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Effects of Varicocelectomy Surgery on Sperm Morphology and Male Fertility

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ABSTRACT

Background: Varicocele is associated with impaired semen parameters and reduced spermatogenesis. Microsurgical varicocelectomy has been shown to improve testicular function. This study aimed to assess its effect on sperm morphology.

Methods: A prospective observational study was conducted on 112 infertile males with Grade II or III clinical varicocele at the Institute of Kidney Diseases (IKD), MTI-Hayatabad Medical Complex, Peshawar, from September 1, 2024, to February 28, 2025. Non-probability consecutive sampling was used. Semen analysis was performed before surgery and repeated six months postoperatively. Outcome variables included sperm morphology, concentration (million/mL), and semen volume (mL). Data were analyzed using SPSS version 26.0. Paired sample t-tests assessed changes, with subgroup analysis by varicocele grade, laterality, age, and infertility duration. A p-value < 0.05 was considered significant.

Results: Mean age was 31.8 ± 5.4 years; mean infertility duration was 3.3 ± 1.8 years. Most patients (68.7%) had unilateral varicocele; Grade III was most common (60.7%). Six months post-surgery, semen parameters improved significantly: sperm morphology increased from 2.2 ± 1.3 to 5.7 ± 1.8 normal forms, concentration from 12.6 to 22.5 million/mL, and volume from 2.5 to 3.0 mL (all p < 0.001).

Conclusion: Microsurgical varicocelectomy significantly improves semen quality in infertile males with clinical varicocele, especially in younger patients with shorter infertility duration.

Keywords: Varicocele, Infertility, Semen Analysis, Spermatozoa.

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INTRODUCTION

Infertility is a major global health issue that affects approximately 10-12% of couples globally, with male factors accounting for over 50% of all instances[1]. Among the various reasons for male infertility, varicocele is one of the most common and medically treatable conditions[2,3]. A varicocele is when the veins in the scrotum become enlarged and twisted, which can affect how well the testicles work. It is present in 15% of all men, although it affects up to 40% of men who are screened for infertility[4].

Varicocele-induced infertility has a complex pathophysiology that includes hormonal abnormalities, oxidative stress, elevated scrotal temperature, hypoxia, and reflux of harmfuls[5]. These elements have a detrimental effect on spermatogenesis, leading to anomalies in sperm motility, concentration, and shape. Sperm morphology, or the size and form of sperm, has been regarded as one of the most important indicators of male reproductive potential among these [6,7]. Male infertility can be effectively treated by focusing on abnormal sperm morphology, which is linked to lower fertilization rates and lower-quality embryos [7].

Microsurgical varicocelectomy has emerged as the gold standard for surgical treatment of clinically significant varicocele due to its lower complication and recurrence rates than other techniques (such as laparoscopic or open non-microsurgical approaches) [8,9]. This technique involves the ligation of dilated veins under an operating microscope, which allows precise identification and preservation of critical structures such as the testicular artery and lymphatic system [9]. Following varicocelectomy, numerous studies have shown improvements in semen parameters, particularly sperm concentration [9,10]; however, the effect on sperm morphology has not always been reported in the literature.

Varicocele is a prevalent and potentially correctable cause of male infertility, yet its impact on specific semen parameters, particularly sperm morphology, remains a subject of debate [11,12]. While microsurgical varicocelectomy is widely regarded as the most effective surgical approach due to its precision and minimal complications, existing literature presents inconsistent findings regarding its influence on sperm morphology [13,14].

Since abnormal sperm shape is closely linked to lower chances of fertilization and worse reproductive results, it's important to determine if surgery can really enhance this aspect. We need to better understand sperm morphology as this is linked with predictive value within male fertility assessment, as well as predicting outcome with assisted reproductive technologies (ART). This association remains clinically relevant in determining the effect of microsurgical varicocelectomy on this factor more clearly. The objective of this study was to assess the effect of microsurgical varicocelectomy on the change in sperm morphology of male patients with diagnosed varicocele.

