Evolving strategies for the management of venous thoracic outlet syndrome

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ABSTRACT

Objective: Traditional management of venous thoracic outlet syndrome (VTOS) has involved catheter-directed thrombolysis (CDT) followed by transaxillary or paraclavicular (PC) first rib resection. More recently, we have adopted an infraclavicular (IC) approach for first rib resection and five other strategies to treat these patients. We report our evolving experience with the treatment of acute VTOS.

Methods: We reviewed our prospectively maintained database to identify patients treated for VTOS. Our strategy includes CDT with pharmacomechanical thrombectomy, IC first rib resection during the same hospitalization, and subclavian vein angioplasty immediately after rib resection. Postoperatively, a sequential compression device was applied to the affected arm and low-dose heparin given through the ipsilateral venous sheath. Antiplatelet therapy was given for 6 weeks and anticoagulation for 6 months. Our strategy evolved from a PC to an IC approach, given that the added morbidity of the supraclavicular approach to allow excision of the posterior portion of the rib may add no benefit with VTOS compared with arterial or neurogenic thoracic outlet syndrome.

Results: There were 51 patients who underwent first rib resection for VTOS, 11 (22%) through a PC approach and 40 (78%) through an IC approach. The average age was 36 years (range, 16-63 years), and the majority were female (36 [71%]) and involved the right subclavian vein (36 [71%]). All patients underwent preoperative CDT, 40 (78%) at our hospital and 11 (22%) elsewhere. Fifty patients (98%) underwent subclavian vein angioplasty after rib resection. A bare-metal stent was placed in two (4%) patients for persistent stenosis. Average length of stay was 3.7 (±2.1) days. Average operative time was 2.2 hours (range, 1.5-3.0 hours) when the IC approach was used vs 3.5 hours (range, 2.5-4.5 hours) for the PC approach ($P < .0001$). Of the entire group, one (2.6%) patient required reoperation for wound hematoma and six (12%) patients underwent repeated endovascular intervention for recurrent vein stenosis during follow-up (average, 38 months; range, 1-240 months). Primary and assisted primary patency rates at 3 years were 78% and 100%, respectively. There were no significant differences in patency rates or complications between the IC and PC approaches.

Conclusions: Our transition to an IC approach demonstrated low perioperative morbidity and excellent subclavian vein patency rates with shorter operative times compared with a PC approach. Our practice has evolved to include IC first rib resection followed by concomitant postoperative venous balloon angioplasty. (J Vasc Surg: Venous and Lym Dis 2019;7:839-44.)

Keywords: Venous thoracic outlet syndrome; Paget-Schroetter syndrome; Rib resection; Infraclavicular; Pharmacomechanical thrombectomy

Venous thoracic outlet syndrome (VTOS) is a rare clinical entity that represents only 5% of all thoracic outlet diagnoses.[1] Furthermore, it is estimated to account for only 3% of all operations performed for thoracic outlet syndromes.[2] The treatment of acute VTOS has evolved considerably over the years from anticoagulation alone to thrombolysis followed by decompression of the costoclavicular space.

Several techniques for venous decompression have been reported, namely, transaxillary (TA), paraclavicular (PC), and infraclavicular (IC) approaches. We previously reported our results using a PC approach for resection of the entire first rib.[3] More recently, our group adopted an IC approach, limiting the resection to just the anterior portion of the rib. We present our evolving treatment strategies for acute VTOS and specifically compare patient outcomes between the PC and IC approaches.

METHODS

A retrospective review of our prospectively maintained database was performed. All patients undergoing first rib resection for VTOS from January 1993 to December 2018 at Pennsylvania Hospital were included for analysis. Formal approval by our Institutional Review Board was deferred in accordance with our institution's policy, given the deidentified nature of this analysis.

Patient variables. Data collected included the patients' demographics, relevant comorbidities, perioperative details, and follow-up data. Patients with symptom onset of >2 weeks (subacute) or ultrasound features

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suggestive of chronic thrombus were generally not offered lysis therapy or rib resection and were simply anticoagulated.

Procedural details. After transfer or admission to our institution and confirmation of VTOS with clinical examination and duplex ultrasound findings, patients received systemic anticoagulation. Venography was performed through an ipsilateral brachial or superficial arm vein sheath. If it was not already done at an outside institution, catheter-directed thrombolysis (CDT) was initiated and continued using tissue plasminogen activator.

Since 2006, one of our evolving strategies to treat VTOS has included pharmacomechanical thrombectomy with the AngioJet (Boston Scientific, Marlborough, Mass) at the time of initial venography, which has been associated with shorter duration of thrombolysis. An infusion catheter was used for the majority of cases after initial treatment to dissolve any residual thrombus.

Contrary to existing recommendations by some in the 1990s and early 2000s, a second new strategy that we adopted was to perform rib resection during the same admission in all patients, given the high risk of recurrent thrombosis with deferred decompression.

