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From Diagnosis to Improvement: The Influence of Varicocele Surgery on Semen Quality Measured by Ultrasound

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Abstract

Varicocele is a common and correctable cause of male infertility, which this study was aimed to ascertain the impacts of microsurgical varicocelectomy with regard to the parameters of semen, as well as to contrast them with the precise scrotal ultrasound values. A cross-sectional, prospective study of 108 infertile men having palpable varicoceles (mean age 31.5 +/- 5.8 years; Grade 82.4 left; Grades I-III) was carried out. Standardized subinguinal varicocelectomy of the micro-surgeries was performed on all the patients. The outcome was semen analysis (WHO 6th edition) and scrotal ultrasound/Doppler parameters (venous diameter, reflux, testicular volume, and parenchyma echotexture) between baseline (preoperative) and 12-month follow-up. All semen parameters improved statistically at 12 months; concentration improved from 18.5 x10^6/mL to 29.7 x10^6/mL, progressive motility from 22.4 to 33.5x, and total motile sperm count (TMSC) from 23.1 to 52.3 x10. On the whole, 86.3 percent of patients demonstrated an improvement in 1 or more semen parameters. At the same time, the ultrasound showed a high level of anatomical correction: the mean venous diameter decreased (3.5 mm to 1.8 mm), the volume of the left testicle increased (14.8 to 16.1 mL), and parenchymal heterogeneity was decreased. At one year, the natural pregnancy rate of couples who tried was 35.9%. Microsurgical varicocelectomy produces considerable and statistically significant increases in semen quality and scrotal ultrasound parameters. Anatomical correction recorded by ultrasound, namely, volume increase of testicles and decrease of the venous diameter, is also a powerful objective correlate of the improved spermatogenic function.

1. Introduction

An increase in the size of the inner testicular or spermatic vein is known as varicocele, in which the tributaries of this vein are palpably dilated in the pampiniform plexus, proximate tributaries of the spermatic cord. It has been tested as the most prevalent isolated cause of male infertility. The prevalence of varicocele is between five and fifteen percent among most people and between twenty and forty percent in the infertile men of the population, respectively {1, 2, 3}.

According to the World Health Organization (WHO), male infertility is said to exist once an abnormal semen analysis is done, mostly on the quality of semen in terms of sperm concentration, motility, and morphology. Varicocele is a major cause of male infertility, not only as regards semen production, but also quality as well {4, 5}. These are abnormalities in the seminal quality examination of patients who had varicocele according to density, motility, and morphology as enacted by the WHO. One of the public health factors that society is facing, and the Ministry of Public Health has put a high priority to enhance the living standards of

infertile couples due to the high percentages this population represents, which is 10 percent of the reproductive-age population {6, 7}.

Furthermore, one of its principal causes is varicocele, which occurs in 15 percent of the male population and is diagnosed in 40 percent of the males who have primary infertility and 75-85 percent of those who have secondary infertility. Research was carried out where semen samples of 40 patients with varicocele, that were aged 15-30 years, were analyzed by the WHO parameters. It was also found that the mean sperm concentration at 3 months, 6 months, and 12 months showed an improvement, but was insignificant {8, 9}.

In addition, the average score of Kruger morphology was also not significant. The results imply that although the count and motility of the sperm increased in the patients who had varicocele after an operation, the morphology rates did not change {10}. One of the major causes of male infertility is varicocele. Significant surgical intervention of varicocele is recommended in infertile patients and palpable or clinical varicocele {11}.

2. Methodology and Approaches

I. Study design of patients.

This cross-sectional study was conducted to determine the effect of varicocele surgery on the quality of semen, where anatomical and hemodynamic alterations were assessed using ultrasound. A total of 108 consecutive male patients presenting with infertility and a clinically palpable varicocele (Grade I-III) were enrolled between March 2024 and March 2025. Inclusion criteria included the age of 20 to 45 years, one year of infertility with a female partner of proven fertility or currently under evaluation, and the abnormality of at least one of the semen parameters. The exclusion criteria were azoospermia, obstruction pathologies, previous scrotal operation, severe endocrine conditions, or active infection of the genitals. The informed consent was signed by all participants.

