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Open surgery appears to be the preferred treatment in patients with nutcracker syndrome: A vascular low frequency disease consortium analysis

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ABSTRACT

Objectives: Nutcracker syndrome (NCS) is an uncommon vascular disease, characterized by anatomical compression of the left renal vein (LRV). Associated symptoms include flank and pelvic pain, as well as hematuria and varicocele. Our objective was to examine the contemporary management of NCS including diagnostic workup for and outcomes of nonoperative and operative treatments.

Methods: Patients diagnosed with NCS between 2000 and 2024 were identified through the Vascular Low Frequency Disease Consortium. Demographic, diagnostic, and treatment modalities were reported, including primary and secondary patency, reintervention, and symptom resolution/recurrence. Patient characteristics were reported using descriptive statistics and Kaplan-Meier analysis was used to report outcomes.

Results: NCS was diagnosed in 250 patients at 17 institutions. The mean patient age at diagnosis was 37 ± 15 years, 90% were female, and 83% were White. Presenting symptoms and findings included nonpositional flank pain (58%), chronic pelvic pain/dyspareunia (49%), hematuria (48%), nonpositional abdominal pain (47%), and varicocele (3.3%). Diagnostic workup of NCS included computed tomography scan of the abdomen/pelvis (84%), venogram (63%), duplex ultrasound examination (35%), and magnetic resonance imaging (17%). Imaging demonstrated a mean aortosuperior mesenteric

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artery angle of 27.7°. On duplex ultrasound examination, the mean peak systolic velocity of the LRV was 108.9 ± 99.0 cm/s at the compression point and 21.7 ± 9.5 cm/s at the hilum, with a peak systolic velocity ratio of 4.98, whereas venography demonstrated a mean renocaval pressure gradient of 3.92 ± 2.40 mm Hg. Nonoperative treatment with oral analgesics (29%), nutritional counseling/feeding regimen (16%), or simple expectant management (55%) was used in 116 patients and successful in 90 patients (78%) with a mean follow-up of 328 days. Indications for nonoperative management included mild symptoms (64%), young age (10%), and patient preference (8.4%). Of the 26 patients (22%) who failed nonoperative treatment, 20 were subsequently managed with surgery. In the 134 patients who underwent surgery, either as initial treatment or after nonoperative failure, 60 (44%) had a LRV transposition, 43 (31%) underwent a gonadal/ovarian vein transposition, 18 (12%) underwent renal autotransplantation, and 19 (13%) underwent endovascular therapy. The overall 3-year primary patency and secondary patency were 65% (95% confidence interval [CI], 51-76) and 96% (95% CI, 88-99), respectively. The 3-year freedom from reintervention and symptom recurrence were 67% (95% CI, 53-78) and 60% (95% CI, 48-70), respectively. Patients who underwent endovascular intervention had inferior primary patency and freedom from symptom recurrence: 35% (95% CI, 1.22-78) and 46% (95% CI, 7.99-79), respectively.

Conclusions: Approximately 20% of patients with NCS initially managed nonoperatively progressed to operative intervention. Surgery was associated with excellent secondary patency, but a substantial number of patients required reinterventions and 40% developed symptom recurrence by 3 years, highlighting the need for judicious patient selection for surgery through preoperative counseling and shared decision-making. Endovascular therapy was associated with significantly worse results for all outcomes and, therefore, is not appropriate as initial treatment. (J Vasc Surg Venous Lymphat Disord 2026;14:102497.)

Keywords: Nutcracker syndrome; Renal vein compression syndrome; Venous compression syndromes; Vascular Low Frequency Disease Consortium; Renal vein stenting; Renal vein transposition; Ovarian/gonadal vein transposition; Renal autotransplantation

Nutcracker syndrome (NCS) is one of many vascular compression syndromes described in the medical literature. As a whole, vascular compression syndromes are frequently underestimated and misdiagnosed owing to their rarity, poor understanding among physicians, and nonspecific symptoms.[1] NCS results from the external compression of the left renal vein (LRV) by the superior mesenteric artery (SMA), which leads to LRV and pelvic vein venous congestion. This anatomical anomaly was first described in 1937[2]; the term "nutcracker" was first used in 1971[3] and the "nutcracker syndrome" was described in 1972 by De Schepper.[4] LRV compression leads to a constellation of symptoms, most commonly described as left flank pain, abdominal pain, hematuria, and sometimes renal dysfunction.[5,6] Left renovascular hypertension may lead to collateral venous reflux through the adrenal and gonadal/ovarian veins, which manifests as pelvic venous congestion, inguinal/pudendal varices, and pelvic pain.[1,6] Although LRV compression is radiographically visualized in approximately 10% of individuals, the incidence and prevalence of those who exhibit NCS are unclear owing to its rarity. Nonetheless, NCS diagnosis and treatment are important to avoid the long-term risk of chronic kidney disease from LRV hypertension and thrombosis.[2]

Optimal diagnostic criteria for NCS are poorly defined, but various degrees of acute angulation between the aorta and SMA are often reported, as well as the percent renal vein compression, evidenced by elevated flow velocities on duplex ultrasound examination, and various pressure gradients obtained on intravascular LRV venogram.[2,7,8] Furthermore, a variety of treatment paradigms have been suggested, including renal vein transposition, gonadal/ovarian vein transposition, renal vein bypass, renal vein stenting, renal autotransplantation, and renal denervation. Yet, given the rarity of NCS, case reports and case series are limited by their low numbers in providing sufficient information for physicians regarding how to best diagnose and treat this syndrome.[2,9,10]

Our objective was to use the Vascular Low Frequency Disease Consortium (VLFDC) methodology to delineate diagnostic criteria for NCS, define current practice patterns regarding NCS, and analyze outcomes associated with various treatment modalities. The advantage of the using the VLFDC methodology is the ability to collect patient data using standardized definitions of variables across collaborating institutions, with the cumulative number of patients large enough to provide statistical power.

