Original articles

Correlation between fetal head dimensions on ultrasound and labor outcomes

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Abstract

Background: Prolonged labor is a risk factor for numerous maternal and fetal complications and is among the primary causes of operative vaginal delivery and emergency cesarean section. Predicting prolonged labor remains challenging.

Objectives: To determine the relationship between fetal head dimensions on ultrasound and the duration of labor as well as other outcomes.

Materials and Methods: A cross-sectional descriptive study was conducted on 191 nulliparous women admitted for delivery at the Hue University of Medicine and Pharmacy Hospital from January 2024 to April 2025. Independent samples t-test or Mann–Whitney U test was used for comparison. Spearman correlation coefficient (rs), multivariable logistic regression and ROC curve analysis were used to assess the association with, and to identify cut-off points for predicting, the risk of cesarean section due to a prolonged second stage of labor.

Results: 34/191 cases underwent cesarean section during the second stage. Fetal head dimensions in the cesarean section group were significantly larger ($p < 0.001$). There was a weak positive correlation between biparietal diameter, head circumference and second stage duration ($p < 0.001$). These indices were larger in cases of complex perineal tears. The Area Under the Curve for biparietal diameter and head circumference in predicting cesarean section due to prolonged second stage was 0.718 and 0.704, respectively. In a multivariable model, only biparietal diameter remained independently associated with this outcome.

Conclusion: Ultrasound measurement of fetal head dimensions has prognostic value for adverse maternal labor outcomes.

Keywords: *Cesarean section; prolonged labor; fetal head biometry.*

1. INTRODUCTION

Prolonged labor is a risk factor of several labor complications regarding both the pregnant women and their infants including asphyxia, perinatal mortality, complicated perineal tears, postpartum hemorrhage as well as postpartum infection [1]. This is also a major contribution to the indication of assisted vaginal delivery and emergency cesarean section [2]. Therefore, a comprehensive understanding of risk factors together with prognostic factors of prolonged labor plays a pivotal role in enhancing labor outcomes. However, predicting prolonged labor remains such a challenge to clinicians. Common etiologies to this condition are, but not limited to, abnormal and unfavorable presentation, insufficient uterine contractions or cephalopelvic disproportion [3]. The two dimensions of the fetal head, which are biparietal diameter (BPD) and head circumference (HC), are measured routinely on ultrasound to estimate fetal weight. Simultaneously, current studies have revealed the correlation between these two indices and certain negative maternal and neonatal labor outcomes. According to Bardin et al. (2016), conducted on 3229 pregnant women, biparietal diameter is an independent risk factor for unplanned obstetrical interventions due to prolonged labor with an OR 1.05 (95% CI 1.02 - 1.09, p = 0.002) [4]. A study of Salman et al. (2019) also revealed the positive correlation between fetal head circumference and the duration of second stage of labour on both nulliparous and multiparous women [5]. In Viet Nam, some studies concern the condition of prolonged and arrested labor as of Cao Ngoc Thanh et al. (2023), in which prolonged labor was associated with induction of labor and transverse or posterior occiput position [6]. However, there is little research on the association between fetal head dimensions and labour outcomes, including prolonged labor. Thus, we conducted this study on "Correlation between fetal head dimensions on ultrasound and labor

outcomes" with two objectives:

(1) To analyze the correlation between fetal head dimensions on ultrasound and labor outcomes.

(2) To determine the prognostic value of fetal head dimensions in predicting the risk of Cesarean delivery.

2. SUBJECTS AND METHODOLOGY

2.1. Subjects

Nulliparous women admitted to the Department of Obstetrics and Gynecology, Hue University of Medicine and Pharmacy Hospital to deliver who satisfied all of the inclusion criteria and had none of the exclusion ones from January 2024 to April 2025.

Inclusion Criteria: Singleton, live, term pregnancy with cephalic presentation.

Exclusion Criteria:

Cesarean section before the second stage of labor

Cesarean section due to fetal distress or obstetric emergency during the second stage.

Uterus with previous surgical scars (ie, myomectomy).

Fetal malformations.

Refusal to participate in the study.

2.2. Research Methodology

Study Design: Cross-sectional descriptive study.

Sample Size: The sample size was calculated by using the formula for estimating a population proportion:

$$n = \frac{Z^2.p\,(1-p)}{d^2}$$

in which:

Z = 1.96 (95% Confidence interval)

p is the incidence of prolonged second stage of labor. According to Shinohara et al. (2020) on 1341 nulliparous women, this incidence was 18.3% [7].

d = 0.06.

