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Diagnostic Value of Umbilical Artery Systolic/Diastolic Ratio and Amniotic Fluid Index for the Prediction of Respiratory Distress Syndrome among Term Pregnancies: A Cross-Sectional Validation Study

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ABSTRACT

The introduction of UA S/D ratio monitoring into the routine antenatal Doppler monitoring can improve the early detection of the at-risk baby and optimize the perinatal care. **Objectives:** To evaluate the diagnostic accuracy of umbilical artery (UA) systolic/diastolic (S/D) ratio, and amniotic fluid index (AFI) in term pregnancies for the prediction of RDS, keeping postnatal findings as the gold standard. **Methods:** This cross-sectional validation study was carried out at Department of Diagnostic Radiology, Pakistan Navy Ship Hafeez Hospital, Islamabad, from November 2024 to June 2025. There were 594 enrolled term pregnant women with term pregnancies. The obstetric ultrasound with color Doppler was performed to measure the umbilical artery S/D ratio and AFI. S/D ratio was declared positive when its >3, and AFI positive when it was < 8 cm. Neonates were followed 72 hours after birth, and the RDS diagnosis was confirmed by clinical and radiological means. Data were evaluated with SPSS version 25.0, and diagnostic indices were calculated. **Results:** The overall prevalence of RDS was 12.6%. For the umbilical artery S/D ratio, sensitivity and specificity were 77.3% and 88.1%, respectively. While for AFI, sensitivity and specificity were 64.0% and 75.7%, respectively. **Conclusions:** The Umbilical artery S/D ratio is a better and more reliable ultrasound parameter than AFI in predicting postnatal RDS in term pregnancies, as the AUC for the UA S/D ratio was found to be 0.840, which reflects its optimal performance, while the AUC for AFI was found to be 0.305, which shows its poor discriminative ability.

INTRODUCTION

Antenatal surveillance is a significant part of prenatal care. As, maternal and child health indicators are often found to be below the global average in Pakistan, and the rates of maternal and neonatal morbidity and mortality are very high [1, 2]. According to UNICEF, the feto-maternal mortality rate in Pakistan is one of the highest in South Asia, with an estimated neonatal death rate of over 42 for every 1000 live births [3]. Respiratory distress syndrome (RDS) has long been considered a pathology of preterm infants, but is now being recognized as a serious complication of term and late-term neonates. The disorder can be abrupt in onset, which triggers rapid clinical progression. Precise prognostication of RDS poses a diagnostic dilemma due to its clinical overlap with various other conditions of transitional neonatal diseases. [4, 5]. One of the main pillars of contemporary obstetric practice is ultrasound imaging, which is used to visualize the fetus in real-time and examine the fetal anatomy, development,

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and well-being in detail [6]. The UA (S/D) ratio and the AFI have become key instruments in the prediction and prevention of adverse perinatal outcomes. The UA S/D ratio measures the resistance in the placental circulation, whereas the AFI gives an estimate of the size of the amniotic fluid; both of these are important indicators of fetal health [7, 8]. Despite several local and global research studies conducted on this topic, the predictive usefulness of these ultrasonographic markers has yielded inconsistent results in forecasting unfavorable perinatal outcomes, and relevant findings for the local population remain elusive [9, 10].

The presence of these inconsistencies indicates that additional research is needed that can offer a fresh perspective and an improved approach to previous approaches. Current study will bridge this gap by the use of a robust methodology and a focus on unique outcome metrics that previous researchers have not extensively examined. This study aims to evaluate the diagnostic accuracy of umbilical artery (UA) systolic/diastolic (S/D) ratio, and amniotic fluid index (AFI) in term pregnancies for the prediction of RDS, keeping postnatal findings as the gold standard.

