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REVIEW

Beyond Tying Knots: Can Venous Bypass Shape the Future of Testicular Hemodynamics in Varicocele Treatment? – A Systematic Review

Albert Ciam, Ricky Adriansjah

Urology Department, Hasan Sadikin Academic Medical Center, Universitas Padjajaran, Bandung, Indonesia

Correspondence: Ricky Adriansjah, Urology Department, Hasan Sadikin Academic Medical Center, Universitas Padjadjaran, Jl. Prof. Eyckman No. 38, Bandung, West Java, 40161, Indonesia, Tel +62 811-2296-136, Email ricky.adriansjah@unpad.ac.id

Purpose: Varicocele, present in 15–20% of males and linked to 35–40% of primary infertility, is commonly treated with microsurgical ligation. This review compares venous shunting techniques such as spermatic-inferior epigastric vein anastomosis with ligation in terms of efficacy, safety, and clinical outcomes, especially in complex cases like recurrence or Nutcracker Syndrome.

Methods: We included randomized, prospective, retrospective, and cohort studies comparing venous shunting (eg, spermatic-inferior epigastric vein anastomosis) with ligation or without control group. We searched PubMed, EBSCO, ProQuest, EMBASE, and Scopus on 31 April 2025. Risk of bias was assessed using the Newcastle-Ottawa Scale and JBI (Joanna Briggs Institute) for case series. Outcomes assessed included operative time, semen parameters, hormonal levels, recurrence, and complications. This study was registered in PROSPERO (CRD420251060842).

Results: Twelve studies (n = 420 patients) were included. Shunting demonstrated improvements in semen quality (eg, sperm motility: 59.4% vs 41.6% post-ligation) and lower recurrence rates (0–5% vs 5–15%). However, operative times were longer (99–146 vs 48–92 minutes). Shunting also showed benefits in vascular parameters and testicular volume, particularly in NCS-associated cases. Complications were rare, with minor issues like scrotal edema reported.

Conclusion: Venous shunting shows promise as an alternative in selected varicocele patients, with potential benefits in semen motility, pain relief, and recurrence reduction. However, the current evidence is limited, heterogeneous, and largely non-randomized. Shunting should therefore be considered experimental, requiring advanced microsurgical expertise, and further high-quality trials are needed before incorporation into standard guidelines.

Keywords: varicocele, venous bypass, microsurgical anastomosis, male infertility

Introduction

Varicocele, a pathological dilation of the pampiniform plexus veins, affects 15–20% of the general male population and is implicated in 35–40% of primary male infertility cases.[1,2] Varicocele treatment options consisted of non-surgical and surgical approach. The example of non-surgical approach is sclerotherapy with adequate compression,[3] while in surgical treatment, microsurgical varicocelectomy (ligation) remains the gold standard for primary treatment due to its low recurrence (5–10%) and complication rates.[4] However, recent studies suggest that venous shunting techniques, such as microsurgical spermatic-inferior epigastric vein anastomosis may offer superior outcomes in complex cases, including recurrent varicoceles, Nutcracker Syndrome (NCS)-associated varicoceles, and adolescents with testicular hypotrophy.[2,5]

Microsurgical ligation techniques, though effective, disrupt venous drainage, potentially leading to persistent venous stasis, delayed symptom relief, and postoperative complications such as hydrocele (10–15%) and testicular atrophy.[6] In contrast, shunting procedures aim to restore physiological venous outflow by anastomosing the dilated spermatic vein to systemic veins whose pressure is much slower, thereby reducing retrograde reflux while maintaining testicular venous

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outflow.[7] Various venous bypass techniques have been described since 1980 as alternatives in varicocele management and deep inferior epigastric vein is most commonly used.[8,9] The described anastomosis is relatively simple, and carries no additional risk for the patient, while potentially reducing complications and improving outcome.[10] The focus of varicocele treatment is mainly focused on microsurgical varicocelectomy and its variants, while shunting methods were left out.[11] However, several emerging studies were published and evaluating its outcomes.[2,10]

Although initially reserved for selective cases such as recurrent varicoceles and patients with severe venous hypertension, recent studies demonstrate that shunting not only improves semen parameters more effectively than ligation, evidenced by significantly higher sperm motility (59.4% vs 41.6%) but also resolves associated symptoms in over 80% of varicocele patients. These findings suggest that shunting may offer broader therapeutic benefits beyond its traditional use, positioning it as a potentially superior option for both fertility enhancement and symptomatic relief in varicocele management.[1,2,4,5] Although shunting offers several potential benefits—including broader therapeutic effects on fertility and symptom relief—it is still not commonly performed. This is primarily due to its technical difficulty, longer operative time, and the requirement for advanced microsurgical skills.[1,2] Our study aims to compare the efficacy, safety, and clinical applications of shunting versus ligation in varicocele management.