METHODS

This study was conducted using the VLFDC program and methodology, with seventeen institutions from five countries participating and contributing patient-level data (Fig 1). The data were retrospectively abstracted at each site using *International Classification of Diseases* (ICD)9/10 diagnostic and Current Procedural Terminology (CPT) procedural codes from medical records spanning the time period of 2000 to 2024. Male and female patients of any age were eligible for analysis if they were diagnosed with NCS, LRV compression syndrome, or underwent any of the following procedures for the above diagnoses: LRV transposition, left ovarian/gonadal vein transposition, LRV stenting, LRV bypass, or left renal

autotransplantation. Patients initially managed nonoperatively or operatively by open or endovascular surgery were included, as were those with the nutcracker diagnosis initially managed nonoperatively who then progressed to operative treatment. Exclusion criteria included patients with retroaortic renal veins, active infection, traumatic renal vein injury, connective tissue disorders, congenital malformations, or other congenital venous anomalies.

No specific diagnostic codes exist for NCS/renal vein compression. Similarly, no specific procedure code exists for the treatment used for NCS. The following codes were used to identify candidates for study inclusion at each institution: (1) CPT code 37799, which is used for other vein procedures/surgeries and may be used for other procedures on veins not involved in treatment of NCS; (2) CPT codes 37236, 37237, 37238, and 37239, which are used for venous stenting/angioplasty and similarly may include other procedures on veins not used for the treatment of NCS; and (3) ICD-9459.2 and ICD-10 I87.1, which are diagnostic for vein compression, but not specific to the renal vein.

Before initiating the study, we performed a feasibility test at the primary investigator's institution (Dartmouth-Hitchcock Medical Center). The vascular surgery section keeps an internal dataset of all patients seen and treated for NCS. We compared a search for the above seven codes through an institutional administrative database with our internal NCS database and found that all patients previously diagnosed with NCS in our clinics were captured by these seven codes in administrative datasets. The study protocol therefore specified that each site may use the previously mentioned codes to help identify candidate subjects, although sites must assess patient records individually for eligibility through chart review, based on these criteria.

Data variables abstracted included demographics, presenting symptoms and signs, radiographic and invasive testing performed, nonoperative and operative treatment strategies, and outcomes. Specifically, outcomes were defined as symptom resolution, type and timing of reintervention, patency of the treatment procedure, complications during index procedure admission, and long-term complications. Analytics regarding treatment techniques were descriptive in nature. Outcomes were analyzed using STATA statistical software. Data are reported as means ± standard deviations or as

ARTICLE HIGHLIGHTS

- **Type of Research:** International, multicenter, retrospective analysis of patient-level data collected through the Vascular Low Frequency Disease Consortium
- **Key Findings:** Patients with nutcracker syndrome present predominantly with pain and hematuria and undergo a battery of tests demonstrating left renal vein compression. Of those treated conservatively, 20% fail nonoperative management. Operative treatment varies between sites and provides 65% primary patency and 67% relief from symptoms at 3 years. Endovascular therapy only provides 35% primary patency and 46% symptom relief.
- **Take Home Message:** This international Vascular Low Frequency Disease Consortium collaborative demonstrates that the workup of and treatment for nutcracker syndrome vary across institutions. Approximately one-half of patients undergo nonoperative management first, of which 20% fail and require an intervention. Open surgical strategies (renal/gonadal/ovarian vein transposition, renal vein bypass, renal autotransplantation) provide durable symptom relief in two-thirds of patients, whereas renal vein stenting has inferior patency and symptom relief.

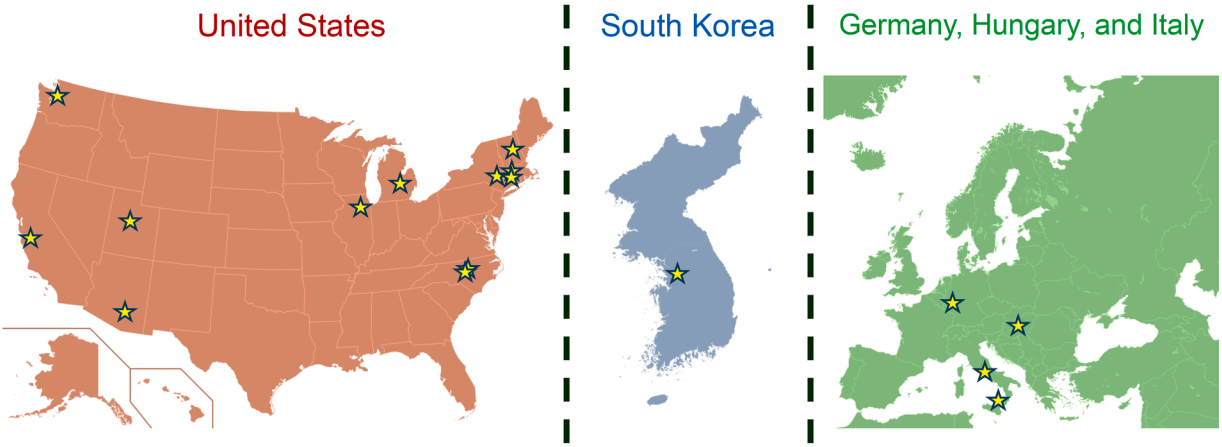


Fig 1. Participant sites. The locations of the institutions that contributed data to this study.

Table I. Patient characteristics

Variable	Value
Total patients	250/250 (100)
Age, years	37 ± 15
Female	227 (91)
Race	
White	208 (83)
Black	12 (5)
Asian/Pacific Islander	11 (4)
Native American	1 (0.5)
Other	11 (4)
Presenting symptoms (may have >1)	
Hematuria	120 (48)
Nonpositional flank pain	144 (58)
Positional flank pain	32 (13)
Nonpositional abdominal pain	117 (47)
Positional abdominal pain	22 (9)
Pelvic congestion/pain, dyspareunia	107 (43)
Varicocele/labial varices	8 (3)
Other	57 (23)

Values are number (%) or mean ± 95% confidence interval.