By calculating so, we estimated a minimum sample size of 159. In fact, we collected 191 nulliparous cases satisfying all of our selection criteria.

Research Protocol:

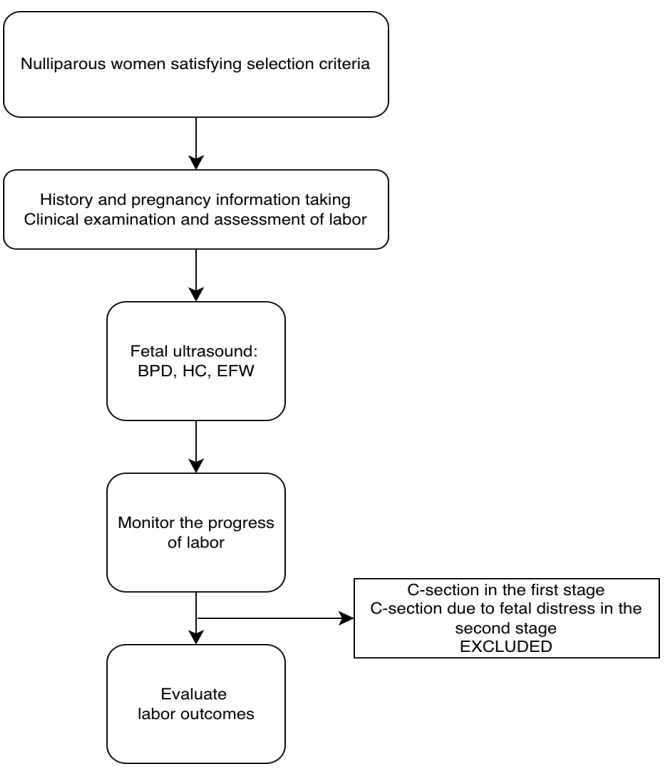

Figure 1. Research process flowchart

Variable Definitions:

Active phase was defined with a starting point of 5cm cervical dilation according to the labour care guide of WHO [8].

Prolonged Second Stage: More than 2 hours in nulliparous women without epidural anesthesia and more than 3 hours in nulliparous women with epidural anesthesia, accompanied by evidence that the fetal head is not rotating or descending despite effective contractions and good pushing efforts.

Cardiotocography (CTG): interpreted according to the 2015 FIGO classification. Tracings classified

as suspicious (category II) were reported as non-assuring. These tracings did not by themselves constitute an indication for operative delivery; cases in which cesarean section was indicated for fetal distress during the second stage were excluded from the study.

Indication for cesarean section during the second stage: all cesarean sections included in this study were performed for a prolonged second stage of labor.

Perineal tears: graded from I to IV with third- and fourth-degree tears (obstetric anal sphincter injury) being classified as complicated perineal tears.

Postpartum hemorrhage: estimated blood loss of at least 500 mL after vaginal delivery.

2.3. Data Analysis and Processing:

Data were entered and processed using Microsoft Excel and SPSS 26.0 software.

Qualitative variables were presented as numbers and percentages.

Quantitative variables were presented as means and standard deviations if normally distributed, or whereas non-normally distributed data were expressed as medians.

A p-value < 0.05 was considered statistically significant.

Independent samples t-test was used to compare means with normal distribution while Mann–Whitney U test was used for values with non-normal distribution.

Spearman rank correlation coefficient (rs) was used to assess the correlation between BPD, HC, and labor duration.

ROC curve analysis was performed to find the optimal cut-off points for indices predicting the risk of cesarean section due to a prolonged second stage.

Multivariable logistic regression was used to determine whether BPD and HC were independently associated with cesarean section due to a prolonged second stage. Both fetal head dimensions, together with the maternal and obstetric variables that were statistically significant on univariate analysis (p < 0.05), were entered into the final model.

2.4. Research Ethics

This study was approved by Hue University of Medicine and Pharmacy, Hue University (Decision No. 133/QD-DHYD, dated January 01st, 2024). Written consent was obtained from all participants, and their personal information was kept strictly confidential.

3. RESULTS

There were 191 pregnant women who met the selection criteria. The median maternal age was 24, and the majority of women had a normal pre-pregnancy BMI. Most cases were terminated before 40 weeks.

Table 1 summarizes general maternal and pregnancy characteristics of the two groups (cesarean section vs. vaginal delivery). There were 34/191 (17.8%) cases of cesarean section which were indicated during the second stage; simultaneously, our study recorded no cases of operative vaginal delivery. Pre-pregnancy BMI in the cesarean section group was significantly higher than in the vaginal delivery group (*p = 0.011*).