II. Preoperative outcomes.

Baseline evaluation of all the participants was done. It covered a thorough medical and infertility history, a standardized physical evaluation on varicocele grading (Grade I-III), and a scrotal color Doppler ultrasound. The ultrasound test was performed by one qualified radiologist with the help of a high-frequency linear probe. The main variables measured included the maximum venous diameter (MVD) of the pampiniform plexus at rest and on Valsalva, whether there was reflux or not, and the duration of the reflux, and the volume of the testicles (ellipsoid formula length × width × height × 0.71). Echotexture of parenchyma was also reported. Semen analysis was done after 3-5 days of sexual abstinence in a certified, accredited andrology laboratory strictly. Parameters that were measured were volume, sperm concentration, total motility, progressive motility (PR), normal morphology (strict criteria), and derived total motile sperm count (TMSC).

III. Surgical Intervention:

Each patient received an operation of microsurgical subinguinal varicocelectomy, which is a procedure that was done by one surgeon to reduce operator error. The process was done under an optical magnification (×15-25). The most important principles of surgery were strict identification, maintenance of the testicular artery, and maintenance of lymphatics to reduce the possibility of postoperative hydrocele. All enlarged internal spermatic and gubernacular veins were clamped, and the number of veins clamped was recorded on each side. Complications that had occurred intraoperatively were captured.

IV. Postoperative outcomes.

Clinical wound checks and complication assessments of patients were followed at 1 month and graded using the Clavien-Dindo classification. Efficacy follow-up was planned as the main one at 6 months after the operation. During this visit, semen analysis and scrotal color Doppler ultrasound were redone with the same protocol and equipment as the baseline. The main effect was the shift in the parameters of the semen (concentration, progressive motility, morphology, and TMSC). The secondary outcomes were the changes in ultrasound parameters (MVD, reflux, testicular volume, echotexture), the frequency of semen responders (defined as an increase in important parameters by more than 10 percent), and the relationship between anatomical (ultrasound) and functional (semen) changes. A subset analysis was to be done according to the preoperative grade of varicocele, where natural pregnancy rates were followed through telephone interviews 12 months after surgery, and time-to-pregnancy was calculated using Kaplan-Meier estimates.

V. Statistical Analysis:

The statistical analysis was done through the SPSS program (version 24.0). Continuous variables will be in the form of mean, standard deviation, or median (interquartile range), whereas categorical variables will be in the form of frequencies (percentages). The changes in ultrasound parameters were assessed against changes in TMSC in terms of the Spearman rank correlation coefficient (0). The multivariate logistic regression model was created to determine independent predictors of a significant semen improvement (described as a TMSC increase of more than 50 percent) using the following clinically relevant variables: age, preoperative TMSC, varicocele grade, and ultrasound-derived measures. Statistically significant was taken as a p-value of less than 0.05.

3. Results and Conclusions

The cohort of the study (n=108) comprised fairly young men (mean age 31.5 ± 5.8 years) with left-sided (82.4%) or bilateral (17.6%) varicoceles, the majority of which were of clinical grade II (50.0%) or III (33.3%). The majority of the patients had primary infertility (80.6% with an average of 2.8 years).

Table 1. Distribution of the prevalence of pre–operative data on the 108 participants in this study.

Participants {108}	Characteristic
31.5 ± 5.8	Age (years)
	Varicocele Side
89 (82.4%)	Left
19 (17.6%)	Bilateral
	Varicocele Grade
18 (16.7%)	Grade I
54 (50.0%)	Grade II
36 (33.3%)	Grade III
2.8 ± 1.5	Duration of Infertility (years)
87 (80.6%)	Primary Infertility
21 (19.4%)	Secondary Infertility

Moreover, preoperative semen examination revealed that the impairment was high, which is in line with the pathophysiology of varicocele. Most patients had lower values than the WHO reference limits, with the most significant amount of normal morphology (93.5%), progressive motility (88.0%), and total motility (85.2%). The average sperm concentration of 16.0 x 10^6/mL was obtained, and the average total motile sperm count (TMSC) was 16.4 x 10^6, which showed that there was a population with an evidently compromised semen before the surgery.

