Sonographic risk assessment for an unplanned operative delivery: a prospective study

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Abstract

Purpose To assess the value of pre-labor maternal and fetal sonographic variables to predict an unplanned operative delivery.

Methods In this prospective study, nulliparous women were recruited at 37.0–42.0 weeks of gestation. Sonographic measurements included estimated fetal weight, maternal pubic arch angle, and the angle of progression. We performed a descriptive and comparative analysis between two outcome groups: spontaneous vaginal delivery (SVD) and unplanned operative delivery (UOD) (vacuum-assisted, forceps-assisted and cesarean deliveries). Multivariate logistic regression with ROC analysis was used to create discriminatory models for UOD.

Results Among 234 patients in the study group, 175 had a spontaneous vaginal delivery and 59 an unplanned operative delivery. Maternal height and pubic arch angle (PAA) significantly correlated with UOD. Analysis of Maximum Likelihood Estimates revealed a multivariate model for the prediction of UOD, including the parameters of maternal age, maternal height, sonographic PAA, angle of progression (AOP), and estimated fetal weight, with an area under the curve of 0.7118.

Conclusion Sonographic parameters representing maternal pelvic configuration (PAA) and maternal–fetal interface (AOP) improve the prediction ability of pre-labor models for a UOD. These data may aid the obstetrician in the counseling process before delivery.

Keywords Angle of progression · Pubic arch angle · Unplanned operative delivery

Introduction

Despite significant advances in modern medicine, pre-labor prediction of an obstructed labor and unplanned operative delivery (UOD) and its consequences [1] remains an unsolved challenge. In everyday practice, the nullipara patient is usually provided with a raw estimate regarding her chances for a spontaneous vaginal delivery rather than a personalized estimate.

According to the classical obstetrical literature, the three main factors involved in labor and delivery are fetal size, the configuration of the pelvis, and effective uterine contractions. The first two parameters can be estimated and quantified before labor onset and used as personal predictive factors [2–8].

The continuing effort to search for objective risk assessment, parallel with the introduction of ultrasound equipment into the delivery rooms, has led to many reports regarding the value of various sono-pelvimetric parameters predicting dysfunctional labor and unplanned operative delivery [9–24]. The angle of progression, widely reported in the literature as a predictive measurement when obtained before the onset of labor, during the first and second stages of labor, and before assisted delivery, represents the fetal head station. The pubic arch angle (PAA), reported by our group [25, 26] and others [27–34] to have a strong negative correlation with...
persistent occiput posterior and mode of delivery, represents the primary pelvic diameter of the pelvic outlet.

Interestingly, some of these parameters are prone to modification by other parameters, such as maternal age [4]. These modifications exemplify the complexity of the labor mechanism, which involves many confounding factors.

The current study assessed the value of maternal and fetal sonographic variables to predict an unplanned operative delivery and created a multivariable predictive model.

Materials and methods

Study design and population

This is a prospective observational study. Nulliparous women carrying a singleton fetus in vertex presentation who opted for a vaginal delivery were recruited at 37.0–42.0 weeks of gestation at the post-date clinic. The sonographic measurements obtained included fetal biometry for estimated fetal weight calculation, AOP (Angle of progression), and PAA. Examinations were performed using E8 or E10 expert machines (GE Medical Systems, Kretz Ultrasound, Zipf, Austria), equipped with an abdominal 4–8 MHz curvilinear transducer. The patient and the attending obstetrician were blinded to the AOP and PAA measurements. Prenatal and delivery outcome parameters were obtained from the electronic medical records. We excluded from analysis cases that underwent a cesarean section during the first stage of labor or following major obstetrical events (placental abruption, cord prolapse).

The Institutional Ethics Committee approved the study, and informed consent was obtained from each participant.

Sonographic measurements

Sonographic measurements were performed by senior obstetricians (Y.G., SP) not involved in labor management. Both measurements were performed by the same operator and calculated in real-time from the 2D image.

Figure 1 illustrates the measurement of the AOP using the technique described by Barbera et al. [15]. With a horizontally positioned transducer, an angle is created between a line drawn through the midline of the pubic symphysis and a line running from the inferior apex of the pubic symphysis, tangential to the fetal skull. Figure 2 demonstrates the measurement of the PAA; with a transversely positioned transducer, an angle is created at the inferior borders of the pubic rami that converge at the middle of the pubic symphysis.

Statistical analysis

The data analysis for this paper was generated using SAS software version 9.4. (SAS Institute Inc., SAS Institute Inc., Cary, NC, USA).

