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ASSESSMENT OF TESTICULAR RESISTIVITY INDEX BY COLOR DOPPLER ULTRASONOGRAPHY AS A PREDICTOR OF MALE SPERMATOGENESIS TAKING SEMEN ANALYSIS AS GOLD STANDARD

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ABSTRACT

Background: Color Doppler Ultrasonography (CDUS) with the testicular resistive index (RI) represents a non-invasive approach to testicular perfusion and its relationship with spermatogenesis.
Objective: To determine the diagnostic quality of testicular resistivity index assessed by Color Doppler Ultrasonography as a predictor of spermatogenesis based on semen analysis as the gold standard.
Methodology: This diagnostic validation cross-sectional study was carried out at the Department of Radiology, Chughtai Lab, Lahore, within a period of three months. The non-probability consecutive sampling method was used to include 257 males between 18 and 50 years with suspected infertility. Color Doppler Ultrasonography was used to measure testicular RI, where RI ≥ 0.6 is abnormal. Sperm count of <million/mL or <39 million per ejaculate defined infertility, and semen analysis was carried out. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic accuracy were estimated. Analysis of ROC curves was conducted.
Results: Out of the 257 participants, 98 (38.1%) were found to be infertile in semen analysis. A RI $\geq$0.6 was detected in 95 (37.0) patients. Sensitivity, specificity, PPV, NPV, and diagnostic accuracy of RI were 86.7%, 93.7%, 89.5%, 92.0%, and 91.8%, respectively. ROC analysis indicated an AUC of 0.91 with an optimum RI cut-off of 0.6.
Conclusion: Testicular resistive index is a dependable non-invasive indicator of spermatogenesis, with a high diagnostic accuracy, and can be used as a useful complement to semen analysis in the diagnosis of male infertility.

KEYWORDS: Male infertility, Testicular resistive index, Color Doppler Ultrasonography, Spermatogenesis

INTRODUCTION

Infertility has been a major issue worldwide, and its prevalence is estimated as 15% of couples of reproductive age.[1] The male factor abnormalities cause almost half of all infertility cases either individually or in combination with female factors.[2] The spectrum of male infertility disorders is broad. The seminogenic dysfunction and disturbed semen parameters are some of the most common reasons.[3] Semen analysis is the gold standard in assessing male reproductive potential, offering objective levels of sperm concentration, motility, morphology, and volume based on set criteria.[4] However, the semen testing has drawbacks such as a variation between analyses, the necessity to collect samples by masturbation (which may be a form of distress to some patients), and the inability to determine the underlying testicular parenchymal activity directly.[5]
The development of imaging technologies has expanded the scope of scrotal ultrasonography in assessing male reproductive health.[6] Gray-scale ultrasound is routinely performed to evaluate testicular morphology and volume, whereas Color Doppler Ultrasonography (CDUS) allows real-time evaluation of testicular vascularity and hemodynamic parameters.[7] These include the Resistive Index (RI), a Doppler-derived measure of vascular resistance that reflects intratesticular blood flow and microcirculatory integrity.[8] Various studies have indicated that men exhibiting abnormal spermatogenesis or pathological semen profiles tend to have high intratesticular resistive indices as compared to men with normal sperm count, indicating a possible association between a weakened blood flow and impaired sperm production.[9-11] The majority of testicular volume of 70-80% consists of seminiferous tubules, where spermatogenesis occurs, any interruption of microvascular perfusion can have a direct effect on the intricate process of sperm formation.[12]
Consequently, there is a strong rationale to investigate the possibility of testicular Resistive Index assessed by Color Doppler Ultrasonography as an adjunctive, non-invasive predictor of spermatogenesis in particular in locations where

repeated or invasive testing is not feasible. It is possible that this imaging modality can provide value-added correlations between the patterns of vascular perfusion and seminal parameters and underlying testicular health, which could be useful to provide earlier diagnosis and more personalized treatment of male factor infertility. The current research aimed to determine the diagnostic usefulness of testicular resistive index (RI) measured by Color Doppler Ultrasonography as a predictor of spermatogenesis, with semen analysis as the gold standard test.