Table 1. General Characteristics

Characteristic	Total (n = 191)	Vaginal delivery (n = 157)	C-section (n = 34)	*p*
Maternal age	24 (6)	24 (6)	25 (6)	*0.084*
Pre-pregnancy BMI	20.8 (2.7)	20.5 (2.6)	22.3 (2.4)	***0.011***
Maternal height	1.55 (0.1)	1.55 (0.1)	1.55 (0.1)	*0.945*
Gestational age	39.3 (1.0)	39.3 (1.0)	39.6 (1.0)	*0.210*

Values are expressed as median (interquartile range). BMI: Body mass index

Table 2. Fetal Dimensions on Ultrasound

Characteristic	Total (n = 191)	Vaginal delivery (n = 157)	C-section (n = 34)	*p*
Head circumference (mm) Median (Min - Max)	324 (292 - 361)	323 (292 - 354)	329 (296 - 361)	***< 0.001***
Biparietal diameter (mm) Median (Min - Max)	92.0 (82.6 - 99)	91.5 (82.6 - 99)	93.5 (85 - 98.5)	***< 0.001***
Estimated fetal weight (g) Median (Min - Max)	3100 (2136 - 3800)	3050 (2350 - 3800)	3200 (2136 - 3600)	*0.070*

There was a statistically significant difference between the two delivery method groups regarding the two concerned fetal head dimension indices ($p < 0.001$). Estimated fetal weight on ultrasound in the cesarean section group was also higher than that in the vaginal delivery group, but this difference was not statistically significant.

Table 3. Correlation between Fetal Head Dimensions and Labor Duration.

Stage of labor	BPD		HC	
	rs	*p*	rs	*p*
Active phase	0.171	***0.018***	0.039	*0.591*
Second stage	0.260	***< 0.001***	0.299	***< 0.001***

rs: Spearman rank correlation coefficient. BPD: Biparietal diameter; HC: Head circumference

HC was not related to the duration of the active phase, whereas BPD showed only a very weak correlation with it (rs = 0.171, p = 0.018). Meanwhile, there was a positive correlation between these two fetal head dimensions and the duration of the second stage of labor ($p < 0.001$) at a weak level.

Table 4. Fetal head dimensions and maternal labor outcomes

Outcome		BPD	*p*	HC	*p*
Occiput position during head engagement	Anterior (n = 103)	91.5 (3.0)	*0.639*	323.0 (13.0)	*0.964*
	Posterior or transverse (n = 54)	91.4 (3.0)		322.5 (11.0)	
Occiput position during head expulsion	Anterior (n = 145)	91.4 (3.0)	*0.523*	323.0 (12.0)	*0.079*
	Posterior (n = 12)	91.9 (3.5)		325.0 (13.3)	
Perineal tears	I - II (n = 145)	91.0 (2.6)	***0.007***	322.5 (12.0)	***0.009***
	III - IV (n = 12)	93.0 (3.5)		329.5 (15.5)	
Postpartum hemorrhage	Yes (n = 7)	94.0 (3.0)	***0.013***	325.0 (4.0)	*0.409*
	No (n = 150)	91.0 (2.8)		323.0 (12.5)	
Second stage	Prolonged (n = 36)	93.5 (2.3)	***0.001***	328.5 (18.0)	***0.002***
	Normal (n = 155)	91.5 (3.0)		324.0 (11.5)	

Values are expressed as median (interquartile range). Occiput position, perineal tears and postpartum hemorrhage were analyzed in the 157 cases of vaginal delivery, whereas the duration of the second stage was analyzed in all 191 women. BPD: Biparietal diameter; HC: Head circumference.

HC and BPD on ultrasound did not differ between engagement and expulsion occiput position groups; however, they were significantly larger in cases of prolonged second stage and complicated perineal tears. BPD in cases of postpartum hemorrhage was also larger compared to cases where this complication did not occur.