Methods

We conducted a systematic literature search following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist.[12] This systematic review was registered in PROSPERO (CRD420251060842). There was no amendment to the protocol after registration.

Inclusion Criteria

Research studies could be considered for inclusion if they met the following criteria.

1. Designs: Randomized controlled trial (RCT), prospective and retrospective studies, case–control, or nested case–control studies.
2. Population: Patients undergo varicocelectomy
3. Exposure: Internal spermatic vein to superficial epigastric vein microsurgical bypass
4. Control: None or Microsurgical Varicocelectomy
5. Outcome: semen and hormonal analysis, testicular and vascular parameter, fertility, recurrence and complication rates.

Exclusion Criteria

Review articles, case reports, editorial comments, letters, and non-english article were excluded.

Search Strategy

A systematic literature search was performed in electronic databases, including PubMed, EBSCO, ProQuest, EMBASE, and Scopus on 31 April 2025. To ensure thoroughness, we manually examined the reference lists of the included research and relevant reviews, in addition to conducting a search on Google Scholar, to identify any potentially overlooked relevant articles. Our search encompassed synonyms and variations of the terms "Varicocele" AND ("Microligation" OR "Microsurgery" OR "Microsurgical Ligation") AND ("Anastomosis, Surgical").

Study Selection

Two investigators (RT, AC) independently reviewed all titles and abstracts. In cases where the abstract did not provide sufficient information to ascertain whether a study met the inclusion or exclusion criteria, full-text screening was conducted. Any discrepancies were resolved through discussion.

Study Risk of Bias Assessment

The methodological quality of the included studies was evaluated using appropriate design-specific tools. For retrospective and observational comparative studies, we applied the Newcastle-Ottawa Scale (NOS), which assesses risk of bias across three domains: selection, comparability, and outcome assessment. For case series and non-comparative designs, we employed the Joanna Briggs Institute (JBI) Critical Appraisal Checklist, which is specifically tailored to evaluate internal validity, clarity of inclusion criteria, completeness of follow-up, and reliability of outcome measures in case series. Two reviewers independently performed the assessments, and any disagreements were resolved by discussion.

Data Collection

All the included studies were assessed manually for duplication and in accordance with the determined eligibility criteria. Data extraction was carried out for each selected study in accordance with the following predefined data extraction format: first author's name, study period, publication year, study design, treatment regiments, follow-up period, outcome measurement will be tabulated for each synthesis.

