Jordan Journal of Applied Science
Natural Science Series

Research Article

Fetal pulmonary artery Doppler's predictive usefulness in newborn respiratory distress syndrome

Mohamed Ali Abbas[1*], Tasnem Ragaa Mayallo[2]

[1]Department of medical physiology, Damietta Faculty of medical, Al Azhar University, Egypt.
[2]Obstetrics and Gynecology Department, Ministry of Health, Damietta, Egypt.

ARTICLE INFO

Article history:
Received 25 May 2024
Accepted 27 Jun 2024
Published 30 Jun 2024

DOI: doi.org/10.35192/jjoas-n.v18i1.1848

***Corresponding author:**
Department of medical physiology, Damietta Faculty of medical, Al Azhar University, Egypt.

Email: drmohamedali122@gmail.com

Keywords:
Doppler indices
Pulmonary artery
Neonatal respiratory

ABSTRACT

Background: The most common cause of respiratory distress in premature infants is newborn respiratory distress syndrome (RDS). When evaluating the pulmonary circulation of a growing fetus, Doppler velocimetry offers a quick and painless method. Decreased pulmonary surfactant levels are linked to RDS, which is a major cause of infant morbidity and mortality since the pulmonary system is the last organ system in the fetus to physiologically mature before extrauterine life.

Aim: This study aims to determine if fetal main pulmonary artery (MPA) Doppler indices can predict neonatal RDS.

Methods: The study included 100 pregnant patients from the Obstetrics and Gynecology Department at Damietta Specialized Hospital, comprising 11 with RDS and 89 without RDS. The Apgar score and the newborn's birth weight (NBW) were recorded at 1 and 5 minutes. Clinical indicators of respiratory distress included the need for supplemental oxygen of 0.4 or more for at least one day, alongside typical chest X-ray findings.

Results: Neonates with RDS had statistically significant lower acceleration time/ejection time ratios, peak systolic velocity (PSV), and systolic/diastolic (S/D) ratios, as well as significantly higher pulsatility index (PI) and resistance index (RI) compared to those without RDS. At a cutoff level of >0.785, the resistance index (RI) had a sensitivity of 100% and specificity of 100% for predicting RDS.

Conclusion: Predicting fetal lung maturity and the subsequent development of newborn RDS with high levels of specificity and sensitivity is possible using fetal pulmonary artery indices.
Keywords: Doppler indices, Pulmonary artery, Neonatal respiratory.

Introduction

Respiratory distress syndrome (RDS) is common cause of respiratory failure and mortality in newborns. Because more people are aware of RDS, which was formerly thought to be predominantly prevalent in preterm newborns, the syndrome is now more routinely detected in term neonates (1)

A significant contributor to newborn morbidity and death is the respiratory distress syndrome (RDS), which is linked to lowering pulmonary surfactant. The last organ system in a developing foetus that needs more uterine life to develop physiologically is the pulmonary system (2)

Evaluation of the Fetal lung development is one of the most critical goals of obstetrical care. Historically, the maturity of the developing Fetal lungs has been assessed via amniocentesis and the examination of the proteins and lipids that make up the amniotic fluid. Amniocentesis, on the other hand, is an invasive procedure that is only recommended for particular purposes, and these tests have a high sensitivity but a low specificity (3) .

Throughout pregnancy, the pulmonary circulatory advances alongside the lungs. Here, the overall quantity of tissue from smooth muscles increases, the total quantity of pulmonary vessels rises and the vascular restriction of the pulmonary arteries somewhat diminishes. It ends up resulting in a constant increase in pulmonary blood flow (4)

Doppler velocimetry is a fast and painless technique for evaluating the Fetal pulmonary circulation. Numerous researchers have assessed Fetal blood flow in the left (or right) pulmonary artery and its lateral branches using Doppler velocimetry (5).

There exists a demonstrated correlation between the Fetal pulmonary artery acceleration time/ejection time ratio (At/Et) and increasing Fetal gestational age (GA) and Fetal lung maturity (FLM) tests in amniotic fluid (6).

