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ORIGINAL RESEARCH

Varicocele grade, laterality, and reproductive outcomes: evidence from a large tertiary-center cohort study

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Abstract

Background: The study aimed to assess the impact of varicocele grade and laterality on semen quality in infertile men and their association with reproductive outcomes following microsurgical varicocelectomy. **Methods**: This retrospective study included 2871 infertile men diagnosed with clinical varicocele at a tertiary urology center (2005–2022). Varicocele grade (I–III) and laterality (unilateral/bilateral) were classified per World Health Organization (WHO) 2000 guidelines. Semen analysis followed WHO 1999/2010 criteria. A subgroup underwent microsurgical varicocelectomy and was followed for 12 months to assess spontaneous pregnancy and time to conception. **Results**: Unilateral varicocele was found in 64.9% and bilateral in 35.1%. Grade II varicocele predominated (80.6%), with Grades I and III comprising 11.4% and 8.0%, respectively. Normal semen parameters were observed in 55.5% of patients; the remainder had abnormalities such as asthenozoospermia (28.9%), oligozoospermia (6.9%), and azoospermia (3.9%). Semen quality did not differ significantly across grades or laterality ($p > 0.05$). Among surgical patients, 40.7% achieved spontaneous pregnancy within 12 months (mean time to conception: 4.3 ± 0.03 months). Neither varicocele grade nor laterality significantly influenced pregnancy rates or timing. **Conclusions**: Varicocele grade and laterality were not significantly associated with semen quality or postoperative pregnancy outcomes. These findings support individualized patient selection for varicocelectomy, considering broader clinical and reproductive factors rather than varicocele classification alone.

Keywords

Varicocele; Varicocelectomy; Semen; Pregnancy

Grado, lateralidad del varicocele y resultados reproductivos: evidencia de un estudio de cohorte en un centro terciario de alta complejidad

Resumen

Antecedentes: Evaluar el impacto del grado y la lateralidad del varicocele sobre la calidad del semen en hombres infértiles y su asociación con los resultados reproductivos después de la varicocelectomía microquirúrgica. **Métodos**: Este estudio retrospectivo incluyó a 2871 hombres infértiles diagnosticados con varicocele clínico en un centro urológico terciario (2005–2022). El grado (I–III) y la lateralidad (unilateral/bilateral) del varicocele se clasificaron según las directrices de la Organización Mundial de la Salud (OMS) 2000. El análisis seminal siguió los criterios de la OMS 1999/2010. Un subgrupo se sometió a varicocelectomía microquirúrgica y fue seguido durante 12 meses para evaluar el embarazo espontáneo y el tiempo hasta la concepción. **Resultados**: Se identificó varicocele unilateral en el 64.9% y bilateral en el 35.1%. Predominó el varicocele de grado II (80.6%), mientras que los grados I y III representaron el 11.4% y 8.0%, respectivamente. Se observaron parámetros normales de semen en el 55.5% de los pacientes; el resto presentó anomalías como astenozoospermia (28.9%), oligozoospermia (6.9%) y azoospermia (3.9%). La calidad del semen no difirió significativamente entre los distintos grados ni según la lateralidad ($p > 0.05$). Entre los pacientes operados, el 40.7% logró embarazo espontáneo dentro de los 12 meses (tiempo medio hasta la concepción: 4.3 ± 0.03 meses). Ni el grado ni la lateralidad del varicocele influyeron significativamente en las tasas de embarazo ni en el tiempo hasta la concepción. **Conclusiones**: El grado y la lateralidad del varicocele no se asociaron significativamente con la calidad del semen ni con los resultados reproductivos posteriores a la cirugía. Estos hallazgos respaldan la selección individualizada de pacientes para varicocelectomía, considerando factores clínicos y reproductivos más amplios en lugar de basarse únicamente en la clasificación del varicocele.

Palabras Clave

Varicocele; Varicocelectomía; Semen; Embarazo

1. Introduction

Varicocele is a prevalent condition affecting approximately 15% of the general male population and up to 40% of men evaluated for infertility [1]. It is characterized by the abnormal dilatation of the pampiniform plexus veins within the scrotum. The pathophysiological mechanisms include elevated scrotal temperature, autoimmunity, testicular hypoxia, oxidative stress, and hormonal dysregulation, which may impair spermatogenesis and reduce male fertility [2, 3].

