Predictive Value of Vein Diameter Threshold and Clinical Factors in Semen Quality Improvement after Varicocelectomy

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ABSTRACT

Objective: To evaluate whether preoperative varicocele vein diameter predicts postoperative semen quality improvement after microsurgical varicocelectomy, to identify a threshold value, and to assess the influence of age and venous reflux on these associations.

Study Design: A descriptive cohort study.

Place and Duration of the Study: Department of Urology, Manisa Celal Bayar University, Manisa, Turkiye, between June 2010 and August 2025.

Methodology: A total of 108 men aged 18–40 years with unilateral left-sided varicocele who underwent subinguinal microscopic varicocelectomy for infertility were included; predefined exclusions were applied. Semen parameters [progressive motility, total sperm count, and Sperm Motility Index (SMI)] were averaged from two preoperative tests and compared with the best value at postoperative 6–12 months. The effects of vein diameter, age, and venous reflux on these outcomes were assessed using chi-squared, Mann-Whitney U, and Spearman tests. ROC analysis evaluated vein diameter as a predictor. A p-value of <0.05 was considered statistically significant.

Results: Larger preoperative vein diameter was associated with ≥40% motility improvement ($p = 0.045$) and ≥420% SMI improvement ($p = 0.049$). Receiver operating characteristic (ROC) analysis identified a 3.4 mm cut-off value for both motility and SMI, with AUC 0.61 and 0.63, respectively. Venous reflux correlated with greater motility improvement ($p = 0.015$), while older age correlated with SMI improvement ($p = 0.019$).

Conclusion: Preoperative vein diameter predicts improvement in progressive motility and SMI after microscopic varicocelectomy; a 3.4 mm threshold shows modest discriminative ability. Venous reflux and age influence specific outcomes and may help guide counselling.

Key Words: *Varicocele, Veins, Semen analysis, Semen quality*.

How to cite this article: Erbatu O, Albaz A, Bilmis M, Ucer O, Temeltas G, Muezzinoglu T. Predictive Value of Vein Diameter Threshold and Clinical Factors in Semen Quality Improvement after Varicocelectomy. *J Coll Physicians Surg Pak* 2026; **36(03)**:293-297.

INTRODUCTION

Varicocele affects around 15% of adult men and represents the most common surgically correctable cause of male infertility.[1] Among men with primary infertility, the prevalence increases to 35–44%, rising further to 45–81% in those with secondary infertility.[2,3] Although varicocele is frequently associated with impaired semen quality, it does not inevitably lead to infertility.[4,5] In cases of clinical varicocele accompanied by abnormal semen parameters, microsurgical varicocelectomy is considered a potentially effective treatment for male infertility.[6] However, not all patients respond similarly to surgery; thus, fertility status, varicocele grade, and semen quality should be evaluated together before making treatment decisions.[6,7]

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Received: August 15, 2025; Revised: November 27, 2025; Accepted: January 05, 2026
DOI: https://doi.org/10.29271/jcpsp.2026.03.293

Semen parameters often improve following varicocelectomy, although the extent of change varies between individuals.[8,9] Which aspects of semen quality are most consistently affected remains unclear.[9] Notably, some patients may show no meaningful improvement, and a subset may even experience a decline in semen quality.[10]

The uncertainty about who will benefit most from varicocelectomy also extends to when these benefits will appear.[11,12] Some studies suggest that the most notable changes emerge within the first three months postoperatively, with little or no additional gain beyond six months.[13] Moreover, the effects of these changes on pregnancy outcomes remain unclear.[14] These uncertainties emphasise the need for objective predictive markers in clinical decision-making.[15] Considering these gaps, this study aimed to evaluate whether preoperative varicocele vein diameter can predict postoperative improvements in semen quality and whether clinical variables, such as age and venous reflux, influence these associations. The study also explored the potential utility of diameter-based threshold values to guide individualised treatment planning.