Table II. Prior abdominal operations

Variable	No. (%)
Total patients with prior abdominal operations	112/250 (45)
Caesarian section	28 (11)
Appendectomy	22 (9)
Laparoscopic cholecystectomy	18 (7)
Hysterectomy	14 (6)
Hernia repair	12 (5)
Tubal ligation	8 (3)
Ovarian cyst removal	8 (3)
Diagnostic laparoscopy	8 (3)
Endometriosis excision	7 (3)
Left common iliac vein stenting	4 (2)
Median arcuate ligament release	4 (2)
Duodenal-jejunal bypass for SMA syndrome	4 (2)
Ovarian/gonadal vein embolization	4 (2)

SMA, Superior mesenteric artery.
Patients may have had more than one operation.

percentages for continuous variables and frequencies and percentages for categorical variables. Outcomes were assessed using Kaplan-Meier life-table analysis. Comparisons between open and endovascular treatment modalities were performed using analysis of variance across multiple modalities or χ^2 if between two modalities.

Institutional review board (IRB) approval was obtained at each participating site. Given the retrospective nature, our deidentification of protected health information, and the low risk to patients resulted in patient informed consent being waived by each IRB. The study principal investigator drafted a study protocol and shared this with each institution for individual IRB approval, ensuring that the protocol and conduct of the study was uniform across sites. A common data dictionary was shared with each site to ensure that data abstraction would also be uniform. All data points were entered into a central data warehouse using the REDCap[11] tool and stored in a secure and encrypted VLFDC file at the University of California, Los Angeles.

RESULTS

Patient characteristics

We included 250 patients who met NCS criteria in this analysis. The mean patient age at diagnosis was 37 ± 15 years, 227 (91%) were female, and 208 (83%) were White. Presenting symptoms and findings included nonpositional left flank pain (58%), followed by macroscopic or microscopic hematuria (48%), nonpositional abdominal pain (47%), and chronic pelvic pain/pelvic congestion/dyspareunia (43%). Positional flank pain (13%) and positional abdominal pain (9%) were less frequently reported, and varicoceles/labial varices were rare (3%) (Table I).

Nearly one-half of the patients (n = 112 [45%]) had prior abdominal surgery, delineated in Table II, including a caesarian section, appendectomy, cholecystectomy, hysterectomy, hernia repair, tubal ligation, ovarian cyst resection, diagnostic laparoscopy, and excision of endometriotic lesions. Few patients had treatment for other compression syndromes, including left common iliac vein stenting, median arcuate ligament release, duodenal-jejunal bypass, and gonadal/ovarian vein embolization.

Diagnostic evaluation

Patients underwent a variety of diagnostic testing as part of their workup, with the majority of patients undergoing multiple tests. Table III shows the frequency of imaging performed on patients as well as the imaging findings. Thirty-five percent of patients underwent duplex ultrasound examination, during which a mean peak systolic velocity of 118 cm/s was measured at the maximum point of compression, and 84% of patients underwent a computed tomography (CT) scan, where the mean aortomesenteric angle was 27.7°. The mean LRV diameter at the most compressed site was 3.5 mm vs 10.7 mm at the renal hilum, resulting in a ratio of 3.06. In addition, 63% of patients underwent a venogram, with a mean renocaval pressure gradient of 3.9 mm Hg. Two-thirds of patients who underwent a venogram were noted to have prominent venous

Table III. Diagnostic workup

Variable	Value
Total patients	250/250 (100)
Patients who underwent CT scan	210 (84)
CT scan findings	
Mean aorto-SMA angle	27.7 ± 14.3°
Mean LRV diameter at maximum compression, mm	3.5 ± 1.5
Mean LRV diameter at hilum, mm	10.7 ± 1.9
Patients who underwent venogram	151 (63)
Venogram findings	
Mean renocaval pressure gradient, mm Hg	3.9 ± 2.4
Patients with enlarged collateral veins	100 (66)
Patients with contrast reflux into collateral veins	75 (50)
Patients who underwent duplex ultrasound	88 (35)
Duplex ultrasound findings	
Mean peak systolic velocity at highest point of LRV compression, cm/s	118 ± 54
Mean peak systolic velocity at renal hilum, cm/s	21 ± 9.5
Mean aorta-SMA distance, cm	1.7 ± 1.4

CT, Computed tomography; *LRV*, left renal vein; *SMA*, superior mesenteric artery.
Values are mean ± standard deviation or number (%).

collaterals, with one-half demonstrating reflux into collateral vein beds, such as the gonadal/ovarian or left adrenal vein. Key diagnostic findings from these imaging studies are highlighted in Fig 2.

Management

Nearly one-half of the patients (n = 116 [46%]) in this study were initially treated nonoperatively; 90 patients (78%) never proceeded to an intervention or operation and were considered to have undergone successful nonoperative therapy. The mean follow-up of the nonoperative patient group was 328 days. However, 26 nonoperative patients (22%) failed conservative management, with persistent symptoms that significantly impaired patient function, and 20 (17%) progressed to operative treatment (Fig 3).

Nonoperative management. Among the 116 patients who were treated nonoperatively, the reasons for using this treatment path were mild symptoms (64%), young age (10%), patient preference (8%), or a general sense of wanting to avoid an operation or intervention. The specific treatment strategy chosen that comprised nonoperative management was predominantly expectant management without further prescription or treatment (55%), followed by oral analgesics (29%), and nutritional counseling with the implementation of a feeding regimen (16%).

Operative management. One hundred thirty-four patients (54%) underwent operative treatment as first-line therapy (Fig 3), with a mean follow-up of 611 days. Twenty patients transitioned to an operation after failing initial nonoperative management. Thus, a total of 154 patients had data available for analysis on operative treatment. Of these patients, 40% underwent a LRV transposition, 29% a gonadal/ovarian vein transposition, 15% LRV stenting, 12% left renal autotransplantation, and 3% a saphenous vein LRV bypass to the vena cava (Fig 4). Most stents used in this cohort were self-expanding bare metal stents (75%), followed by balloon-expandable stent grafts (19%) and balloon-expandable bare metal stents (6%).