The clinical grading of varicocele, typically classified from Grade I (palpable only during Valsalva) to Grade III (visible through the scrotal skin), has been widely investigated as a potential prognostic factor for semen quality [1]. Several studies have shown that higher-grade varicoceles are associated with significantly poorer sperm concentration, motility, and morphology [4, 5]. Conversely, other studies reported no consistent correlation between clinical grade and seminal parameters, suggesting a complex and multifactorial relationship [6, 7].

Furthermore, the recent guidelines of the European Association of Urology recommend surgical correction of clinical varicocele only in cases of impaired semen quality, regardless of the varicocele grade or laterality [8]. This recommendation reflects growing consensus that anatomical severity alone does not reliably predict reproductive outcomes.

The aim of the present study is to clarify whether varicocele severity and laterality are independently associated with semen abnormalities in a large cohort of infertile men.

2. Materials and methods

2.1 Study design and population

This retrospective cohort study included 2871 male patients diagnosed with clinical varicocele who were evaluated and treated at the Republican Specialized Scientific-Practical Medical Center of Urology (RSSPMCU) between January 2005 and December 2022. The study received approval from the RSSPMCU institutional ethics committee (No. 5 from 25 August 2023). All patients provided informed consent at the time of evaluation and allowed the use of anonymized data for research purposes.

2.1.1 Inclusion criteria

— Aged 18–50 years;

— History of infertility (failure to achieve pregnancy after ≥12 months of unprotected intercourse);

— Clinical diagnosis of varicocele confirmed by Doppler ultrasonography;

— Availability of at least one complete semen analysis.

Additionally, men with clinically palpable varicocele and normal semen parameters were included in the study based on shared decision-making in cases of unexplained infertility lasting more than three years (>3 years), absence of identifiable female factors, and lack of response to empirical antioxidant therapy; their inclusion also served the purpose of epidemiological characterization of the broader population of infertile men with varicocele.

2.1.2 Exclusion criteria

— History of previous varicocelectomy or inguinal/scrotal surgery;

— Congenital or acquired obstructive azoospermia (normal testicular size, serum follicle stimulating hormone (FSH) levels);

— Cryptorchidism, testicular tumors, or genetic causes of infertility (*e.g.*, Klinefelter syndrome, Y chromosome microdeletions)[1];

— Use of hormonal therapy in the preceding three months;

— Active genitourinary infections or systemic disease affecting fertility;

— Female factor of infertility.

Demographic and clinical data such as age, duration of infertility, history of spontaneous pregnancies, testicular volume (measured via ultrasound), and side of varicocele were extracted from patient records.

In selected cases with normal semen parameters but long-standing unexplained infertility, varicocelectomy was performed based on clinical judgment and shared decision-making, considering the presence of palpable varicocele and absence of identifiable female infertility factors.

2.2 Clinical evaluation and varicocele grading

All patients underwent a standard physical examination in a warm room, in standing position, with and without Valsalva maneuver. Varicocele was graded according to the World Health Organisation (WHO) 2000 classification, incorporating both palpatory and ultrasonographic criteria (in debatable cases) [9]:

— Grade I: reflux visible on Doppler only with Valsalva;

— Grade II: reflux visible at rest with dilated veins during Valsalva;

— Grade III: continuous reflux with visible scrotal vein dilation at rest.

Laterality was recorded as unilateral (left or right) or bilateral based on clinical and sonographic findings. In case of discrepancy between palpation and ultrasonography, Doppler data were prioritized.

Infertility was classified as primary (no prior pregnancies) or secondary (history of at least one prior pregnancy, spontaneous or assisted).

2.3 Semen analysis

Semen samples were collected by masturbation into sterile containers after 2–7 days of sexual abstinence. Samples were examined within one hour of ejaculation in a controlled laboratory environment. Semen analyses performed between 2005 and 2010 were evaluated according to WHO 1999 criteria, while assessments from 2011 onward followed WHO 2010 guidelines. Unfortunately, strict sperm morphology assessment using Tygerberg criteria was only implemented in the laboratory of RSSPMCU at the end of 2024. As a result, morphology data by strict criteria were not included in the present analysis.

The following semen parameters were assessed:

— Semen volume (mL);

— Sperm concentration (million/mL);

— Progressive and total motility (%);

— Total progressively motile sperm count (million).