METHODS

The study was conducted in the Department of Diagnostic Radiology in collaboration with the Department of Gynecology and Obstetrics of Pakistan Navy Ship Hafeez Hospital, Islamabad. Patients were enrolled between November 2024 and May 2025 after obtaining the approval of the institutional ethics committee via approval letter no. 491/17. Participants were recruited using a non-probability consecutive sampling technique after getting informed written consent. Sample size was calculated by using the sensitivity and specificity sample size calculator by incorporating the sensitivity of AFI as 43.75%, specificity as 79.66%, and expected prevalence of RDS as 16% [11]. and keeping the 95% confidence interval and a 10% precision, the sample size was calculated as 594 pregnant women. Females with singleton term pregnancies (i.e., gestational age ≥36 weeks) with cephalic presentation and admitted for delivery, having a maternal age between 22 and 35 years, were included. While mother with preeclampsia or gestational diabetes, anemia, fetuses with a confirmed diagnosis of IUGR, sepsis, and those having congenital anomalies were excluded. A detailed clinical history, physical examination, and ultrasound with Aplio i600 color Doppler were performed for each participant at the time of enrollment. A consultant radiologist with a minimum of three years of teaching experience, who was blinded to the study participant conducted all the ultrasound examinations to ensure consistency and reliability of measurements. AFI and UA S/D were measured as per standard procedure, and AFI was labelled as positive if its value was <8cm, and UA S/D was positive if the ratio was>3. Every enrolled patient was given 72 hours of observation after delivery. RDS was labelled as positive if the patient had any two of the following conditions: 1) Tachypnea (respiratory rate > 60 breaths/ min) + nasal flaring, 2) Intercostal and subcostal recessions, 3) expiratory grunting, and 4) central cyanosis. RDS was confirmed through the radiologic workup, showing any of the following patterns: 1) reduced lung volume with a fine granular pattern of lung parenchyma and peripherally extending air bronchograms, 2) hypo-aerated lungs showing a prominent and uniformly distributed reticulogranular pattern than usual. Increased air bronchograms will be observed. 3) Reticulogranular opacities are present throughout both lungs, with prominent air bronchograms and total obscuration of the cardiac silhouette as per criteria defined in MSD manual and Sweet LR [12]. All the demographic, clinical, and ultrasound data were recorded on an organized proforma that was particularly designed by the combined consultation of radiologist and gynecologist and was tested and validated on the first ten patients to ensure the perfection of performa. Data entry was done by the principal investigator herself or under the strict supervision to maintain the reliability of the data.

SPSS version 25.0 was used to analyze the data. Diagnostic accuracy parameters of the ultrasound AFI and umbilical artery S/D ratio were evaluated by constructing 2×2 contingency tables. To reduce bias and compare consistency, stratified analysis was conducted on the potential confounding variables such as maternal age, gestational age, neonatal gender, mode of delivery, gravidity, and parity.

RESULTS

The mean maternal age and gestational age of the study participants were 28.3 ± 4.1 years and 38.5±1.4 weeks, respectively. Mean umbilical artery SD ratio and AFI were 2.79 ± 0.52 and 9.7 ± 5.63cm, respectively. Most of the study subjects (51.5%) belonged to the age group 22-28 years, while 64.1% of the subjects presented at≥38 weeks of gestational age. We further noticed that 67.2% deliveries were vaginal and neonates were male dominant (52.4%). Moreover, we analyzed that 20.2% of patients were positive for RDS on the U/A SD ratio, while 29.3% were positive on the AFI. However, as per gold standard criteria, only 12.6% of total neonates had postnatal RDS (Table 1).

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Table 1: Clinical and Demographic Profile of Study Subjects (n=594)

Variables		Frequency (%)
Maternal Age Group	22–28 Years	306 (51.5%)
	29–35 Years	288 (48.5%)
Gestational Age Group	≥38.0 Weeks	381 (64.1%)
	36.0–37.9 Weeks	213 (35.9%)
Neonatal Gender	Male	311 (52.4%)
	Female	283 (47.6%)
Mode of Delivery	Vaginal	399 (67.2%)
	C-section	195 (32.8%)
Gravida	Multigravida	343 (57.7%)
	Primigravida	251 (42.3%)
Parity	Multipara	357 (60.1%)
	Primipara	237 (39.9%)
RDS Predicted by UA S/D	Positive	120 (20.2%)
	Negative	474 (79.8%)
RDS Predicted by AFI	Positive	174 (29.3%)
	Negative	420 (70.7%)
Postnatal RDS (Gold Standard)	Positive	75 (12.6%)
	Negative	519 (87.4%)

The Umbilical artery S/D ratio was found to have high specificity (88.1%; 95%CI) and acceptable sensitivity (77.3%; 95%CI) in predicting postnatal RDS with a positive LR of 6.5 and a negative LR of 0.26 (Table 2).