Descriptive and comparative pre-labor parameters were compared between two outcome groups: spontaneous vaginal deliveries and unplanned operative deliveries, including vacuum-assisted, forceps-assisted, and cesarean deliveries. Sub-analysis was performed to assess differences between vaginal assisted and cesarean deliveries.

Fig. 1 Transperineal ultrasound imaging and measurement of the pubic arch angle (PAA). An angle is created between lines drawn at the inferior borders of the pubic rami that converge at the middle of the pubic symphysis.
We excluded from the analysis women who underwent a cesarean delivery following a major obstetrical event, such as placental abruption, cord prolapse, or during the first stage of labor.

Continuous variables are presented as mean ± standard deviation (SD), and categorical variables are presented by (N, %).

Logistic regression was used to calculate odds ratios (OR) in univariate and multivariable risk models for UOD.

Results

A total of 244 women were recruited for the study. Ten underwent a cesarean delivery following a major obstetrical event (placental abruption, cord prolapse) or during the first stage of labor for nonreassuring fetal monitor and were excluded from final analysis. Of the remaining 234 women, 59 (25.2%) had an unplanned operative delivery. In the unplanned operative delivery group, successful operative vaginal delivery occurred in 36 women (15.4%) and cesarean delivery in 23 (9.8%).

Maternal and fetal sonographic and demographic characteristics are presented in Table 1. No significant differences were seen between the SVD and the UOD group regarding maternal age, maternal BMI, fetal biometric parameters (bi-parietal diameter, head circumference, and abdominal circumference), estimated fetal weight, and neonatal birth weight (p > 0.05). The sonographic PAA (p < 0.01) and maternal height (p < 0.05) differed significantly between groups. The difference in the AOP between the outcome groups was borderline (p = 0.055). The optimal cut-off values for the AOP and PAA were 102.11° and 96.25°, respectively.

Of note, sub-analysis revealed a significant difference in the AOP between the vaginal delivery group (spontaneous and assisted/instrumental) (105.45° ± 17.31°) in comparison to the cesarean delivery group (AOP=99.18° ± 11.13°).

Multivariate logistic regression with ROC analysis created a discriminatory model for UOD. The discriminatory ability of the model was measured by concordance, c, which is equivalent to the area under the receiver-operating characteristic curve.

Various models were used to analyze a combination of prenatal ultrasound variables. (Table 2, Fig. 3). The models that included pre-labor sonographic measurements performed better than models that included only clinical parameters. The best model with an area under the curve of 0.7118 included maternal age and height, sonographic PAA and AOP, and EFW.

Discussion

This prospective study presented a personalized risk assessment of the likelihood of a UOD in nulliparous term patients based on a combination of maternal and fetal sonographic measurements obtained before labor onset. According to our findings, a UOD can be mainly predicted by AOP, PAA, maternal age, maternal height, and EFW.

UOD is associated with a higher likelihood of adverse maternal and neonatal outcomes. Cesarean delivery performed during the second stage of labor is associated with a higher risk for complications, including postpartum
hernia, infection, and damage to the cervix. Operative vaginal deliveries are associated with a greater incidence of maternal anal sphincter injury, neonatal intracranial hemorrhage, subgaleal hematoma, and shoulder dystocia. Prelabor identification of patients at high risk for UOD is of great importance as it may assist in deciding the optimal mode of delivery for the specific patient.

It seems reasonable that using a combination of parameters to predict UOD would perform better than a single parameter in the complex labor process, which involves many confounding factors.

For many years, a physical examination has been the primary tool for assessing the maternal pelvis. However, clinical pelvimetry is in danger of becoming a lost art without appropriate training, and its application in the diagnosis of cases prone to protracted labor is limited [35–37]. Extensive research efforts have been invested in finding a non-invasive, objective, quantitative tool to predict a successful vaginal delivery. Various sono-pelvimetric parameters were reported to predict dysfunctional labor and unplanned operative delivery [12–22]. The trans-perineal sono-pelvimetric measurement of the AOP, which describes the fetal head station, was proven to be a reliable parameter with high measurement reproducibility [25–31]. Among classic pelvimetric parameters, the infra-pubic angle, the primary measure of the pelvic outlet, is measured easily by ultrasound and was reported by our group and others [26–29] to be an independent risk factor for UOD. Some authors prefer to use PAA measurements obtained from 3-D ultrasound imaging [27–29]. We have chosen to use 2-D ultrasound imaging applicable by all ultrasound machines and transducers in all clinical settings and is more easily used bedside, enabling real-time measurements.