Samples were categorized as normal or as having specific abnormalities as follows:

— Oligozoospermia: $<$15 million/mL;

— Asthenozoospermia: $<$32% progressive motility;

— Azoospermia: complete absence of spermatozoa;

— Combined disorders: *e.g.*, oligoasthenozoospermia (OA).

All laboratory personnel were blinded to the clinical grade and laterality of varicocele. Due to limited follow-up and incomplete clinical records, semen analysis results at 6 months post-surgery were available only for a small proportion of patients. Therefore, semen quality after varicocelectomy was not included in the analysis of reproductive outcomes.

Although some patients had previous semen assessments from other institutions, these were often not documented in full; only qualitative diagnostic terms such as “asthenozoospermia” or “oligozoospermia” were noted in their medical records, without complete numerical data. Therefore, only semen analyses performed in our center were considered for consistency and methodological standardization. The retrospective design of the study and the incompleteness of external data limited the feasibility of including two consecutive semen analyses in most cases.

2.4 Surgical technique

All varicocelectomies were performed by three experienced urological surgeons under spinal anesthesia. Approximately half of the procedures were carried out using loupe-assisted inguinal/subinguinal access, while the other half were performed with the aid of an operating microscope. Both techniques were functionally identical to the standard inguinal or subinguinal microsurgical approach, with meticulous preservation of lymphatic vessels and the testicular artery. All procedures followed recognized microsurgical principles to minimize recurrence, hydrocele formation, and vascular injury. Although there are technical differences between the two, existing literature suggests that when properly performed, both approaches can yield similar fertility outcomes. Due to incomplete operative records, subgroup analysis by surgical technique was not performed.

2.5 Follow-up and pregnancy assessment

Pregnancy outcomes were assessed at 12 months post-surgery in all patients with available follow-up data, regardless of the surgical approach. Follow-up information was collected through direct clinical visits or phone interviews. Outcomes were stratified by infertility type (primary or secondary), varicocele grade, and laterality. Six patients achieved pregnancy through assisted reproductive technologies (ART). As ART has only become widely accessible in Uzbekistan since approximately 2020, the number of such cases was limited. These cases were included in the overall analysis; however, due to their small number, they did not influence the overall pregnancy rate.

[1]Note: Genetic testing (karyotyping and Y chromosome microdeletion analysis) has been available in our country only in the past five years and remains limited in Uzbekistan. Therefore, only patients with confirmed genetic abnormalities were excluded.

2.6 Statistical analysis

Patients were stratified into groups based on varicocele grade (I–III) and laterality (unilateral *vs*. bilateral). Semen quality parameters, including sperm concentration, motility, and others, were compared across these groups to assess potential associations with varicocele severity and laterality. Categorical variables (*e.g.*, normal *vs*. abnormal semen parameters) were analyzed using the Chi-square test or Fisher's exact test, depending on expected cell counts. Continuous variables were first assessed for normal distribution using the Kolmogorov-Smirnov test; normally distributed variables were compared using the independent samples Student's t-test. For comparisons involving more than two groups, multiple pairwise Chi-square tests were performed with Bonferroni correction to adjust for multiple testing. A two-sided p-value < 0.05 was considered statistically significant. A formal power analysis was not performed, as the study was descriptive and involved a large cohort. We believe the sample size provided sufficient statistical power. All statistical analyses were conducted using IBM SPSS Statistics version 21.0 (IBM Corp., Armonk, NY, USA).

3. Results

A total of 2871 infertile men with clinically confirmed varicocele were included in the final analysis. The demographic and basic clinical characteristics of the cohort are presented in Table 1, which summarizes the age distribution, type of infertility, and varicocele severity.

As shown in Table 1, the vast majority of patients presented with Grade II varicocele (80.6%), and most cases were associated with primary infertility (82.6%). The median age was 29 years, and 96.1% of all patients were between 21 and 40 years old, highlighting the predominant reproductive age group affected.

3.1 Semen quality by varicocele laterality and grade

The relationship between varicocele laterality and semen parameters is outlined in Table 2, which compares the prevalence of normal and abnormal semen analysis results in unilateral versus bilateral varicocele cases.