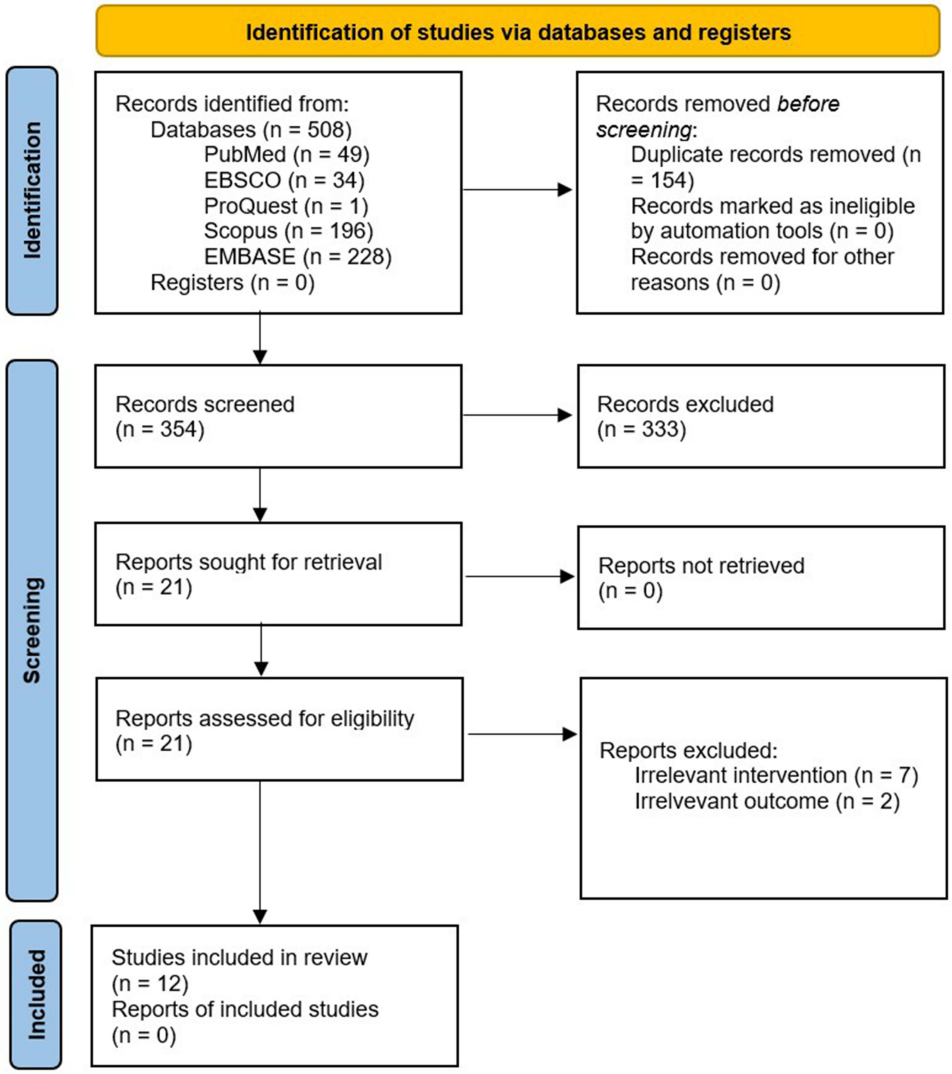

Figure 1 PRISMA Flow Diagram.

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Result

Study Characteristics

A total of 508 studies were identified through database searches and manual exploration (Figure 1). After removing duplicates, 354 studies underwent initial screening based on their titles and abstracts. Then, 333 studies were excluded because they did not fit the inclusion criteria or metthe exclusion criteria. Twenty studies were further assessed to determine their eligibility criteria, all in English, A total of 12 studies involving 420 patients were included in this review (Table 1).[1,2,5–7,9,10,13–17] All studies investigated the outcomes of microscopic internal spermatic-inferior epigastric vein anastomosis or its variants in the treatment of varicocele, with or without nutcracker syndrome (NCS). Study designs included retrospective (n=5), prospective (n=5), cohort (n=1), and one unspecified. A total of 3 studies directly compare shunting and ligation only techniques. Risk of bias assessment results are presented in Supplementary Tables 1 and 2. A meta-analysis was not performed because the included studies were highly heterogeneous in design, sample size, and outcome reporting. Differences in semen analysis protocols, follow-up duration, and surgical techniques prevented reliable pooling of data. Given the absence of randomized trials and standardized measures, a narrative synthesis was considered more appropriate.

Operative Time and Hospital Stay

Operative time was consistently longer for shunting compared to ligation varicocelectomy (Table 2). For instance, Dou et al reported a significantly longer mean operative time in the shunting group (99.6 ± 12.9 minutes) compared to control (48.9 ± 9.1 minutes, $p<0.01$), while Zhang et al also noted longer duration in the intervention group (146.3 ± 14.3 vs 92.3 ± 8.7 minutes, $p=0.015$). Hospital stays ranged from 2 to 7 days across studies, with no significant differences between intervention and control groups where applicable.

Semen Parameters and Hormonal Outcomes

Most studies observed improvements in semen quality postoperatively, particularly in sperm count and motility. For example, Li et al documented an increase in sperm count from 15.8 ± 4.53 to 30.0 ± 3.52 $\times 10^6$/mL and motility from 26.8% to 59.4% at 12 months. Dou et al found a significantly greater improvement in sperm motility in the shunting group compared to controls. However, changes in serum testosterone levels were inconsistent, with some studies reporting no significant postoperative change.

Testicular and Vascular Parameters

Improvements in testicular volume and vascular parameters were frequently reported, especially in patients with NCS. Hao et al and Li et al showed significant decreases in peak venous velocity and PV ratios postoperatively, indicating effective decompression of the renal vein. Several studies also noted stabilization or catch-up growth in hypotrophic testicles.

Fertility Outcomes

Natural conception was reported in multiple studies though data were often limited. For example, 80% of partners in Li et al conceived naturally, Dou et al reported 8 pregnancies in the shunting group compared to 6 in the control group though the difference was not statistically significant, and only 2 out of 35 cases in Li et al study that were naturally pregnant.