Before 2000, we followed traditional treatment methods, performing first rib resection through a combined supraclavicular and infraclavicular (PC) approach. Given the increased potential morbidity associated with a PC approach, including brachial plexus, thoracic duct, and subclavian artery injuries, a third evolving strategy we adopted was rib resection performed solely through an IC approach. After 2006, we performed all first rib resections for VTOS in this fashion. The IC approach allowed resection of most of the first rib, leaving only a small posterior remnant, but avoided exposing, retracting, and potentially damaging structures in the supraclavicular space. Venolysis with direct visualization of the most medial aspect of the subclavian vein was performed in all procedures, which is an advantage of the IC approach compared with a TA approach.

After rib resection, we then performed completion venography in our hybrid endovascular operating room through the existing ipsilateral upper extremity venous sheath. Residual stenosis at the thoracic outlet was managed with balloon angioplasty. Stent placement was considered only for significant recoil causing persistent severe stenosis.

An additional adjunct in our practice includes both a compression bandage and a sequential compression device applied to the ipsilateral upper extremity in the immediate postoperative period to maintain high flow through the ipsilateral subclavian vein and to prevent recurrent thrombosis.

Finally, since 2006, we maintained the venous sheath in the ipsilateral upper extremity and infused low-dose heparin (500 units/h) until discharge to prevent recurrent venous thrombosis.

Patients were maintained on aspirin or clopidogrel for 6 weeks postoperatively. Patients were started on therapeutic anticoagulation 2 or 3 days postoperatively (historically with warfarin and more recently with novel oral anticoagulants). Anticoagulation was continued for 6 months postoperatively.

Postoperative follow-up protocol. All patients were observed postoperatively in our clinic and our Intersocietal Commission for the Accreditation of Vascular Laboratory-accredited noninvasive vascular laboratory at 1 week, 3 months, and 6 months and then annually thereafter to assess patency and to determine the need for reintervention for recurrent stenosis.

Statistical analysis. All statistics were performed with Microsoft Excel (Redmond, Wash). The χ^2 test and *t*-test were performed to determine significance. Kaplan-Meier analysis was used to determine patency.

ARTICLE HIGHLIGHTS

- **Type of Research:** Single-center retrospective analysis of prospectively maintained database
- **Key Findings:** Compared with transaxillary and paraclavicular techniques in 11 patients, an infraclavicular approach for thoracic outlet decompression for 40 venous thoracic outlet syndrome cases was a safe and effective alternative with comparable overall patency rates at 3-year follow-up (100%).
- **Take Home Message:** An infraclavicular approach to thoracic outlet decompression for venous thoracic outlet syndrome appears to be safe and provides excellent midterm outcomes.

RESULTS

From January 1993 to March 2019, there were 51 patients who underwent first rib resection for VTOS; 11 (22%) were performed through a PC approach between 1993 and 2006, and 40 (78%) were performed through an IC approach from 2000 to 2019 (all procedures performed after 2006 were through an IC approach). Baseline characteristics and demographics of the patients are shown in the Table. The average age of the patients was 36 years (range, 16-63 years). The majority of cases involved the right subclavian vein (36 [71%]) and female patients (28 [55%]).

All patients underwent preoperative CDT, 40 (78%) at our hospital and 11 (22%) at an outside hospital before presentation to our institution. Since 2006, we adopted use of pharmacomechanical thrombectomy with AngioJet. In cases of residual thrombus, an infusion catheter was left for continued lytic therapy. In all but two cases (4%), complete resolution of thrombus was observed.

Table. Baseline patient characteristics and comorbidities

	All patients	PC patients	IC patients
No.	51	11	40
Age, years	36.7 ± 12.9	32.9 ± 12.5	37.7 ± 12.7
Sex			
Male	23 (45)	6 (55)	17 (43)
Female	28 (55)	5 (45)	23 (57)
Race			
White	47 (92)	10	37
Black	3 (6)	1	2
Hispanic	1 (2)	0	1
Comorbidities			
Hypertension	6 (12)	1 (9)	5 (13)
Hyperlipidemia	6 (12)	0	6 (15)
Tobacco use	2 (4)	0	2 (5)
Operative side			
Left	15 (29)	3 (27)	12 (30)
Right	36 (71)	8 (73)	28 (70)

IC, Infraclavicular; *PC*, paraclavicular.
Categorical variables are presented as number (%). Continuous variables are presented as mean ± standard deviation.

Almost all (50 [98%]) patients underwent balloon angioplasty of the thoracic inlet after rib resection for residual subclavian vein stenosis. The average balloon diameter was 12 mm (range, 8-16 mm). A bare-metal stent was placed early in our experience in two (4%) patients in the IC group for persistent stenosis or recoil of the medial subclavian vein near the sternum despite balloon angioplasty. A 12-mm Wallstent (Boston Scientific) was used in both cases. The average operative time was 2.2 hours (range, 1.5-3 hours) when the IC approach was used vs 3.5 hours (range, 2.5-4.5 hours) when the PC approach was used ($P < .0001$).