METHODOLOGY

This was a cross-sectional diagnostic validation study and was done in the Department of Radiology in Chughtai Lab, Lahore, Pakistan. The study was carried out over a period of three months from 4th March,2026 to 3rd June,2026 Ethical approval was received by the institutional review board (IRB) of, Approval no:1387, dated: 13th Feb, 2026

They enrolled 257 patients, and the sample was determined by the sensitivity and specificity of the testicular resistive index (RI), assuming a sensitivity of 90%, a specificity of 76.7%, 95% confidence level, a margin of error of 8%, and an infertility prevalence among men of about 21.9%.[13] Participants were selected by means of non-probability consecutive sampling.

The study included males between the ages of 18 and 50 years who either had a clinical suspicion of infertility, which is defined as the lack of conceiving after at least 12 months of unprotected intercourse, or had symptoms indicative of impaired spermatogenesis, which includes reduced ejaculate volume, sexual dysfunction, and testicular pain. Patients with abnormal results in prior semen analysis, such as oligospermia, asthenospermia, or azoospermia, and patients with no prior fertility history, but who came to the clinic due to routine infertility assessment, were also taken into consideration. Patients were excluded where there was inadequate information in the ultrasound reports or semen analysis results, where they had a history of testicular surgery, known obstructive azoospermia, congenital absence of the vas deferens, active genitourinary infection, recent scrotal trauma, systemic disease affecting fertility, use of drugs or hormonal therapy known to affect spermatogenesis in the previous six months,

The individuals who met the inclusion criteria were recruited, and a detailed clinical history and examination were performed on them, along with the collection of related past medical records. Simple demographics and clinical data, such as name, age, presenting complaints history, were gathered. A testicular ultrasound was conducted with a GE ultrasound machine in a standardized procedure. The patients were placed in the supine posture with a cloth beneath the thighs to pad and lift the scrotum. Following palpation of the scrotum and testes, a linear probe was employed to locate the capsular branches of the testicular artery, and the resistive index was taken.

After the ultrasound, all the patients were sent back to the Urology department to undergo semen analysis. A pathologist who was not informed about the ultrasound findings confirmed or ruled out infertility. Findings of semen analysis were recorded in a structured data collection form, sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and the overall diagnostic accuracy of testicular ultrasound to abnormal spermatogenesis were calculated. The information was also recorded in an organized form. There was no breach of patient privacy or data confidentiality, and informed consent was signed in the local language by all the subjects. Two diagnosis methods were used to identify the infertile men.

In the Color Doppler Ultrasonography, a testicular resistive index (RI) of 0.6 or above was regarded as a sign of impaired spermatogenesis and was termed infertility. In semen analysis, infertility was categorized using conventional parameters: a sperm count of less than 15 million sperm per milliliter of semen or less than 39 million sperm per ejaculate was deemed abnormal, and these patients were coded as infertile. True positive cases were considered as patients who were infertile by both ultrasound and semen examination, and true negative cases involved patients with a normal RI by ultrasound and normal sperm count. False positive cases were found in patients who presented with abnormal ultrasound results and normal semen analysis, and false negative cases were those who had normal RI on ultrasound but reduced sperm count on semen analysis.

SPSS version 22 was used to analyze data. Continuous variables such as age, period of symptoms, testicular RI, semen parameters, sperm count, and motility were reported as mean ± standard deviation. Frequency and percentages were used to express categorical variables such as fertility status (normal vs. abnormal spermatogenesis). Pearson or Spearman correlation coefficients were used to determine the correlations between testicular RI and semen analysis results, based on the data distribution. The analysis of Receiver Operating Characteristic (ROC) curves was used to estimate the diagnostic accuracy of testicular RI and to define an optimal cut-off point in terms of sensitivity and specificity. A p-value of below 0.05 was considered significant.

