of labor), and neonatal information (including newborn weight, 1 and 5 minutes Apgar scores, UABGA pH, UABGA BE, UABGA lactate, and NICU transfer rate) were collected.

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Ethics Committee of the Third Affiliated Hospital of Sun Yat-sen University, with the approval No. [2021]02-399-01. Lingnan Hospital of Sun Yat-sen University was also informed and agreed with this study. As the Lingnan Hospital of Sun Yat-sen University is the

sub-center of the Third Affiliated Hospital of Sun Yat-sen University, it shares the same Ethics Committee for all clinical researches with the Third Affiliated Hospital of Sun Yat-sen University. Individual consent for this retrospective analysis was waived.

Labor management methods and UABGA methods

The 2020 Guidelines for Normal Childbirth were used as the criteria for observing the management of labor: the diagnosis of prolonged second stage of labor was made without intralesional anesthesia >3 hours or with intralesional anesthesia >4 hours in nulliparous women, or without intralesional anesthesia >2 hours or with intralesional anesthesia >3 hours in multiparous women, and cesarean delivery or vaginal device delivery was performed according to the situation. Labor stage progression was checked by at least two staff members in order to exclude the personal observation bias. After delivery, the umbilical artery was punctured with a heparinized empty needle for blood sampling during delayed cord ligation (at least 60 seconds) for normal term infants who did not require resuscitation according to the 2021 Expert Consensus on Clinical Application of Umbilical Artery Blood Gas Analysis (8). Retention of umbilical artery blood samples was performed during delayed cord ligation or prior to ligation of the umbilical cord when the cord pulsation stopped (1 to 3 minutes after birth). For infants who required immediate resuscitation, the umbilical cord was clamped right after birth, and a midwife not involved in neonatal resuscitation identified the umbilical artery at the end of the umbilical cord and placenta and punctured the sample within minutes before placenta abruption. In our center, we use a Siemens RAPIDPoint500 rapid blood gas analyzer. We sealed the needle with soft rubber covers to isolate the air as soon as it was removed from the umbilical artery puncture site. The test was performed within 1 minute and the results were available immediately. The measure of UABGA pH is 7.35 to 7.45, BE is –3 to 3 mmol/L, lactate is 0.5 to 2.0 mmol/L; and the measure of NICU transfer is neonatal asphyxia, neonatal respiratory distress, or metabolic acidosis.

Statistical analysis

Statistical software SPSS 22.0 was used to analyze the data of this study. Quantitative data were expressed as mean and standard deviation (SD) if they met the normal distribution, median and interquartile range (IQR) when skewed, and the *t*-test was used for comparisons between groups. Qualitative data were expressed as percentages (%), and the chi-square (χ^2) test or Fisher's exact test was used for comparisons between groups. Linear regression analysis was used for multi-factor analysis of quantitative data, and logistic regression analysis was used for multi-factor analysis of qualitative data. Linear regression analysis and logistic regression analysis curve fitting were used to fit the trend graphs, respectively. The multi-factorial regression was adjusted by confounding factors such as maternal age, parity, gestational week, high-risk pregnancy factors, BMI before pregnancy, induced delivery, oxytocin during labor stage, labor analgesia, abnormal fetal position in labor stage, vaginal device delivery, length of first labor stage, and weight of the newborn, which were selected by clinical experience and previous studies (9). Differences were considered statistically significant at $P<0.05$.

Results

There were 3,997 cases of delivery in our center during the study period, among which 2,518 cases were vaginal deliveries. We excluded 378 preterm deliveries, breech deliveries, or twin deliveries from the vagina.