As demonstrated in Table 2, abnormal semen parameters were detected in 44.5% of patients. The proportion was slightly higher in the bilateral varicocele group (46.6%) compared to the unilateral group (43.5%), but the difference was not statistically significant ($p = 0.1175$).

Table 3 summarizes the relationship between varicocele grade and semen quality. Among patients with Grade I varicocele, 49.1% had normal semen, compared to 56.2% with Grade II and 57.4% with Grade III. Although the overall difference was statistically significant ($p = 0.045$), none of the pairwise comparisons between grades I–II, II–III, or I–III remained significant after applying the Bonferroni correction ($p = 0.06$).

TABLE 1. Demographic and clinical characteristics of patients with infertility and varicocele, n = 2871.

Characteristic	Number of Patients (n)	Percentage (%)
Age in years, median (IQR)	–	29 (27–33)
Primary infertility	2371	82.6%
Secondary infertility	500	17.4%
Grade I varicocele	328	11.4%
Grade II varicocele	2313	80.6%
Grade III varicocele	230	8.0%
Total	2871	100.0%

IQR: Interquartile Range.

TABLE 2. Semen quality by varicocele laterality, n = 2871.

Laterality of Varicocele	Normal Semen, n (%)	Abnormal Semen, n (%)	Total, n	*p*-value
Unilateral	1054 (56.5%)	810 (43.5%)	1864	
Bilateral	538 (53.4%)	469 (46.6%)	1007	
Total	1592 (55.5%)	1279 (44.5%)	2871	0.1175*

**p value for abnormal semen distribution.*

TABLE 3. Semen quality by varicocele grade, n = 2871.

Varicocele Grade	Total Patients (n)	Normal Semen (n)	Abnormal Semen (n)	*p*-value
Grade I	328	161 (49.1%)	167 (50.9%)	
Grade II	2313	1299 (56.2%)	1014 (43.8%)	
Grade III	230	132 (57.4%)	98 (42.6%)	
Total	2871	1592 (55.5%)	1279 (44.5%)	0.06*

**p value is obtained after Bonferroni-correction.*

3.2 Pregnancy outcomes following varicocelectomy

Postoperative reproductive outcomes were assessed in terms of natural pregnancy rates and time to conception. Information on pregnancy outcomes were obtained from 2258 patients who had been operated for clinical varicocele and abnormal semen or normal sperm with long infertility treatment history (>3 years), and were successfully contacted by phone. Of these, 920 (40.7%) patients reported spontaneous pregnancy within 12 months after surgery, while 1338 (59.3%) did not. Table 4 presents these results by varicocele grade.

Table 4 demonstrates that spontaneous pregnancy rates did not differ significantly among patients with different grades of varicocele. Although Grade II cases had the highest observed pregnancy rate (41.8%) compared to Grade I (36.5%) and Grade III (36.7%), these differences did not reach statistical significance (Bonferroni-corrected $p = 0.4$), indicating that varicocele grade alone may not be a reliable predictor of natural conception following surgery.

Table 5 summarizes pregnancy outcomes based on varicocele laterality. Among the 1338 patients with unilateral varicocele, 532 (39.6%) achieved spontaneous pregnancy within 12 months postoperatively, whereas 388 of the 920 bilateral cases (42.2%) achieved pregnancy. While bilateral cases showed a marginally higher pregnancy rate, the difference was not statistically significant ($p = 0.213$). Taken together, these findings suggest that neither clinical grade nor laterality of varicocele had a statistically significant effect on postoperative fertility outcomes in this large patient cohort.

The average time to conception was similar between groups, around 4.3 months. Taken together, the results of this large-scale clinical cohort demonstrate that neither varicocele grade nor laterality had a statistically significant effect on semen quality or postoperative natural conception rates. However, the detailed phenotyping of semen parameters, coupled with surgical outcome data, provides a robust dataset for informing individualized treatment decisions in infertile men with varicocele.

In addition, it should be mentioned than none of the patients with azoospermia achieved spontaneous pregnancy or underwent testicular sperm extraction (TESE) within the observed follow-up period.

3.3 Semen parameter—specific pregnancy outcomes

Table 6 provides a breakdown of specific types of semen abnormalities found in the total cohort, regardless of laterality or grade.

Asthenozoospermia was the most prevalent disorder, affecting 28.9% of all patients. Isolated oligozoospermia and other defects were relatively rare. Azoospermia was present in 3.9% of the cohort, underlining the severe end of the spectrum of testicular dysfunction among patients with varicocele.