METHODS

This observational prospective study took place at the Institute of Kidney Diseases (IKD), Hayatabad Medical Complex, Peshawar, MTI, to assess the effect of microsurgical varicocelectomy upon sperm morphology in the infertility population diagnosed with and experiencing the clinical implications of grade II or III varicocele. The data collection period took place over 6 months from the 1st of September 2024 to the 28th of February 2025. The target population was infertile male patients in the age bracket of 20 to 45 years, determined and diagnosed with clinical varicocele (by clinical examination, grade II-III), as well as confirmed by Doppler ultrasonography. A non-probability consecutive sampling method was used in this study. All eligible patients who presented during the study period and fulfilled the inclusion criteria were enrolled sequentially until the required sample size was met.

The inclusion criteria were men with primary or secondary infertility of more than 12 months duration, clinical varicocele, abnormal sperm morphology and willingness to undergo microsurgical varicocelectomy and follow-up assessments. Patients were not included if they had a mild varicocele, had surgery on their varicocele or testicles before, had no sperm, known genetic issues, urinary infections, used hormone or antioxidant treatments recently (within 3 months), had long-term health problems, or could not attend follow-up visits.

The sample size was calculated using OpenEpi version 3.01. Considering a confidence level of 95%, power of 80%, and an expected prevalence of abnormal morphology of sperm of 78.0% in men with varicocele, the minimum required sample size was estimated to be 100[15]. To compensate for possible dropouts and enhance statistical power, a total of 112 patients were enrolled in the study.

Eligible patients underwent standard microsurgical subinguinal varicocelectomy, performed by a single experienced urologist using an operating microscope. This approach was selected to ensure precision and to minimize variability in surgical technique. Semen samples were collected at two specific time points: before surgery (baseline) and six months post-surgery.

Participants were advised to maintain a period of sexual abstinence for 2 to 7 days before each semen sample collection. Semen was collected by masturbation into sterile, wide-mouthed containers in a private room at the hospital. All samples were analyzed within one hour of collection in the andrology laboratory of the Institute of Kidney Diseases (IKD), Hayatabad Medical Complex, to ensure sample integrity.

Semen analysis followed the World Health Organization (WHO) Laboratory Manual protocols [16,17]. Sample collection and semen analysis were conducted in accordance with the procedures with particular emphasis on sperm morphology assessed using strict Tygerberg criteria under high-power microscopy [18,19]. Only sperm exhibiting a normal head, midpiece, and tail were considered morphologically normal. Other parameters of semen quality, such as sperm concentration (million/mL) and semen volume (mL), were assessed according to WHO (2021) and were assessed by trained andrologists, to ensure consistency, and to control for inter-observer reliability[16].

The independent variable for this study was microsurgical varicocelectomy, which was the clinical intervention that was sought to improve semen quality. It was introduced at baseline and was subsequently observed at individual 6-month semen analysis follow-ups. The primary dependent variable was sperm morphology, expressed as the percentage of sperm with normal morphology. The additional dependent variables were sperm concentration (million/mL) and semen volume (mL). These variables were documented through history, clinical examination, and Doppler ultrasonography at baseline. Stratification and subgroup analysis were conducted to explore whether these factors influence the parameters of semen post-surgery.

The Statistical Package for the Social Sciences (SPSS) version 26.0 was used to enter and analyze all of the data that was gathered. The study participants' demographic and baseline clinical parameters were compiled using descriptive statistics. Depending on the distribution's normality, continuous variables like age, sperm concentration, semen volume, and the proportion of morphologically normal sperm were either reported as medians with interquartile ranges (IQR) or as means ± standard deviation (SD). Frequencies and percentages were used to display categorical factors like laterality and varicocele grade.

A paired sample t-test was used for normally distributed continuous variables to compare mean values at baseline and six months after surgery to evaluate the impact of microsurgical varicocelectomy on semen characteristics, namely sperm morphology. The Wilcoxon signed-rank test was employed as a non-parametric substitute when the data did not have a normal distribution. The Chi-square test was employed to compare categorical data between groups (e.g., unilateral vs. bilateral varicocele). A p-value of less than 0.05 was deemed statistically significant.

