Original Article

Diagnostic Accuracy of Maternal Renal Interlobar Vein Impedance Index in the Prediction of Pre-eclampsia at 20-24 Weeks

Suchita Sureshkumar Bahurupe[1], Kajal Mitra[2], Prashant Onkar[3], Suresh Phatak[3]

Abstract

Background : Pre-eclampsia (PE) is a major hypertensive disorder of pregnancy and a leading cause of maternal and perinatal morbidity and mortality. Early prediction remains a clinical challenge. This study aimed to assess the diagnostic value of the maternal Renal Interlobar Vein Impedance index (RIVI) measured during the mid-trimester as a predictor of preeclampsia.

Materials and Methods : This prospective cohort study included 50 pregnant women who underwent renal Doppler ultrasound between 20 and 24 weeks of gestation. Doppler parameters assessed included the renal interlobar artery Resistance Index (RI) and Renal Interlobar Vein Impedance index (RIVI) on both sides. Participants were followed until delivery, and preeclampsia was diagnosed based on the presence of hypertension with proteinuria. Statistical analysis was performed using SPSS to calculate sensitivity, specificity, Positive Predictive Value (PPV), Negative Predictive Value (NPV) and diagnostic accuracy.

Results : Preeclampsia developed in 13 women (26%). The diagnostic accuracy of RIVI was 54.0% on the right side and 46.0% on the left. Right-sided RIVI showed a sensitivity of 76.92% and specificity of 45.95%, while left-sided RIVI demonstrated higher sensitivity (92.31%) with lower specificity (29.73%). The highest negative predictive value (91.67%) was observed with left RIVI. Renal interlobar artery RI demonstrated lower predictive performance, with a maximum diagnostic accuracy of 64.0%.

Conclusion : Maternal renal interlobar vein impedance index, particularly on the left side, shows higher sensitivity than arterial RI for predicting preeclampsia and may serve as a useful adjunct in mid-trimester screening.

Key words : RIVI, Renal Interlobar Vein, Pre-eclampsia, Hypertension, RI.

Pre-eclampsia (PE) is a significant hypertensive disorder of pregnancy, affecting 2-8% of pregnancies Worldwide, with rates as high as 5-15% in India[1]. This condition contributes substantially to both maternal and perinatal morbidity and mortality[2]. It is characterized by the new onset of hypertension and proteinuria after 20 weeks of gestation and can lead to severe complications for both the mother and the fetus[3]. These complications include eclampsia, HELLP syndrome (hemolysis, elevated liver enzymes, and low platelet count), preterm birth, Intrauterine Growth Restriction (IUGR) and placental abruption[2,3]. Despite extensive research efforts, the precise cause of Pre-eclampsia remains elusive[4]. Researchers believe it involves a complex interaction of genetic, immunological, and environmental factors[4]. Early prediction and timely management of the condition are critical in reducing the risk of severe outcomes for both the mother and the fetus[5].

To predict the development of Pre-eclampsia, several clinical parameters and biomarkers are currently in use[6]. These include maternal characteristics such as age, parity, and a history of Pre-eclampsia[6]. Biochemical markers like placental growth factor and soluble fms-like tyrosine kinase-1, as well as biophysical markers such as uterine artery Doppler, are also commonly used[7]. Among these, uterine artery Doppler Ultrasonography, performed between 20-24 weeks of gestation, has become a valuable tool for assessing the risk of Pre-eclampsia[8]. This method evaluates the uteroplacental blood flow, and increased resistance or abnormal waveforms in the uterine artery are often associated with impaired placentation, which is a hallmark of Pre-eclampsia[9]. However, while the uterine artery Doppler can offer insights into the risk of developing the condition, its predictive accuracy is limited[10]. This limitation has prompted the search for additional markers to enhance the early detection of Pre-eclampsia[10].

One promising new marker that has emerged is the maternal Renal Interlobar Vein Impedance (RIVI) index[11]. Recent studies suggest that this index, measured using

Editor's Comment :

- Renal Interlobar Vein Impedance index (RIVI), particularly of the left kidney, demonstrates high sensitivity and negative predictive value for the early prediction of Pre-eclampsia at 20-24 weeks of gestation.
- Compared to the traditional renal interlobar artery Resistive Index (RI), RIVI shows superior diagnostic accuracy, reflecting early renal and systemic microvascular changes associated with Pre-eclampsia.
- Color Doppler assessment of RIVI is a simple, non-invasive and reproducible technique that can be easily incorporated into routine obstetric ultrasound.
- Early identification of high-risk pregnancies using RIVI may allow timely intervention and improved maternal and fetal outcomes.
- Larger multicentric studies are warranted to validate its routine clinical application.

