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ORIGINAL RESEARCH

Impact of microscopic varicocelectomy on semen parameters and fertility outcomes

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Abstract

Background: This study aimed to evaluate the postoperative changes in semen parameters and natural pregnancy rates following microsurgery performed for male infertility in a single tertiary center. **Methods**: Between November 2017 and January 2024, 168 subfertile men with clinically palpable varicocele and at least one year of infertility history underwent microsurgery under spinal anesthesia. Patients with confounding conditions such as cryptorchidism, genital infections, prior scrotal surgeries, or female partner factors impairing fertility were excluded. Preoperative and postoperative semen analyses (1–3 months before and 6–8 months after surgery) were performed according to The World Health Organization guidelines. Semen parameters assessed included sperm concentration, progressive motility, and morphology. Patients were followed for at least 12 months postoperatively, and pregnancy outcomes (spontaneous or assisted reproductive technology were recorded. **Results**: The mean age of participants was 29.5 ± 4.6 years. The majority had Grade II or III varicocele, and 58.3% presented with left-sided varicocele. Postoperatively, significant improvements were observed in all semen parameters: median sperm concentration increased from 12.5 to 18 million/mL ($p < 0.001$), progressive motility improved from 25.74% ± 11.32% to 29.33% ± 7.72% ($p < 0.001$), and morphologically normal sperm percentage increased from 1% to 3% ($p < 0.001$). Overall, 96.4% of patients achieved successful paternity; 80.8% conceived spontaneously while 19.2% required assisted reproductive technology. The mean time to conception was 22.0 ± 5.7 months. **Conclusions**: Microsurgical subinguinal varicocelectomy was associated with improvements in semen parameters and high subsequent natural pregnancy rates in men with clinical varicocele. These findings support microsurgical subinguinal varicocelectomy as a reasonable first-line surgical option in appropriately selected patients, while recognizing that the need for assisted reproductive technology may still arise. Further multicenter studies are warranted to confirm long-term reproductive outcomes and refine patient selection.

Keywords

Infertility; Varicocele; Varicocelectomy; Semen; Spermiogram; Microsurgery

Impacto de la varicocelectomía microscópica en los parámetros seminales y los desenlaces de fertilidad

Resumen

Antecedentes: Este estudio tuvo como objetivo evaluar los cambios posoperatorios en los parámetros seminales y las tasas de embarazo natural tras la microcirugía realizada por infertilidad masculina en un único centro terciario. **Métodos**: Entre noviembre de 2017 y enero de 2024, 168 varones subfértiles con varicocele clínicamente palpable y al menos un año de historial de infertilidad se sometieron a microcirugía bajo anestesia espinal. Se excluyeron los pacientes con condiciones de confusión como criptorquidia, infecciones genitales, cirugías escrotales previas o factores de la pareja femenina que afectaran la fertilidad. Los análisis seminales preoperatorios y posoperatorios (1–3 meses antes y 6–8 meses después de la cirugía) se realizaron conforme a las directrices de la Organización Mundial de la Salud. Los parámetros seminales evaluados incluyeron concentración espermática, motilidad progresiva y morfología. Los pacientes fueron seguidos durante al menos 12 meses en el posoperatorio y se registraron los desenlaces de embarazo (espontáneo o mediante técnicas de reproducción asistida). **Resultados**: La edad media de los participantes fue de 29.5 ± 4.6 años. La mayoría presentaba varicocele de grado II o III, y el 58.3% tenía varicocele izquierdo. En el posoperatorio se observaron mejoras significativas en todos los parámetros seminales: la mediana de la concentración espermática aumentó de 12.5 a 18 millones/mL ($p < 0.001$), la motilidad progresiva mejoró de 25.74% ± 11.32% a 29.33% ± 7.72% ($p < 0.001$) y el porcentaje de espermatozoides morfológicamente normales aumentó de 1% a 3% ($p < 0.001$). En conjunto, el 96.4% de los pacientes logró paternidad; el 80.8% concibió de forma espontánea y el 19.2% requirió técnicas de reproducción asistida. El tiempo medio hasta la concepción fue de 22.0 ± 5.7 meses. **Conclusiones**: La varicocelectomía subinguinal microscópica se asoció con mejorías en los parámetros seminales y con altas tasas posteriores de embarazo natural en varones con varicocele clínico. Estos hallazgos respaldan a la varicocelectomía subinguinal microscópica como una opción quirúrgica de primera línea razonable en pacientes apropiadamente seleccionados, reconociendo que la necesidad de técnicas de reproducción asistida puede seguir siendo necesaria en algunos casos. Se precisan estudios multicéntricos adicionales para confirmar los resultados reproductivos a largo plazo y optimizar la selección de candidatos.