General information

Of the 2,140 total cases, 55.19% (1,181/2,140) were nulliparous women and 44.81% (959/2,140) were multiparous women [including 38.50% (824/2,140) P2 and 6.31% (135/2,140) P3 or more multiparous women], with a mean age at delivery of 30.13±3.86 years, a mean gestational week of delivery of 39.45±0.97 weeks, and mean BMI before pregnancy of 20.70±2.56 kg/m^2. Furthermore, 44.07% (943/2,140) of cases had high-risk pregnancy comorbidities, 34.49% (738/2,140) of cases had induced deliveries due to various etiologies, 50.05% (1,071/2,140) of cases had labor analgesia, 44.72% (957/2,140) of cases used oxytocin during labor, 2.06% (44/2,140) of cases had abnormal fetal position during labor, and 5.47% (117/2,140) of cases used vaginal device deliveries. The duration of the first stage of labor was 6.83 (4.25, 10.75) hours and the duration of the second stage of labor was 0.437 (0.22, 1.22) hours. The average neonatal birth weight was 3,161.52±355.32 g, the average 1 minute Apgar score was 9.93±0.47, and the average 5 minutes Apgar score was 9.99±0.14. The neonatal UAGBA results were pH 7.26±0.09, BE –4.38±3.05 mmol/L, and lactate 4.45±1.67 mmol/L (there

Table 1 Patient characteristics and outcome parameters

Patient characteristics/outcome parameters	Vaginal delivery cases: length of the second stage of labor (min)				
	Total (n=2,140)	Q1: 0–59.9 (n=1,483)	Q2: 60–119.9 (n=367)	Q3: 120–179.9 (n=209)	Q4: ≥180 (n=81)
Age (years)	30.13±3.86	30.44±3.95	29.29±3.57	29.26±3.40	30.35±3.66
Gestational week (weeks)	39.45±0.97	39.39±0.97	39.57±0.99	39.57±0.88	39.67±1.03
BMI (kg/m^2)	20.70±2.56	20.88±4.31	20.35±2.36	20.04±2.05	20.66±2.33
Parity, n (%)					
P1	1,181 (55.19)	581 (39.18)	327 (89.10)	196 (93.78)	77 (95.06)
P2	824 (38.50)	771 (51.99)	379 (10.08)	13 (6.22)	3 (3.70)
P3 and more	135 (6.31)	131 (8.83)	3 (0.82)	0 (0.00)	1 (1.23)
Vaginal delivery after CS, n (%)	45 (4.69)	37 (4.10)	7 (17.5)	0 (0.00)	0 (0.00)
High-risk pregnancy, n (%)	943 (44.07)	659 (44.44)	174 (47.41)	83 (39.71)	27 (33.33)
Induced delivery, n (%)	738 (34.49)	507 (34.19)	151 (41.14)	97 (46.41)	31 (38.27)
Labor analgesia, n (%)	1,071 (50.05)	561 (37.83)	287 (63.92)	155 (74.16)	68 (83.95)
Oxytocin during labor stage, n (%)	957 (44.72)	483 (32.57)	154 (78.20)	168 (80.38)	70 (86.42)
Abnormal fetal position in labor stage, n (%)	44 (2.06)	21 (1.42)	9 (2.45)	11 (2.56)	3 (3.70)
Vaginal device delivery rate, n (%)	117 (5.47)	36 (2.43)	20 (5.45)	31 (14.83)	30 (37.04)
Length of first stage of labor (hours)	6.83 (4.25, 10.75)	5.80 (3.67, 9.25)	9.33 (6.67, 12.79)	9.83 (6, 13.17)	10.42 (7.63, 14.30)
Length of second stage of labor (hours)	0.437 (0.22, 1.22)	0.228 (0.17, 0.50)	1.37 (1.15, 1.59)	2.37 (2.17, 2.65)	3.33 (3.13, 3.75)
Weight of newborn (g)	3,161.52±355.32	3,159.68±362.88	3,151.23±334.53	3,208.85±337.78	3,278.40±322.89
1 minute Apgar score	9.93±0.47	9.95±0.44	9.92±0.46	9.86±0.61	9.83±0.60
5 minutes Apgar score	9.99±0.14	9.99±0.11	9.99±0.12	9.97±0.30	10.00±0.00
UABGA pH	7.26±0.09	7.28±0.08	7.24±0.08	7.23±0.08	7.23±0.09
UABGA BE (mmol/L)	−4.38±3.05	−3.78±2.89	−5.50±2.92	−5.82±2.83	−6.38±3.54
Lactate (mmol/L)[#]	4.45±1.67	4.12±1.56	5.11±1.72	5.31±1.52	5.31±1.90
NICU rate, n (%)	289 (13.50)	152 (10.25)	71 (19.35)	46 (20.01)	20 (24.69)

