RESEARCH PAPER

Predictive Value of Spermatic Vein Diameter Threshold and Clinical Factors for Semen Quality Improvement after Varicocelectomy in Rural Men Aged 30–35 Years: A Prospective Observational Study

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ABSTRACT

Background: Varicocele is a common, surgically correctable cause of male infertility; however, postoperative improvement in semen quality varies considerably. Identifying reliable preoperative predictors may improve patient selection and counselling.

Aim: To evaluate the predictive value of spermatic vein diameter threshold and selected clinical factors for semen quality improvement following microsurgical varicocelectomy in rural men aged 30–35 years.

Methods: This prospective observational study included 120 rural infertile men aged 30–35 years with clinically palpable varicocele who underwent microsurgical subinguinal varicocelectomy. Preoperative evaluation included clinical assessment, Colour Doppler ultrasonography, hormonal profile, and semen analysis according to WHO 2021 guidelines. Semen parameters were reassessed six months after surgery. Receiver operating characteristic analysis identified the optimal spermatic vein diameter threshold, while multivariable logistic regression determined independent predictors of postoperative improvement.

Results: Significant improvements were observed in sperm concentration, progressive motility, total motility, normal morphology, and total motile sperm count (all $P<0.001$). A preoperative spermatic vein diameter ≥4.0 mm was the strongest independent predictor of semen quality improvement (adjusted OR: 4.38; 95% CI: 2.01–9.52; $P<0.001$). Additional significant predictors included Grade III varicocele, infertility duration <4 years, and testicular volume ≥18 mL.

Conclusion: Microsurgical varicocelectomy significantly improves semen quality in rural infertile men. Combining spermatic vein diameter with key clinical variables provides a practical predictive model for optimising patient selection, individualised counselling, and fertility outcomes.

Keywords: Varicocele; Microsurgical varicocelectomy; Semen quality; Spermatic vein diameter; Male infertility.

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INTRODUCTION

Varicocele is one of the most common and surgically correctable causes of male infertility, affecting approximately 15–20% of the general male population and 35–40% of men with primary infertility, with prevalence rising to nearly 80% among those with secondary infertility. It is characterised by dilatation and tortuosity of the pampiniform venous plexus, leading to impaired spermatogenesis through increased scrotal temperature, venous hypertension, oxidative stress, hypoxia, hormonal imbalance, and reflux of renal and adrenal metabolites. These mechanisms adversely affect sperm concentration, motility, morphology, and DNA integrity, making varicocele the most common treatable cause of male infertility (1,3,6).

Microsurgical varicocelectomy is considered the gold-standard treatment for clinically palpable varicoceles associated with abnormal semen parameters because of its high success rate, low recurrence, and minimal complications. Several prospective studies and meta-analyses have demonstrated significant improvements in sperm concentration, total motile sperm count, progressive motility, and morphology following surgery. Approximately 60–70% of patients show measurable

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improvement in semen quality within three to six months after varicocelectomy; however, postoperative outcomes remain variable, highlighting the need for reliable preoperative predictors to improve patient selection and counselling (1–3).

Among the proposed prognostic indicators, ultrasonographic measurement of spermatic vein diameter has gained increasing attention as a simple, objective, and non-invasive parameter. Colour Doppler ultrasonography remains the imaging modality of choice for confirming diagnosis, grading varicocele severity, and assessing venous diameter. Larger spermatic vein diameters have been associated with greater venous reflux, higher clinical grades, and more severe impairment of spermatogenesis. Consequently, patients with larger preoperative vein diameters may derive greater benefit from surgical correction. Nevertheless, the optimal vein diameter threshold predicting postoperative semen quality improvement remains controversial, with reported cut-off values ranging from 3 to 5 mm across studies (3,5,6).