Palabras Clave

Infertilidad; Varicocele; Varicocelectomía; Semen; Seminograma (espermograma); Microcirugía

1. Introduction

Infertility is defined as the inability of a couple to achieve pregnancy despite having regular, unprotected sexual intercourse for at least one year which affects approximately 15% of couples worldwide and concerns more than 20 million men [1]. Male factors are responsible, either solely or in combination, for about half of all infertility cases [2]. The main causes of male infertility include erectile dysfunction, genital infections, hormonal imbalances, immunological disorders, genetic anomalies, and varicocele [3]. Varicocele is characterized by the dilation, elongation, and tortuosity of the pampiniform plexus veins due to structural abnormalities [4]. This venous insufficiency may lead to testicular pain, impaired function, and in advanced cases, testicular atrophy [5]. Varicocele is the most common and surgically or endovascularly correctable cause of male infertility [6]. While it is observed in approximately 10–15% of the general male population, its prevalence increases to 30–40% among men diagnosed with primary infertility [7].

Etiologically, varicoceles are commonly classified as primary—caused by valvular incompetence and anatomic factors—and secondary—resulting from extrinsic venous obstruction [8]. Congenital anatomical abnormalities such as nutcracker syndrome, weak venous wall structure, or insufficient valvular function [5]. Acquired environmental and lifestyle factors, including prolonged standing, physical inactivity, and increased intra-abdominal pressure due to intense exercise, all of which can impair venous return and result in reflux [9]. Rare pathological conditions, such as intra-abdominal masses that cause secondary varicoceles by compressing the spermatic vein externally [10].

In adult men, there are two primary indications for varicocele surgery. Chronic testicular pain or cramp-like discomfort, and abnormal semen analysis findings in men experiencing infertility [2]. Additionally, surgical intervention may be recommended in cases of decreased testicular function, testicular atrophy, non-obstructive azoospermia, low semen quality prior to assisted reproductive techniques (ART), sperm DNA fragmentation, or increased oxidative stress [11].

Management of clinically significant varicocele focuses on definitive correction of venous reflux—most commonly microsurgical subinguinal varicocelectomy or radiologic embolization—while lifestyle/expectant measures serve only as adjuncts; pharmacologic or antioxidant therapy does not provide a definitive solution to this anatomical condition [3, 8].

Among surgical methods, MV is increasingly favored due to its minimally invasive nature, low complication and recurrence rates, significant improvements in postoperative semen parameters (SP), and positive effects on fertility [6, 12]. This technique is typically performed via inguinal or subinguinal approaches. The microsurgical subinguinal varicocelectomy (MSV) offers advantages such as utilizing the superficial anatomy of the spermatic cord, avoiding dissection of the external oblique muscle, and the possibility of performing the procedure under local anesthesia. As a result, surgical trauma is minimized, and recovery time is shortened. However, due to the higher number of venous structures and the presence of fine-caliber testicular arteries, intraoperative Doppler assistance is often required in this approach, which may lead to a prolonged operative time [13].

At our center, the MSV technique is routinely preferred for the treatment of male infertility. In this study, we present our follow-up outcomes regarding the postoperative changes in SP and natural pregnancy rates following this surgical procedure.

2. Materials and methods

2.1 Patients

Between November 2017 and January 2024, a total of 168 subfertile male patients underwent MSV under spinal anesthesia at our center. Eligible participants were men with a history of infertility for at least one year, clinically palpable varicocele confirmed on physical examination, and significantly abnormal SP documented in at least two separate semen analyses. Exclusion criteria involved: cryptorchidism, testicular trauma, testicular torsion, genital infections (*e.g.*, prostatitis, seminal vesiculitis, urethritis), presence of leukocytospermia; reproductive system malformations or absence of vas deferens; history of previous scrotal or varicocele surgery; and known genetic abnormalities. Couples were also excluded if the female partner had tubal obstruction or ovulatory dysfunction. Additionally, couples were excluded if they met any of the following criteria. History of spontaneous miscarriage in the female partner within the year prior to surgery. Inability to maintain regular sexual intercourse postoperatively due to contraceptive use or other reasons. The presence of serious reproductive pathologies, such as chromosomal abnormalities.