[#], there are 57/2,140 missing the data of lactate, that we excluded from the analysis. Quantitative variables are shown as mean ± SD or median (IQR). BMI, body mass index; CS, Caesarean section; UABGA, umbilical artery blood gas analysis; BE, base excess; NICU, neonatal intensive care unit; SD, standard deviation; IQR, interquartile range.

are 57/2,140 missing the data of lactate), with a NICU transfer rate of 13.50% (289/2,140). When we grouped the 2,140 cases using a group spacing of 60 minutes, there was a total of 1,483 cases (69.30%) in the 0–59.9 minutes group, 367 cases (17.15%) in the 60–119.9 minutes group, 209 cases (9.77%) in the 120–179.9 minutes group, and 81 cases (3.79%) in the 180+ minutes group (*Table 1*).

Correlation between the length of the second stage of labor and UABGA pH, BE, lactate, and NICU transfer rate

After adjustment for confounding factors (*Table 2*, model 4), it was found that every 1 hour increase in the length of the second stage of labor decreased the UABGA pH by 0.01 [95% confidence interval (CI): −0.02 to −0.01, P<0.001; *Table 2*,

Table 2 Multivariable linear regression of the length of the second stage of labor and UABGA pH, BE, and lactate

Model	UABGA pH (n=2,140)			UABGA BE (n=2,140)			UABGA Lac (n=2,083)		
	Adjusted β	Adjusted 95% CI	Adjusted P value	Adjusted β	Adjusted 95% CI	Adjusted P value	Adjusted β	Adjusted 95% CI	Adjusted P value
Model 1[a]	−0.02	−0.02 to −0.01	<0.001	−0.76	−0.92 to −0.60	<0.001	0.38	0.29 to 0.47	<0.001
Model 2[b]	−0.02	−0.02 to −0.01	<0.001	−0.75	−0.91 to −0.58	<0.001	0.38	0.29 to 0.47	<0.001
Model 3[c]	−0.01	−0.02 to −0.01	<0.001	−0.65	−0.82 to −0.47	<0.001	0.38	0.28 to 0.48	<0.001
Model 4[d]	−0.01	−0.02 to −0.01	<0.001	−0.66	−0.84 to −0.48	<0.001	0.39	0.29 to 0.50	<0.001

[a], model 1: adjusted for age, parity, gestational weeks, high-risk pregnancy factors, BMI before pregnancy; [b], model 2: adjusted as model 1, additionally adjusted for induced delivery; [c], model 3: adjusted as model 2, additionally adjusted for oxytocin during labor stage, labor analgesia, abnormal fetal position in labor stage, vaginal device delivery, length of first labor stage; [d], model 4: adjusted as model 3, additionally adjusted for weight of newborn. UABGA, umbilical artery blood gas analysis; BE, base excess; Lac, lactate; CI, confidence interval; BMI, body mass index.

Figure 1A], decreased the UABGA BE by 0.66 mmol/L (95% CI: −0.84 to −0.48, P<0.001; *Table 2*, *Figure 1B*), increased the UABGA lactate value by 0.39 mmol/L (95% CI: 0.29 to 0.50, P<0.001; *Table 2*, *Figure 1C*), and increased the NICU transfer rate by 26% (95% CI: 1.07 to 1.48, P=0.005; *Table 3*, *Figure 1D*).