This study sought to examine the likelihood to employ Doppler hints and the Fetal major pulmonary artery to prepare for the first development of a condition called neonatal respiratory distress syndrome (RDS).

Patients and methods

One hundred expectant mothers were attending Damietta Specialized Hospital Obstetrics & Gynaecology Department between the first of June (2022) and the end of June (2023) participated in a prospective cohort study.

Inclusion criteria:

At (37–38) weeks gestation, the female gives birth to one baby.

Exclusion criteria included

serious structural anomaly or Fetal chromosomal disorders, Fetal advancement at or below the ninety percentile for Fetal age, as well as any health issues pertaining to the mother's pregnancy, such as gestational diabetes and preeclampsia and antenatal corticosteroid administration.

Neonatal follow up:

We shall record the newborn's birth weight (NBW) and their Apgar score (at 1 and 5 minutes). We shall search for these

symptoms in addition to the standard chest X-ray results regarding reticulo granular patterns, air bronchograms, and ground glass physical characteristics, clinical manifestations of breathing difficulties and supplemental oxygen need of 0.4 or greater for at least 24 hours.

Methodology

We carried out the research using a Voluson S10 ultrasound machine, stting the Doppler gain and scale to optimal levels for clear waveform presentation. The examiner proceeded to follow the MPA until it split in half halfway between the breathing valve and the left and right branches' dividing line at the thoracic horizontal view. While the pulsed Doppler sample gate is changed to a 3mm size, the insonation angle will stay at 15°. The Doppler gain and scale will be altered to provide the most accurate velocity waveform representation that clearly demonstrates the (PSV) and early diastolic notch. The sudden systolic peak blood flow gave the MPA Doppler waveform its unique shape, sometimes known as a "spike and dome" pattern. A minuscule notch of reversed flow is also discernible at the end of the systole. It's crucial to identify the MPA waveform from the ductus arteriosus wave, which has a triangular shape and a more rounded, fuller, and diastolic flow.

The optimal Fetal MPA waveform needs to be produced first, before manually tracing the required Doppler velocity variables three times and averaging the results. A few of the significant factors were the systolic/diastolic (S/D) proportions, pulsating indicator (PI), resistant index (RI), PSV, and At/Et ratio. The At/Et ratio was obtained by dividing the amount of time (At) that passed from the start of the systole of the ventricular to the time peak velocity had been achieved by the length (Et) of the systole of the ventricular chambers.

Statistical analysis

The SPSS programme (Version 24) for Microsoft was used to code, process, and analyse the obtained data. We shall use the proper statistical tests as required. Statistically significant values are those with a 0.05 (5%) or lower probability.

Sample size calculation

The specimen size was selected using the equation below

Assuming a five percent threshold of significance and a power estimate of 80% for the investigation, the computed sample size will be eighty individuals, using the following formula (7).

$$n = \frac{Z^{i} * P * (1-P)}{d^2}$$

Where:
Z = For the ninety-five percent confidence level, use 1.96.
p = anticipated (4%) rate of respiratory distress in neonates.
d = margin of error for reliability is 0.03

We increased the sample size to one hundred individuals in order to increase the power of the study and adjust for protocol mistakes with missing data.

Ethical consideration

An informed consent obtained from each patient, after full explanation of the study protocol. The data was only be used for study, and no information on the patient's personality was be disclosed, despite the patient's right to withdraw (Confidentiality will be ensured).

Results

Regarding mother age, newborn sex, and labour, there is no statistically significant difference between neonates with respiratory distress syndrome (RDS) and those without RDS Table 1.

Table 1. Comparison of demographic data of the studied population

		RDS	No RDS	Independent student T test/ chi-square test	
		N=11	N=89	t/X2	p-value
Maternal age years	Range	20-25	20-30	-0.437	0.663
	Mean ± SD	22.64 ± 2.06	22.93 ± 2.12		
Sex	Female	5 (45.5%)	50 (56.2%)	0.455	0.500
	Male	6 (54.5%)	39 (43.8%)		
Labor	Yes	2 (18.2%)	33 (37.1%)	1.537	0.215
	No	9 (81.8%)	56 (62.9%)		

Regarding APGAR score at 1 minute and 5 minute times, and there is no statistically noteworthy difference between premature babies with RDS and those without RDS. Neonatals with RDS had statistically considerably more NICU attendance and needed oxygen treatment than neonates without RDS. In comparison to neonates without RDS, the birth weight of neonates with RDS was statistically significantly lower. Regarding mother age, sex, and labour, there is no statistically noteworthy distinction between newborns with RDS and those without RDS Table 2.