Department of Radiodiagnosis, NKP Salve Institute of Medical Sciences and Research Centre, Nagpur, Maharashtra 440019
[1]MD, Resident and Corresponding Author
[2]MD, Professor and Head
[3]MD, Professor
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Ultrasonographic Color Doppler, may be a novel and reliable tool for predicting Pre-eclampsia[11,12]. The kidneys play a crucial role in maintaining Blood Pressure and fluid balance during pregnancy and changes in renal hemodynamics are thought to contribute to the pathophysiology of Pre-eclampsia[13]. RIVI measures the resistance to blood flow within the renal interlobar veins, with higher values indicating increased renal vascular resistance[12]. This increased resistance is hypothesized to be associated with the early stages of Pre-eclampsia, reflecting both systemic endothelial dysfunction and altered renal perfusion[13]. As such, RIVI may provide a useful early marker for detecting Pre-eclampsia before clinical symptoms become evident[11,12].

Ultrasonographic color Doppler is a non-invasive imaging technique that provides real-time information about blood flow dynamics in various organs, including the kidneys[14]. It is already an important tool in obstetric care, used to monitor fetal well-being, placental function, and maternal hemodynamics[14]. The use of color Doppler to assess RIVI is relatively new, but initial findings suggest that combining this method with existing predictive markers could improve the accuracy of early detection[15]. By identifying women at risk of Pre-eclampsia earlier in their pregnancy, healthcare providers can intervene in a timely manner, potentially preventing the progression of the disorder and reducing its adverse effects[5].

Given the high incidence of Pre-eclampsia and the limitations of current screening methods, particularly in countries like India, there is a pressing need to identify novel and reliable markers for early detection[1,16]. Preliminary studies have shown that RIVI may correlate with the development of Pre-eclampsia, but larger cohort studies are needed to validate these findings[11,12]. This study aims to assess the diagnostic accuracy of RIVI at 20-24 weeks of gestation, contributing to the refinement of screening protocols and improving outcomes for both mothers and their babies[11]. If successful, the integration of RIVI into current screening strategies could significantly enhance the early identification and management of Pre-eclampsia, ultimately improving maternal and fetal health[12,15].

Material and Methods

The study population consisted of 50 pregnant women who were referred to the Radiology Department for routine Ultrasound evaluations of fetal health. Participants were recruited through convenience sampling. Inclusion criteria required that participants be in their first pregnancy, with a gestational age between 20 to 24 weeks, determined by their Last Menstrual Period (LMP). Women were excluded if they had a known history of Diabetes Mellitus (DM), Hypertension (HTN) or Renal disease prior to pregnancy, or if parenchymal kidney disease was detected on gray-scale Ultrasound before the Doppler examination.

Pre-eclampsia was diagnosed by an Obstetrician who monitored the participants throughout the study. Diagnostic criteria for Pre-eclampsia included elevated Blood Pressure readings (greater than 140/90 mmHg) and Proteinuria (protein levels of +1 or higher in urine tests).

The Doppler Ultrasound examination involved a detailed review of the renal parenchyma, excluding any major disturbances and a Doppler study of the interlobar arteries and veins in both kidneys. To ensure accurate results, the Doppler angle was minimized by selecting the mid-point of the medullary vessel, where the most consistent readings could be obtained. The impedance index, an important measurement in the study, was also recorded. To standardize the procedure, all Ultrasounds were performed by a single Radiologist, ensuring consistency in the technique and interpretation of results. Before the Ultrasound, all patients underwent a thorough physical and clinical examination.

The Doppler Ultrasound examinations were performed using a SAMSUNG RS 80A and SAMSUNG HS70 machine with convex probe frequency of 1-7MHz. Key study variables included the participant's age, gestational age, Body Mass Index (BMI) and Doppler Ultrasound indices. Measurements included the renal interlobar artery Resistance Index (RI) and the Renal Interlobar Vein Impedance (RIVI) index, which were obtained from both kidneys and documented for further analysis.