Effect of the length of the second stage of labor on the results of UABGA

In the stratified analysis, we grouped the 2,140 cases into four subgroups and adjusted the confounding factors mentioned in statistical methods. In the linear or logistic regression analysis between every two groups, we found that only when the time increase from the 0–59.9 minutes subgroup to 60–119.9 minutes subgroup, the UABGA pH decreased by 0.02 (P=0.001) (*Table 4*), the UABGA BE decreased by 0.87 (P<0.001) mmol/L (*Table 5*), and the UABGA lactate level increased 0.63 (P<0.001) mmol/L (*Table 6*). In the other subgroups from 60–119.9 minutes subgroup to 180+ minutes subgroup in UABGA pH, BE, lactate, or in any subgroups of NICU transfer rate, there are no statistically significant difference when every 60-minute increase between subgroups (P>0.05, *Tables 4*-*7*).

Influence of parity, induced delivery, labor analgesia, vaginal device delivery, and other factors on the results of UABGA

We found that high-risk pregnancy, induced delivery, labor analgesia, oxytocin use during labor, and vaginal device delivery were important confounding factors affecting both the length of the second stage of labor and the results of neonatal UABGA in our past experience. Additional subgroup and sensitivity analyses concerning the above factors are presented in *Table 4*. The results showed that the length of the second stage of labor in the natural labor group was negatively correlated with the UABGA pH and BE and positively correlated with lactate (β: −0.02, −0.80, 0.48, P<0.001), whereas the length of the second stage of labor in the vaginal device delivery group was not significantly correlated with UABGA pH, BE, or lactate (β: 0.00, −0.24, 0.11, P=0.816, 0.413, 0.533; *Table 8*).

Discussion

As the management of labor has had a tendency towards a longer observation time in the last several years, the purpose of this study was to provide valid evidence for the safety of increased length of the second stage of labor and its effects on neonatal condition. However, maternal age, parity (impact on the length of total labor stage), high-risk comorbidities (impact on maternal cardiopulmonary function and oxygenation), the gestational week of delivery (impact on placental function), BMI before pregnancy (impact on the thickness of the pelvic floor), the use of oxytocin and labor analgesia, induced labor, the length of the first stage of labor, vaginal device delivery, and neonatal weight also affect the length of the second stage of labor, as well as the results of UABGA. Therefore, the interaction of these confounding factors should be removed from the data analysis of this study. From the multi-factorial regression analysis results, it is clear that an increase in the length of the second stage of labor causes a decrease in