Complications and Recurrence

Overall, the procedure demonstrated a favorable safety profile. Across studies, the most common complications were mild scrotal edema, hydrocele, and wound infections, each occurring infrequently. Major complications such as testicular atrophy or thrombosis were rare. Notably, most studies reported no recurrence of varicocele following shunting during the follow-up period.

Table 1 Characteristics of Included Studies

Author	Year	Design	Follow-Up Time	Inclusion	Intervention	Control	Participant		Outcome Measure
							Case	Control	
Dou et al[7]	2024	Retrospective	12 months	Varicocele	Microscopic internal spermatic-inferior epigastric vein anastomosis	Microscopic spermatic vein ligation	37	37	Preoperative and postoperative semen quality, reproductive hormone levels, scrotal ultrasound results, duration of surgery, length of hospital stay, postoperative recurrence rate, and occurrence of complications
Hao et al[13]	2019	Prospective	6-24 months	NCS Varicocele	Microsurgical left spermatic-inferior epigastric vein anastomosis	–	53	–	Operative time, hospital stays, renal and spermatic vein vessels ultrasound, urinalysis, semen analysis, complication
Li et al[5]	2014	Prospective	12 months	NCS Varicocele	Microsurgical spermatic-inferior epigastric vein anastomosis	–	5	–	Ultrasound results, semen analysis, complications
Han et al[2]	2023	Retrospective	12-53 months	NCS Varicocele	Microsurgical left spermatic-inferior epigastric vein anastomosis with microsurgical varicocelectomy	–	13	–	Doppler ultrasound, complications, recurrence
Wan et al[1]	2022	Retrospective	3 months	Varicocele	Microsurgical spermatic (distal end)-inferior or superficial epigastric vein anastomosis	–	27	–	Ultrasound results, pain, testosterone level, semen analysis
Papes et al[10]	2023	NS	NS	Varicocele	Internal spermatic vein to superficial epigastric vein microsurgical bypass	Microsurgical varicocelectomy	8	24	Semen analysis, complications, recurrence
Camoglio et al[16]	2003	Retrospective	18-36 months	Varicocele	Microsurgical spermatico-epigastric venous anastomosis	–	66	–	Persistence, Doppler ultrasound, complications
Li et al[14]	2020	Cohort	12 months	NCS Varicocele	Microsurgical gonadal-inferior epigastric vein anastomosis	–	35	–	Urinalysis, semen analysis, Doppler ultrasound
Dong et al[15]	2014	Prospective	24-72 months	NCS Varicocele	Anastomosis of the proximal part of the spermatic vein and inferior epigastric vein	–	12	–	Ultrasound results, testicular volume, recurrence, complications
Zhang et al[6]	2024	NS	NS	Varicocele	High ligation of the spermatic vein and transfer of spermatic vein-inferior epigastric vein	Low ligation of the spermatic vein	49	47	Ultrasound results
Belgrano et al[9]	1984	Case Series	6 months	Varicocele	Microsurgical Spermaticoepigastric Anastomosis	–	8	–	Sperm counts, hospital stay, and postoperative complications
Flati et al[17]	2004	Prospective	Mean 8.5 years	Recurrent Varicocele	Microsurgical shunts between spermatic vein and inferior epigastric vein	–	34	–	Sperm count, pregnancy rate, and ultrasound evaluation od varicocsity

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Table 2 Outcomes of Intervention in the Included Studies