RESULTS

The mean age of participants was 32.5 ± 6.8 years, and the average infertility period was 18.2 ± 5.3 months. The percentage of the participants with past semen analysis was found to be 42.8%. The most frequent clinical manifestations were reduced ejaculate volume (22.6%), followed by sexual dysfunction (13.6%), and testicular discomfort (10.5%) in the participants. (Table 1)

Table 1: Demographic Characteristics of Study Participants (n = 257)

Variable	Mean ± SD / n (%)
Age (years)	32.5 ± 6.8
Duration of Infertility (months)	18.2 ± 5.3
History of Previous Semen Analysis	110 (42.8%)
Clinical Symptoms	
Decreased ejaculate volume	58 (22.6%)
Sexual dysfunction	35 (13.6%)
Testicular discomfort	27 (10.5%)

Semen examination showed that the mean sperm count was 18.7 ± 10.5 million/mL and that the total sperm count per ejaculate was 45.2 ± 22.8 million. Mean sperm motility was 52.3 +14.7 and mean normal morphology was 6.8 +3.4. According to WHO criteria, 38.1% men were found to be infertile, and 61.9% were found to have normal spermatogenesis.(Table 2)

Table 2: Semen Analysis Findings (n = 257)

Semen Parameter	Mean ± SD / n (%)
Sperm count (million/mL)	18.7 ± 10.5
Total sperm count (million/ejaculate)	45.2 ± 22.8
Motility (%)	52.3 ± 14.7
Normal morphology (%)	6.8 ± 3.4
Infertile (based on WHO criteria)	98 (38.1%)
Fertile (based on WHO criteria)	159 (61.9%)

Color Doppler Ultrasonography revealed that 37.0% participants had testicular resistive index (RI) of ≥ 0.6, which showed abnormal testicular perfusion, whereas 63.0% had a RI of <0.6, which showed normal limits. (Table 3)

Table 3: Testicular Resistive Index Findings on Color Doppler Ultrasonography (n = 257)

RI Category	n (%)
RI < 0.6 (normal)	162 (63.0%)
RI ≥ 0.6 (abnormal)	95 (37.0%)

Cross-tabulation of Doppler results with semen analysis revealed that 85 participants were infertile on the ultrasound and semen analysis (true positive), 10 participants had abnormal RI and normal semen parameters (false positive), 13 participants had normal RI and abnormal semen parameters (false negative), and 149 were normal at both tests (true negative). (Table 4)

Table 4: Cross-tabulation of Color Doppler RI vs Semen Analysis Findings

	Semen Analysis Infertile	Semen Analysis Normal	Total
Color Doppler RI ≥ 0.6	85 (TP)	10 (FP)	95
Color Doppler RI < 0.6	13 (FN)	149 (TN)	162
Total	98	159	257

According to the analysis, the sensitivity of Color Doppler RI ≥0.6 to infertility prediction was 86.7%, specificity was 93.7%, positive predictive value (PPV) was 89.5%, and negative predictive value (NPV) was 92.0% with an overall diagnostic accuracy of 91.8%. (Table 5)

Table 5: Diagnostic Accuracy of Color Doppler Ultrasound in Predicting Infertility

Parameter	Value (%)
Sensitivity	86.7
Specificity	93.7
Positive Predictive Value (PPV)	89.5
Negative Predictive Value (NPV)	92.0
Overall Diagnostic Accuracy	91.8

Correlation analysis indicated that there were significant inverse correlations between testicular RI and significant semen parameters. The resistive index was negatively associated with sperm count ($r = -0.62$, $p < 0.001$), total sperm count ($r = -0.59$, $p < 0.001$), sperm motility ($r = -0.47$, $p = 0.002$), and normal morphology ($r = -0.35$, $p = 0.014$). This is an indication that an increase in intratesticular vascular resistance is linked to defective spermatogenesis. (Table 6)