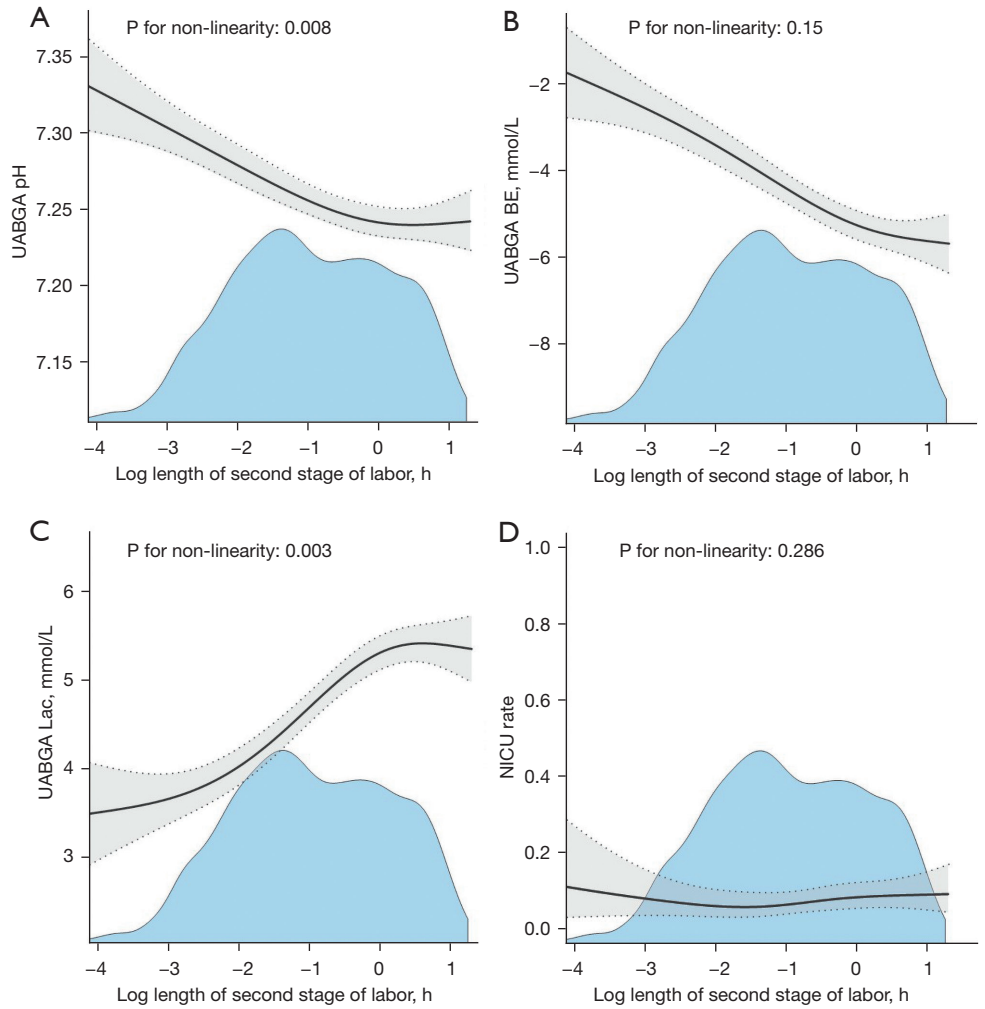

Figure 1 Multivariable regression analyses curve fitting of the length of the second stage of labor and the UABGA pH, BE, lactate, and NICU transfer rate, with adjustment for age, gestational weeks, high-risk pregnancy factors, BMI before pregnancy, induced delivery, oxytocin during labor stage, labor analgesia, abnormal fetal position in labor stage, vaginal device delivery, length of first labor stage, and weight of the newborn. (A) Linear regression analyses curve fitting of the length of the second stage of labor (ln) and the UABGA pH. (B) Linear regression analyses curve fitting of the length of the second stage of labor (ln) and the UABGA BE. (C) Linear regression analyses curve fitting of the length of the second stage of labor (ln) and the UABGA lactate. (D) Logistic regression analyses curve fitting of the length of the second stage of labor (ln) and the NICU transfer rate. UABGA, umbilical artery blood gas analysis; BE, base excess; Lac, lactate; NICU, neonatal intensive care unit; BMI, body mass index.

UABGA pH and BE and an increase in lactate. However, further subgroup analyses clearly showed prolonging after 120 minutes in the second stage of labor did not negatively impact on UABGA and the NICU transfer rate.

A multicenter study from the Clinical Research Group of Multiple Organ Damage of Neonatal Asphyxia (11) found that pH <7.00 and BE <–16.00 mmol/L had a higher specificity and positive predictive value for the diagnosis of neonatal asphyxia and multiple organ damage. In this study, the effect of an increasing duration of the second stage of labor on UABGA pH, BE, and lactate was mild. This may be related to the mode and method of labor management in our center, as most cases of fetal distress are promptly transferred to cesarean section or vaginal device delivery, preventing the occurrence of neonatal metabolic acidosis and neonatal ischemic-hypoxic brain injury. Due to multiple constraints such as medical ethics and the clinical guidelines on practical management, it was also not possible to observe

Table 3 Multivariable logistic regression of the length of the second stage of labor and NICU transfer rate

Model	NICU transfer rate (n=2,140)		
	Adjusted OR	Adjusted 95% CI	Adjusted P value
Model 1[a]	1.30	1.13 to 1.51	<0.001
Model 2[b]	1.29	1.11 to 1.49	0.001
Model 3[c]	1.21	1.03 to 1.42	0.018
Model 4[d]	1.26	1.07 to 1.48	0.005