Table 2: Diagnostic Accuracy Analysis of U/A SD Ratio for Predicting the Postnatal RDS

Umbilical Artery S/D Ratio	Postnatal RDS Positive	Postnatal RDS Negative	Total
Positive (Test +)	58 (48.3%) (True Positive)	62 (51.7%) (False Positive)	120 (20.2%)
Negative (Test –)	17 (3.6%) (False Negative)	457 (96.4%) (True Negative)	474 (79.8%)
Total	75 (12.6%)	519 (87.4%)	594 (100%)

Sensitivity = 77.3%, Specificity = 88.1%, Positive Predictive Value (PPV) = 48.3%, Negative Predictive Value (NPV) = 96.4%, Overall Diagnostic Accuracy = 86.6%, Positive Likelihood Ratio (LR+) = 6.50 and Negative Likelihood Ratio (LR–) = 0.26

On the other hand, AFI demonstrated a relatively lower sensitivity (64.0%; 95%CI) as well as specificity (75.7%; 95%CI) for predicting the postnatal RDS with a positive LR of 2.64 and a negative LR of 0.47. However, the overall accuracy of the AFI was in an acceptable range (74.3%;95%CI)(Table 3).

Table 3: Diagnostic Accuracy Analysis of AFI for Predicting the Postnatal RDS

Amniotic Fluid Index (AFI)	Postnatal RDS Positive	Postnatal RDS Negative	Total
Positive (Test +)	48 (27.6%) (True Positive)	126 (72.4%) (False Positive)	174 (29.3%)
Negative (Test –)	27 (6.4%) (False Negative)	393 (93.6%) (True Negative)	420 (70.7%)
Total	75 (12.6%)	519 (87.4%)	594 (100%)

Sensitivity = 64.0%, Specificity = 75.7%, Positive Predictive Value (PPV) = 27.6%, Negative Predictive Value (NPV) = 93.6%, Overall Diagnostic Accuracy = 74.3%, Positive Likelihood Ratio (LR+) = 2.64 and Negative Likelihood Ratio (LR–) = 0.47

ROC curves were generated for both parameters, and we found an AUC for the UA S/D ratio of 0.840, which reflects its optimal performance for the prediction of RDS (Figure 1).

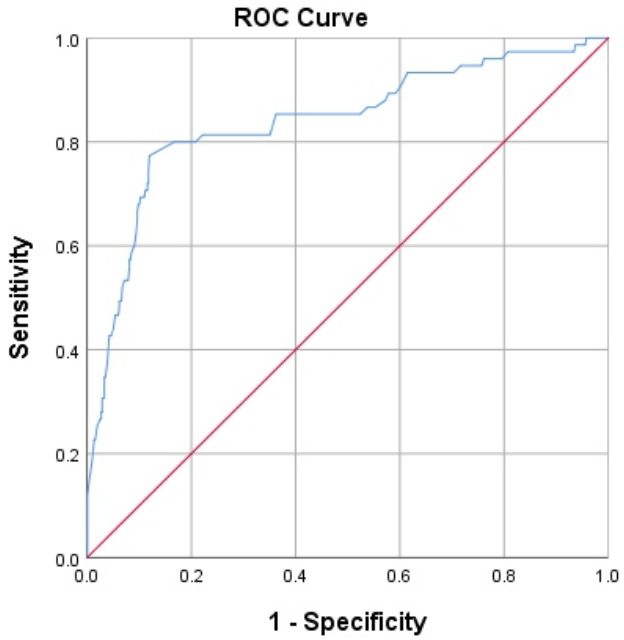

Figure 1: ROC Curve Analysis of Umbilical Artery SD Ratio for Predicting RDS

AUC for AFI was found to be 0.305, which shows its sub-optimal discriminative ability (Figure 2).

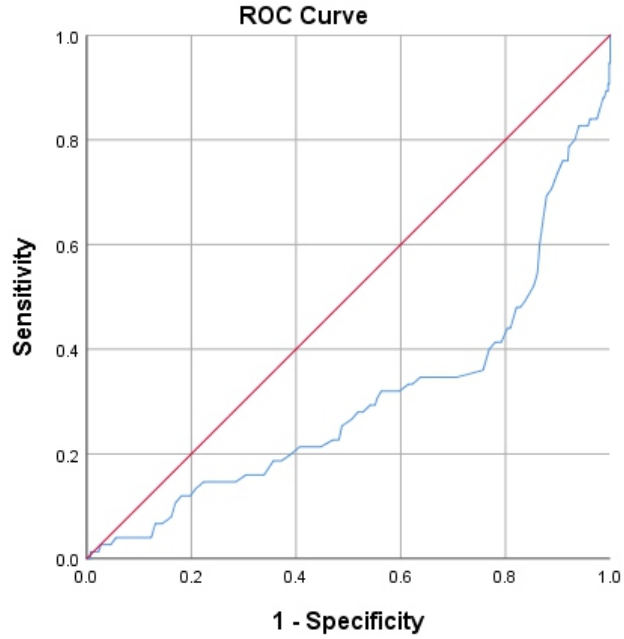

Figure 2: ROC Curve Analysis of AFI For Predicting RDS

Stratified analysis showed a high level of diagnostic performance in all maternal, fetal, and obstetric subgroups