Table 6: Correlation between Testicular RI and Semen Parameters

Semen Parameter	Correlation Coefficient (r)	p-value
Sperm count	-0.62	<0.001
Total sperm count	-0.59	<0.001
Motility (%)	-0.47	0.002
Normal morphology (%)	-0.35	0.014

The diagnostic value of testicular RI was also confirmed with the help of the Receiver Operating Characteristic (ROC) curve analysis. The area under the curve (AUC) stood at 0.91, and this was a good indication of good discrimination between infertile and fertile men. The best value of RI cut-off was determined as 0.60, which matched a sensitivity of 86.7% and specificity of 93.7 %. (Table 7)

Table 7: ROC Curve Analysis for Testicular RI as Predictor of Abnormal Spermatogenesis

Parameter	Value
Area Under Curve (AUC)	0.91
Optimal RI Cut-off	0.60
Sensitivity at Cut-off	86.7
Specificity at Cut-off	93.7

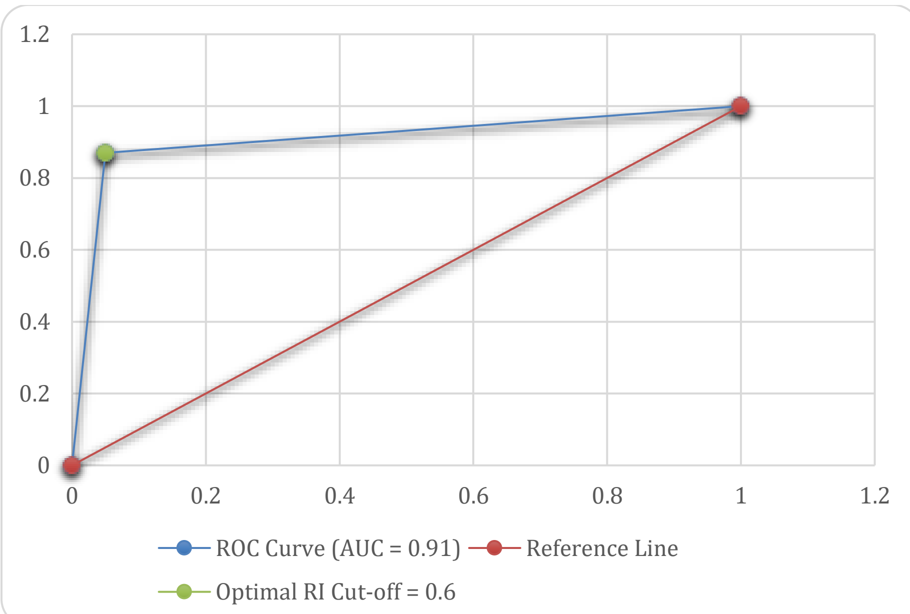

Figure 1: ROC Curve: Testicular RI for Predicting Abnormal Spermatogenesis

DISCUSSION

The current research assessed the predictive value of testicular resistive index (RI) assessed by color doppler ultrasonography as a predictor of spermatogenesis by semen analysis as the gold standard. We have shown that an RI cut-off of 0.6 showed high diagnostic accuracy with a sensitivity of 86.7, specificity of 93.7, and overall accuracy of 91.8. Also, there was a strong negative association between RI and semen parameters, which implies that elevated intratesticular vascular resistance is linked to poor spermatogenesis.