METHODOLOGY

A total of 108 patients were included in this descriptive study. No formal power analysis was performed; instead, the entire dataset of patients treated at the Department of Urology, Manisa Celal Bayar University, Manisa, Turkiye, between June 2010 and August 2025 was analysed. All patients underwent subinguinal microscopic varicocelectomy for infertility during this period. Exclusion criteria were age <18 or >40 years, history of chemotherapy, hormonal profile abnormalities, steroid use, testicular volume loss, presence of a solitary testis, or azoospermia. Testicular volume was measured using Doppler ultrasonography and calculated according to the Lambert formula (length × width × height × 0.71). A volume <12 mL was considered as testicular volume loss. All Doppler ultrasonography examinations were performed using a standardised protocol in the dedicated ultrasound unit of the radiology department. Only patients with unilateral left-sided varicocele were included; a small number of bilateral cases were excluded to ensure anatomical homogeneity.

Semen parameters were calculated as the mean of two preoperative analyses performed after 3–4 days of abstinence. For postoperative analysis, the higher value between the 6^{th} and 12^{th} months was used for comparison. Although early postoperative changes in semen parameters may be observed as early as the third month or even earlier, routine 3-month semen analyses were not included in this study. As a tertiary referral centre receiving patients from distant regions, many 3-month semen analyses were performed in outside laboratories; therefore, the 6-month semen analysis conducted in the institutional laboratory, which operates in coordination with the fertility clinic and uses automated systems, was adopted as the standardised postoperative follow-up time point in this study. The primary parameters assessed were progressive motility, total sperm count, and Sperm Motility Index (SMI). SMI is a composite indicator calculated by multiplying the proportions of fast and slow progressive motile sperm by the sperm concentration. Kruger morphology was not included due to its narrow numeric range and high interobserver variability.

Changes in semen parameters after surgery were calculated as percentages. Patients were grouped according to improvement status and were analysed using continuous variables based on change rates. Continuous variables were expressed as mean ± standard deviation (SD) or median. Categorical variables were compared using the chi-squared test. Skewed data were analysed using the Mann-Whitney U test and the Spearman's rank correlation test. ROC analysis assessed the predictive value of preoperative vein diameter for a predefined level of improvement. Associations between changes in semen parameters and clinical variables (age and reflux ≥2 seconds during the 10–15-second Valsalva manoeuvre) were examined. All analyses were performed using IBM SPSS Statistics 23.0, and a p-value <0.05 was considered statistically significant.

RESULTS

The mean age of the cohort was 27.8 ± 5.0 years. The median preoperative left varicocele vein diameter was 3.6 mm (range: 2.2–5.2 mm). Venous reflux during the Valsalva manoeuvre was observed in 52.7% of patients (57/108). The median preoperative progressive motility was 4.55% (range: 0.3–50.0%), total sperm count was 79.15 million (range: 3.0–573.5 million), and SMI was 15.0 (range: 3.0–354.0). Postoperative improvement in progressive motility was observed in 66.7% of patients (n = 72), with a median improvement of 44.8% (range: 0–463.6%). Sperm count improved in 61.1% (n = 66), with a median increase of 25.1% (range: 0–3160.0%). SMI improved in 52.8% of patients (n = 57), with a median increase of 29.5% (range: 0–1333.3%).

The relationship between patient age and postoperative improvement in semen parameters was evaluated. For progressive motility, the median age was 27.5 years in patients with improvement and 28.5 years in those without (p = 0.822). For total sperm count, the median age was 28.0 years in both groups (p = 0.912). In contrast, SMI improvement was associated with older age (28.8 ± 4.9 *vs.* 26.6 ± 4.9 years; p = 0.019, Figure 1). The presence of reflux was investigated for postoperative improvements. For each semen parameter, a two-step analysis was performed. First, categorical improvement status was compared using the chi-squared test, which showed no significant asso-ciations for progressive motility (p = 0.152), sperm count (p = 0.087), or SMI (p >0.99). Next, improvement percentages were compared using the Mann-Whitney U test. A significant difference was observed only for progressive motility (p = 0.015), with reflux-positive patients showing higher median improvement (86.7%) than those without reflux (32.0%). No significant diffe-rences were found for sperm count (p = 0.154; median improvement: 1.3% with reflux *vs.* 47.3% without) or SMI (p = 0.199; median improvement: 50.0% *vs.* 9.0%).