Outcomes

For the 154 patients who underwent an operative procedure, the primary patency of the index repair was 82% (95% confidence interval [CI], 73-89) at 1 year, 74% at 2 years (95% CI, 63-83), and 65% (95% CI, 51-76) at 3 years, whereas secondary patency was 98% (95% CI, 91-100) at 1 year, 96% (95% CI, 88-99) at 2 years, and 96% (95% CI, 88-99) at 3 years, respectively (Fig 5, *A*). Reinterventions on the index procedure were performed in 17% (95% CI, 11-26) of patients at 1 year, 23% (95% CI, 16-35) of patients at 2 years, and 33% (95% CI, 23-47) of patients at 3 years. Twenty-eight patients in the overall cohort underwent reinterventions: 24 of these were performed after an index open surgery, and 4 were performed after an index endovascular procedure. Ten patients underwent reintervention for renal vein stenosis, 3 patients underwent reintervention for renal vein occlusion, and 15 patients underwent reintervention for persistent (only partial initial improvement) or recurrent symptoms (complete initial improvement). All but one of the reinterventions (27/28) were technically successful. The unsuccessful case was characterized by an unsuccessful endovascular recanalization of an LRV transposition that occluded 345 days after the index operation.

Twenty-four patients underwent revision after an index open surgical procedure (LRV transposition or gonadal vein transposition). Eight of these were open surgical revisions: left ovarian vein to left CIV transposition (n = 1), LRV to left splenic vein bypass with GSV (n = 1), patch enlargement of a fibrotic portion of the LRV with GSV (n = 1), renal autotransplantation (n = 3), and left nephrectomy (n = 2). The two nephrectomies were performed after one renal vein and one gonadal vein transposition, each for recurrent symptoms and both patients' symptoms resolved following nephrectomy. Sixteen were endovascular procedures: angioplasty or stenting of the LRV, angioplasty/stenting of the transposed ovarian vein (if index gonadal vein transposition



Fig 2. Key diagnostic findings. Summary of key measurements obtained on computed tomography (CT) angiography, venography, and duplex ultrasound examination as part of the workup for nutcracker syndrome (NCS). *LRV*, left renal vein; *PSV*, peak systolic velocity; *SMA*, superior mesenteric artery.

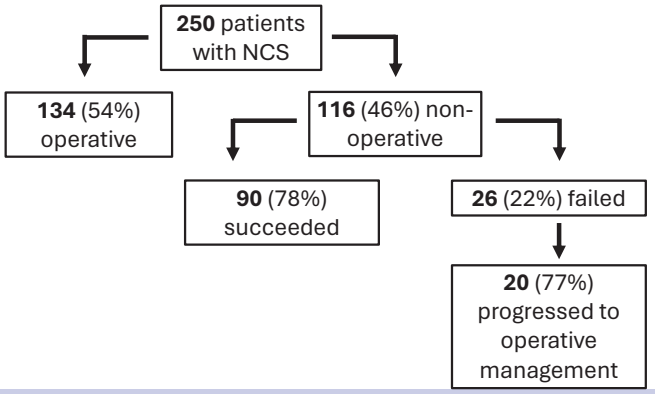


Fig 3. Patient management. Flow chart depicting the number of patients who underwent operative, nonoperative, and endovascular treatment for nutcracker syndrome (*NCS*).

was performed), left ovarian vein embolization, and left common iliac vein stenting.

Four patients underwent revision after an index endovascular procedure. One of these procedures was open surgical revision and three were endovascular reinterventions. The open surgical revision was a stent explant on postoperative day 7 after index LRV stenting. This was performed during the same admission: the patient's symptoms did not improve after the index procedure and worsened, prompting stent explantation. Endovascular procedures included two angioplasty procedures for restenosis of LRV stents. Both of these stents remain patent. A third patient underwent index LRV stenting, which was uncomplicated, but stent migration into the inferior vena cava (IVC) was noted on follow-up imaging. This patient underwent endovascular stent retrieval which was successful, and the LRV remains patent.

There were two instances of stent migration in this cohort. One LRV stent was ma-deployed and migrated into the IVC during deployment. The stent was ultimately removed from the LRV and intentionally deployed in the IVC. This patient was offered open surgery to remove the stent and perform a LRV transposition, but the patient declined this procedure and was lost to follow-up. In the second case, the index procedure was balloon angioplasty of the LRV, and the reintervention was LRV stenting. On subsequent follow-up, the renal vein stent was noted to have migrated into the IVC. The patient underwent a second reintervention to retrieve the stent endovascularly.

Symptom recurrence was noted among 26% (95% CI, 18-36) of patients at 1 year, 36% (95% CI, 27-47) at 2 years, and 40% (95% CI, 30-52) at 3 years (Fig 5, *B*). To characterize symptom improvement after operative strategy, we assessed whether each presenting symptom was completely improved, partially improved (persistent compared with preoperatively), or not at all improved compared with preoperatively. Symptom relief was unknown if the patient was lost to follow-up. This symptom relief was captured at the initial postoperative visit and again at the most recent follow-up visit (Fig 6).

We then studied symptom recurrence. Each initial symptom prompting repair was assessed, and the symptom was defined as recurrent if (1) there was initial partial symptom resolution post treatment that worsened during follow-up at any time, or (2) if there was initial complete symptom resolution post treatment that worsened to partial or complete preoperative severity at any time during follow-up. Symptom recurrence is depicted in Fig 7.