Table 2. Comparison of APGAR score, need for oxygen therapy, gestational age and neonatal birth weight of the studied population

		RDS	No RDS	Independent student T test	
		N=11	N=89	t	p-value
APGAR 1min	Range	6-7	6-7	-0.098	0.923
	Median (IQR)	7 (1)	7 (1)		
	Mean ± SD	6.56 ± 0.50	6.55 ± 0.52		
APGAR 5 min	Range	7-9	8-9	2.156	0.050
	Median (IQR)	8 (1)	9 (1)		
	Mean ± SD	8.18 ± 0.59	8.54 ± 0.52		
Admission for O2 ttt	Yes	11 (100%)	29 (32.6%)	18.539	<0.0001
	No	0 (0%)	60 (67.4%)		
Admission duration (days)	Range	1 - 7	8 - 10	11.107	<0.0001
	Mean ± SD	9.00 ± 1.00	3.17 ± 1.70		
Neonatal birth weight gm	Range	11 (100%)	29 (32.6%)	13.968	<0.0001
	Mean ± SD	3479.29 ± 450.85	2751.18 ± 69.05		
Gestational age weeks	Range	37-38	37-38	1.818	0.080
	Mean ± SD	37.74 ± 0.44	37.09 ± 0.30		

Neonates with RDS have statistically significant lower At/Et, PSV, S/D and statistically significant higher PI, RI than those without RDS Table 3.

Table 3. A comparison of the population under study's Fetal pulmonary artery Doppler.

		RDS	No RDS	Student t test	
		N=11	N=89	t	p-value
At/Et	Range	0.33 – 0.35	0.34 – 0.42	-17.326	<0.0001
	Mean ± SE	0.33 ± 0.01	0.39 ± 0.02		
PSV	Range	72.67 - 73.37	75.54 - 77.79	-30.481	<0.0001
	Mean ± SE	73.02 ± 0.35	76.64 ± 0.51		
PI	Range	1.68 - 2.23	2.48 - 2.61	22.527	<0.0001
	Mean ± SE	2.52 ± 0.05	2.07 ± 0.14		
RI	Range	0.80 - 0.83	0.73 - 0.77	18.508	<0.0001
	Mean ± SE	0.82 ± 0.01	0.75 ± 0.01		
S/D	Range	6.13 - 7.13	6.63 - 7.55	1.771	0.098
	Mean ± SE	6.94 ± 0.29	7.11 ± 0.37		

The relationships between At/Et, PSV, and S/D are statistically significantly inverse, although, RI and the length of oxygen therapy had a statistically significant positive interaction Table 4.

Table 4. Relationship between Fetal pulmonary artery Doppler measurements and oxygen therapy duration.

	The duration of oxygen therapy	
	r	p-value
NBW	0.152	0.132
At/Et	-0.443	<0.0001
PSV	-0.519	<0.0001
PI	-0.085	0.403
RI	0.432	<0.0001
S/D	-0.578	<0.0001

At/Et had sensitivity of 94.4% and specificity of 90.9% to estimate RDS at cut off level of 0.346, PSV had sensitivity of 100% and specificity of completely for predicting RDS at cut off level of 74.45, PI had sensitivity of completely and specificity of fully for predicting RDS at cut off level of >2.35, RI had sensitivity of 100% and specificity of 100% for predicting RDS at cut off Table 5.