Statistical Analysis :

Data were entered into Microsoft Excel and analyzed using SPSS version 24.0. Quantitative variables were expressed as mean and Standard Deviation, while qualitative variables were shown as proportions. The Student's t-test was used to compare variables between normal and Pre-eclampsia groups. Receiver Operating Characteristic (ROC) curve analysis was applied to determine the optimal cut-off points for RI and RIVI, along with their sensitivity, specificity, Positive Predictive Value (PPV) and Negative Predictive Value (NPV). A p-value of less than 0.05 was considered significant. Interobserver variability was assessed using Cohen's Kappa statistic.

Results

Of 50 pregnant women included, 13 developed Pre-eclampsia (26%) and 37 had a normal pregnancy.

Diagnostic accuracy of Renal Interlobar Vein Impedance index for Pre-eclampsia prediction

Table 1 presents the diagnostic accuracy for the Renal Interlobar Vein Impedance Index (RIVI) was found to be 54.0% for the right renal interlobar vein and 46.0% for the

Table 1 — *Presents the diagnostic accuracy for the Renal Interlobar Vein Impedance Index (RIVI) for both right and left interlobar renal veins.*

Right Renal Interlobar Vein Impedance (RIVI)			Sensitivity Analysis	Left Renal Interlobar Vein Impedance (RIVI)			Sensitivity Analysis
	PE+ (n=13)	PE- (n=37)	Sensitivity=76.92% Specificity=45.95%		PE+ (n=13)	PE- (n=37)	Sensitivity=92.31% Specificity=29.73%
RIVI (<0.4)	3	20	PPV=33.33%	RIVI (<0.4)	1	26	PPV=31.58%
RIVI (>0.4)	10	17	NPV=85.0%	RIVI (>0.4)	12	11	NPV=91.67%
P value (Fisher Exact) - 0.0002				P value (Fisher Exact) - <0.0001			

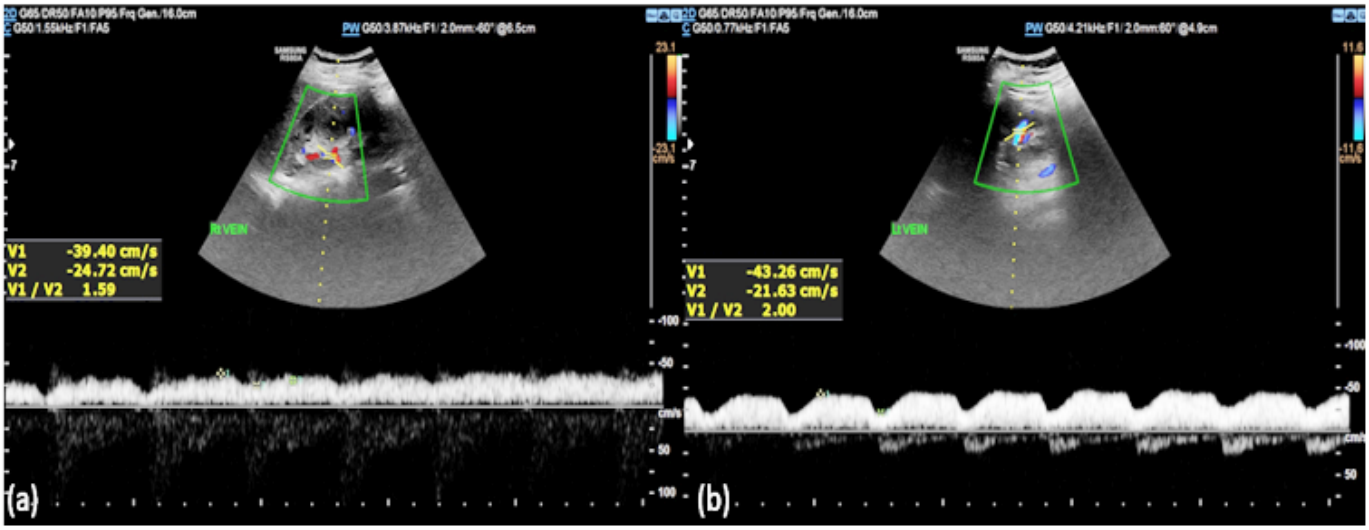

Fig 1(a) & (b) — Showing Bilateral Maternal Renal Interlobar Vein Doppler Flow Indices

left. When comparing RIVI to clinical diagnosis as the gold standard, the Right renal interlobar vein showed a sensitivity of 76.92%, specificity of 45.95%, a positive predictive value of 33.33%, and a negative predictive value of 85.0%. In contrast, the Left renal interlobar vein demonstrated higher sensitivity at 92.31%, but with lower specificity at 29.73%. Its positive predictive value was 31.58%, and the negative predictive value was 91.67%. Overall, the Left RIVI proved to be more useful in predicting the development of Pre-eclampsia compared to the Right side.