These results are in line with a recent prospective study conducted by Sharma et al. 2025, who found that the values of RI were significantly higher in infertile men than in fertile controls (0.63 vs 0.53, p=0.001), indicating that RI is a promising predictor of spermatogenesis.[9] Their findings corroborate our finding that high levels of RI have a strong negative correlation with low sperm concentration and motility. Likewise, Mulyadi et al. (2026) established that Doppler-derived RI had a significant relationship with semen quality, which further supported the fact that testicular blood flow is a critical factor in spermatogenesis.[14]

Our results also coincide with previous yet still topical investigations. The results of the study by Dalili et al. (2021) showed that RI was higher among infertile men with varicocele, and that microvascular perfusion abnormality is associated with low sperm production.[15] Similarly, researchers, who have assessed Doppler indices, have repeated conclusions that a higher vascular resistance is related to lower sperm count and motility. The Hue University study also found the mean RI values to be approximately 0.59-0.61 in infertile men which confirms the clinical usefulness of our cut-off value of 0.6.[16]

Regarding the accuracy of diagnosis, our findings are consistent with the literature. The sensitivity and specificity of RI measurement in detecting infertile men were demonstrated to be good by Zolfaghar-Khani et al., which supports its use as a non-invasive method of diagnosis.[17] Our study also found high area under the curve (AUC = 0.91) which further confirms the high discriminative power of RI that is consistent with the high levels of RI in recent Doppler-based infertility studies.

Likewise, new developments in imaging-based infertility forecasts have focused on the significance of testicular hemodynamics. A 2025 study involving the use of ultrasound-based predictive modeling proved that testicular vascularity-based imaging parameters can be reliably used to predict semen quality, which supports the idea that semen spermatogenesis relies heavily on testicular vascularity.[18] This is in agreement with our ROC results (AUC = 0.91), which is good diagnostic performance of RI.

A close negative association between RI and sperm count (r = -0.62) was also found in our study and this observation is congruent with previous clinical observations. Research comparing testicular hemodynamics has shown uniformly negative correlations between Doppler indices and semen parameters. Indicatively, it has been identified that higher vascular resistance correlates with lower sperm motility and concentration since microcirculation in seminiferous tubules is impaired.[19, 20]

The observed diagnostic accuracy of the present study is similar or even better than previous studies. A study evaluated the RI among infertile men with moderate to high levels of sensitivity and specificity, which indicated that Doppler ultrasound can be used as a valuable supplement to semen examination.[17] Standardized methods of measurement and rigorous inclusion criteria, which increase the reliability of RI assessment, may explain our improved accuracy.

There were some limitations of this study, which must be taken into account in the interpretation of the results. Since the study is a single-center study with a relatively small sample size, the extent to which the findings can be applied to the broader population can be limited. The cross-sectional design also restricted the possibility of developing a causal relationship between elevated testicular resistive index and impaired spermatogenesis. Moreover, the Doppler measurements are operator-dependent and can be inter-observer-variable even when standardized protocols are used. The gold standard of semen analysis itself is susceptible to physiological variability and may be optimally accurate after repeated samples, which was not done in this study.

Multicenter designs utilizing larger and more diverse populations should be considered in future research to enhance generalizability of the results. It is suggested that longitudinal studies should be conducted to determine a causal effect between testicular resistive index and alterations in spermatogenesis in the course of time. More parameters can be included in the form of hormonal profiles, genetic markers, and more sophisticated imaging methods that can contribute to the increased diagnostic accuracy. It is also important to standardize Doppler measurement techniques to reduce inter-observer variability. In addition, it may be utilized to identify clinical utility, as the role of testicular RI in assessing treatment response and predicting fertility outcomes may be enhanced.

CONCLUSION

The testicular resistive index estimated by the use of Color Doppler Ultrasonography is a non-invasive and effective predictor of spermatogenesis with a high diagnostic accuracy as compared to semen analysis. A significant negative association between RI and the main semen parameters emphasizes the pivotal importance of testicular microvascular perfusion in male fertility. RI is also an effective adjunct tool in the analysis of male infertility with an optimal cut-off of 0.6 that can help distinguish between normal and impaired spermatogenesis. The integration of Color Doppler assessment into mainstream clinical practice can help in earlier diagnosis, making patient experiences more comfortable as they will no longer need multiple semen analyses, and finally, the contribution to more specific and effective management approaches among infertile men.

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