[a], model 1: adjusted for age, parity, gestational weeks, high-risk pregnancy factors, BMI before pregnancy; [b], model 2: adjusted as model 1, additionally adjusted for induced delivery; [c], model 3: adjusted as model 2, additionally adjusted for oxytocin during labor stage, labor analgesia, abnormal fetal position in labor stage, vaginal device delivery, length of first labor stage; [d], model 4: adjusted as model 3, additionally adjusted for weight of newborn. NICU, neonatal intensive care unit; OR, odds ratio; CI, confidence interval; BMI, body mass index.

the UABGA of many cases of significantly prolonged second stage of labor (>4 hours for nulliparous women and >3 hours for multiparous women). By grouping the 2,140 cases with a group spacing of 60 minutes, we revealed that after 1 hour of second stage, each 60-minute increase in the length of labor did not significantly change neonatal UABGA pH, BE, or lactate, suggesting that the current limit of 4 hours (nulliparous) or 3 hours (multiparous) for the length of the second stage of labor does not significantly increase the risk of adverse outcomes such as metabolic acidosis in neonates.

Previous studies showed that the effect of prolonged second stage of labor (>3 hours in nulliparous/2 hours in multiparous women) on neonatal outcome was inconclusive (12,13). However, they failed to discuss cases prolonged over 4 hours in the second stage of labor, as they were limited by the old management model of labor stage. Other studies by Thorp *et al.* (14), Cavoretto *et al.* (15), Ekengård

Table 4 β of UABGA pH for every 60-minute increase in the length of the second stage of labor

Subgroups by every 60-minute	Crude			Adjusted		
	β	95% CI	P value	β	95% CI	P value
Q1 and Q2	−0.04	−0.05 to −0.03	<0.001	−0.02	−0.03 to −0.01	0.001
Q2 and Q3	−0.01	−0.02 to 0.01	0.247	−0.01	−0.02 to 0.01	0.324
Q3 and Q4	0.00	−0.02 to 0.02	0.756	0.00	−0.02 to 0.03	0.685
Total	−0.02	−0.03 to −0.02	<0.001	−0.01	−0.02 to −0.01	<0.001

Comparison of UABGA pH in subgroups from Q1 to Q4 shows that only when the time increases from the 0–59.9 minutes subgroup to 60–119.9 minutes subgroup, worsen the UABGA pH. Q1 was the 0 to 59.9 minutes group in the second stage of labor (n=1,483). Q2 was the 60 to 119.9 minutes group in the second stage of labor (n=367). Q3 was the 120 to 179.9 minutes group in the second stage of labor (n=209). Q4 was the over 180 minutes group in the second stage of labor (n=81). UABGA, umbilical artery blood gas analysis; CI, confidence interval.

Table 5 β of UABGA BE for every 60-minute increase in the length of the second stage of labor

Subgroups by every 60-minute	Crude			Adjusted		
	β	95% CI	P value	β	95% CI	P value
Q1 and Q2	−1.72	−2.05 to −1.38	<0.001	−0.87	−1.23 to −0.51	<0.001
Q2 and Q3	−0.32	−0.81 to 0.17	0.197	−0.31	−0.81 to 0.20	0.230
Q3 and Q4	−0.55	−1.34 to 0.23	0.166	−0.41	−1.23 to 0.41	0.332
Total	−1.14	−1.27 to −1.00	<0.001	−0.66	−0.84 to −0.48	<0.001

Comparison of UABGA BE in subgroups from Q1 to Q4 shows that only when the time increases from the 0–59.9 minutes subgroup to 60–119.9 minutes subgroup, worsen the UABGA BE. The basis for grouping was the same as *Table 4*. UABGA, umbilical artery blood gas analysis; BE, base excess; CI, confidence interval.