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of the umbilical artery S/D ratio. The accuracy of diagnosis was high (85-88% across maternal age groups). Likewise, there was similarity in the accuracy of both gestational age groups. By mode of delivery, accuracy was nearly identical in vaginal and cesarean deliveries, i.e., 86.5% VS 86.2%. In case of gravidity and parity, diagnostic efficacy remained consistent (Table 4).

Table 4: Stratified Diagnostic Accuracy of Umbilical Artery S/D Ratio for Prediction of Postnatal RDS

Stratification Variables	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Overall Accuracy (%)	LR+	Lr-
Maternal Age Group							
22–28 Years	71.9%	86.9%	39.0%	96.4%	85.3%	5.49	0.32
29–35 Years	81.4%	89.4%	57.4%	96.5%	88.2%	7.68	0.21
Gestational Age Group							
≥38 Weeks	77.1%	89.2%	50.7%	96.4%	87.1%	7.13	0.26
36.0–37.9 Weeks	77.8%	86.0%	44.7%	96.4%	85.0%	5.56	0.26
Neonatal Gender							
Female	75.8%	90.4%	51.0%	96.6%	89.0%	7.90	0.27
Male	78.6%	85.9%	46.5%	96.3%	86.5%	5.59	0.25
Delivery Mode							
Vaginal Delivery	80.0%	87.4%	47.6%	96.8%	86.5%	6.36	0.23
Cesarean Section	72.0%	89.4%	50.0%	95.6%	86.2%	6.78	0.31
Gravidity							
Primigravida	78.1%	87.7%	48.1%	96.5%	87.3%	6.34	0.25
Multigravida	76.7%	88.3%	48.5%	96.4%	87.2%	6.56	0.26
Parity							
Primipara	77.4%	86.9%	47.1%	96.2%	86.0%	5.91	0.26
Multipara	77.3%	88.8%	49.3%	96.5%	87.6%	6.90	0.26

On the other hand, AFI showed moderate sensitivity, which was 62-67%, and specificity as well, which was 69-80%, across all subgroups. Overall diagnostic accuracy was found to be highest in multipara and vaginal deliveries, that was 77.9% and 77.2%, respectively. Detailed stratification analysis for the diagnostic accuracy of AFI for predicting postnatal RDS is illustrated (Table 5).

Table 5: Stratified Diagnostic Accuracy of AFI for Predicting Postnatal RDS (n=594)

Stratification	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Overall Accuracy (%)	LR+	Lr-
Maternal Age							
22–28 Years	62.5%	76.3%	23.5%	94.6%	74.8%	2.64	0.49
29–35 Years	65.1%	75.1%	31.5%	92.5%	73.6%	2.62	0.46
Gestational Age							
≥38 Weeks	62.5%	78.1%	29.1%	93.5%	76.1%	2.85	0.48
36.0–37.9 Weeks	66.7%	71.5%	25.4%	93.7%	70.9%	2.34	0.47
Neonatal Gender							
Female	63.6%	78.0%	27.6%	94.2%	76.3%	2.89	0.47
Male	64.3%	73.6%	27.6%	93.0%	72.3%	2.44	0.49
Delivery Mode							
Vaginal Delivery	64.0%	79.1%	30.5%	93.9%	77.2%	3.06	0.46
C-Section	64.0%	68.8%	23.2%	92.9%	68.2%	2.05	0.52
Gravidity							
Primigravida	65.6%	73.5%	26.6%	93.6%	72.5%	2.48	0.47
Multigravida	62.8%	77.3%	28.4%	93.5%	75.5%	2.77	0.48
Parity							
Primipara	64.5%	69.4%	24.1%	92.9%	68.8%	2.11	0.51
Multipara	63.6%	79.9%	30.8%	94.0%	77.9%	3.17	0.46