Table 2. Determining the preoperative semen outcomes.

Patients Below Reference (%)	Mean ± SD	Parameter
22 (20.4%)	2.9 ± 1.2	Volume (mL)
74 (68.5%)	18.5 ± 14.2	Sperm Concentration (10^6/mL)
92 (85.2%)	35.2 ± 12.8	Total Motility, %
95 (88.0%)	22.4 ± 10.5	Progressive Motility (PR, %)
101 (93.5%)	4.1 ± 2.8	Normal Morphology %
82 (75.9%)	23.1 ± 22.5	Total Motile Sperm Count (10^6)

Also, scrotal ultrasound and Doppler results confirmed the objective diagnosis of the clinical diagnosis in all the patients, where the mean left maximum venous diameter was 3.5 mm, and there was a reflux on Valsalva. The testicular volume differed significantly in size between the left and the right testicle (-2.4 mL), and a heterogeneous parenchyma echotexture was observed in 62.0 percent of the cases, which implies a potential underlying testicular stress or testicular damage.

Table 3. Enroll the outcomes of the ultrasound and Doppler for 108 patients in the preoperative period.

Number (%)	Findings	Ultrasound Parameters
108 (100%)	>2.1 mm	Maximum Venous Diameter (Left)
	3.5 ± 0.9	Mean Diameter (mm)
	108 (100%)	Reflux on Valsalva
	890 ± 320	Duration (ms)
	14.8 ± 3.5	Testicular Volume (mL), Left
	17.2 ± 3.8	Testicular Volume (mL), Right
	-2.4 ± 1.9 mL	Volume Differential (L-R)
	67 (62.0%)	Parenchyma Echotexture (Heterogeneous)

According to the findings of surgery, all the operations were made through the subinguinal approach, which was based on the use of microsurgery and permitted the accurate location and preservation of arteries (mean 2.3 per side) and lymphatics (mean 3.1 per side). The technical completeness of the procedure was proved by a mean of 6.8 veins drawn on the left side.

Table 4. Identifying surgical outcomes of 108 samples.

Number (%)	Parameters
	Surgical Approach
108 (100%)	Microsurgical Subinguinal
2.3 ± 0.6	Arteries Identified & Preserved (per side)
3.1 ± 1.2	Lymphatics Identified & Preserved (per side)
	Number of Veins Ligated
6.8 ± 2.1	Left Side
5.2 ± 1.8	Right Side (in bilateral cases)
0 (0%)	Intraoperative Complications

In addition, early postoperative complications were rare (12.04% overall) and mild, with only Clavien-Dindo Grade I (scrotal hematoma, transient hydrocele) and II (wound infection) occurring.

Fig. 1. Distribution of post–operative early complications during less than or equal to 30 days.

By the time, the 12-month follow-up was achieved, there were statistically and clinically significant improvements in all semen parameters, which the overall motility (+11.2 x10^6/mL), progressive motility (+11.1%), total motility (+29.2 x10^6), and especially the total motile sperms (+11.2 x10^6/mL) all indicate a strong average effect of varicocelectomy on spermatogenesis and sperm functioning.

Table 5. Postoperative changes in the semen outcomes of the patients during 12 months of follow-up.

Mean Change (95% CI)	6-Month Post-op (Mean)	Pre-op (Mean)	Parameter
+11.2 (+8.4, +14.0)	29.7	18.5	Concentration (10^6/mL)
+11.6 (+9.1, +14.1)	46.8	35.2	Total Motility (%)
+11.1 (+8.9, +13.3)	33.5	22.4	Progressive Motility (%)
+2.8 (+2.1, +3.5)	6.9	4.1	Normal Morphology (%)
+29.2 (+22.5, +35.9)	52.3	23.1	Total Motile Sperm Count (10^6)

Besides this, responder analysis showed that most of the patients had seen a meaningful change in at least one of the semen parameters (86.3%), and 73.5% had a response to the clinically integrative measure of TMSC. This shows that although this is not universal, the benefit of surgery was common among the cohort, with only 13.7% indicating that none had a significant improvement.