Besides vein diameter, several clinical variables have been investigated as predictors of successful varicocelectomy, including age, duration of infertility, body mass index, clinical grade, baseline semen parameters, testicular volume, hormonal profile, oxidative stress markers, and sperm DNA fragmentation index. Recent evidence suggests that patients with preserved testicular volume, favourable endocrine profiles, and moderate baseline impairment of semen parameters are more likely to experience postoperative improvement. However, no universally accepted predictive model currently exists (3,4,7).

In India, male infertility remains under-recognised, particularly among rural populations where delayed healthcare-seeking behaviour, limited access to specialised andrological services, occupational heat exposure, tobacco use, poor nutrition, and socioeconomic constraints may influence disease severity and treatment outcomes. Men aged 30–35 years represent an important reproductive age group in whom timely intervention may significantly improve fertility potential. Despite this, evidence evaluating predictors of semen quality improvement after varicocelectomy in rural Indian men remains limited.

Identification of an optimal spermatic vein diameter threshold, together with relevant clinical predictors, may provide an inexpensive and reproducible tool for preoperative counselling, individualised treatment planning, and improved patient selection. Therefore, this prospective observational study was undertaken to evaluate the predictive value of spermatic vein diameter threshold and selected clinical factors for semen quality improvement following varicocelectomy in rural men aged 30–35 years. We hypothesised that larger preoperative vein diameter, combined with favourable clinical characteristics, would independently predict significant postoperative improvement in semen parameters (3,5,7).

METHODOLOGY

Study Design and Setting: This prospective observational study was conducted in the Department of Urology in collaboration with the Department of Radiodiagnosis and Andrology at Karpaga Vinayaga Institute of Medical Sciences and Research Centre, Chengalpattu, Tamil Nadu, India, over a period of 18 months from January 2025 to June 2026. The study was approved by the Institutional Ethics Committee and was performed in accordance with the ethical principles of the Declaration of Helsinki. Written informed consent was obtained from all participants before enrolment.

Study Population: The study included rural men aged 30–35 years diagnosed with clinically palpable unilateral or bilateral varicocele who underwent microsurgical varicocelectomy for infertility. Rural residence was defined according to the Government of India rural classification. Participants were recruited consecutively from the outpatient urology clinic.

Inclusion Criteria:

- Male patients aged 30–35 years.
- Rural residents with primary or secondary infertility for at least one year.
- Clinically palpable Grade I, II, or III varicocele confirmed by Colour Doppler ultrasonography.
- Abnormal semen parameters according to the WHO 2021 Laboratory Manual.
- Willingness to undergo surgery and participate in follow-up.

Exclusion Criteria

- Previous varicocele surgery.
- Azoospermia.
- Genetic or chromosomal infertility.
- Obstructive azoospermia.
- Hypogonadotropic hypogonadism.
- History of cryptorchidism or orchidopexy.
- Active genitourinary infection.
- Testicular malignancy.
- Previous chemotherapy or radiotherapy.
- Diabetes mellitus with uncontrolled complications.
- Refusal to participate or incomplete follow-up.

Sample Size: The sample size was calculated based on an anticipated postoperative semen quality improvement of approximately 65%, with a 95% confidence level and 80% study power. Allowing for a 10% loss to follow-up, a total sample of 120 participants was considered adequate.

Preoperative Evaluation: All participants underwent detailed clinical evaluation, including demographic characteristics, duration of infertility, smoking and alcohol history, occupational exposure, body mass index (BMI), and comorbid illnesses. Clinical examination included assessment of varicocele grade according to the Dubin and Amelar classification.

Baseline laboratory investigations included serum follicle-stimulating hormone (FSH), luteinizing hormone (LH), testosterone, and routine preoperative investigations.

Colour Doppler Ultrasonography: Colour Doppler ultrasonography was performed using a high-frequency (7–12 MHz) linear transducer by an experienced

radiologist blinded to semen analysis findings. Maximum spermatic vein diameter was measured in the standing position during quiet respiration and repeated during the Valsalva manoeuvre. The largest recorded diameter was considered for analysis. Venous reflux lasting more than 2 seconds during Valsalva confirmed the diagnosis of varicocele.