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DISCUSSION

Although the Umbilical Artery S/D ratio is a direct hemodynamic indicator of the placental resistance and consequent fetal hypoxemia, AFI is a more general measure of fetal health and uteroplacental perfusion [13, 14]. The two parameters are therefore hypothetically involved in the pathways that result in dysfunctional pulmonary maturation and RDS [15, 16]. This research thus attempted to critically review and compare the diagnostic accuracy of these parameters of ultrasound on the specific prediction of RDS in term pregnancies with the view to providing evidence on their rational use in clinical practice. The study has shown that the umbilical artery S/D ratio is a better predictor of postnatal respiratory distress syndrome in term pregnancies, which has greater specificity, positive likelihood ratio, and overall diagnostic accuracy, and has a significantly higher area under the receiver operating characteristic curve. Both AFI and UA S/D ratio illuminated a high NPV that reflected that these tests have a strong capability to rule out postnatal RDS among our local population. However, the umbilical artery S/D ratio remains superior across all the diagnostic accuracy indices in comparison with AFI in predicting the neonatal RDS. The positive likelihood ratio (LR+) was 6.50, which means that the probability of a positive test result in neonates with RDS is 6.5 times higher than the probability of a positive test result in neonates without RDS, whereas the negative likelihood ratio (LR-) was 0.26, which implies that the likelihood of RDS given a negative outcome was low. Also, the area under the ROC curve (AUC) of the umbilical artery S/D ratio is 0.840, which indicates a good discriminatory power (table 2 and figure 1). The higher specificity and LR+ of the UA S/D ratio suggest greater competence to rule out the risk of RDS in case of an abnormal UA S/D ratio [17]. The NPV of the normal umbilical artery S/D ratio that will exclude postnatal RDS was 96.4%. This high NPV was justified by the low false-negative (3.6% of negative tests) and is similar in stratified subgroups (96.2-96.8%) (see table 2 and 4). The negative likelihood ratio (LR) was also 0.26, which once again highlights the validity of a normal finding in eliminating RDS. Our findings are sound in the pathophysiological basis. A high umbilical artery S/D ratio indicates a higher vascular resistance of the placenta, resulting in chronic fetal hypoxemia. This hypoxic condition has been known to alter the surfactant production and maturation in the fetal lungs, hence predisposing the neonate to RDS at birth [18]. AFI, being a volume measure of the amniotic fluid, is a more comprehensive measure of fetal health and placental competence. Oligohydramnios (AFI <8 cm) may be related to uteroplacental insufficiency, but it is also affected by a broader range of factors, including membrane integrity and fetal renal function, which can be used to understand why it is less specific and less predictive of RDS [19, 20]. The more modest LR+ of our study suggests that oligohydramnios alone is a weaker discriminator of imminent neonatal respiratory compromise at term, particularly when membranes are intact, and labor management is standardized [21]. Notably, the PPVs of the two tests were rather low, which is predictable in an environment with low disease prevalence (12.6%) and highlights a Bayesian concept that even special tests will provide poor PPV when the risk of the baseline is low. In contrast, the NPVs were outstanding, i.e., normal UA S/D and/or sufficient AFI have a significant impact on reducing the post-test risk of RDS and can be reassuring in the absence of other risk factors [22]. Current study findings are inconsistent with a few recent studies. In a recent study Sharma M and colleagues, while attempting to assess the value of umbilical artery S/D ratio and AFI for adverse fetal outcome, they reported that the prevalence of postnatal RDS as adverse outcome was 16% (n=16/100), while, the sensitivity and specificity of umbilical artery S/D ratio was 62.5% and 91.52% respectively, while the sensitivity and specificity of AFI was 43.75% and 79.66% respectively, where the RDS was confirmed through clinical and radiological neonatal findings within 72 hours of delivery among suspected neonates [11]. In contrast to Sharma *et al.* who evaluated the UA S/D ratio in a small sample population that represented a broad range of deleterious perinatal outcomes and a relatively lower sensitivity [11], this study included a bigger sample of term pregnancies and exhibited better and more predictive accuracy of postnatal respiratory distress syndrome (RDS). This difference is likely due to the increased consistency of the UA S/D ratio in low-risk term gestations. The main strengths of the study are the explicit juxtaposition of the UA S/D ratio and amniotic fluid index (AFI) with RDS as the main outcome and stratified analyses in the context of salient confounding variables in term pregnancies. The ensuing findings support the hypothesis that the UA S /D ratio is a better Doppler predictor of fetal surveillance in respiratory risk, but that the AFI should be applied as an adjunct rule-out measure rather than as a key predictive variable. Diagnostic performance of UA S/D ratio showed high consistency in all the study confounders as accuracy tended to cluster around 85 to 88 percent with LR- 0.25, indicating the strength of UA S/D as a term screening tool. In the case of AFI, accuracy was consistent but low in comparison with UA S/D. In multipara and vaginal delivery, accuracy was low but consistent (~ 77-78 percent and 68-69 percent). The positive LR values of AFI did not frequently exceed 3 altogether in any subgroup, which supports the argument that it is a better rule-out predictor, as opposed