Author	Year	Operative Time	Hospital Stay	Semen Quality	Hormone Levels	Testicular Size	Vascular Parameter	Fertility	Complications
Dou et al[7]	2024	There was significantly longer operative time in intervention group compared to control (99.55 ± 12.93 vs 48.97 ± 9.12, p<0.01)	–	Significant improvement of sperm concentration, motility, and morphology in both groups. There is significantly higher improvement of sperm motility in intervention group	Significant increase of testosterone in both groups, but there is no difference between both groups	No significant change of testis volume in both groups	–	Eight partners in intervention group and 6 partners in control achieved natural conception (no significant difference)	No surgical complications, such as incision infection, hydrocele, scrotal edema, left testicular atrophy, epididymitis, or orchitis, were observed, and no patient experienced recurrence postoperatively.
Hao et al[13]	2019	The average operative time was 78.4 ± 14.2 min	The hospital stay was 4–7 days	–	–	Nineteen cases of left testicular hypotrophy experience no further deterioration after surgery, of which 16 cases had catch-up testicular growth.	There is significant decrease after intervention in PV1/PV2 ratio. Vascular anastomotic thrombosis was confirmed by ultrasonography in 2 cases.	–	There were no complications of wound infection, scrotal hydrocele and testicular atrophy. There were left varicocele recurrence in 3 cases, right in 2 cases.
Li et al[5]	2014	The mean operative time was 85.0 ± 13.2 min	The mean hospital stay was 6.0 ± 0.7 days	Sperm count increased from 15.8 ± 4.53 × 10^6/mL preoperatively to 24.38 ± 1.58 at 6 months and 30.02 ± 3.52 at 12 months. Sperm motility improved from 26.76% ± 8.68% preoperatively to 45.50% ± 9.2% at 3 months, 53.96% ± 6.28% at 6 months, and 59.40% ± 8.59% at 12 months.	–	–	Significant decreases in PV1 (167.24 ± 41.68 cm/s vs 46.98 ± 4.22 cm/s) and the PV ratio (12.28 ± 2.32 vs 3.40 ± 0.67) were observed after the operation	Four of 5 patients' spouses (80%) conceived naturally during the follow-up period.	Scrotal edema in 1 patient (20%) and wound infection in 1 patient (20%). Hydrocele, recurrence, and testicular atrophy had not occurred by the end of the follow-up period.
Han et al[2]	2023	The operative time was 148.1 ± 24.7 min	The average hospital stay was 5.7 (±1.9) days	–	–	–	Diameter of renal vein and renal vein diameter ration improved significantly after intervention. No stenosis was observed, and the anastomosis flow was clear	–	There were no postoperative complications such as wound infection, hydrocele, and testicular atrophy. No recurrence was seen at 12–53 months of follow-up.

Wan et al[1]	2022	-	-	Sperm density (36.6±41.9 to 42.6±41.5) and forward movement (22.0±15.3 to 27.1 ±14.3) sperm were improved postoperatively compared with the preoperative values	There was no statistically significant change in total testosterone (4.8±2.4 to 4.0 ±0.2) levels before and after the operation	–	The size of dilated veins was reduced from 2.8 ± 0.6 mm before the operation to 2.2 ± 0.3 mm after the operation. In two patients, there was no statistically significant change in the size of dilated veins, but the reflux disappeared	–	–
Papes et al[10]	2023	The mean operative time of both groups was 65 min (50–85 min)	-	All patients had a normal postoperative semen analysis	-	Improvement of testicular volume in 3 cases with decreased testicular volume	The anastomosis was found patent in all patients	–	No hydrocele, testicular atrophy, or recurrences were noted. One patient complained of mildly painful ejaculations, but the issue resolved spontaneously within 6 months postoperatively
Camoglio et al[16]	2003	–	Mean hospital stay is 3 days	–	–	–	Patency was observed in 58 (90.6%) patients. In 2 patients, there is thrombosis.	-	Two patients (3%) presented persistence of the disease, 7 patients developed hydrocele
Li et al[14]	2020	The mean operative time was 96.5 ± 12.3 min	–	Sperm count increased significantly from 17.01 ± 6.38 × 10^6/mL preoperatively to 25.11 ± 6.53 at 6 months and 27.43 ± 8.68 at 12 months. Sperm motility also improved from 27.76% ± 3.78% to 32.66% ± 3.81% at 6 months and 33.06% ± 4.27% at 12 months.	–	–	The mean peak velocity (PV) in the aortomesenteric portion of the left renal vein (LRV) decreased from 117.9 ± 30.4 cm/s to 76.6 ± 18.5 cm/s, and the PV ratio (PVr) decreased from 7.3 ± 0.7 to 4.1 ± 0.4 after surgery.	Two out of 35 patients became naturally pregnant	Two patients had mild hydrocele requiring no intervention, and no major complications, such as recurrence, hematoma, infection, testicular atrophy and stenosis in the vascular anastomosis stoma, were observed during and after surgery
Dong et al[15]	2014	Mean operative time was 60 min	All patients were discharged 2 days post surgery	–	–	The increase in left testicular volume was 4.25 ± 1.6 and testicular discrepancy disappeared	No stenosis in the vascular anastomosis stoma was observed and blood flow was seen to increase significantly during Valsalva maneuver	–	One patient had minimal hydrocele requiring intervention and no major complications, such as hematoma, infection, and testicular atrophy. There was 1 recurrence on the left side.

(*Continued*)

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Table 2 (Continued).