Open vs endovascular treatments

The frequency with which each of the various operations was performed was too low for a meaningful

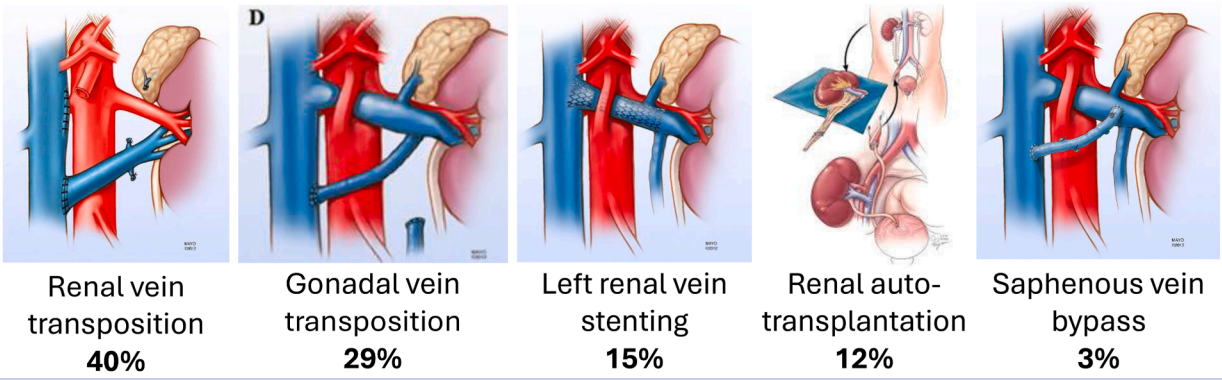


Fig 4. Operative management. The percent of patients who underwent each of the listed treatment approaches.

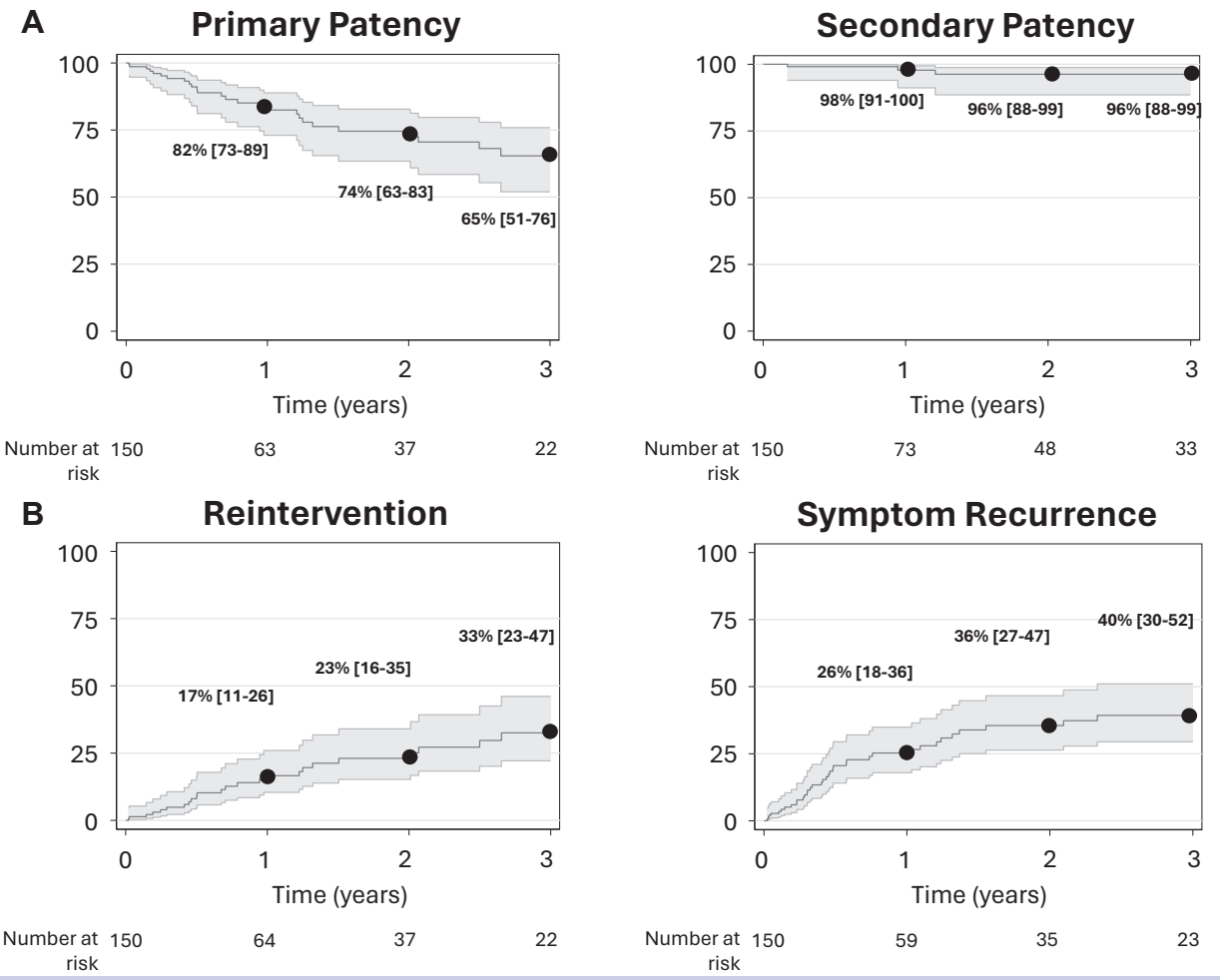


Fig 5. Outcomes among all patients who underwent operative management. Kaplan-Meier curves depicting freedom from **(A)** loss of primary patency, freedom from loss of secondary patency, **(B)** requiring a reintervention, and experiencing recurrence of symptoms.

comparison between all operative outcomes owing to a low statistical power. We therefore conducted a comparison between endovascular treatment (LRV stenting) and a composite of all open surgical treatments (LRV transposition, gonadal/ovarian vein transposition, renal autotransplantation, and LRV bypass). Patients treated with an endovascular intervention were older (43.5 years vs 34.7 years; $P < .01$), had a similar American Society of Anesthesiologists grade, and had a similar rate of prior abdominal operations (Table IV). Endovascular patients