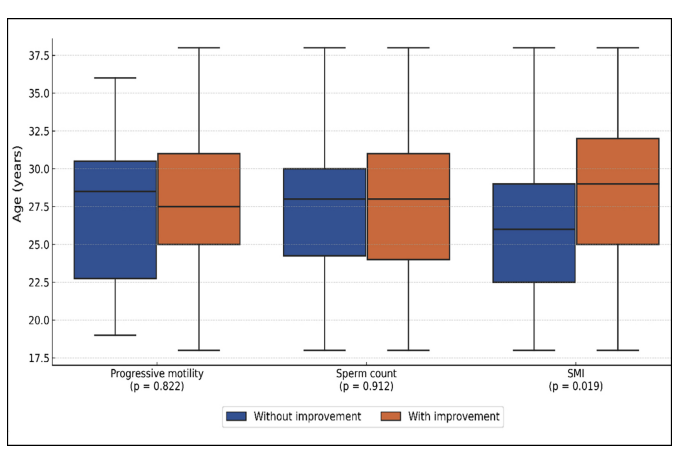

Figure 1: Age distribution by postoperative improvement status in semen parameters.

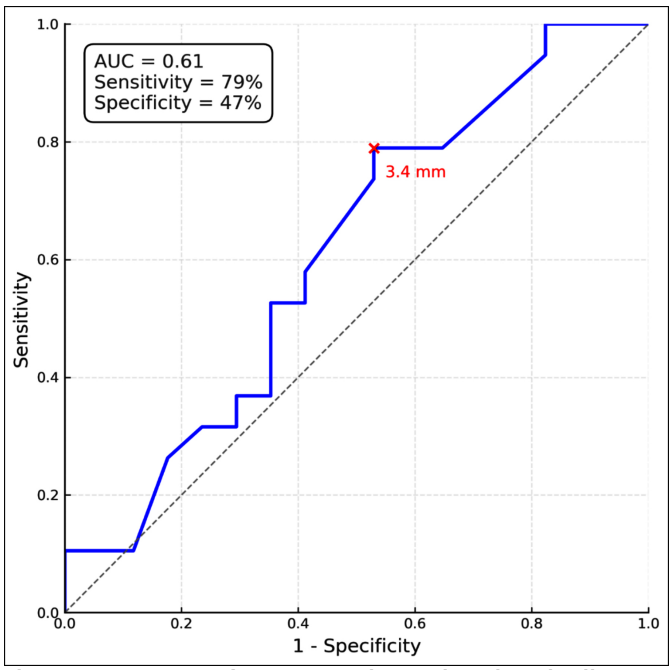

Figure 2: ROC curve for preoperative varicocele vein diameter predicting ≥40% improvement in progressive motility.

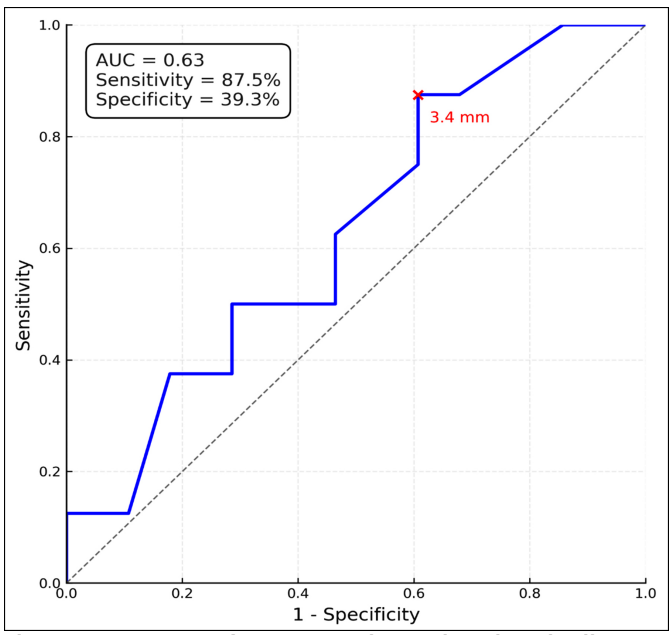

Figure 3: ROC curve for preoperative varicocele vein diameter predicting ≥420% improvement in SMI.