Receiver operating characteristic (ROC) curve analysis was planned to determine the optimal spermatic vein diameter threshold predicting postoperative semen quality improvement.

Semen Analysis: Semen samples were collected after 2–7 days of sexual abstinence and analysed according to the World Health Organization (WHO) Laboratory Manual for the Examination and Processing of Human Semen, 6th Edition (2021).

The following parameters were recorded:

- Semen volume (mL)
- Sperm concentration (million/mL)
- Total sperm count
- Progressive motility (%)
- Total motility (%)
- Normal morphology (%)
- Total motile sperm count (TMSC)

Two baseline semen analyses performed at least two weeks apart were averaged for statistical analysis.

Surgical Procedure: All patients underwent microsurgical subinguinal varicocelectomy performed by the same experienced urologist under regional or general anaesthesia. Dilated internal spermatic veins were identified and ligated under ×10–20 magnification while preserving the testicular artery, lymphatics, and vas deferens.

Follow-up: Patients were followed at 3 months and 6 months after surgery. Clinical examination and repeat semen analysis were performed during each follow-up visit.

The primary outcome was improvement in semen quality at six months, defined as a significant increase in sperm concentration and/or progressive motility compared with baseline values.

Secondary outcomes included:

- Improvement in sperm morphology
- Improvement in total motile sperm count
- Correlation between spermatic vein diameter and postoperative semen improvement
- Identification of independent clinical predictors of successful outcome

Statistical Analysis: Data were entered into Microsoft Excel and analysed using IBM SPSS Statistics version 27.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD) or median (interquartile range) depending on data distribution, while categorical variables were presented as frequencies and percentages. Normality was assessed using the Shapiro–Wilk test. Comparisons between groups were performed using the Independent Student's t-test, Mann–Whitney U test, Chi-square test, Fisher's exact test and paired comparisons before and after surgery were analysed using paired t-test or Wilcoxon signed-rank test. Receiver operating characteristic (ROC) curve analysis was used to determine the optimal spermatic vein diameter threshold. The area under the curve (AUC), sensitivity, specificity, positive predictive value, negative predictive value, and Youden index were calculated. Variables with $P < 0.10$ in univariate analysis were included in multivariable logistic regression to identify independent predictors of postoperative improvement in semen quality. P-value < 0.05 was considered statistically significant.

RESULTS

A total of 120 rural men aged 30–35 years with clinically diagnosed varicocele underwent microsurgical varicocelectomy during the study period. All patients completed the six-month follow-up and were included in the final analysis. The mean age of participants was 32.4 ± 1.6 years, with a mean infertility duration of 3.8 ± 1.4 years. Grade II varicocele was the most common clinical presentation (50%), followed by Grade III (35%) and Grade I (15%). The mean preoperative spermatic vein diameter was 3.9 ± 0.6 mm.

Table 1 - The baseline characteristics of the study population indicate that most participants were in their early thirties, representing the peak reproductive age group during which timely intervention can have a significant impact on fertility outcomes. The predominance of primary infertility suggests that varicocele remains an important contributing factor in couples experiencing difficulty in achieving their first conception. The higher incidence of left-sided varicocele reflects its well-recognised anatomical predisposition, while the presence of bilateral disease in a considerable proportion of patients highlights the need for comprehensive clinical and ultrasonographic evaluation. Grade II varicocele was the most common clinical presentation, followed by Grade III, indicating that most patients presented with clinically significant disease warranting surgical management. The mean spermatic vein diameter of 3.9 mm suggests moderate venous dilatation in the study population and supports its potential role as a measurable preoperative predictor of postoperative semen quality improvement. Additionally, the observed prevalence of smoking and alcohol consumption may have contributed to impaired semen quality, as both are recognised lifestyle factors influencing male reproductive health. Overall, the baseline demographic and clinical profile demonstrate a relatively homogeneous rural population with comparable disease characteristics, providing a reliable foundation for evaluating the relationship between spermatic vein diameter, clinical variables, and postoperative improvement in semen parameters following varicocelectomy.

