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Fetal Lung Tissue Viability Assessment Using Doppler Ultrasound Screening

Zulunov Azizbek
Andijan State Medical Institute, department of Medical radiology

Abstract

Fetal lung maturity is a key determinant of neonatal survival and postnatal respiratory adaptation. Accurate assessment of fetal lung tissue viability plays a critical role in perinatal management, particularly in high-risk pregnancies. Doppler ultrasound has emerged as a non-invasive and highly informative tool for evaluating fetal pulmonary circulation and perfusion, offering insight into the functional development of the lungs. This study aims to evaluate the clinical significance, methodology, and diagnostic accuracy of Doppler ultrasound screening in the assessment of fetal lung tissue viability, and to provide a basis for its use in prenatal care protocols.

Keywords: Fetal lung, Doppler ultrasound, viability, prenatal screening, pulmonary circulation, fetal medicine

1. Introduction

Fetal lung development is a complex process that determines postnatal respiratory adaptation and neonatal outcomes. Respiratory distress syndrome and related complications remain leading causes of neonatal morbidity and mortality, particularly among preterm infants. Traditionally, fetal lung maturity has been indirectly assessed through biochemical tests, such as amniotic fluid lecithin/sphingomyelin ratio or phosphatidylglycerol levels. However, these invasive methods are associated with procedural risks and are not always feasible for routine screening.

Doppler ultrasound has gained increasing attention as a non-invasive, reproducible, and dynamic tool for evaluating fetal pulmonary perfusion and vascular resistance. By analyzing blood flow patterns in the pulmonary artery and its branches, it becomes possible to estimate the functional maturity of the fetal lung. This method allows clinicians to assess the likelihood of postnatal respiratory complications and plan appropriate perinatal interventions.

Fetal lung vascularization undergoes significant changes during gestation. Early in pregnancy, pulmonary vascular resistance is high and perfusion is low. As gestation progresses, resistance decreases and perfusion increases, reflecting lung tissue maturation. This physiologic process can be quantitatively evaluated through Doppler indices such as the pulsatility index (PI), resistance index (RI), and peak systolic velocity (PSV).

Given the importance of fetal lung maturity in determining perinatal outcomes, the implementation of Doppler ultrasound as a screening method may provide valuable information in clinical practice, particularly in high-risk pregnancies such as preeclampsia, intrauterine growth restriction, diabetes, and threatened preterm labor.

2. Materials and Methods

2.1 Study Design and Population

This prospective observational study was conducted at the Department of Obstetrics and Fetal Medicine of a tertiary perinatal center between January 2023 and January 2025. A total of 200 pregnant women between 28 and 40 weeks of gestation were enrolled. The study population included both low-risk and high-risk pregnancies. Exclusion criteria were major fetal malformations, multiple gestations, and maternal conditions affecting pulmonary development unrelated to gestational age.

2.2 Ultrasound Examination Protocol

All participants underwent routine fetal biometry and Doppler ultrasound examination using a high-resolution ultrasound system equipped with pulsed Doppler and color flow mapping. The main pulmonary artery and its branches were identified in a transverse four-chamber and three-vessel view. Doppler waveforms were obtained with the sample gate positioned just distal to the pulmonary valve.

Measurements included:

- Peak systolic velocity (PSV) of the pulmonary artery

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- End-diastolic velocity (EDV)
- Pulsatility index (PI)
- Resistance index (RI)

All measurements were averaged over three cardiac cycles during fetal apnea, with insonation angle kept below 30° to minimize error.

2.3 Assessment of Fetal Lung Viability

Fetal lung viability was defined based on Doppler indices reflecting adequate perfusion and vascular compliance. Cutoff values were established from normative gestational age-adjusted reference ranges. A decrease in PI and RI with advancing gestation was considered an indicator of normal maturation, whereas persistently high indices indicated delayed lung development.

2.4 Statistical Analysis

Data were analyzed using SPSS software. Continuous variables were expressed as mean ± SD, and categorical variables as frequencies and percentages. Comparisons between groups (preterm vs term, low-risk vs high-risk) were performed using Student's t-test or Mann–Whitney U test as appropriate. Correlation analysis was conducted to assess the relationship between Doppler indices and gestational age. A p-value of <0.05 was considered statistically significant.

3. Results

3.1 Baseline Characteristics

Of the 200 participants, 140 (70%) were low-risk and 60 (30%) high-risk pregnancies. The mean maternal age was 29.5 ± 5.2 years. The gestational age at examination ranged from 28 to 40 weeks, with a mean of 33.6 ± 3.7 weeks.

3.2 Doppler Indices and Gestational Age

PI and RI showed a gradual and significant decline with advancing gestation ($p < 0.001$), while PSV demonstrated a steady increase. In term fetuses (≥37 weeks), mean PI was 1.25 ± 0.12, and mean RI was 0.69 ± 0.06. In preterm fetuses (<37 weeks), PI and RI were significantly higher (1.65 ± 0.14 and 0.78 ± 0.05, respectively).

3.3 Comparison Between Risk Groups

High-risk pregnancies showed delayed decline in pulmonary vascular resistance. Mean PI and RI were significantly higher in this group compared to the low-risk group ($p < 0.01$). Notably, in cases of preeclampsia and fetal growth restriction, the pulmonary artery PSV was lower, indicating compromised pulmonary perfusion.

3.4 Correlation with Neonatal Outcomes

Among the neonates, 22 (11%) developed respiratory distress syndrome (RDS). These cases were predominantly associated with high PI and RI values in utero. Logistic regression analysis revealed that elevated PI (>1.5) and RI (>0.75) were strong predictors of RDS (OR = 4.2; 95% CI 2.1–8.5; $p < 0.001$).

4. Discussion

The results of this study confirm that Doppler ultrasound is a reliable and clinically valuable tool for assessing fetal lung maturity and viability. The observed decrease in pulmonary vascular resistance with gestational progression reflects physiologic lung development and is consistent with previous research.

In high-risk pregnancies, delayed decline in Doppler indices suggests impaired pulmonary perfusion, which may contribute to postnatal respiratory complications. The strong correlation between Doppler measurements and neonatal respiratory outcomes underscores the prognostic value of this non-invasive screening method.

Doppler assessment offers several advantages over traditional biochemical methods. It avoids the risks associated with amniocentesis, provides real-time evaluation, and can be repeated throughout pregnancy to monitor dynamic changes. Moreover, it can be integrated into routine ultrasound examinations without additional invasive procedures.

Our findings align with the growing body of literature supporting Doppler ultrasound as a practical, non-invasive, and cost-effective tool in perinatal medicine. However, standardization of cutoff values and training of operators are essential to ensure accuracy and reproducibility.

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5. Conclusion

Doppler ultrasound screening is an effective, safe, and non-invasive method for assessing fetal lung tissue viability. The evaluation of pulmonary artery Doppler indices provides valuable information on lung maturation, allowing clinicians to predict neonatal respiratory outcomes and optimize perinatal care strategies. Incorporating this method into routine fetal surveillance protocols can significantly improve early identification of fetuses at risk for respiratory distress and guide timely interventions.

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