Fig 2 shows the ROC curve analysis for the Left Renal Interlobar Vein Impedance Index (RIVI) against Pre-eclampsia (PE) shows an excellent AUC of 0.964 with a statistically significant asymptotic significance of 0.000. The 95% confidence interval for the AUC ranges from 0.885 to 1.000, confirming the reliability of Left RIVI in differentiating between PE and non-PE cases

Fig 3 shows the ROC curve analysis for Right Renal Interlobar Vein Impedance Index (RIVI) shows an AUC of 0.929, indicating high diagnostic accuracy with significant statistical reliability in differentiating between Right RIVI and Pre-eclampsia (PE).

Diagnostic Accuracy of Interlobar Artery RI for Pre-eclampsia Prediction :

Table 2 shows the diagnostic accuracy for the Resistivity Index (RI) of the renal interlobar artery was 19.61% for the Right side and 64.0% for the Left side. In sensitivity analysis comparing RI to clinical diagnosis as the gold standard, the Right renal interlobar artery demonstrated a sensitivity of 23.08%, specificity of 18.42%, a positive predictive value of 8.82%, and a negative predictive value of 41.18%, resulting in a diagnostic accuracy of 19.61%. Conversely, the Left renal interlobar artery showed a

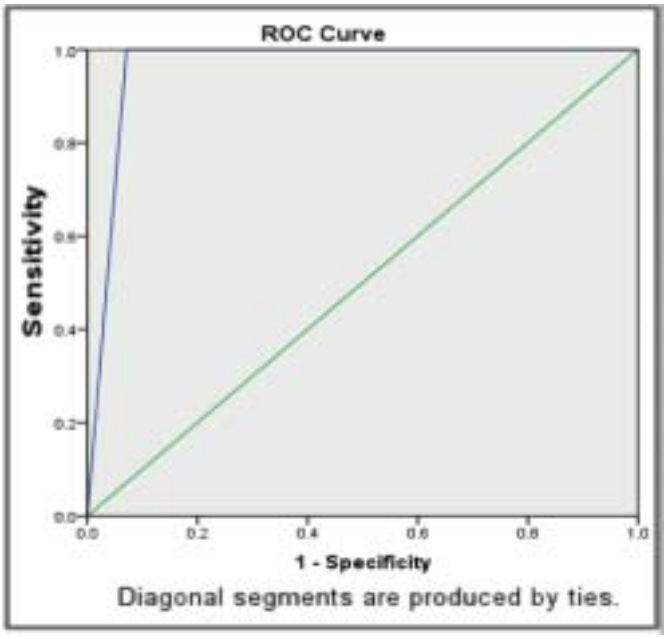

Fig 2 — Shows the ROC curve analysis for the Left Renal Interlobar Vein Impedance Index (RIVI) agai

Table 2 — *Showing the diagnostic accuracy for the Resistivity Index (RI) of the right and left renal interlobar arteries.*

Right Renal Interlobar artery RI			Sensitivity Analysis	Left Renal Interlobar artery RI			Sensitivity Analysis
	PE+ (n=13)	PE- (n=37)	Sensitivity=23.08% Specificity=18.42%		PE+ (n=13)	PE- (n=37)	Sensitivity=15.38% Specificity=81.08%
RI (>0.7)	10	31	PPV=8.82%	RI (>0.7)	11	7	PPV=22.22%
RI (<0.7)	3	7	NPV=41.18%	RI (<0.7)	2	30	NPV=73.17%
P value (Fisher Exact) - 0.54				P value (Fisher Exact) - <0.0001			

sensitivity of 15.38%, a much higher specificity of 81.08%, a positive predictive value of 22.22% and a negative predictive value of 73.17%, yielding a diagnostic accuracy of 64.0%. While RI was not as effective a predictor of imminent Pre-eclampsia (PE), it can still be used alongside RIVI for predicting the condition. Notably, the Left RI was more predictive of PE compared to the Right, similar to the findings for RIVI.