To further explore the relationship between semen abnormalities and fertility outcomes, we performed a subgroup analysis stratifying patients according to key semen pathologies. Follow-up pregnancy data were analyzed for individuals with asthenozoospermia, oligozoospermia, cryptozoospermia, and azoospermia (Table 7).

As shown in Table 7, spontaneous pregnancy was achieved in 48.7% of patients with asthenozoospermia and 38.4% of those with oligozoospermia, with the difference reaching statistical significance ($p = 0.018$). Among azoospermic men, 5 out of 68 patients (7.4%) achieved pregnancy; all of these cases involved assisted reproductive technologies (ART) following testicular sperm extraction (TESE), as reported by the patients during follow-up. Notably, these procedures were not performed at our center. No pregnancies were observed in the cryptozoospermia subgroup. These findings highlight the markedly lower fertility outcomes in patients with severely impaired spermatogenesis.

TABLE 4. Pregnancy outcomes by varicocele grade, n = 2258.

Varicocele Grade	Pregnancy Achieved (n)	No Pregnancy (n)	Pregnancy Rate (%)
Grade I	97	169	36.5
Grade II	758	1057	41.8
Grade III	65	112	36.7
Total	920	1338	40.7
p-value*			0.4*

**Real p = 0.136; Bonferroni-corrected p-value = 0.4.*

TABLE 5. Pregnancy outcomes by varicocele laterality, n = 2258.

Laterality	Pregnancy Achieved (n)	No Pregnancy (n)	Pregnancy Rate (%)
Unilateral	532	806	39.6%
Bilateral	388	532	42.2%
Total	920	1338	40.7%
p-value			0.213

TABLE 6. Types of semen abnormalities in the entire cohort, n = 1279.

Semen Abnormality	Number of Patients (n)	Percentage (%)
Asthenozoospermia	830	28.9%
Oligozoospermia	199	6.9%
OA	77	2.7%
Azoospermia	111	3.9%
Total abnormal	1279	44.6%

OA: oligoasthenozoospermia.

TABLE 7. Pregnancy outcomes by semen abnormality.

Semen abnormality	Patients with follow-up (n)	Pregnancies (n)	Pregnancy rate (%)
Asthenozoospermia	677	330	48.7%
Oligozoospermia	159	61	38.4%
Azoospermia	68	5*	7.4%
Cryptozoospermia	29	0	0.0%

**All 5 pregnancies occurred following TESE and ART. These procedures were not performed at this center but were reported by the patients during follow-up.*

4. Discussion

Varicocele remains one of the most prevalent and potentially correctable causes of male infertility, particularly in men with abnormal semen parameters and clinical signs of scrotal vein dilatation. Despite its long-standing recognition, the extent to which varicocele severity and laterality impact semen quality and fertility outcomes continues to be debated [10]. The present study offers one of the largest single-center cohorts assessing these associations in detail.

In our cohort of 2871 infertile men with clinical varicocele, semen abnormalities were present in 44.5% of the cases. This is consistent with previously published findings by Damsgaard *et al*. [4] (2016), who reported impaired semen quality in 40–50% of young men with varicocele in a multicenter European study. Similarly, Pallotti *et al*. [5] (2018) and Pasqualotto *et al*. [11] (2005) identified a strong association between varicocele and oligoasthenoteratozoospermia, especially in higher clinical grades.

We observed no statistically significant correlation between varicocele grade or laterality and the frequency or type of semen abnormalities. This finding aligns with results from Shomarufov *et al*. (2020) [12] and Bozhedomov *et al*. [6] (2021), who demonstrated that varicocele severity did not consistently predict sperm DNA integrity or semen parameters damage. But other studies and meta-analyses support the idea of varicocele grade impact on surgery's outcomes [13, 14].

The postoperative pregnancy rate in our study was 40.7%, with an average time to natural conception of 4.3 months. These results are in line with those reported by Machen *et al*. [15] (2020) who reported the same pregnancy rate (40.7%) after varicocele repair and Persad *et al*. [16] (2021), who described mean conception times between 4 and 6 months.