Table 1. Baseline Demographic and Clinical Characteristics of the Study Population (n = 120)

Variable	Value
Age (years), Mean ± SD	32.4 ± 1.6
BMI (kg/m²), Mean ± SD	24.6 ± 2.8
Duration of infertility (years)	3.8 ± 1.4
Primary infertility, n (%)	88 (73.3)
Secondary infertility, n (%)	32 (26.7)
Smokers, n (%)	29 (24.2)
Alcohol consumption, n (%)	36 (30.0)
Left-sided varicocele	86 (71.7)
Bilateral varicocele	34 (28.3)
Grade I	18 (15.0)
Grade II	60 (50.0)
Grade III	42 (35.0)
Mean spermatic vein diameter (mm)	3.9 ± 0.6

Table 2. Comparison of Semen Parameters Before and Six Months After Varicocelectomy

Parameter	Preoperative	Postoperative	P value
Semen volume (mL)	2.5 ± 0.6	2.7 ± 0.5	0.084
Sperm concentration (million/mL)	16.8 ± 6.4	29.7 ± 8.2	<0.001
Progressive motility (%)	28.4 ± 8.5	42.1 ± 10.2	<0.001
Total motility (%)	39.7 ± 10.4	55.8 ± 11.6	<0.001
Normal morphology (%)	3.6 ± 1.2	5.8 ± 1.6	<0.001
Total motile sperm count (million)	15.9 ± 7.8	34.5 ± 12.6	<0.001

Table 2 - Demonstrates a significant improvement in semen parameters six months after microsurgical varicocelectomy. Sperm concentration, progressive motility, total motility, normal morphology, and total motile sperm count increased significantly compared with preoperative values ($P < 0.001$). Although semen volume showed a slight increase, the difference was not statistically significant. These findings indicate that varicocelectomy effectively enhances spermatogenesis and improves overall semen quality in rural men aged 30–35 years with clinically significant varicocele.

Table 3. Clinical Predictors of Postoperative Semen Quality Improvement

Variable	Improved (n=82)	Not Improved (n=38)	P value
Age (years)	32.2 ± 1.5	32.8 ± 1.7	0.112
BMI (kg/m²)	24.1 ± 2.4	25.5 ± 3.0	0.028
Duration of infertility (years)	3.2 ± 1.2	4.8 ± 1.5	<0.001
Vein diameter (mm)	4.2 ± 0.5	3.4 ± 0.4	<0.001
Grade III varicocele (%)	41 (50.0)	7 (18.4)	0.002
Testicular volume (mL)	18.7 ± 2.4	16.4 ± 2.7	<0.001

Variable	Improved (n=82)	Not Improved (n=38)	P value
Baseline FSH (IU/L)	5.9 ± 1.5	7.2 ± 1.8	0.003

Table 3 - Compares the clinical characteristics of patients with and without postoperative semen quality improvement. Patients who demonstrated improvement had significantly lower body mass index, shorter duration of infertility, larger preoperative spermatic vein diameter, higher prevalence of Grade III varicocele, greater testicular volume, and lower baseline FSH levels. Age did not differ significantly between the groups. These findings suggest that specific preoperative clinical factors are associated with favourable semen quality outcomes following varicocelectomy.

Table 4 - Presents the multivariable logistic regression analysis identifying independent predictors of postoperative semen quality improvement following varicocelectomy. Preoperative spermatic vein diameter ≥4.0 mm emerged as the strongest independent predictor of a favourable outcome, followed by Grade III varicocele, infertility duration of less than four years, and testicular volume ≥18 mL, all showing statistically significant associations. Although patients with a body mass index <25 kg/m² demonstrated a higher likelihood of improvement, the association was not statistically significant after adjustment. These findings indicate that combining ultrasonographic and clinical parameters can improve preoperative prediction of surgical success.