Fig 4 shows the ROC curve for the Right Renal Interlobar Artery Resistive Index (RI) indicates good diagnostic accuracy with an AUC of 0.893, demonstrating its effectiveness in distinguishing between Right renal interlobar artery RI and Pre-eclampsia (PE).

Fig 5 shows the ROC curve for the Left Renal Interlobar Artery Resistive Index (RI) shows high diagnostic accuracy, with an AUC of 0.929 and a standard error of 0.056, indicating statistical significance (p<0.001), and a 95% confidence interval of 0.819 to 1.000, confirming its reliability in distinguishing between Left renal interlobar artery RI and Pre-eclampsia (PE).

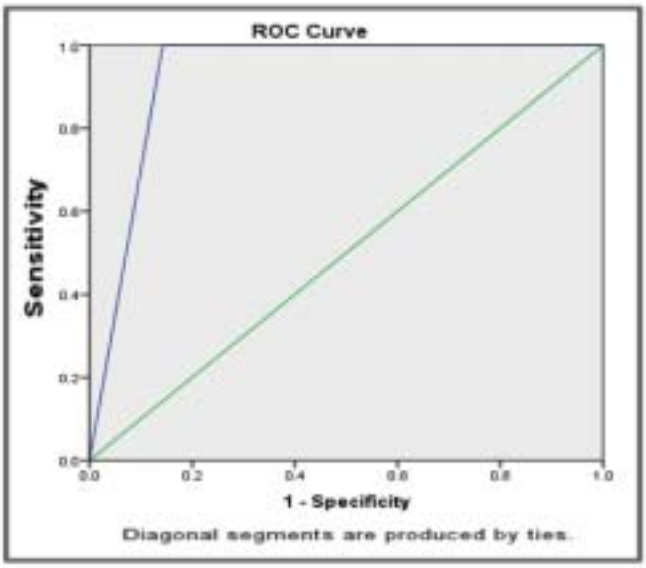

Fig 4 — Shows the ROC curve for the Right Renal Interlobar Artery Resistive Index (RI)

Discussion

Doppler Ultrasound measurements showed that the mean maximum velocity of the Left renal interlobar vein (16.46 cm/s) was lower than that of the Right (24.36 cm/s), consistent with studies by Patel, *et al* (2017) and Ahmed, *et al* (2019)[17,18] who also observed asymmetry in renal vein velocities. This asymmetry may result from anatomical or physiological differences, with the right kidney's proximity to the liver influencing venous return

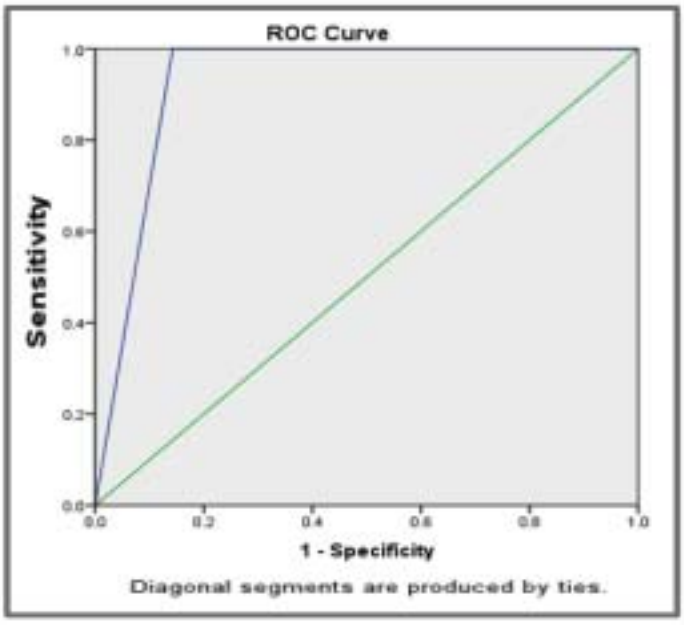

Fig 3 — Shows the ROC curve analysis for Right Renal Interlobar Vein Impedance Index (RIVI)