Interestingly, according to our data, the difference in AOP was significant only when we compared the vaginal delivery (spontaneous or instrumental) and cesarean delivery groups. We did not find a difference between spontaneous vaginal delivery and any UOD (instrumental

| Parameter                              | SVD          | UOD          | OR, 95% Confidence limits | Pr > Chi-Square |
|----------------------------------------|--------------|--------------|---------------------------|----------------|
| Maternal demographic parameters        |              |              |                           |                |
| Age (years)                            | 29.8 ± 4.6   | 30.8 ± 4.4   | 1.039 (0.978–1.104)       | 0.14           |
| Height (m)                             | 1.65 ± 0.06  | 1.63 ± 0.06  | 0.012 (<0.001–0.995)      | 0.031          |
| Body mass index (kg/m²)                | 23.2 ± 4.6   | 23.5 ± 5.1   | 0.994 (0.932–1.059)       | 0.684          |
| Gestational age at delivery (weeks)    | 40.3 ± 0.99  | 40.4 ± 0.77  | 1.395 (0.990–1.965)       | 0.346          |
| Maternal sonographic parameters        |              |              |                           |                |
| PAA                                    | 100.47 ± 8.26| 96.44 ± 7.69 | 0.954 (0.923–0.987)       | 0.001          |
| AOP                                    | 106 ± 17.08  | 101 ± 15.92  | 0.972 (0.955–0.989)       | 0.055          |
| Fetal sonographic parameters           |              |              |                           |                |
| EFW (g)                                | 3456.2 ± 380.7| 3508.6 ± 413.2| 1.000 (1.000–1.001)       | 0.374          |
| BPD (mm)                               | 93.56 ± 3.69 | 93.98 ± 2.97 | 1.024 (0.942–1.113)       | 0.338          |
| HC (mm)                                | 335.1 ± 11.1 | 336.0 ± 12.2 | 1.006 (0.988–1.023)       | 0.580          |
| AC (mm)                                | 341.5 ± 17.5 | 345 ± 19.3   | 1.015 (0.999–1.032)       | 0.166          |
| Birth outcome                          |              |              |                           |                |
| Birth weight (g)                       | 3418.6 ± 386.5| 3421.5 ± 444.2| 1.000 (0.999–1.001)       | 0.962          |
| Cord arterial pH                       | 7.27 ± 0.08  | 7.25 ± 0.09  | 1.000 (0.999–1.001)       | 0.395          |

Table 2 Analysis of maximum likelihood estimates for an unplanned operative delivery

| Parameter                              | Estimate | Standard error | Wald chi-square | Pr > Chi-square |
|----------------------------------------|----------|----------------|-----------------|-----------------|
| Intercept                              | 11.1241  | 4.3341         | 6.5876          | 0.0103          |
| Maternal age                           | 0.0787   | 0.0361         | 4.7568          | 0.0292          |
| Maternal height                        | −6.2871  | 2.6520         | 5.6200          | 0.0178          |
| Pubic arch angle                       | −0.0338  | 0.0183         | 3.4242          | 0.0642          |
| Angle of progression                   | −0.0302  | 0.00970        | 9.7048          | 0.0018          |
| Estimated fetal weight                 | 0.000716 | 0.000446       | 2.5791          | 0.1083          |
These findings are consistent with findings in previous studies that a narrower AOP correlates with cesarean deliveries, while a wider AOP correlates with a spontaneous or instrumental vaginal birth [18–20].

Giuseppe et al. [38] explored the performance of a predictive model for detecting the need for UOD and reported that HC and pubic angle were independent risk factors for UOD, and the combination of maternal height, pubic angle, and head circumference showed the best results. Others have reported similar results regarding the effect of a large head circumference and an unplanned cesarean section [3–7].

However, in our study group, neither BPD nor head circumference negatively influenced the statistical model for predicting a UOD. According to the results reported by Mujugira et al. [4], maternal age modified the association between fetal head circumference and primary cesarean section [3–7].

Limitations of this study are a relatively high rate of UOD and lack of stratification of the analysis according to cervical status and Bishop score.

The study’s main strengths rely on its prospective design, representing a low-risk population for obstetrical complications regarding maternal age, maternal BMI, fetal head indices, and birth weight; and in the fact that the patients and the attending obstetricians were blinded to the sonographic measurements.

**Conclusion**

This study presents a simple bedside tool that combines pelvic configuration measurements and the maternal–fetal interface performed using real-time 2-D ultrasound images. This information may aid obstetricians in the decision-making and counseling process before and during delivery, especially in rural or indigent areas where appropriately timed transfer to a district hospital may affect maternal and neonatal morbidity. This study will be followed by further research to validate the model’s strength in specific obstetrical subpopulations.

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