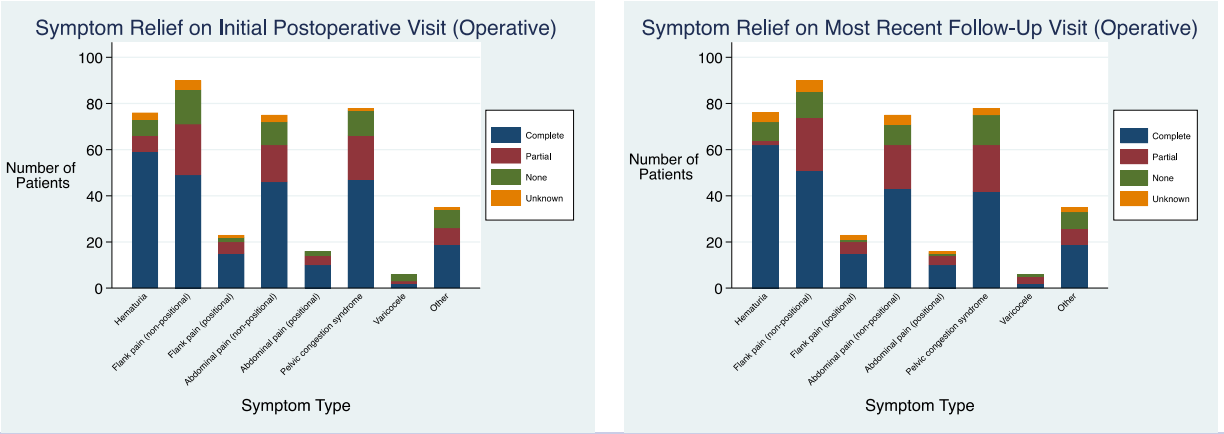


Fig 6. Symptom relief after operative treatment. Symptom relief on initial postoperative visit (*left*) or most recent follow-up visit (*right*) after index operative strategy (open or endovascular) or progression from nonoperative management to operative strategy, stratified by symptom type (n = 154). Patients who were lost to follow-up by their most recent follow-up visit are labeled "unknown."

had a much shorter length of hospital stay (1.3 days vs 5.8 days; $P < .01$). Open surgical patients trended toward a higher rate of postoperative readmission (8.5% vs 4.6%), but this comparison did not attain statistical significance.

At 30 days post index procedure, there were no patients who developed acute venous thromboembolism, acute kidney injury, or wound infection requiring reoperation. Four patients in the open surgical group developed a wound infection that was managed with antibiotics alone, whereas no patients in the endovascular group developed an infection (Table IV).

There were significant differences in long-term outcomes between endovascular and open surgical treatment of NCS. The primary patency at 3 years was 36% among endovascular patients vs 67% for open surgical patients ($P < .01$); however, the secondary patency was equivalent at three years between the two modalities. One hundred percent of endovascular patients and 96% of open patients (P = NS) (Fig 8, *A*) had renal vein patency. Symptom recurrence (44%) was higher among endovascular patients than open surgical patients (39%) at 3 years ($P = .04$) (Fig 8, *B*). Reinterventions occurred twice as often among endovascular (64%) compared with open surgical patients (30%) at 3 years ($P < .01$).

DISCUSSION

This analysis of NCS patients on the current treatment paradigm of this disease process and the associated outcomes. We found that approximately one-half of patients first proceed with nonoperative/noninvasive treatment. This pathway proves to be successful in approximately 80% of patients; however, approximately 20% proceed to surgery at a later time. Operative treatment varies greatly between institutions, yet the majority perform LRV or gonadal/ovarian vein transposition. Approximately 15% of patients underwent an endovascular treatment consisting of LRV stenting. Forty percent of patients experienced recurrence of their initial symptoms by 3 years after treatment. Operative treatment is associated with the need for revision in approximately 33% of patients by 3 years, whereas patients who undergo endovascular treatment have a 50% lower primary patency rate and 50% higher reintervention rate within 3 years and experience a slightly higher rate of symptom recurrence compared with open surgical treatments.

A recently published Delphi consensus on NCS highlights the varied opinions on how to evaluate, diagnose, and treat NCS.[12] Among 20 international experts on NCS, three rounds of review were required to achieve consensus on a majority of 37 statements regarding NCS. However, experts did not agree on diagnostic cutoff values for NCS, in part perhaps owing to a lack of high-level data regarding diagnostic criteria. In our cohort, we identified several key diagnostic criteria that are highlighted in Fig 2: a mean aorto-SMA angle of 27.7° on CT scan, a mean renocaval pressure gradient of 3.9 mm Hg on venogram, and a mean peak systolic velocity of 118 cm/s in the LRV at its point of maximal compression on duplex ultrasound examination, with a ratio of 4.98. These findings align with data published in a literature review in 2017 by Ananthan et al,[2] as well as a literature review by Velasquez et al in 2018.[13] However, our series adds the benefit of more long-term follow-up data regarding outcomes associated with these diagnostic criteria and homogenous collection through a purpose-built database across institutions.

The Delphi consensus also stated that experts agree on LRV transposition as the first-line treatment choice, whereas endovascular stenting should be used with caution owing to concerns of stent migration.[12] This opinion is echoed by Duncan in her publication on

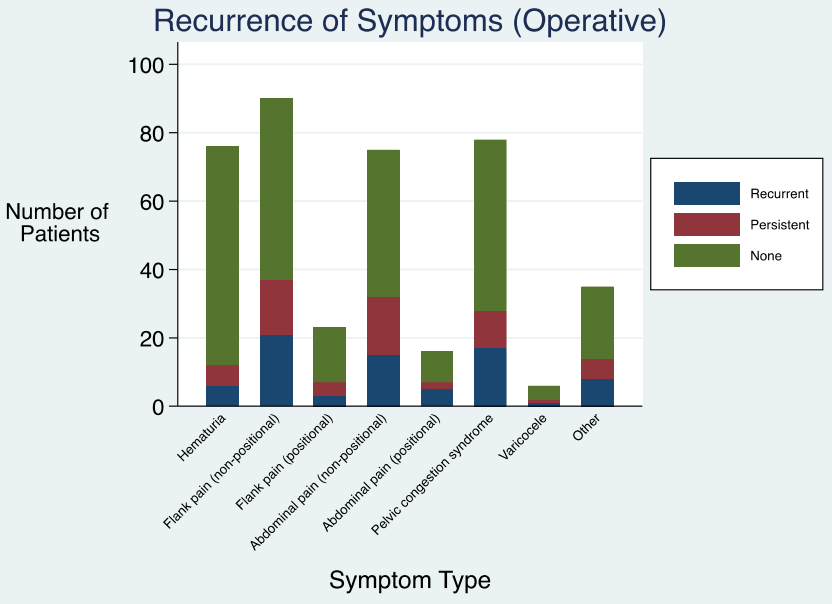


Fig 7. Symptom recurrence after operative treatment. Recurrence of symptoms after index operative strategy (open or endovascular) or progression from nonoperative management to operative strategy (n = 154), stratified by symptom type.