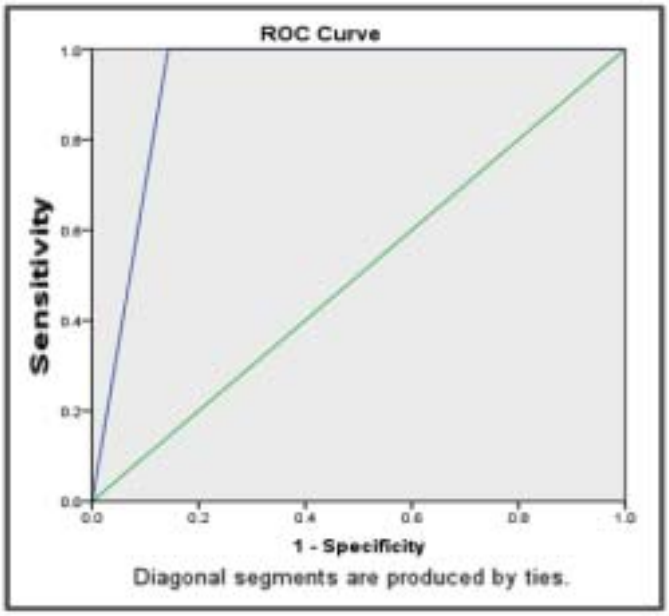

Fig 5 — Shows the ROC curve for the Left Renal Interlobar Artery Resistive Index (RI)

and flow dynamics[19]. Additionally, the difference in mean velocity (delta V) and Renal Interlobar Vein Impedance (RIVI) underscores the importance of evaluating each kidney independently during Doppler assessments.

The Resistivity Index (RI) of the renal interlobar arteries also showed asymmetry, with the Left side having a higher mean RI (0.56) than the Right side (0.43). This finding aligns with Gupta, *et al* (2020)[20] who suggested the Left kidney's longer renal artery and different hemodynamic forces could explain the difference. Sensitivity analysis revealed that RIVI, particularly on the left side, was a more reliable predictor of Pre-eclampsia (PE) than RI. The Left RIVI demonstrated a sensitivity of 92.31% and a Negative Predictive Value (NPV) of 91.67%, higher than those of the right RIVI and both sides' RI. These results are consistent with studies by Davis and Thompson (2021) and Li, *et al* (2022)[21,22], which highlighted the higher diagnostic accuracy of renal impedance measurements for detecting systemic vascular resistance changes linked to PE, improving maternal and fetal outcomes through timely intervention.

Several studies have explored the predictive value of the maternal Renal Interlobar Vein Impedance Index (RIVI) for Pre-eclampsia (PE). Balci, *et al* (2016)[11] found that women who developed PE had significantly higher RIVI, suggesting it as a reliable early marker for the condition. Gyselaers (2012)[12,23] confirmed that RIVI was elevated in both early-onset and late-onset PE, linking it to lower birth weight and higher Proteinuria in early-onset cases. Another study by Gyselaers (2012) established reference values for RIVI, noting a gestation-dependent increase, especially in the Left kidney for PE cases[23]. Salehi, *et al* (2012)[24] found that the Left kidney's RIVI was a significant predictor of PE, while Moura, *et al* (2017)[25] observed that RIVI was not a reliable first-trimester predictor of hypertensive disorders. Ma'yesh (2018)[26] reported that PE affected fetal renal blood flow, suggesting potential long-term health impacts. Overall, RIVI is a useful tool for predicting and managing PE, though its early-pregnancy predictive value is limited.

RIVI demonstrated superior diagnostic accuracy, particularly on the left side, with higher sensitivity and negative predictive value than RI, indicating its reliability for early PE detection[21,22]. This aligns with existing research suggesting that venous impedance indices like RIVI are better indicators of microvascular changes associated with PE than arterial indices. While RI has been a standard in prenatal care, the study advocates for RIVI's inclusion as a more precise measure[21].

Conclusion

Based on the study's findings, it is recommended that the Renal Interlobar Vein Impedance Index (RIVI) be integrated into routine prenatal screening for Pre-eclampsia (PE), particularly in Urban Tertiary Care settings where the population resembles the study demographic (well-educated, mainly housewives, urban dwellers). Given RIVI's superior diagnostic accuracy and sensitivity—especially on the left side—it should be utilized as a primary screening tool for early PE detection, potentially replacing or complementing the traditional Resistivity Index (RI).

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