2.2 Preoperative evaluation

All varicoceles were graded using the Dubin and Amelar classification system, with grade I varicoceles being palpable only with Valsalva, grade II varicoceles being palpable without Valsalva, and grade III varicoceles being readily visible through the scrotal skin; subclinical varicoceles were not included [14]. All MSVs were performed by the same surgeon. Varicocele diagnosis was based on palpation and scrotal ultrasonography findings. Color Doppler ultrasonographic criteria included: a resting internal spermatic vein diameter >2 mm, significant increase in venous diameter with increased intra-abdominal pressure, or retrograde venous flow observed during the Valsalva maneuver [3].

For semen analysis, patients were instructed to maintain 3–5 days of sexual abstinence. Semen samples were analyzed according to the World Health Organization criteria [15].

Patients received counseling on treatment options, costs, and potential complications. Options included varicocelectomy and ART such as intrauterine insemination (IUI) and in vitro fertilization (IVF). Data obtained via telephone follow-up were recorded in the patients' medical records and archived as part of clinical follow-up. The primary outcomes of the study were changes in SP, pregnancy rates (spontaneous and ART-assisted), and the frequency of ART usage.

All patient data were evaluated in accordance with confidentiality principles and used solely within the institution. Demographic and clinical data were recorded, including the age of both partners, duration and type of infertility (primary or secondary), body mass index (BMI), side of varicocelectomy, and varicocele grade. All patients were followed for at least one year. During follow-up, changes in SP, pregnancy outcomes, time to conception, and need for ART were documented.

2.3 Semen analysis

Almost all men underwent at least two semen analyses pre- and postoperatively. To minimize potential inter-laboratory variability, only semen analyses performed at the same laboratory 1–3 months before and 6–8 months after surgery were included in the data analysis.

Samples were collected via masturbation following 3–5 days of sexual abstinence. After liquefaction, standard SP (volume, concentration, motility, morphology) were evaluated [16].

2.4 Surgical technique

All patients underwent MSV with preservation of testicular arteries and lymphatics. Briefly, a 2–3 cm skin incision was made just inferior to the external inguinal ring. The testis was delivered into the operative field, and all external and gubernacular veins were ligated. Under operating microscope magnification ($6\times$ to $25\times$), the internal and external spermatic fasciae were incised, and the testicular artery and lymphatics were carefully identified and preserved. All internal and external spermatic veins were ligated or clipped and transected. The vas deferens and accompanying vascular structures were preserved. Veins of the vas deferens with a diameter ≥ 2 mm were ligated and excised [17].

2.5 Postoperative evaluation

Postoperative semen analyses were conducted 6–8 months after surgery [18, 19]. The time to achieve live-birth pregnancy was recorded and classified according to the mode of conception—natural intercourse or ART. ART included IVF and IUI procedures. Patient data were kept confidential and used exclusively within the institution.

2.6 Statistical analysis

Distribution of paired differences was assessed with the Shapiro-Wilk test. Sperm concentration and morphology were non-normal and are presented as median (interquartile range, IQR); pre- *vs.* post-operation comparisons used the Wilcoxon signed-rank test. Progressive motility satisfied normality and is presented as mean $\pm$ standard deviation (SD); comparisons used the paired-samples t-test. Analyses used paired observations only, two-sided p values (with values < 0.001 shown as $p < 0.001$). Units for sperm concentration are $\times 10^6$/mL.

3. Results

A total of 168 male patients were included in the study. The mean age of the participants was 29.5 ± 4.6 years (range: 18–

44), with a mean BMI of 25.76 ± 2.3 kg/m^2 (range: 21.2–31.3). The mean age of their female partners was 26.5 ± 4.0 years (range: 19–40), and their mean BMI was 24.4 ± 3.2 kg/m^2 (range: 16.4–33.8). Regarding the clinical characteristics, the majority of patients had Grade II (41.1%) or Grade III (38.7%) varicocele, while 20.2% had Grade I. Varicocele was left-sided in 58.3% of cases and bilateral in 41.7%. Primary infertility was present in 84.5% of the patients, whereas 15.5% had secondary infertility. The median duration of infertility was 18.0 months, ranging from 12 to 84 months (Table 1).