Table IV. Open surgical vs endovascular treatment for nutcracker syndrome (NCS)

Variable	Open (n = 129)	Endovascular (n = 22)	*P* value
Age, years, mean (95% CI)	34.7 (13.4)	43.5 (16.7)	<.01
ASA classification			
I	26 (20%)	1 (4.6%)	NS
II	73 (57%)	16 (73%)	NS
III	25 (19%)	4 (18%)	NS
IV	0 (0%)	1 (4.6%)	NS
Prior abdominal operation	48%	50%	NS
Postoperative length of stay, days	5.8 (4.5)	1.3 (3.1)	<.001
Unplanned readmission	8.5%	4.6%	NS
30-Day postoperative complications			
Acute venous thromboembolism	0	0	NS
Acute kidney injury	0	0	NS
Wound infection (managed medically)	4 (3.1%)	0	NS
Wound infection (requiring operation)	0	0	NS

ASA, American Society of Anesthesiologists; *CI*, confidence interval; *NS*, not significant.

how to treat NCS.[9] Our cohort demonstrates that current practice follows this recommendation, with 40% of operative treatment being LRV transposition and 29% gonadal/ovarian vein transposition. Similar trends are noted in systematic reviews of NCS case series/cohort studies where LRV transposition or gonadal/ovarian vein transposition dominate.[6,13]

Endovascular stenting has become more prevalent in recent years and even extravascular stenting with laparoscopic assistance has been described.[14] Although these reviews cite lower rates of endovascular occlusion and better symptom relief that our cohort, they are limited in follow-up time compared with our cohort that provides >3 years of follow-up.

The concern about stenting a LRV in an otherwise healthy young patient remains significant. No good long-term outcomes data exist in this cohort and purpose-built stents for this anatomy are lacking. Usually, venous stents designed for iliac and caval thrombosis are used in the renal vein, which is much

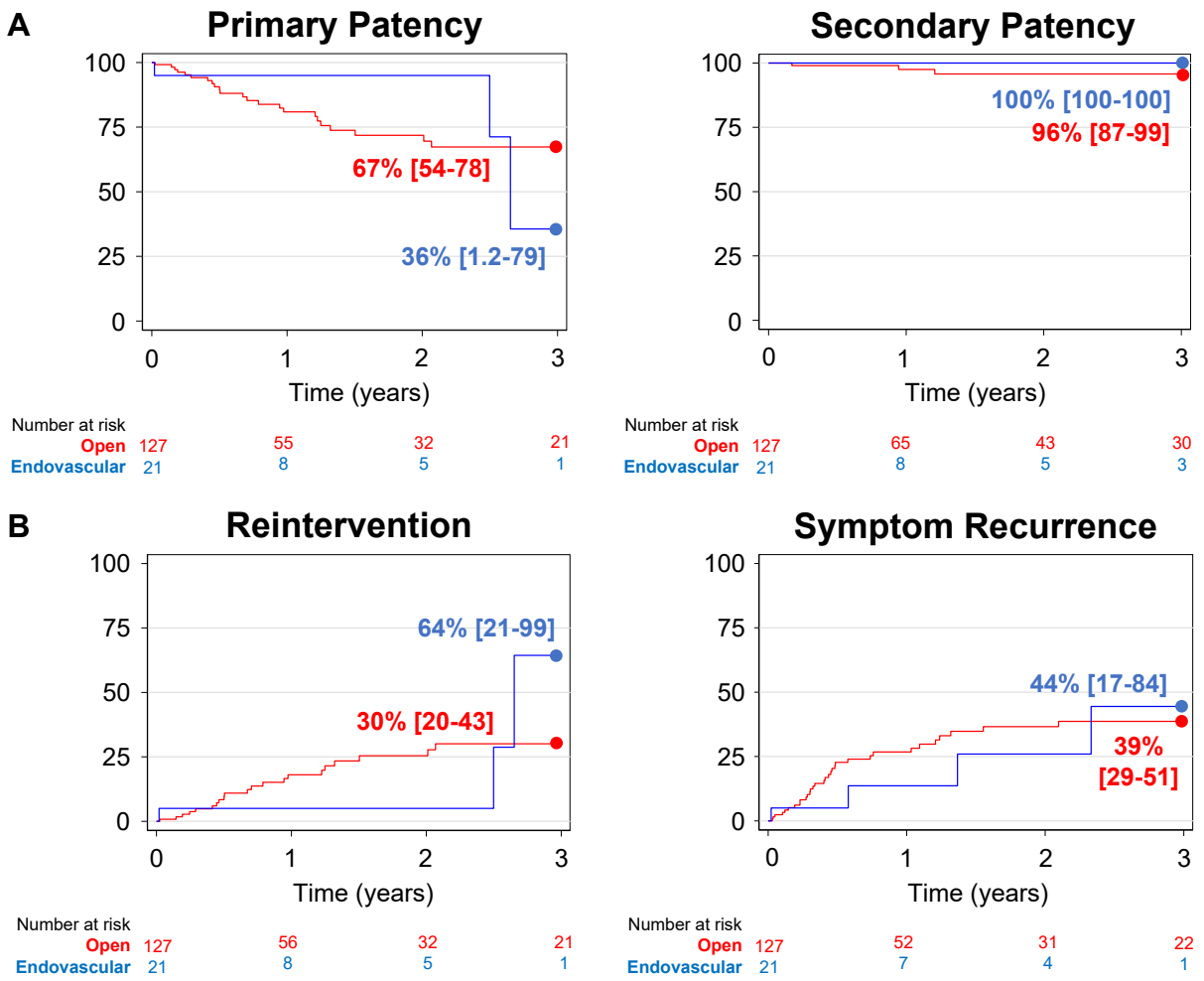


Fig 8. Comparison of outcomes between open surgical and endovascular treatment. Kaplan-Meier curves depicting **(A)** freedom from loss of primary patency, freedom from loss of secondary patency, **(B)** requiring a reintervention, and experiencing recurrence of symptoms. Comparisons between open surgical (*red*) and endovascular (*blue*) treatments.