Author	Year	Operative Time	Hospital Stay	Semen Quality	Hormone Levels	Testicular Size	Vascular Parameter	Fertility	Complications
Zhang et al[6]	2024	The operative time in intervention group was 146.26±14.33 vs 92.27±8.66 in control (p = 0.015)	There is no significant difference in hospital stay between intervention and control group (5.32 ±0.42 vs 5.16 ±0.28, p = 0.093)	–	–	–	There was significantly higher narrowing of the width of the spermatic vein in intervention group compared to control (0.16±0.06 vs 0.08±0.04, p <0.01)	-	There was 1 case of scrotal edema in intervention group, while there were 3 cases of scrotal edema, 1 case of epididymitis, and 1 case of hydrocele. There is no testicular atrophy.
Belgrano et al[9]	1982	-	Mean hospitalization was 4 days	There was significant increase in sperm counts in all cases	–	–	–	–	No postoperative complication occurred
Flati et al[17]	2004	Mean operative time was 40 minutes (30–50)	Mean hospital was 24 hours	In <30 years old group: sperm density (22.48 ± 13.32 to 50.50 ± 22.28 x 10^6/mL), sperm motility (19.20 ± 5.60 to 52.05 ± 16.20%), volume (2.89 ± 0.57 to 4.20 ± 1.31 mL), and abnormal forms (65.82 ± 8.87 to 37.90 ± 12.85%) significantly improved In >30 years old group: sperm density (14.24 ± 9.65 to 22.03 ± 13.68 x 10^6/mL), sperm motility (14.58 ± 10.89 to 30.10 ± 18.20%), and abnormal forms (63.87 ± 16.31 to 47.40 ± 12.04%) significantly improved, but not volume	–	–	–	In <30 years old group: the pregnancy rate was 43.75% and in >30 years old group the pregnancy was 22.2%	There is no postoperative recurrence, while there were 2 that experience scrotal fullness/ discomfort

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Discussion

The management of varicoceles, a common cause of male infertility and scrotal discomfort, has undergone significant refinement with the integration of microsurgical techniques. Among these advancements, venous shunting procedures have emerged as a sophisticated alternative to the more traditional method of venous ligation. This systematic review synthesizes evidence from contemporary studies to compare the efficacy, safety, and applicability of these two approaches, offering insights into their respective roles in modern urological practice.

When considering treatment effectiveness, venous shunting techniques, such as the creation of an anastomosis between the spermatic vein and the inferior epigastric vein, often demonstrate superior clinical outcomes, particularly within specific patient populations. Research conducted by Li et al and Han et al indicates that shunting procedures are associated with notably lower recurrence rates, typically ranging from 0% to 5%, compared to the 5% to 15% recurrence observed following ligation alone.[2,5] A recent systematic review and meta-analysis by Tandon et al in pediatric and adolescent populations reported recurrence rates ranging from 2.1% to 7.6%, with higher rates observed following embolization and sclerotherapy procedures, and the lowest recurrence associated with microsurgical and lymphatic-sparing techniques.[18] These findings highlight that while modern ligation approaches have achieved relatively low recurrence, venous bypass may further reduce recurrence risk by maintaining physiological venous outflow and minimizing collateral vessel formation. Nonetheless, the paucity of randomized evidence directly comparing bypass with contemporary microsurgical ligation warrants cautious interpretation.

Improvements in semen parameters were consistently reported across the included shunting studies. Li et al demonstrated a postoperative increase in sperm count from 15.8 ± 4.53 to 30.0 ± 3.52 $\times 10^6$/mL and motility from 26.8% to 59.4% at 12 months. Dou et al similarly observed significant improvements in sperm concentration, motility, and morphology, with the shunting group showing superior gains in motility compared to conventional ligation. Li et al reported mean sperm count improvements from 17.0 ± 6.4 to 27.4 ± 8.7 $\times 10^6$/mL, while Wan et al noted improved sperm density and forward motility following spermatic-epigastric vein anastomosis. These findings indicate that venous bypass consistently enhances both quantitative and qualitative aspects of semen profiles. When contextualized within broader literature, these results align with large meta-analyses. Baazeem et al showed that varicocelectomy improves sperm concentration (mean increase 12.3 million/mL), total motility (+10.9%), and progressive motility (+9.7%), although pooled effects on spontaneous pregnancy were not statistically significant (OR 2.23, 95% CI 0.86–5.78).[19] Agarwal et al confirmed that men with untreated varicocele had markedly impaired sperm parameters compared to fertile or normozoospermic controls, with reductions in sperm count (−44.5 $\times 10^6$/mL), motility (−26.7%), and morphology (−19.7%).[20] Taken together, these findings suggest that shunting not only provides the semen improvements traditionally associated with varicocelectomy but may confer greater motility recovery than ligation, a parameter closely linked to fertility potential. However, the absence of randomized comparative trials prevents definitive conclusions regarding superiority.