Patients were grouped based on the presence or absence of postoperative improvement in progressive motility, and preoperative vein diameters were compared using the Mann-Whitney U test. Although the diameter was slightly higher in patients with improvement (3.65 mm *vs*. 3.40 mm), the difference was not statistically significant (p = 0.196). The Spearman's rank correlation also revealed no significant association (ρ = 0.113, p = 0.243). To further explore subgroup effects, patients were stratified by various improvement thresholds, and vein diameters were reanalysed. Among thresholds ranging from 10 to 200%, only the ≥40% group showed a statistically significant difference in pre-operative diameter (p = 0.045). Patients with ≥40% improvement (n = 57) had a median diameter of 3.8 mm, compared to 3.5 mm in those with <40% improvement (n = 51). ROC analysis demonstrated modest discriminative ability (AUC = 0.61) and identified 3.4 mm as the optimal cut-off, yielding a sensitivity of 79% and a specificity of 47.1% (Figure 2). When patients were divided into two groups based on sperm count improvement status, the median varicocele diameter was 3.50 mm in patients with improvement and 3.75 mm in those without. However, the difference was not statistically significant (p = 0.073). The Spearman's rank correlation analysis revealed a weak but statistically significant inverse association between vein diameter and sperm count improvement (p = –0.195, p = 0.043).

Comparing patients with and without SMI improvement, the median preoperative vein diameter was 3.60 mm in the improvement group and 3.50 mm in the no-improvement group. The difference was not statistically significant (p = 0.075). The Spearman's correlation revealed a weak, non-significant positive association between diameter and SMI improvement (p = 0.186 and p = 0.055, respectively). A threshold analysis was then performed by incrementally stratifying SMI improvement percentages. Among thresholds ranging from 10 to 600%, only the ≥420% group showed a statistically significant difference in preoperative diameter (p = 0.049). Such high percentages reflect several-fold relative improvements from very low baseline values, rather than high absolute percentages. Patients with ≥420% improvement (n = 24) had a median diameter of 3.8 mm, compared to 3.5 mm in those with <420% improvement (n = 84). ROC analysis yielded an AUC of 0.63, and the optimal cut-off value was again 3.4 mm, with 87.5% sensitivity and 39.3% specificity (Figure 3).

DISCUSSION

This study aimed to evaluate the predictive value of preoperative clinical factors, such as vein diameter, age, and venous reflux, on postoperative improvement in semen parameters following microsurgical varicocelectomy. It provides statistically significant clinical evidence supporting a widely accepted clinical fact. A larger vein diameter was significantly associated with greater improvement in progressive motility and SMI. In subgroup analysis, patients with at least 40% improvement in progressive motility had significantly larger median vein diameters compared to those with less improvement (p = 0.045). Similarly, those with 420% or more improvement in SMI also had significantly larger diameters (p = 0.049). In addition, ROC curve analysis identified a shared threshold of 3.4 mm for predicting meaningful improvement in both parameters. Venous reflux was associated with better improvement in progressive motility, while increasing age showed a positive correlation with SMI improvement. The results are partly consistent with previous studies; however, some differences were also found.

The impact of varicocelectomy in men with severe oligozoospermia (defined as a sperm concentration below 5 million/mL) was investigated in an original study with meta-analysis by Majzoub *et al*.[16] The reported mean age in their cohort was 37.1 years, with a mean preoperative left spermatic vein diameter of 3.70 mm. In comparison, the patients in this cohort were younger (mean: 27.8 years), and the mean vein diameter was similar (3.67 mm). Both studies demonstrated a significant postoperative increase in progressive motility. In the study by Majzoub *et al*., the mean progressive motility improved from 4.39 to 9.13% (p = 0.002). In this cohort, when expressed as a relative change from baseline, postoperative progressive motility increased by a median of 44.8%. In that study, a significant increase in sperm concen-tration was observed after varicocelectomy from 1.55 ± 1.37 to 7.56 ± 12.24 million/mL (p <0.001). In this cohort, sperm count improved in 61.1% of patients, with a median increase of 25.1% (range: 0–3160.0%). While this study was not limited to men with severe oligozoospermia, the observed outcomes suggest that this subgroup may still derive considerable benefit from surgical correction, consistent with previously reported results.