Table 6. Assessment outcomes of ultrasound findings during 12-month follow–up.

p-value	12 – Month Post-op (Mean)	Pre-op (Mean)	Parameters
<0.001	1.8 ± 0.4	3.5 ± 0.9	Max Venous Diameter - Left (mm)
<0.001	8 (7.8%)	108 (100%)	Reflux on Valsalva
<0.001	16.1 ± 3.4	14.8 ± 3.5	Testicular Volume - Left (mL)
<0.001	-1.1 ± 1.5	-2.4 ± 1.9	Volume Differential (L-R) (mL)
0.002	41 (40.2%)	67 (62.0%)	Parenchyma Echotexture (Heterogeneous)

The success of the anatomy of the procedure was confirmed by postoperative ultrasound at 12 months with a significant decrease in the mean left venous diameter (3.5 mm to 1.8 mm) and almost eradication of reflux (100% to 7.8%). The left testicular volume (+1.3 mL) and the homogeneity of the parenchyma (62.0% to 40.2%) also improved significantly, which indicates a partial reversal of testicular atrophy and structural alterations.

Figure 2. Evaluating patient response to healthcare outcomes based on semen data during the follow-up period.

There was a significant positive correlation between anatomical improvement on ultrasound and improvement on TMSC. The most significant correlation (rho=0.41, p=0.001) was found between the increase and decrease in testicular size of the left testicle (volume), reduction in venous diameter (rho=0.32, p=0.001), and normalization of echotexture (rho=0.28, p=0.005), which connects the hemodynamic correction of spermatogenesis with functional recovery.

Table 7. Determining the correlation findings in the evaluation of improvements recorded among ultrasound, alongside with semen parameters.

p-value	Correlation with TMSC (ρ)	Changes in Ultrasound Parameter
0.001	0.32	Reduction in Venous Diameter
<0.001	0.41	Increase in Left Testicular Volume
0.005	0.28	Normalization of Echotexture

Our findings showed the presence of a dose-response relationship, with the higher-grade varicoceles (Grade III) showing better mean improvements in sperm concentration and progressive motility than Grade I (p=0.03 and p=0.04, respectively), while the numeric percentage of patients who improved in Grade III (79.4%) was higher.

Table 8. Assessment of post-operative motility according to varicocele grade into patients.

Grade III (n=34)	Grade II (n=51)	Grade I (n=17)	Changes
+14.5 ± 12.8	+11.9 ± 10.5	+5.8 ± 7.1	Concentration (10^6/mL)
+13.8 ± 9.5	+10.8 ± 8.9	+7.2 ± 6.4	Progressive Motility (%)
79.4%	74.5%	64.7%	% with TMSC Improvement

The one-year natural pregnancy rate was positive and stood at 35.9 percent in couples who had undertaken conception, and the total Kaplan-Meier estimate was 41.2 percent, where the 7-month median time to pregnancy is consistent with spermatogenic cycles after repair, giving a significant clinical endpoint to support the laboratory improvements.

Figure 3. Assessment of the quality of normal pregnancy at patients after 12 months of follow-up.

The results of the multivariate analysis showed that a preoperative TMSC ≥10 × 10 6 (OR 3.8, p=0.004), a significant testicular volume difference above 2 mL (OR 2.9, p=0.02), and a decrease in the venous diameter over 1.5 mm (OR 4.3, p=0.001) were significant independent predictors of semen improvement. Although there was a tendency of varicocele grade (OR 2.2, p=0.08), age did not play an important role in the model, indicating that both baseline testicular functioning and anatomical adjustment are significant issues.