shorter and thus more likely to result in stent migration. This is evidenced by the multitude of case reports of migrated LRV stents.[15-18] Our cohort further highlights that, in the long term, renal vein stenting requires more than twice the number of reinterventions compared with other open surgical treatment techniques, in part owing to migration, and is associated with a higher rate of symptom recurrence in patients. We feel it is important to note that renal vein stents should be oversized to avoid migration and those patients should be well-hydrated at the time of implantation because the size of the vein increases with hydration status.

Should LRV stenting be used to treat NCS, we feel it is imperative to follow these patients closely with surveillance studies. In fact, we found that even open surgical treatment requires a high rate of reinterventions to maintain a patent repair. This finding underscores the importance of long-term surveillance. We suggest surveillance imaging post operatively, with duplex ultrasound at 30 days, 6 months, and then annually.

We were surprised to find that, despite surgical treatment, ≤40% of patients developed symptom recurrence over 3 years. This number is significantly higher than other published studies, but we included a significantly longer follow-up period than other studies. This finding may result from a selection bias in patients with symptom recurrence who may be more likely to present for follow-up and seek alleviation of their symptoms than those who improve become lost to follow-up. More studies are warranted to better elucidate the durability of symptom relief after NCS surgery as more institutions implement long-term surveillance programs for these patients.

An evolving treatment modality for NCS is robotic-assisted LRV or gonadal/ovarian vein transposition. Several case reports and case series describe the feasibility of this approach and report promising early results,

such as shorter length of hospital stay, more rapid recovery, and better pain control.[19-21] This approach may also provide lower perioperative risks and morbidity associated with endovascular therapies, but with the added durability associated with the traditional open surgical techniques. More studies are required to elicit the long-term durability of robotic-assisted LRV surgery.

Based on our findings, we provide the following practice recommendations. First, it is paramount that a thorough diagnostic evaluation be performed, consisting of duplex ultrasound examination, CT scan, and venogram. It appears reasonable to pursue initial nonoperative management for NCS because 80% of patients do not progress to more invasive treatment. If operative treatment is warranted or chosen, we recommend open surgery with LRV or gonadal/ovarian vein transposition. Last, it is imperative to continue long-term surveillance in all NCS patients, regardless of treatment pathway.

Our study has limitations. It was conducted in a retrospective fashion; thus, the data were limited to what was available in the medical record. This study design also introduces bias in that patients with complications, recurrent symptoms, or other concomitant issues are more likely to return for follow-up and thus may skew outcomes. The study does provide a real-world sampling of practice patterns. However, this means that equipoise between treatment modalities is biased by individual surgeon opinions, level of comfort with a specific treatment modality, and institutional preferences regarding how to treat NCS. Additionally, participation in the VLFDC was voluntary. Although we obtained data from 17 international institutions, this sample may be biased toward institutions involved in academia and research and not provide a holistic overview of how NCS is treated broadly across all practice paradigms. Arguably, many vascular surgeons may not follow nonoperative patients for long time periods, thus limiting the long-term data availability regarding nonoperative management. This would require a prospective study design to track nonoperative patients. Furthermore, follow-up for some patients, especially those who underwent endovascular treatment, was limited with only five patients at 2 years. Last, individual cohorts were small, limiting our ability to statistically compare them in terms of anatomical and patient-level predictors and outcomes, or between specific interventions.

CONCLUSIONS

The majority of patients with anatomical and physiological evidence for NCS can be successfully managed conservatively. Approximately 20% of those initially managed nonoperatively progressed to operative intervention. Surgery was associated with excellent secondary patency, but a substantial number of patients required reinterventions and 40% developed symptom recurrence by 3 years, highlighting the need for judicious patient selection for surgery. The limited endovascular data in this study suggest that endovascular therapy has poorer outcomes than open surgery and, therefore, presents a suboptimal initial treatment choice for NCS. Long-term surveillance is indicated for all patients, regardless of treatment modality.

AUTHOR CONTRIBUTIONS

Conception and design: BDS, AP, KW
Analysis and interpretation: BDS, AP, PL, KW
Data collection: BDS, AP, LW, JC, DS, RP, LNW, CS, YE, SP, JH, MM, CG, CF, PB, GL, BKS, AG, MB, BA, FS, NM, GD, FB, KM, MA, ZS, DZ, KA, JJ, SC, MS, ST, WZ, JT, PL, KW
Writing the article: BDS, AP
Critical revision of the article: BDS, AP, LW, JC, DS, RP, LNW, CS, YE, SP, JH, MM, CG, CF, PB, GL, BKS, AG, MB, BA, FS, NM, GD, FB, KM, MA, ZS, DZ, KA, JJ, SC, MS, ST, WZ, JT, PL, KW
Final approval of the article: BDS, AP, LW, JC, DS, RP, LNW, CS, YE, SP, JH, MM, CG, CF, PB, GL, BKS, AG, MB, BA, FS, NM, GD, FB, KM, MA, ZS, DZ, KA, JJ, SC, MS, ST, WZ, JT, PL, KW
Statistical analysis: BDS, AP
Obtained funding: Not applicable
Overall responsibility: BDS

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