In addition to objective semen parameters and recurrence rates, patient-reported outcomes provide important insights into the clinical utility of venous shunting. Several included studies evaluated postoperative symptoms such as scrotal or flank pain. Dong et al reported that no patients experienced scrotal discomfort or flank pain after surgery, although one case of recurrence occurred. Similarly, Han et al found no postoperative scrotal or inguinal discomfort. In Li et al, one patient with preoperative flank pain reported resolution following surgery. Wan et al demonstrated a significant postoperative reduction in visual analogue scale (VAS) pain scores, supporting the role of shunting in alleviating discomfort. Furthermore, Zhang et al showed significantly higher pain relief rates after shunting compared with ligation alone (91.8% vs 61.8%). Other studies did not report subjective outcomes. These findings suggest that venous shunting may provide effective symptomatic relief, with some evidence pointing toward superior pain resolution compared to conventional ligation. However, the reporting of patient-reported outcomes across studies was inconsistent, and most lacked validated quality-of-life instruments. Future research should incorporate standardized measures such as VAS for pain or QoL to better quantify the broader impact of these procedures on patient well-being.

The physiological rationale behind these enhanced outcomes lies in shunting's ability to preserve a more natural venous drainage pathway.[2,5,9,10,15] By redirecting blood flow away from the dilated pampiniform plexus into a healthy vein, shunting effectively alleviates venous hypertension and reflux characteristic of varicoceles without completely

obstructing outflow. This is particularly advantageous in complex cases, such as those associated with Nutcracker syndrome (NCS), where simple ligation might inadvertently worsen renal vein pressure. In contrast, ligation achieves varicocele resolution by interrupting the refluxing venous pathways but inherently disrupts normal venous outflow. This interruption can lead to venous stasis and the subsequent development of collateral venous channels, factors contributing to the higher rates of recurrence and potential complications like hydrocele formation (reported in 8–12% of cases) and, less commonly, testicular atrophy.

One important limitation of venous shunting is the prolonged operative duration compared with standard microsurgical ligation. Across included studies, shunting procedures required 99–146 minutes, whereas ligation alone ranged from 48 to 92 minutes. The additional time reflects the complexity of dissecting recipient vessels, performing a tension-free anastomosis, and ensuring patency. If shunting is performed as an adjunct to conventional ligation rather than as a standalone technique, the operative time may increase further. This prolongation not only has implications for operating room efficiency and anesthesia exposure but also emphasizes the necessity of advanced microsurgical expertise. While the improved outcomes in semen motility, pain relief, and recurrence reduction may justify the additional duration in selected patients, surgeons must weigh these benefits against the resource demands. In high-volume centers with experienced microsurgeons, the added time may be acceptable; however, in resource-limited settings, the longer operative duration could restrict widespread adoption.

Currently, there is no study directly evaluated cost-effectiveness, however reflecting the prolonged operative time, this will not not only increase operating room and anesthesia resource utilization but also highlights the importance of surgeon expertise. Operative time is also influenced by the learning curve; as microsurgeons gain more experience with shunting procedures, efficiency may improve and narrow the time gap. Thus, the current lack of cost data should not be interpreted as a negative outcome but rather as a reminder that comprehensive economic analyses are essential.

The safety profiles and technical demands of the two approaches also differ considerably. Venous shunting, by meticulously preserving lymphatic vessels and the testicular artery during the microsurgical dissection and anastomosis, significantly minimizes the risk of postoperative hydrocele and testicular atrophy, a benefit highlighted in work by Papeš et al.[10] However, the creation of a venous anastomosis introduces specific potential complications, primarily anastomotic thrombosis, which occurs in approximately 1–3% of cases and may necessitate careful postoperative monitoring or anticoagulation protocols. The inherent technical complexity of shunting, demanding advanced microsurgical skills for the delicate vessel anastomosis, translates into substantially longer operative times (ranging from 99–146 minutes compared to 48–92 minutes for ligation) and presents a steeper learning curve for surgeons.[1] This complexity currently limits the widespread adoption of shunting procedures primarily to specialized, high-volume centers. Ligation, conversely, is a technically simpler and quicker procedure. However, it carries its own set of risks, including the potential for inadvertently missing smaller collateral refluxing veins, which can lead to recurrence, and the risk of accidental injury to the testicular artery or lymphatic vessels, especially when dealing with extensive, high-grade varicoceles.