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to a rule-in test. Combined, stratification implies that UA S/D is the main parameter of Doppler used to make decisions, and AFI provides some supplementary data, especially when ruling out the risk of RDS [23]. When the study discusses the clinical implications, these study findings can be beneficial for the triage and surveillance of pregnancy at term. It was established that the normal UA S/D meaningfully reduces the likelihood of neonatal respiratory disorders, so that these cases may be managed by routine obstetric care rather than being escalated just because of respiratory risk factors. Secondly, the normal UA S/D has a significant negative effect on the probability of early RDS, and these situations can be managed by routine obstetrics without increasing risks, only in the context of respiratory danger. Thirdly, Additional intrapartum care, preparedness of neonatal resuscitation, and prompt pediatric attention are warranted in subjects with an S/D ratio >3 and who's positive LR is meaningfully higher. Furthermore, the presence of low AFI (<8 cm) is not sufficient to declare high risk of RDS, but as AFI returns to normal, its high NPV should be used to support de-escalation in otherwise low-risk term pregnancies. Our study findings further implicated that when UA S/D is used hand-in-hand with clinical context (maternal comorbidities, intrapartum events, fetal heart rate patterns), it will be the most effective risk calibration than any given measure. Prediction can be further refined, where possible, with the addition of complementary Dopplers (e.g., middle cerebral artery or cerebroplacental ratio). Prioritization of UA S/D measurement in resource-constrained environments provides the highest payoff to detect the neonates who might need to receive early respiratory support/NICU preparedness, and the unnecessary escalations can be safely avoided by the normal studies.

Despite the various strengths and clinical implications, this study is not free from limitations. To begin with, single-center design and non-probability consecutive sampling can raise the question of generalizability outside similar tertiary settings. Second, cross-sectional validation has no causal inferences or longitudinal risk evaluation. Third, the study has not included other Doppler indices (e.g., MCA, CPR) or biophysical parameters; combining them is likely to perform better and predict better. Fifth, misclassification can be introduced through potential variability of measurement (e.g., fetal breathing, operator expertise) and lack of formal inter-observer reliability testing. At last, early RDS was the only available outcome; no longer-term respiratory follow-up and NICU course were examined. Combined Doppler parameters (UA S/D ratio, MCA, CPR) neonatal respiratory follow-up and cost-effectiveness analysis should be validated on the basis of long-term follow-up of multicenter prospective studies in the future in order to be regularly integrated into term pregnancy surveillance protocols.

CONCLUSIONS

This study's results demonstrated the diagnostic superiority of UA S/D ratio over AFI. An increased UA S/D ratio (>3) in clinical practice should be considered an opportunity to take proactive action, such as to activate the neonatal resuscitation team upon birth, prepare to provide immediate respiratory support, and expedited delivery planning should other alarming aspects be observed. On the other hand, an isolated low AFI (<8 cm) is a red flag that should be carefully monitored as a marker of fetal well-being but should not be used to cause high-risk interventions in otherwise normal term pregnancies. Instead, it must be used as additional information to help in decision-making in cases where UA S/D results are marginal or other clinical considerations are concerned. The regular introduction of the UA S/D ratio into routine third-trimester Doppler surveillance regimes in the context of term pregnancy may help to improve perinatal risk assessment, resource allocation, especially in resource-limited settings, and reduce the number of unnecessary interventions, and ensure that infants at high risk are ready to be born promptly.

Authors' Contribution

Conceptualization: AK
Methodology: AK, MS, NG
Formal analysis: AK
Writing and Drafting: AK, MS, NH, SS, FKM
Review and Editing: AK, MS, NH, SS, FKM, NG

All authors approved the final manuscript and take responsibility for the integrity of the work

Conflicts of Interest

All the authors declare no conflict of interest.

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