The Institute of Kidney Diseases (IKD), MTI Hayatabad Medical Complex, Peshawar's Institutional Review and Ethical Committee approved the study on August 22, 2024, with Approval No. 1730. All participants were thoroughly informed about the study's goals, methods, possible advantages, and data confidentiality before giving their signed informed consent. The study was conducted with strict adherence to the Declaration of Helsinki's ethical guidelines.

RESULTS

The study included a total of 112 infertile male participants diagnosed with clinical varicocele. The mean age of the participants was 31.8 ± 5.4 years, indicating a relatively young adult population. The average duration of infertility was 3.3 ± 1.8 years, suggesting a prolonged period of reproductive concern before intervention. Most participants (n=77; 68.8%) had unilateral varicocele, while 35 (31.2%) presented with bilateral involvement. In terms of severity, 68 (60.7%) patients were diagnosed with Grade III varicocele, whereas 44 (39.3%) had Grade II varicocele, reflecting a higher proportion of advanced disease among the study cohort. These baseline features provide a detailed overview of the demographic and clinical characteristics of the patients who underwent

Table 1: Baseline Characteristics of Study Participants (n = 112).

Variable		Mean± SD/ n (%)
Age (years), mean ± SD	-	31.8 ± 5.4
Duration of Infertility (years)	-	3.3 ± 1.8
Laterality of Varicocele	Unilateral	77 (68.8%)
	Bilateral	35 (31.2%)
Grade of Varicocele	Grade II	44 (39.3%)
	Grade III	68 (60.7%)

Data are presented as mean ± standard deviation (SD) for continuous variables and as number (percentage) for categorical variables.

There was a statistically significant improvement in all semen parameters six months following microsurgical varicocelectomy. The mean percentage of morphologically normal sperm increased from 2.2 ± 1.3% at baseline to 5.7 ± 1.8% postoperatively. Sperm concentration also improved significantly, rising from a baseline mean of 12.6 ± 4.9 million/mL to 22.5 ± 7.4 million/mL at six months. The semen volume increased from 2.5 ± 0.8 mL to 3.0 ± 1.2 mL. These findings indicate substantial enhancements in both the structural and functional aspects of sperm after surgical intervention **Table 2**.

Table 2: Comparison of Semen Parameters at Baseline and 6 Months Post-Surgery (n = 112).

Semen Parameter	Baseline Mean ± SD	6 Months Post-op Mean ± SD	t-value	p-value
Sperm Morphology (% normal)	2.2 ± 1.3	5.7 ± 1.8	9.64	0.0001*
Sperm Concentration (million/mL)	12.6 ± 4.9	22.5 ± 7.4	doi: 10.51	0.0001*
Semen Volume (mL)	2.5 ± 0.8	3.0 ± 1.2	3.69	0.0003*

A paired t-test was used to compare mean values of semen parameters at baseline and 6 months post-surgery. *A p-value < 0.05 was considered statistically significant.

Stratified analysis revealed significant improvements in sperm morphology across all subgroups. Among participants aged ≤30 years, the mean percentage of morphologically normal sperm improved from 2.5 ± 1.3% at baseline to 6.5 ± 1.7% at six months post-surgery. In contrast, those aged >30 years showed an increase from 1.8 ± 1.4% to 4.9 ± 1.8%. Similarly, participants with a shorter duration of infertility (≤3 years) exhibited an improvement from 2.6 ± 1.2% to 6.4 ± 1.6%, while those with infertility lasting >3 years showed an increase from 1.8 ± 1.3% to 4.8 ± 1.8%. These findings suggest that younger age and shorter duration of infertility were associated with greater improvements in sperm morphology following microsurgical varicocelectomy (Table 3).