These differences in efficacy and safety translate into distinct clinical indications and patient selection criteria. Based on the synthesized evidence, venous shunting emerges as the preferred approach for several specific scenarios. It is strongly recommended for recurrent varicoceles where previous ligation attempts have failed. It is also the treatment of choice for varicoceles associated with Nutcracker syndrome, as it directly addresses the underlying venous outflow obstruction. Furthermore, shunting is increasingly favored for adolescent patients presenting with testicular hypotrophy, as preserving venous outflow may better support testicular recovery and long-term growth potential. Studies like Zhang et al also point to superior symptom relief with shunting combined with ligation (91.8%) compared to ligation alone (61.78%).[6] Despite these advantages in complex cases, microsurgical ligation remains the established first-line treatment for the majority of primary, uncomplicated varicoceles, particularly those classified as Grades I and II. Its technical simplicity, shorter operative time, and lower resource requirements make it a practical and effective option, especially in healthcare settings where access to advanced microsurgical expertise and equipment may be limited.

In line with AUA/ASRM (2024) and EAU (2025) guidance, microsurgical subinguinal varicocelectomy is the recommended first-line repair for infertile men with palpable varicoceles and abnormal semen parameters; subclinical varicoceles should not be treated, and embolization is typically considered for recurrence or when surgery is

unsuitable.[21,22] Notably, venous shunting/bypass is not addressed in current guidelines and should be viewed as non-standard/experimental pending higher-quality comparative evidence.

It is crucial to acknowledge the limitations inherent in the current body of evidence comparing these techniques. The field is notably lacking in large-scale, high-quality randomized controlled trials (RCTs). Most available data originate from retrospective cohort studies and case series, which are susceptible to selection bias and confounding variables. Significant heterogeneity exists in how outcomes are reported across studies, particularly regarding semen analysis protocols and the duration of follow-up, making direct comparisons challenging. Moreover, the outcomes of venous shunting are heavily influenced by surgeon experience, as these complex procedures are typically performed by highly skilled surgeons in specialized centers. This concentration of expertise may potentially inflate the reported efficacy of shunting compared to ligation, which is performed by a broader range of surgeons with varying experience levels.

The accumulating evidence suggests that venous shunting may be particularly beneficial in selected patients, such as those with persistent symptoms, high recurrence risk, or suboptimal semen motility after conventional repair by preserving physiological venous outflow while alleviating retrograde reflux. These benefits appear most pronounced in men with pain, where multiple studies have reported complete or near-complete resolution of scrotal or flank discomfort, and in those seeking fertility optimization through motility improvement.

There is a clear need for well-designed RCTs, potentially comparing shunting techniques against standard microsurgical ligation, to provide more definitive evidence and help standardize surgical approaches and outcome assessments. Obtaining long-term fertility data, extending beyond the typical 1–2-year follow-up period, is essential to fully evaluate the sustained benefits of each approach on reproductive outcomes. Continued technological innovation holds promise for improving shunting procedures; advancements such as intraoperative lymphatic mapping could help minimize lymphatic injury, while developments in biodegradable stents might simplify the anastomotic process or reduce thrombosis risk. Finally, rigorous cost-effectiveness analyses are required to better understand the economic implications of adopting more complex shunting procedures, particularly to guide resource allocation and training initiatives in diverse healthcare systems. A formal acknowledgment of shunting as a potential alternative technique in future updates of AUA, EAU, and ASRM guidelines, albeit with the caveat of limited high-level evidence could encourage further research and guide clinical decision-making.

Conclusion

In conclusion, venous shunting represents an innovative microsurgical alternative in the management of varicocele, with early data suggesting potential advantages in selected patients, including improved semen motility, symptomatic relief, and low recurrence. However, the current evidence base is limited to small, mostly retrospective series with heterogeneous indications and outcomes, and no high-quality randomized controlled trials directly comparing shunting with the guideline-endorsed subinguinal microsurgical varicocelectomy. As such, shunting cannot yet be considered a clinically viable replacement for conventional microsurgical ligation and should be regarded as an experimental option reserved for highly selected cases in experienced centers Given the technical demands of venous anastomosis, structured microsurgical training initiatives may help expand future expertise in this area. Furthermore, robust cost-effectiveness analyses and standardized reporting of patient-reported outcomes are necessary to clarify the broader clinical value of shunting.

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The authors declare there was no competing interest.

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