Table 5. The RDS prediction's sensitivity, specificity, and cutoff values for At/Et, PSV, PI, RI, and S/D

	Cutoff point	Area under curve	Std. Error	senstivity%	specificity%	Asymptotic 95% Confidence Interval	
						Lower Bound	Upper Bound
At/Et	<0.346	0.995	0.006	94.4%	90.9%	0.984	1.000
PSV	<74.45	1.000	0.000	100%	100%	1.000	1.000
PI	>2.35	1.000	0.000	100%	100%	1.000	1.000
RI	>0.785	1.000	0.000	100%	100%	1.000	1.000
S/D	<6.93	0.607	0.060	59.6%	54.4%	0.488	0.725

Discussion

There is no statistically important distinction between neonates with and without RDS in terms of the mother's age, the baby's gender, or labour. Our results supported Khalil et al.'s study (8) finding that RDS is not significantly associated with maternal age or parity, as well as Alsheikh et al. (9) observation of similar rates of RDS in neonate.

This suggests that Apgar scores at 1 and 5 minutes may not be sufficient indicators for early identification of RDS in neonates. Our findings are congruent with that of Büke et al.'s study (10), which found no meaningful differences in the 5th minute APGAR scores between newborns with and without RDS. However, the 5min APGAR score in the research by Abdelhamid et al. (11) showed statistically significant variations between newborns with RDS and those without RDS. In contrast, Eldeeb et al. (12) observed that compared to healthy newborns, RDS neonates had substantially lower Apgar scores at 5 min, lower birth weights, and were all committed to neonatal ICU.

The current study revealed that neonates with RDS required oxygen treatment at higher rates than neonates without RDS, and that their time in the NICU was statistically substantially longer. A research by Keshuraj et al. (13), which indicated that neonatal intensive care unit (NICU) admission rates likewise displayed a significant pattern of distinction, with 100% hospitalisation necessary for RDS (+) newborns and only 33.2% for RDS (-) babies, supported our findings. In a manner similar to this, Khalil et al.'s study (8) revealed that the need for NICU hospitalisation differed extensively between the two groups. In addition, the Laban et al. study's (14) analysis of the criteria for NICU admission disclosed statistically significant variations between the two groups. Less than a 24-hour monitoring time was enough for two of the RDS newborns.

In the present study, neonates with RDS had substantially smaller neonatal weights upon birth than those without RDS. There is no statistically important difference between neonates with RDS and those without it when considering of gestational age. In the research by Moety et al. (15), higher amniotic fluid index values, lower estimated Fetal weights on ultrasound, lower mean birth weights, and noticeably lower GA at delivery were all seen for foetuses that had RDS. In Li et al. (16) studied the data and found that the age of gestation, delivery gestational age, and baby birth weight of babies in the NRDS group were likewise substantially fewer than those in the non-NRDS group. The discrepancy may be due to a different sample size. A newborn's condition called respiratory distress syndrome (RDS) can be predicted through the pulmonary arteries resistance index (PA -RI) and Fetal lung volume (FLV) (17).

In a study by Keshuraj et al. (13). The median MPA PI values of the RDS (+) group foetuses were found to be higher when they were statistically compared. Statistical analysis of the mean MPA RI values revealed that RDS (+) group newborns had higher values. In contrast to the RDS (-) group, PSV was significantly lower in RDS-positive fetuses. The S/D ratio did not show any discernible variations between the two groups' results.

Also, PI and RI were significantly greater in RDS newborns than in non-RDS infants, according to Taha et al. (18). Both PSV and the At/Et ratio showed a significant difference between newborns with RDS and the control group. Relative to neonates without RDS, neonates with RDS had a substantially higher HD RI. Compared to newborns without RDS, neonates with RDS had significantly lower PSV and At/Et ratios.

Additionally, Alsheikh et al. (9) and Khalifa et al.'s study (19) found that MPA PI and RI values were substantially greater in RDS-affected foetuses than in control foetuses. In comparison to the previous result, MPA At/Et was considerably lower.