Table 5. Fetal head dimensions and neonatal outcomes

Outcomes		BPD	*p*	HC	*p*
CTG	**Non-assuring (n = 21)**	92.0 (3.6)	*0.120*	326.0 (11.0)	*0.227*
	Assuring (n = 170)	92.0 (3.0)		324.0 (11.0)	
1-minute APGAR	**≤ 7 (n = 8)**	92.4 (3.0)	*0.205*	324.5 (11.3)	*0.567*
	> 7 (n = 183)	92.0 (3.0)		324.0 (11.2)	

Values are expressed as median (interquartile range). BPD: Biparietal diameter; HC: Head circumference; CTG: Cardiotocography

Table 5 shows no relationship between head dimensions and perinatal outcomes of the newborn. In our study, no cases of category-III CTG or 5-minute APGAR score of below 7 were reported. Non-assuring CTG was recorded in 21 women (5 in the cesarean section group and 16 in the vaginal delivery group).

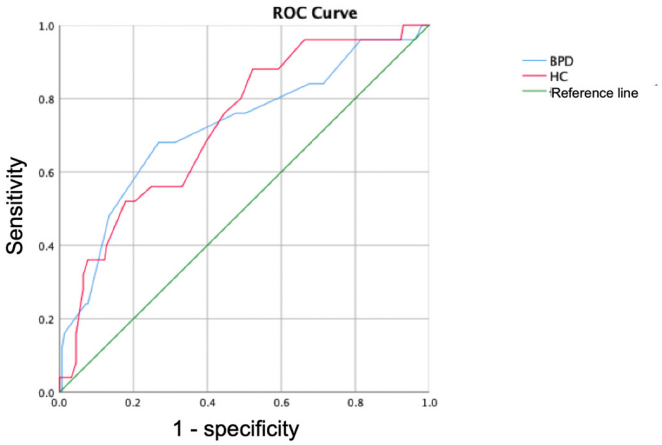

Figure 2. ROC curve using BPD and HC to predict the risk of Cesarean section due to prolonged second stage.
BPD: Biparietal diameter; HC: Head circumference

When analyzing the ROC curve of BPD and HC to predict the risk of cesarean section due to a prolonged second stage, the Area Under the Curve was 0.718 and 0.704, respectively, with $p < 0.001$. The optimal cut-off point for BPD was 92.9 mm with a sensitivity and a specificity of 67.6% and 73.2%, respectively. For HC, the cut-off point was 329.5mm with a sensitivity and a specificity of 50% and 82.2%, respectively.

In a multivariable model containing BPD, HC and pre-pregnancy BMI, only BPD remained independently associated with cesarean section due to a prolonged second stage (aOR 1.31 per millimetre; 95% CI 1.08 - 1.59; p = 0.007). The association of HC with this outcome was no longer statistically significant (aOR 1.04 per millimetre; 95% CI 1.00 - 1.09; p = 0.071), as was the case for pre-pregnancy BMI (aOR 1.19; 95% CI 0.99 - 1.43; p = 0.061).

4. DISCUSSION

In our study, the median fetal BPD on ultrasound was 92 mm (82.6 - 99 mm) and HC was 324 (292 - 361) mm, which is quite similar to the results of Huynh Thi Nhu Ngoc et al. (2023), where the mean BPD in the group with fetal weight 2700 - 3500 g was 91.8 ± 3.7 mm (81 - 102) [9]. In the study by Bardin et al. (2016), the mean BPD was 93.1 ± 2.9 mm and mean HC was 335.5 ± 55.5 mm [4]. According to Dall'Asta (2023), the mean HC was 331.1 ± 13.0 mm [10]. This difference may be due to racial factors, and the number of macrosomic fetuses in our study was limited. As what was reported in our research, the estimated fetal weight had a median of 3100 gr, which was markedly smaller compared to the abovementioned studies. To illustrate, birth weight reported by Dall'Asta et al. was 3365 g and that of Bardin was 3473 g [4, 10].

Both HC and BPD in the cesarean section group were significantly higher than their counterpart. According to Dall'Asta, neonatal HC in cases of cesarean section due to prolonged labor was larger; furthermore, large HC was proved to be an independent risk factor for cesarean indication due to prolonged labor, alongside maternal height [10]. This aligns with Elvander's results, where the rate of cesarean section due to various causes increased as HC increased, with the most remarkable difference noted in the group with cesarean section due to prolonged labor [11]. According to Shinohara et al., BPD in cases of cesarean due to labor arrest was significantly higher than that in the vaginal delivery group (94 mm vs. 92 mm) [7]. As for Karaaslan et al., there was a noticeable difference in BPD between the group of vaginal delivery and cesarean section due to labour arrest, however, this difference was insignificant when making a comparison between the former group and the group of C-section due to any indication [12]. These results support the theory that cephalopelvic disproportion is a factor leading to prolonged labor, but plays little role in the indication of emergency c-section.