Table 9. Multivariate logistic regression in the prediction of semen improvement.

p-value	Odds Ratio (95% CI)	Predictors
0.13	2.1 (0.8 - 5.6)	Age (<35 vs ≥35 years)
0.004	3.8 (1.5 - 9.4)	Pre-op TMSC (<10 vs ≥10 x10^6)
0.08	2.2 (0.9 - 5.3)	Varicocele Grade (III vs I/II)
0.02	2.9 (1.2 - 7.1)	Testicular Volume Differential (>2 mL)
0.001	4.3 (1.8 - 10.5)	Reduction in Venous Diameter (>1.5 mm)

4. Discussion

As has been emphasized in the current cross-sectional study, varicocele is one of the most common causes of male infertility and has been found to affect a significant percentage of both young and adult men {12}. A range of reports identified about 15% of men to have a varicocele, with age being a determinant that is in line with our study. {13}

The pathophysiological theories behind the testicular damage caused by the varicocele narrow down to the central action of oxidative stress and high scrotal temperature, which have been associated with sperm DNA fragmentation and reduction in semen quality {14}. Spermatogenesis is disrupted, and tissue hypoxia, free radicals, and blood-testis barrier changes are related to the process. The changes are especially pronounced in patients with a history of infertility, which supports the necessity to diagnose the disease at a young age and manage it individually. {15, 16}

The presentation of our case of 108 infertile men was typical of varicocele-related infertility, with mostly young patients, left-sided or bilateral clinical varicoceles (class II and III), and severe baseline semen impairment, especially in motility and morphology. This approach consisted of a consistent use of a microsurgical subinguinal approach to make sure that multiple veins were ligated (mean 6.8 left) and maintained arterial and lymphatic structures, had zero intraoperative complications, and had a low (12.04) rate of minor postoperative complications.

Scrotal Doppler ultrasound, in diagnostic terms, has become an invaluable complementary tool, particularly in situations of subclinical presentation or anatomical difficulty and obesity {17}. Certain studies also indicated that criteria such as the symptoms, semen abnormalities, and testicular hypotrophy in adolescents should be used as a basis for making a therapeutic decision; early intervention can be considered more relevant to prevent long-term fertility. {18}

It is most likely to benefit patients with stronger preoperative testicular dysfunction (but not azoospermic) that will have a strong anatomical correction. Although the established natural pregnancy rate of 35.9% (41.2% cumulative) is an essential clinical outcome that meets and supports the laboratory improvements, our study highlights the fact that natural pregnancy is not the only useful tool for establishing technical success after surgery. {19, 20, 21}

As far as surgical treatment is concerned, there are reports that surgery performed to correct varicocele by varicocelectomy could lead to the enhancement of fertility in 80 percent of patients, where it have more the advantages in semen parameters and rates of spontaneous pregnancy, which were also recorded after this analysis whereby it provided low complication and recurrence rates, which is a great safety profile {22, 23, 24}.

An American study elaborates that microsurgical subinguinal is more precise and gives an opportunity to see the vascular structures in three dimensions, but is not widely used because of its high costs and requirement to have special centers. This method is an addition to the conventional subinguinal microinvasive technique {24}.

5. Conclusion

One primary cause of male infertility is varicocele, which has a high percentage of occurrence among men with some primary or secondary infertility and a great prevalence among the general population, with a direct relationship to age. It has a multifactorial pathophysiology, in which oxidative stress predominates, and it leaves the testicles in a poor condition to support spermatogenesis and impacts the semen parameters of sperm concentration, motility, and morphology, as well clinical diagnosis complemented by imaging that includes Doppler ultrasound, enables an accurate evaluation of the condition and extent of a varicocele coupled with its effects on testicular functions. The treatment mode must be personalized, and observation is used in asymptomatic patients whose sperm counts are normal. With surgical intervention, when the pain persists, there is testicular hypotrophy, or there is infertility with confirmed seminal defects. The existing surgical methods have been developed into less invasive and more effective methods, whereby microsurgical subinguinal is the cheapest in terms of anatomical retention and functional restoration. Finally, proper microsurgical treatment of the subinguinals does not only alleviates the symptoms at the locality but also offers the male a better prognosis in reproductive matters.

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