Table 3: Comparison of baseline characteristics with Change in Sperm Morphology at 6 Months Post-Surgery (n=112).

Variable		Baseline Mean ± SD	6 Months Post-op Mean ± SD	t-value	p-value
Age Group (years)	≤30 years	2.5 ± 1.3	6.5 ± 1.7	doi: 10.94	0.0001*
	>30 years	1.8 ± 1.4	4.9 ± 1.8	8.08	0.0001*
Duration of Infertility	≤3 years	2.6 ± 1.2	6.4 ± 1.6	12.01	0.0001*
	>3 years	1.8 ± 1.3	4.8 ± 1.8	4.73	0.0001*

Data are stratified by age and duration of infertility. Differences in mean sperm morphology from baseline to 6 months were analyzed using a paired t-test within each subgroup. *A p-value < 0.05 was considered significant.

Following microsurgical varicocelectomy, a downward trend was observed in both the proportion of bilateral varicocele and the higher-grade (Grade III) cases, although these changes did not reach statistical significance. Specifically, the percentage of patients with bilateral varicocele decreased from 31.2% (35) at baseline to 16.9% (19) at six months postoperatively, while unilateral cases dropped slightly from 68.8% (77) to 54.4% (61), p = 0.2544. Regarding severity, the proportion of Grade III varicoceles reduced from 60.7% (68) to 38.3% (43), whereas Grade II cases declined marginally from 39.3% (44) to 33.0% (37), p = 0.3353. These trends, although not statistically significant, suggest a clinical improvement in varicocele status after surgery **Table 4**.

Table 4: Laterality and Varicocele Grade at baseline and 6 Months Post-Varicocelectomy (n = 112).

Variable		Baseline n (%)	6 Months Post-op n (%)	Chi-square (χ^2)	p-value
Laterality	Unilateral	77 (68.8%)	61 (54.4%)	1.29	0.2544
	Bilateral	35 (31.2%)	19 (16.9%)		
Grade of Varicocele	Grade II	44 (39.3%)	37 (33.0%)	0.93	0.3353
	Grade III	68 (60.7%)	43 (38.3%)		

Association was tested using the Chi-square test. A p-value < 0.05 was considered statistically significant.

The horizontal clustered bar chart illustrates the improvement in semen parameters following microsurgical varicocelectomy. At 6 months post-surgery, a notable increase was observed across all measured parameters. These improvements suggest a positive impact of varicocelectomy on male reproductive potential over a 6-month follow-up period (**Figure 1**).

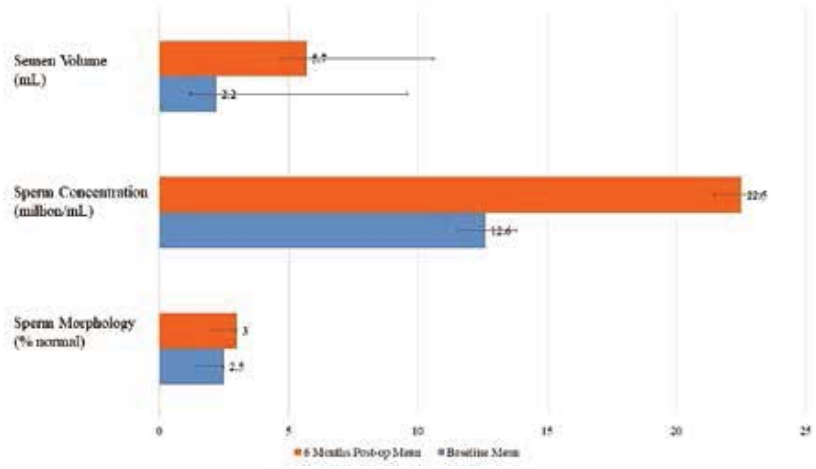

Figure 1: A Clustered Bar Chart showing the Comparison of Semen Parameters at Baseline and 6 Months Post-Surgery.

Orange and blue bars show the mean values, while black bars show the standard deviations.