Table 6 β of UABGA lactate for every 60-minute increase in the length of the second stage of labor

Subgroups by every 60-minute	Crude			Adjusted		
	β	95% CI	P value	β	95% CI	P value
Q1 and Q2	0.99	0.8 to 1.17	<0.001	0.63	0.43 to –0.83	<0.001
Q2 and Q3	0.20	0.09 to 0.48	0.174	0.23	–0.07 to 0.52	0.134
Q3 and Q4	0.00	–0.42 to 0.42	0.999	0.02	–0.43 to 0.47	0.934
Total	0.60	0.52 to 0.68	<0.001	0.39	0.29 to 0.50	<0.001

Comparison of UABGA lactate in subgroups from Q1 to Q4 shows that only when the time increases from the 0–59.9 minutes subgroup to 60–119.9 minutes subgroup, worsen the UABGA lactate. The basis for grouping was the same as *Table 4*. UABGA, umbilical artery blood gas analysis; CI, confidence interval.

Table 7 β of the NICU transfer rate for every 60-minute increase in the length of the second stage of labor

Subgroups by every 60-minute	Crude			Adjusted		
	β	95% CI	P value	β	95% CI	P value
Q1 and Q2	2.10	1.54 to 2.86	<0.001	1.42	0.99 to –2.04	0.056
Q2 and Q3	1.18	0.78 to 1.79	0.445	1	0.62 to 1.59	0.985
Q3 and Q4	1.16	0.64 to 2.12	0.625	0.81	0.42 to 1.59	0.547
Total	1.52	1.34 to 1.71	<0.001	1.26	1.07 to 1.48	0.005

Comparison of NICU transfer rates in subgroups from Q1 to Q4 shows that only when the time increases from the 0–59.9 minutes subgroup to 60–119.9 minutes subgroup, worsen the NICU transfer rate. The basis for grouping was the same as *Table 4*. NICU, neonatal intensive care unit; CI, confidence interval.

Table 8 Additional subgroup and sensitivity analyses of vaginal device delivery

Confounding factors	N	pH		BE		Lactate	
		Adjusted β (95% CI)	P	Adjusted β (95% CI)	P	Adjusted β (95% CI)	P
High-risk pregnancy							
No	1,197	–0.01 (–0.02 to 0.00)	0.005	–0.67 (–0.91 to –0.43)	<0.001	0.41 (0.27 to 0.54)	<0.001
Yes	943	–0.01 (–0.02 to 0.00)	0.008	–0.64 (–0.92 to –0.36)	<0.001	0.39 (0.23 to 0.54)	<0.001
Induced delivery							
No	1,354	–0.01 (–0.02 to 0.00)	0.014	–0.66 (–0.89 to –0.42)	<0.001	0.39 (0.25 to 0.52)	<0.001
Yes	786	–0.01 (–0.02 to –0.01)	0.001	–0.66 (–0.96 to –0.37)	<0.001	0.41 (0.24 to 0.57)	<0.001
Labor analgesia							
No	1,069	–0.01 (–0.02 to 0.00)	0.005	–0.78 (–1.10 to –0.45)	<0.001	0.52 (0.34 to 0.69)	<0.001
Yes	1,071	–0.01 (–0.02 to 0.00)	0.002	–0.59 (–0.82 to –0.37)	<0.001	0.35 (0.22 to 0.48)	<0.001
Oxytocin							
No	1,183	–0.01 (–0.02 to 0.00)	0.004	–0.92 (–1.24 to –0.60)	<0.001	0.59 (0.41 to 0.77)	<0.001
Yes	957	–0.01 (–0.02 to –0.01)	<0.001	–0.58 (–0.81 to –0.35)	<0.001	0.33 (0.20 to 0.46)	<0.001
Vaginal device delivery							
No	2,023	–0.02 (–0.02 to –0.01)	<0.001	–0.80 (–1.00 to –0.61)	<0.001	0.48 (0.37 to 0.59)	<0.001
Yes	117	0.00 (–0.01 to 0.02)	0.816	–0.24 (–0.82 to 0.33)	0.413	0.11 (–0.24 to 0.46)	0.533

BE, base excess; CI, confidence interval.