Both Palmisano *et al*. and Shomarufov *et al*. in their studies identified preoperative vein diameter and venous reflux as significant predictors of postoperative improvement in semen parameters.[17,18] In Palmisano's study, patients with ultrasound grade III varicocele, defined by spontaneous reflux and a vein diameter greater than 3 mm, showed significant improve-ment in sperm concentration after surgery (p = 0.035).[17] Similarly, Shomarufov *et al*. emphasised a vein diameter greater than 2.5 mm as a key predictor and reported reflux as a strong prognostic factor.[18] In this study, vein diameter was also significantly higher in patients with marked improvement in progressive motility and SMI. Reflux-positive patients exhibited greater improvement in progressive motility compared to those without reflux (86.7% *vs*. 32.0%, p = 0.015). However, unlike Palmisano *et al*., who reported the greatest gains in sperm count, especially in older patients,[17] this study found that larger vein diameter was more strongly associated with improvements in progressive motility and SMI than with sperm count. Furthermore, while Shomarufov *et al*. did not report a specific cut-off beyond the >2.5 mm threshold,[18] the ROC analysis identified a shared cut-off value of 3.4 mm for predicting ≥40% improvement in motility and ≥420% improvement in SMI. Additionally, no age-related trend was observed for count or motility in this cohort, whereas SMI showed a significant association with age (p = 0.019). Reflux, on the other hand, was not associated with changes in sperm count or SMI in this data, in contrast to its broader predictive role in the systematic review.

A recent review by Crafa *et al*. and the nomogram study by Liu *et al*. identified vein diameter and reflux as key preoperative predictors of semen quality improvement after varico-celectomy.[19,20] The review reported that patients with vein diameters greater than 5 mm experienced greater improvements in sperm concentration (p <0.05).[19] In the nomogram study, the average vein diameter was also significantly greater in patients who showed postoperative improvement (3.41 ± 0.57 mm) compared to those without improvement (3.15 ± 0.49 mm; p = 0.001). Furthermore, regression analysis identified vein diameter as an independent predictor (OR = 3.26, p = 0.004).[20] Similarly, this study demonstrated significantly larger vein diameters in patients with ≥40% improvement in progressive motility and ≥420% improvement in SMI. Regarding reflux, Crafa *et al*. reported that the disappearance of venous reflux after varicocele repair was significantly associated with increased rates of both spontaneous pregnancy and live birth.[19] In this cohort, although reflux was not linked to sperm count improvement, it was significantly associated with progressive motility improve-ment (p = 0.015). Liu *et al*.'s model reported no significant age difference between patients with and without TPMSC improvement.[20] These findings were consistent for motility and sperm count but showed a significant association between older age and SMI improvement (p = 0.019).

This study has some limitations. Its retrospective design may introduce selection bias. Fertility outcomes, such as pregnancy, were not evaluated. Despite a standardised protocol, Doppler ultrasonography is an operator-dependent procedure.

CONCLUSION

Preoperative varicocele vein diameter is a significant predictor of improvement in progressive motility and SMI after microscopic varicocelectomy. A threshold of 3.4 mm shows modest discriminative value. Venous reflux is associated with greater improvement in progressive motility, while older age correlates with better SMI outcomes. These findings may help guide individualised patient selection and preoperative counselling in varicocelectomy candidates.

ETHICAL APPROVAL:
This study was approved by the Ethical Committee of Manisa Celal Bayar University Health Sciences, Manisa, Turkiye (Approval No. 20.478.486/3180; date: 4th June 2025).

PATIENTS' CONSENT:
Informed consent was obtained from all participants.

COMPETING INTEREST:
The authors declared no conflict of interest.

AUTHORS' CONTRIBUTION:
OE: Conception and design of the study, and drafting of the manuscript.
AA, OU: Critical revision of the manuscript.
MB: Data analysis.
GT, TM: Approval of the final version and overall responsi-bility for the work.
All authors approved the final version of the manuscript to be published.

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