A research by Khalil et al. (8) complemented our findings, suggesting that the AT/ET mean in MPA Doppler velocimetry was significantly lower in foetuses who subsequently had RDS than in those who did not. While utilising a gestational age-specific threshold reached of less than or equal to the fifth percentile, Guan et al.'s study (20) found that AT independently could predict RDS with a sensitivity of 78.6% and an accuracy of 89.7%. The AT/ET ratio could foresee RDS with a sensitivity and specificity of 71.4% and 93.1%, respectively. The cutoff value of 0.305 for At/Et provided an accuracy of 76.4% and a specificity of 91.6% for the prediction of neonatal RDS with an area under the curve of 0.899.

In Khalifa et al. (19), the ideal MPA PI and RI thresholds were 2.33 cm/s and 0.89 cm/s, correspondingly. The probability of RDS in babies with an MPA PI 2.33 cm/s and or RI 0.89 cm/s was much lower, with diagnostic accuracy of 94.4% and 88.1%, respectively. AUC = 0.94 and 0.96, correspondingly, with a 0.001 meaningful level.

Eldeeb et al.'s study (12) additionally discovered the acceptable value for the ROC curve evaluation to anticipate newborn RDS was 0.75, with PA-RI 82.95% specificity and 76.27% sensitivity, and a cutoff of 28 cm3 for Fetal lung volume for newborn RDS development, with 65.91% specificity and 72.88% sensitivity. Combining the two indices produced a more reliable and sensitive predictor with 83% accuracy, 100% sensitivity, 65.91% particulars, 66.3% positive predictive value, and 100% negative prediction value.

Conclusion

Our research led us to the conclusion that Fetal pulmonary artery indices had a high sensitivity and specificity for predicting Fetal lung maturity and, consequently, the emergence of neonatal RDS. Although the main pulmonary artery At/Et measurement distinguished significantly between foetuses who developed RDS and those who did not, it is advised to combine it with other measurements because when used alone, it exhibits lower specificity across the range of gestational ages.

Declaration of Competing Interest

Regarding this paper, the authors disclose no conflicts of interest.

Data sharing plans

Data are available from the corresponding author upon reasonable request

Funding

The authors pledge that no money was received for this project.

Author contribution

Each author made an equal contribution to the study.

References

1. Liu J. Respiratory distress syndrome in full-term neonates. J Neonatal Biol 2012; S1: e001. DOI: 10.4172/2167-0897.S1-e001
2. Kamath BD, Macguire ER, McClure EM, Goldenberg RL, Jobe AH. Neonatal mortality from respiratory distress syndrome: lessons for low-resource countries. Pediatrics. 2011 Jun;127(6):1139-46. doi: 10.1542/peds.2010-3212.
3. Spong CY, Mercer BM, D'Alton M, Kilpatrick S, Blackwell S, Saade G. Timing of indicated late-preterm and early-term birth. Obstet Gynecol. 2011 Aug;118(2 Pt 1):323-333. doi: 10.1097/AOG.0b013e3182255999.
4. Schenone MH, Samson JE, Jenkins L, Suhag A, Mari G. Predicting fetal lung maturity using the fetal pulmonary artery Doppler wave acceleration/ejection time ratio. Fetal Diagn Ther. 2014;36 (3):208-14. doi: 10.1159/000358299.
5. Kim SM, Park JS, Norwitz ER, Hwang EJ, Kang HS, Park CW, Jun JK. Acceleration time-to-ejection time ratio in fetal pulmonary artery predicts the development of neonatal respiratory distress syndrome: a prospective cohort study. Am J Perinatol. 2013 Nov;30(10):805-12. doi: 10.1055/s-0032-1333132.