There was a statistically significant improvement in all evaluated semen parameters following surgery (Table 2). The median sperm concentration increased from 12.5 × 10^6/mL preoperatively to 18 × 10^6/mL postoperatively ($p < 0.001$, Wilcoxon signed-rank test). Similarly, the percentage of morphologically normal sperm improved from a median of 1% to 3%, which was also statistically significant ($p < 0.001$, Wilcoxon signed-rank test). In contrast, progressive sperm motility, which was normally distributed, showed a significant increase from 25.74% ± 11.32% to 29.33% ± 7.72% after surgery ($p < 0.001$, paired-samples t-test).

Following MSV, successful paternity was achieved in 162 patients (96.4%), while 6 patients (3.6%) remained infertile during the follow-up period. Among those who achieved paternity, 131 (80.8%) conceived spontaneously and 31 (19.2%) required ART, and the mean time to conception was 22.0 ± 5.7 months (Table 3).

Complications were relatively rare. Two patients (1.2%) developed a superficial wound infection; the incision was opened and allowed to heal via secondary intention. Two men (1.2%) of the patients developed epididymitis, accompanied by fever, and were treated with antibiotics. One patient (0.6%) exhibited an inadvertent arterial injury during surgery; however, his postoperative total motile count remained unchanged, and he did not develop testicular atrophy. Finally, one patient (0.6%) exhibited a recurrence of the varicocele at the 12-month follow-up. In this particular case, however, the patient had already achieved conception, and thus no treatment was given for the recurrence. No patient developed a hydrocele.

4. Discussion

4.1 Key findings

In this single-centre cohort of 168 men with clinical varicocele, MSV was associated with improvements across SP—higher sperm concentration, better progressive motility, and improved morphology—and high subsequent paternity, most by spontaneous conception. These observations align with prior randomized and observational evidence that surgical repair in carefully selected men can improve semen quality and reproductive outcomes [18, 20, 21]. While effect sizes vary across studies, our findings reinforce that benefit is most apparent when preoperative SP are abnormal and clinical varicocele is present [3].

TABLE 1. Demographic characteristics of the study population.

Variable	Mean ± SD/n (%)	Range
Age (yr)	29.5 ± 4.6	18–44
Body mass index, BMI (kg/m^2)	25.76 ± 2.3	21.2–31.3
Partner's age (yr)	26.5 ± 4.0	19–40
Partner's BMI (kg/m^2)	24.4 ± 3.2	16.4–33.8
Varicocele grade		
Grade I/Grade II/Grade III	34 (20.2%)/69 (41.1%)/65 (38.7%)	-
Varicocele side		
Left/Bilateral	98 (58.3%)/70 (41.7%)	-
Type of infertility		
Primary/Secondary	142 (84.5%)/26 (15.5%)	-
Duration of infertility (mon)	18.0 (median)	12–84

SD: standard deviation; BMI: body mass index.

TABLE 2. Changes in semen parameters before and after microsurgical varicocelectomy.

Variable	Preoperative	Postoperative	p value
Sperm concentration (×10^6/mL)	12.5 (IQR: 8–20)	18 (IQR: 15–25)	<0.001*
Progressive motility (%)	25.74 ± 11.32	29.33 ± 7.72	<0.001**
Morphologically normal sperm (%)	1 (IQR: 0–2)	3 (IQR: 2–4)	<0.001*

*Variables presented as median (IQR) for sperm concentration and morphologically normal sperm, and as mean ± SD for progressive motility. p values are two-sided (values < 0.001 shown as p < 0.001). *Wilcoxon signed-rank test; **paired-samples t-test. IQR: interquartile range.*

TABLE 3. Fertility outcomes following varicocelectomy.

Variable	Mean ± SD/n (%)
Paternity outcome	
Successful/Unsuccessful	162 (96.4%)/6 (3.6%)
Type of conception	
Spontaneous/ART	131 (80.8%)/31 (19.2%)
Time to conception following surgery (mon)	22.0 ± 5.7

ART: assisted reproductive techniques; SD: standard deviation.