DISCUSSION

This study evaluated the impact of microsurgical varicocelectomy on semen parameters in 112 infertile men with clinically diagnosed varicocele. The findings indicate significant postoperative improvements in sperm morphology, concentration, and semen volume, aligning with existing literature on the benefits of surgical intervention for male infertility due to varicocele.

The mean age of participants was 31.8 ± 5.4 years, and the average duration of infertility was 3.3 years. These findings are consistent with previous studies which reported a mean participant age of 29.6 ± 5.0 years[20], while another reported a mean age of 32.6 ± 4.4 years [21]. The majority (68.7%) of cases involved unilateral varicocele, while 31.2% had bilateral involvement. Comparable distributions were observed in the study which noted unilateral cases to be more prevalent, reinforcing the notion that left-sided or unilateral varicoceles are more commonly encountered clinically [22].

In terms of varicocele severity, Grade III was the most frequent (60.7%), suggesting late presentation and diagnosis, a trend also reported by another study which found higher-grade varicoceles to be more common in infertile populations, likely due to their more pronounced impact on testicular thermoregulation and venous reflux [23].

With sperm concentration increasing from 12.6 million/mL to 22.5 million/mL, sperm morphology improving from 2.2% to 5.7% normal forms, and semen volume increasing from 2.5 mL to 3.0 mL, postoperative examination showed notable changes in semen parameters. These results are consistent with a meta-analysis demonstrated that microsurgical varicocelectomy improves sperm quality and reproductive outcomes in a statistically significant way [24].

The observed postoperative increase in normal sperm morphology is particularly noteworthy. Prior research has highlighted morphology as a sensitive marker of varicocele-induced testicular damage [25]. Therefore, the notable morphological improvements documented here further highlight how well microsurgical methods work to reverse varicocele's harmful effects on spermatogenesis.

The stratified analysis demonstrated that younger age (≤30 years) and a shorter duration of infertility (≤ 3 years) were associated with more marked improvements in sperm morphology. Similar trends have been documented in the literature. A study reported that younger men and those with recent onset of infertility showed better recovery in sperm parameters post-surgery, possibly due to less chronic testicular damage and higher regenerative potential[26]. These findings suggest that early surgical intervention could yield more favorable reproductive outcomes. Therefore, clinicians should consider these variables when counseling patients about varicocelectomy.

One limitation of this study is the absence of a control group, which limits causal inference. Additionally, fertility outcomes such as pregnancy or live birth rates were not assessed. Future studies should include a control arm, longer follow-up duration, and more comprehensive outcomes to further substantiate the benefits of microsurgical varicocelectomy.

CONCLUSION

Among infertile males with clinical varicocele, microsurgical varicocelectomy produced statistically significant improvements in semen parameters. Younger patients and those with a shorter duration of infertility showed greater benefit. While changes in varicocele laterality and grading were observed postoperatively, they were not statistically significant. These findings support the use of microsurgical varicocelectomy as an effective intervention for male infertility, especially when performed early in the disease course.

LIST OF ABBREVIATIONS

ART: Assisted Reproductive Technologies
Cm: Centimeter
DNA: Deoxyribonucleic Acid
IKD: Institute of Kidney Diseases
IQR: Interquartile Range
mL: Milliliter

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CONFLICT OF INTEREST

The authors declare no conflict of interest related to this study.

ETHICAL APPROVAL

The ethical approval for the study was provided by the MTI-Hayatabad Medical Complex, Peshawar (No. 1730; Date: 22.08.2024).

AUTHORS' CONTRIBUTIONS

MAJ: Conceptualization, methodology, data collection, data analysis, manuscript drafting, supervision. **SF:** Data interpretation, literature review, manuscript drafting. **SZUR:** Data collection, patient follow-up, manuscript drafting, and critical review of the manuscript. **KUR:** Surgical intervention, clinical validation, manuscript drafting, manuscript review. **IK:** Statistical analysis, manuscript drafting, formatting, and final approval of the manuscript.

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