Importantly, our findings indicate that pregnancy outcomes were not significantly different between patients with unilateral and bilateral varicocele. This confirms earlier observations by Lima *et al*. [17] (2020) and Machen *et al*. [15] (2020), who reported comparable results regardless of laterality. Although some studies, including a randomized controlled trial (RCT) by Sun *et al*. [18] (2018) and an observational study by Niu *et al*. [19] (2018), have suggested a more pronounced impact of bilateral varicocele and its surgical correction on fertility outcomes, our findings do not support this conclusion with regard to postoperative spontaneous pregnancy rates.

Overall, our data support the use of microsurgical varicocelectomy in carefully selected patients with clinical varicocele and infertility. However, the absence of a direct correlation between grade or laterality and outcome suggests that surgical decisions should be guided by broader fertility profiles and not based solely on anatomical classification.

This study has several limitations. First, pregnancy outcomes were collected retrospectively via telephone interviews, which may introduce recall bias. Due to limited staff capacity, follow-up calls were made once, with one repeat attempt for non-responders. Extended monitoring—particularly of ART outcomes—was not feasible. Second, postoperative semen analysis was not available for the majority of patients due to incomplete follow-up, which limited our ability to correlate spontaneous pregnancy outcomes with improvements in semen parameters—a significant limitation in evaluating the biological effect of varicocelectomy. Third, information on female partners' reproductive health was also obtained by phone during interviews with male participants and was not complete (age, body mass index (BMI), and other important characteristics were omitted), without access to formal gynecological records. Fourth, some patients with normal semen parameters but a prolonged history of non-effective infertility treatment (>3 years) also underwent varicocelectomy, which may have introduced selection bias. The inclusion of patients with normal semen parameters is justified by evidence suggesting that varicocele may impair sperm function beyond standard semen metrics, and surgical correction in this subgroup may still enhance reproductive outcomes, particularly in couples with prolonged unexplained infertility [20]. Fifth, hormonal profiles (FSH, luteinizing hormone (LH), testosterone) were not uniformly available for most patients, which limits insight into endocrine-related infertility factors. Sixth, the use of two different surgical approaches—loupe-assisted and microscope-assisted varicocelectomy—represents a methodological limitation, as outcomes were not analyzed separately due to insufficient subgroup data. Finally, seventh, the lack of strict morphology assessment (Tygerberg criteria) further constrained the evaluation of sperm quality. Despite these limitations, the present study provides one of the largest and most clinically detailed datasets on male infertility associated with varicocele. It offers valuable real-world insights into current management practices and outcomes, highlighting important clinical trends. The findings contribute meaningfully to the existing body of evidence and emphasize the need for future prospective, multicenter studies to validate and expand upon these results.

5. Conclusions

This large single-center study provides comprehensive evidence on the clinical and reproductive outcomes associated with varicocele in infertile men. Neither varicocele grade nor laterality was significantly associated with semen quality or pregnancy rates. However, a spontaneous pregnancy rate of 40.7% within 12 months after surgery suggests potential effectiveness of microsurgical varicocelectomy in selected patients, though further prospective studies are needed to confirm causality. These results highlight the importance of individualized patient evaluation and support the integration of surgical treatment into broader fertility management strategies.

ABBREVIATIONS

WHO, World Health Organization; RCT, Randomized Controlled Trial; IQR, Interquartile Range; SPSS, Statistical Package for the Social Sciences; RSSPMCU, Republican Specialized Scientific-Practical Medical Center of Urology; OA, Oligoasthenozoospermia; ART, assisted reproductive technologies; TESE, testicular sperm extraction; FSH, follicle stimulating hormone; LH, luteinizing hormone; BMI, body mass index.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on reasonable request from the corresponding author.

AUTHOR CONTRIBUTIONS

SG and FA—designed the research study. AS and JY—performed the research. SM—provided help and advice on manuscript revision and overall supervision. DM—analyzed the data. AS—wrote the manuscript. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study received approval from the RSSPMCU institutional ethics committee (No. 5 from 25 August 2023). All patients provided informed consent at the time of evaluation and allowed the use of anonymized data for research purposes.

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CONFLICT OF INTEREST

The authors declare no conflict of interest. Azizbek Shomarufov is serving as the Guest Editor of this journal. The authors declare that Azizbek Shomarufov was not involved in the peer review or editorial decisions related to this manuscript. Full responsibility for the editorial process for this article was delegated to EFP.

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