et al. (16), Paine *et al.* (17), and Kanninen *et al.* (18) only focused on influencing factors such as maternal oxygen status, prenatal computerized cardiotocography (cCTG) condition, maternal force pattern, or whether giving fundal pressure in the second stage of labor impacted the UABGA results. Yudkin *et al.* (19) examined 885 cases of vaginal delivery and investigated the effect of maternal factors (e.g., number of deliveries), intrapartum complications (e.g., placental abruption, preeclampsia, fetal distress), intrapartum medications (e.g., pethidine use), and vaginal device delivery on the outcome of neonatal UABGA. Veisy *et al.* (20) evaluated the effect of prenatal aerobic exercises on maternal and neonatal outcomes. These studies failed to standardize the use of pH, BE, and lactate results in UABGA as the representation of neonatal outcome, which are most directly related to neonatal metabolic acidosis, or failed to effectively remove the interplay of multiple confounding factors such as maternal condition, prenatal complications, and intrapartum anesthetic medication, or failed to analyze for a single index, so the validity of the results was not high. In this study, we stratified the effects of multiple confounding factors on the length of second stage of labor and UABGA, such as high-risk pregnancy complications, induction of labor, use of labor analgesia or oxytocin during labor, and vaginal device delivery, among others. In a recent meta-analysis (21) contained many up-to-date studies which the prolong of second stage of labor renewed to >4 hours in nulliparous/3 hours in multiparous women followed the new management of labor stage, however the neonatal outcomes were mainly assessed by Apgar scores. In our study, we used the new standard to manage the labor stage and UABGA as an accurate index of neonatal outcomes. We also stratified the effects of multiple confounding factors on the length of second stage of labor and UABGA. The correlation between the length of second stage of labor and UABGA pH, BE, and lactate was clear, regardless of the groups divided according to high-risk pregnancy complications, induction of labor, and use of labor analgesia or oxytocin during labor or not. In contrast, in the device delivery group, there was no significant correlation between the length of the second stage of labor and the results of UABGA. This may be related to the reason for device delivery, as only 29 of the 117 vaginal device deliveries were due to prolonged second stage of labor, while 88 of the 117 vaginal device deliveries were due to fetal distress. Fetal distress and other etiologies themselves can aggravate neonatal metabolic acidosis, so the interference of device delivery with the length of second stage of labor and the interference of fetal distress with the results of UABGA may have led to the insignificant correlation between the length of the second stage of labor and the results of UABGA in the assisted delivery group.

The strengths of this study were the large sample size (2,140 cases) and the elimination of multiple confounding factors that have been used in previous studies. Furthermore, this study selected UABGA pH, BE, and lactate, which are the 3 most relevant indicators for neonatal metabolic acidosis and neonatal ischemic-hypoxic encephalopathy according to the latest guidelines and expert consensus, eliminating the interference of insensitive indicators in UABGA. Using stratified analysis, we found that the current new labor management paradigm with 3/4 hours as the criterion for prolonged second stage of labor did not show significant worsening of UABGA, thus demonstrating the safety of the current second stage of labor management criteria.

However, this study is still a single-center study. The sample size can be expanded and the credibility of the results can be increased by a multicenter joint study in the future.

Conclusions

An increased length of the second stage of labor resulted in a slight decrease in pH and BE of UABGA and a slight increase in lactate and neonatal NICU transfer rates. Therefore, under the new criteria for the management of labor stage, an increase in the length of the second stage of labor from 3 to 4 or more hours did not negatively impact newborns.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Ethics Committee of the Third Affiliated Hospital of Sun Yat-sen University, with the approval No. [2021]02-399-01. Lingnan Hospital of Sun Yat-sen University was also informed and agreed with this study. As the Lingnan Hospital of Sun Yat-sen University is the sub-center of the Third Affiliated Hospital of Sun Yat-sen University, it shares the same Ethics Committee for all clinical researches with the Third Affiliated Hospital of Sun Yat-sen University. Individual consent for this retrospective analysis was waived.

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