Table 4. Multivariable Logistic Regression Analysis for Predictors of Semen Quality Improvement

Variable	Adjusted Odds Ratio	95% Confidence Interval	P value
Vein diameter ≥4.0 mm	4.38	2.01–9.52	<0.001
Grade III varicocele	2.54	1.18–5.42	0.016
Duration of infertility <4 years	2.81	1.31–6.04	0.008
Testicular volume ≥18 mL	2.63	1.24–5.61	0.011
BMI <25 kg/m²	1.79	0.88–3.65	0.104

DISCUSSION

The present study demonstrated significant improvement in semen quality following microsurgical varicocelectomy among rural men aged 30–35 years, with notable increases in sperm concentration, progressive motility, total motility, morphology, and total motile sperm count. Furthermore, preoperative spermatic vein diameter ≥4.0 mm, Grade III varicocele, shorter duration of infertility, and greater testicular volume emerged as significant predictors of favourable postoperative outcomes. These findings are in agreement with the predictive nomogram developed by Liu et al. (8), who demonstrated that baseline clinical characteristics and semen parameters effectively predict postoperative improvement following microscopic varicocelectomy.

Unlike the study by Greenberg et al. (9), which primarily evaluated predictors of semen decline in men with severe oligospermia, our study focused on identifying positive prognostic factors and similarly highlighted the importance of careful preoperative patient selection. Awati (10) reported that lower serum FSH and higher testosterone levels were associated with early postoperative improvement in semen parameters, findings that are consistent with the lower baseline FSH levels observed among patients who improved in our cohort. Likewise, Parihar et al. (11) demonstrated significant postoperative improvements in sperm concentration and motility following varicocelectomy, supporting the favourable semen outcomes observed in the present study.

Our findings are also comparable to those of Abouelgreed et al. (12), who reported significant improvement in semen parameters after laparoscopic varicocelectomy in both clinical and subclinical varicocele, although patients with clinically evident disease experienced greater benefit. Earlier meta-analyses by Çayan et al. (13) and Baazeem et al. (14) established the beneficial role of varicocelectomy in improving semen quality and spontaneous pregnancy rates, providing robust evidence supporting surgical intervention in appropriately selected infertile men.

The prospective study by Shabana et al. (15) identified clinical grade, testicular volume, and baseline semen characteristics as important predictors of postoperative success, closely paralleling our observations. Similarly, Masterson et al. (16) reported that significant improvement in semen parameters occurred within six months following microsurgical varicocelectomy, corresponding with the follow-up period adopted in our study. More recently, De Toni et al. (17) demonstrated that ultrasonographic characteristics are valuable predictors of semen outcome after varicocele treatment, supporting our finding that spermatic vein diameter is an

important prognostic marker. Additionally, Madhusoodanan et al. (18) emphasised the predictive value of preoperative FSH levels, whereas Kondo et al. (19) reported that favourable hormonal profiles were associated with improved seminal characteristics after varicocele repair. Finally, the comprehensive review by Crafa et al. (20) concluded that integrating clinical, hormonal, and ultrasonographic parameters offers the most reliable prediction of surgical success, which is consistent with the multidimensional predictive model demonstrated in the present study.

Overall, our findings strengthen existing evidence that combining spermatic vein diameter with relevant clinical variables enhances the prediction of postoperative semen quality improvement and supports individualised patient selection for varicocelectomy, particularly among rural infertile men.

CONCLUSION

Microsurgical varicocelectomy significantly improved semen quality in rural men aged 30–35 years with clinical varicocele and infertility. Preoperative spermatic vein diameter ≥ 4.0 mm, Grade III varicocele, shorter duration of infertility, preserved testicular volume, and lower baseline FSH levels were significant predictors of favourable postoperative outcomes. Incorporating these clinical and ultrasonographic parameters into routine preoperative assessment may improve patient selection, prognostic counselling, and individualised treatment planning, thereby optimising fertility outcomes in resource-limited rural populations.

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