6. Guan Y, Li S, Luo G, Wang C, Norwitz ER, Fu Q, Tu X, Tian X, Zhu J. The role of doppler waveforms in the fetal main pulmonary artery in the prediction of neonatal respiratory distress syndrome. J Clin Ultrasound. 2015 Jul-Aug;43(6):375-83. doi: 10.1002/jcu.22219.
7. Daniel, W. Biostatistics: A foundation for Analysis in the Health Sciences, 1999, 7th ed. New York: John Wiley and Sons.
8. Khalil, O. A., Abdel Ghany, H. S., Osman, N. M. M., & Abdelhamid, M. K. (2019). The role of different fetal pulmonary artery Doppler indices in the prediction of neonatal respiratory distress syndrome. Minia Journal of Medical Research, 30(2), 64-71.
9. Alsheikh AM, Elsadek AM, Gebreel S A. Relation Between Fetal Doppler Pulmonary Artery Indices and Neonatal Respiratory Distress Syndrome In Term Neonates. International Journal of Medical Arts, 2021; 3(1), 1046-1052. doi: 10.21608/IJMA.2020.43097.1172
10. Büke B, Destegül E, Akkaya H, Şimşek D, Kazandi M. Prediction of neonatal respiratory distress syndrome via pulmonary artery Doppler examination. J Matern Fetal Neonatal Med. 2019 May;32 (10):1640-1645. doi: 10.1080/14767058.2017.1413549.
11. Abdelhamid MK, Ghani HS, Khalil OA, El-Gelany S, Osman NM. Quantitative ultrasound texture analysis of fetal lung versus fetal pulmonary artery Doppler as a predictor of neonatal respiratory distress syndrome (RDS). International Journal of Medical Imaging, 2020; 8(2), 23. doi: 10.11648/j.ijmi.20200802.12
12. Eldeeb B., El-Shourbagy KH, El-Shorbagy SH. Which is more accurate measuring pulmonary artery resistance index or 4D lung volume for prediction of neonatal respiratory distress in preterm pregnancies?. Egypt J Radiol Nucl Med. 2023; 54, 30.
13. Keshuraj V, Prakash A, Boruah DK. Validity of Fetal Doppler indices in predicting postnatal respiratory distress syndrome: a prospective study. Egypt J Radiol Nucl Med. 2022; 53, 183. doi: 10.1186/s43055-022-00865-2
14. Laban M, Mansour GM, Elsafty MS, Hassanin AS, EzzElarab SS. Prediction of neonatal respiratory distress syndrome in term pregnancies by assessment of fetal lung volume and pulmonary artery resistance index. Int J Gynaecol Obstet. 2015 Mar;128 (3):246-50. doi: 10.1016/j.ijgo.2014.09.018.
15. Moety GA, Gaafar HM, El Rifai NM. Can fetal pulmonary artery Doppler indices predict neonatal respiratory distress syndrome? J Perinatol. 2015 Dec;35(12):1015-9. doi: 10.1038/jp.2015.128. Epub 2015 Oct 22. PMID: 26491853.
16. Li Q, Xu L, Zhang L. The Role and Clinical Value of Optimized Fetal Main Pulmonary Artery Doppler Parameters in the Diagnosis and Prognosis Monitoring of Neonatal Respiratory Distress Syndrome. Computational and Mathematical Methods in Medicine, 2022. doi: 10.1155/2022/1682225.
17. Wang S, Wang Y, Gao M, Tan Y. Acceleration time to Ejection time ratio in fetal pulmonary artery system can predict neonatal respiratory disorders in gestational diabetic mellitus women. Clin Hemorheol Microcirc. 2022;80(4):497-507. doi: 10.3233/CH-211265.
18. Taha HMG, GhorabNMA, Al-NamoryMM, HusseinNA. Role of fetal pulmonary artery Doppler in prediction of neonatal respiratory distress in neonates of diabetic mothers. Int J Reprod Contracept Obstet Gynecol; 2022; 11:3236-41.
19. Khalifa YEA, Aboulghar MM, Hamed ST, Tomerak RH, Asfour AM, Kamal EF. Prenatal prediction of respiratory distress syndrome by multimodality approach using 3D lung ultrasound, lung-to-liver intensity ratio tissue histogram and pulmonary artery Doppler assessment of fetal lung maturity. Br J Radiol. 2021 Dec;94(1128):20210577. doi: 10.1259/bjr.20210577. PMC8631030.
20. Guan Y, Li S, Luo G, Wang C, Norwitz ER, Fu Q, Tu X, Tian X, Zhu J. The role of doppler waveforms in the fetal main pulmonary artery in the prediction of neonatal respiratory distress syndrome. J Clin Ultrasound. 2015 Jul-Aug;43(6):375-83. doi: 10.1002/jcu.22219.