Our study showed that the duration of the active phase was not related to HC and was only very weakly related to BPD. According to Ostborg et al. (2017), active phase lasted longer in patients whose labor was induced than those with spontaneous labour [13]. Conversely, there was a positive correlation between these two indices and the duration of the second stage. This is consistent with the increased

risk of cesarean section due to labor arrest in the second stage when fetal head dimensions are large. According to Shinohara et al., in nulliparous women, the risk of prolonged second stage increases by 18% when the Z-score of BPD increases by 1 unit after adjusting for confounding factors, with an aOR of 1.18 (95% CI 1.02 - 1.37, *p < 0.001*) [7]. In our study, BPD and HC in cases with prolonged second stage were significantly larger than in cases with a normal second stage, regardless of the eventual modes of delivery. In the multivariable model, only BPD remained independently associated with cesarean section risk, whereas the association of HC was no longer significant. This suggests that the prognostic information carried by the two measurements largely overlaps, and that biparietal diameter is the more informative of the two in nulliparous women.

In 157 vaginal delivery cases, fetal head dimensions were similar across fetal position groups, during both engagement and expulsion. In the study by Yagel et al. (2018), head circumference and birth weight above the 90th percentile did not increase the risk of posterior position during labor [14]. However, when posterior position was combined with a head circumference of greater than the 90th percentile, the risk of prolonged second stage or obstetric intervention rised. Regarding other adverse maternal outcomes, our study showed that fetal head dimensions in the complex perineal tear group were significantly larger than in the remaining group. According to Meyer et al., fetal head circumference on ultrasound is an independent risk factor for obstetrics-related anal sphincter injury with aOR = 1.03 (95% CI 1.001 - 1.06, *p = 0.04)* [15]. Results from Ortega on 2,057 pregnant women yielded similar findings. Biparietal diameter may narrow as the fetal head descends; therefore, some studies, such as Bardin's, showed no relationship between this index and complex perineal tears [4, 16]. However, that study was conducted on both nulliparous and multiparous women, which may contribute to the difference compared to our study. A meta-analysis conducted by Mohd et al. (2023) also indicated that there was a significant association between larger neonatal head circumference and the occurrence of obstetric anal sphincter injury, which is equivalent to third and fourth-grade perineal tears in our study [17]. BPD in cases with postpartum hemorrhage was also significantly larger, consistent with Bardin's results. According to this author, the incidence of hemorrhage in the group with BPD from 94 - 96 mm was significantly higher than in the 91 - 93 mm group (*p = 0.02*) [4].

When assessing fetal outcomes, there was no relationship between fetal head dimensions and fetal health status, including the interpretation of cardiotocograph and APGAR scores. According to Bardin et al., neonatal outcomes were similar across different BPD groups, including 1-minute and 5-minute APGAR scores, NICU admission rates, or physical injuries in newborns [4].

When analyzing the ROC curve using BPD and HC to predict the risk of cesarean section due to prolonged second stage, the Area Under the Curve of these two indices was seemingly equivalent, measured at 0.718 and 0.704 respectively, indicating good predictive capability. This result is similar to Dall'Asta, where the AUC of head circumference in predicting cesarean section due to labor dystocia was 0.71 (95% CI 0.64 - 0.77, *p < 0.001*) [10]. In our study, the optimal cut-off for BPD was 92.9mm with a sensitivity and specificity of 67.6% and 73.2%, respectively. This cut-off point is smaller than in Shinohara's study (2020), which had a cut-off of 94mm, but has higher sensitivity and specificity compared to that author's results (53.1% and 65.1%) [7]. This difference may be rooted from the distinction in the birth weight of the Japanese population as in Shinohara's study and the Vietnamese population in ours. For HC, the cut-off of 329.5 mm gave a specificity of 82.2% but a sensitivity of only 50%, so half of the women who eventually required a cesarean section would be missed, indicating that HC is more useful for ruling in than for ruling out risk. Overall, these results indicate that BPD and HC on ultrasound have prognostic value for the progress of labor, particularly its second stage, although neither index should be used in isolation as a screening test.

5. CONCLUSION

In nulliparous women with full-term singleton pregnancies, fetal head dimension measurements on ultrasound, especially biparietal diameter, are of great efficiency in prognosing the risk of adverse maternal labor outcomes such as prolonged labor, emergency cesarean section due to labor arrest, complex perineal tears, or postpartum hemorrhage. No relationship was found between these measurements and neonatal outcomes.

DISCLOSURE STATEMENT

All authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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