4.2 Relationship to prior literature

The predominance of Grade II–III disease and the sizeable bilateral rate reflect typical surgical series focused on clinically significant lesions [22, 23]. Consistent with meta-analytic data, higher grades and bilateral involvement are generally linked to more pronounced baseline impairment and a greater likelihood of postoperative gain in SP and pregnancy potential [24, 25]. Our motility gains were modest compared with concentration and morphology—an observation reported elsewhere and possibly explained by slower recovery trajectories or heterogeneous sensitivity of motility to venous reflux correction [26, 27]. Overall, the pattern of change we observed aligns with the literature: concentration and morphology often improve earlier and more clearly; motility may lag but can still carry meaningful clinical impact when combined with increased total sperm output [14, 28].

4.3 Clinical implications

The demographic profile (younger age, mostly non-obese BMI), high proportion of Grade II–III/bilateral disease, and abnormal baseline SP describe patients most likely to benefit from MSV [3, 29]. Routine use of artery- and lymphatic-sparing technique and intraoperative Doppler likely supported low complication/recurrence rates and may have preserved functional gains [17, 30]. Practically, these data support offering MSV as a first-line surgical option to appropriately selected subfertile men with clinical varicocele before proceeding to assisted reproduction, with the caveat that individual response varies with grade, laterality, baseline SP, and partner factors [3, 20].

4.4 Strengths

Key strengths include a uniform surgical approach by the same team, standardized pre/post semen testing in the same laboratory and windows (1–3 months pre-op, 6–8 months post-op), and ≥12-month follow-up for pregnancy outcomes. The large proportion achieving paternity—predominantly spontaneous—provides functional corroboration of laboratory changes and reduces sole reliance on surrogate endpoints.

4.5 Limitations and future directions

The retrospective, single-centre design without a control group limits causal inference and external validity. Selection and referral patterns may have enriched for higher-grade/bilateral disease; partner variables were not fully standardized; semen analyses, although uniform by site, were not blinded; and telephone follow-up can introduce reporting bias. Future work should include prospective, multicentre cohorts with standardized partner assessment and semen protocols, live-birth as the primary endpoint with time-to-event analyses, and exploration of predictive markers (clinical, oxidative-stress, and molecular) to refine selection. Comparative studies of surgical techniques versus early referral to ART will help clarify sequencing in comprehensive fertility pathways.

5. Conclusions

In a carefully selected cohort of men with clinical varicocele, MSV was associated with clinically meaningful improvements in semen concentration, progressive motility, and morphology, alongside high paternity rates—most achieved by spontaneous conception. These findings support MSV as a reasonable first-line surgical option prior to assisted reproduction in appropriately selected patients [2]. Given the retrospective design and potential selection factors, results should be interpreted cautiously; multicentre studies using live-birth as the primary endpoint and standardized partner evaluation are warranted to confirm generalizability and optimize candidate selection.

AVAILABILITY OF DATA AND MATERIALS

The datasets supporting the findings of the current study are openly available at https://doi.org/10.5281/zenodo.15866201.

AUTHOR CONTRIBUTIONS

NA—conceived and designed the study, collected data, and wrote the draft. İÜ—reviewed the literature, performed the analyses, and prepared the manuscript. Both authors provided critical feedback to each other and contributed to the final manuscript after discussing the results and commenting on the manuscript. The manuscript has been read and approved by both authors. There are no other persons who met the authorship criteria but are not listed. Both authors have approved the order of authors listed in the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was approved by the Istanbul Medipol University Non-Interventional Clinical Research Ethics Committee (decision no. 800; meeting date 03 July 2025; notification E-10840098-202.3.02-4533 issued 10 July 2025). All procedures involving human participants adhered to the ethical standards of the institutional and/or national research committee and to the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. The official approval document is openly available at https://doi.org/10.5281/zenodo.17187250. The authors certify that appropriate patient consent forms were obtained; in these forms, patients consented to the reporting of their clinical information in the journal. Patients understand that their names and initials will not be published and that due efforts will be made to protect their identity; however, complete anonymity cannot be guaranteed. Informed consent was obtained from the patient at every treatment step, during which a healthcare professional educated the patient about the risks, benefits, and alternatives of a given procedure or intervention.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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