Postoperative complications included one reoperation 3 weeks postoperatively for a wound hematoma secondary to anticoagulation in the IC group (2.6% [1/40]; a bleeding site was not identified). No reoperations were required in the PC group (0% [0/11]; $P = .59$). One patient (2.6% [1/40]) in the IC group had a postoperative pneumothorax requiring chest tube placement vs none in the PC group ($P = .59$). There were no nerve injuries or infections. There were no perioperative deaths or other major complications. The overall complication rate was not significantly different between the PC group (0% [0/11]) and the IC group (5.2% [2/40]; $P = .44$).

There were no additional angioplasty or stent procedures performed after rib resection during the index admission. All patients were started on therapeutic anticoagulation 2 to 3 days postoperatively. Before 2013, all patients (30) were maintained on warfarin. Since 2013, all patients (21) were maintained on a novel oral anticoagulant.

During follow-up (mean, 38 months; range, 1-240 months), six (12%) patients underwent repeated endovascular intervention for recurrent vein stenosis (6/40 IC, 0/11 PC; $P = .21$). Both patients who had a stent placed in the medial subclavian vein after rib resection required reintervention including balloon angioplasty or insertion of stent graft to maintain patency. Overall IC and PC patency rates are shown in Figs 1 to 3. The overall 1-year primary and assisted primary patency rates were 91% and 100%, respectively. There was no significant difference between IC and PC primary patency at 1 year ($P = .22$). The overall 3-year primary and assisted primary patency rates were 78% and 100%, respectively. There was no significant difference between IC and PC primary patency at 3 years ($P = .10$). Overall assisted patency rates were 100% in each group at 60-month follow-up.

DISCUSSION

The optimal surgical strategy for management of VTOS remains controversial. Historically, subclavian vein decompression was performed through a TA or PC approach.[3-7] More recently, there has been increased interest by our group and others in an IC approach.[8-10] Since 2006, all decompressions by our group for VTOS have been done in this fashion. Our current results suggest that this is a safe and effective surgical strategy for the management of VTOS patients with only a few minor complications observed.

Proponents of the TA and PC approaches note the ability to expose and to excise the entire first rib. We believe these approaches are more technically challenging. Despite the fact that TA and PC approaches are generally reported from high-volume centers, complication rates are significant. Reports suggest pneumothorax rates of 5% to 25% for the TA and PC approaches.[11,12] Other complications, such as wound infection, hematoma, hemothorax, thoracic duct injury, nerve injury, and vascular injury, have been reported in the literature.[11-14] In our series, the complication rate was significantly lower than in previous reports, with only one pneumothorax requiring chest tube and a 5.2% overall complication rate. Clearly, the IC approach would be expected to be associated with the same rate or a lower rate of complications compared with the PC approach because both approaches require the same exposure of the anterior half of the rib with its attendant risk of pneumothorax. The PC approach also employs additional exposure of the upper posterior part of the rib with its inherent risk of brachial plexus, thoracic duct, and subclavian artery injuries. Although there were slightly more minor complications in our series in the IC group, we treated many more patients with the IC approach (40) than with the PC approach (11).

Whereas the results of the TA and PC techniques are promising and still considered the standard for comparison, we believe they add complexity to surgical

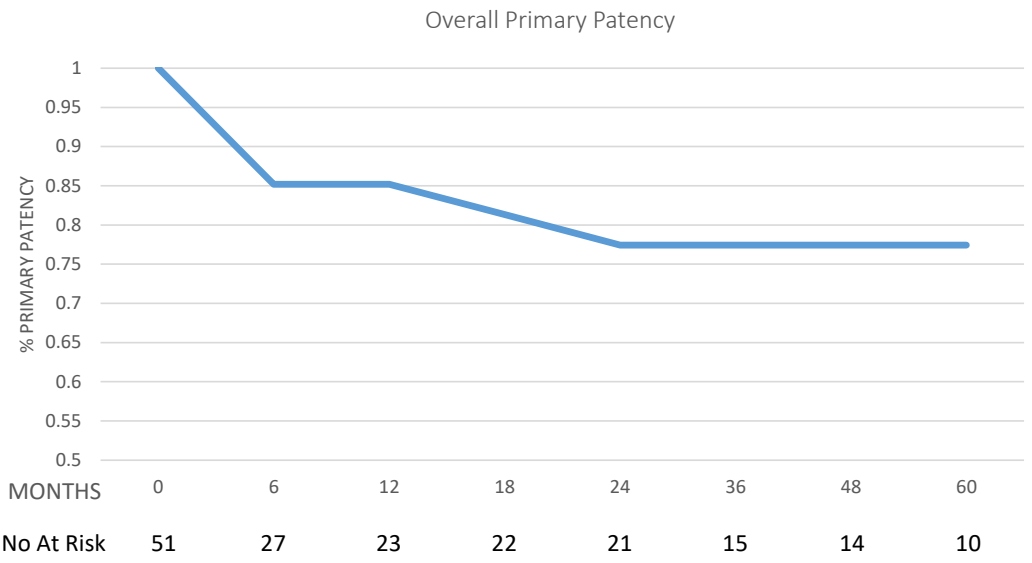

Fig 1. Overall subclavian vein primary patency, paraclavicular (PC) and infraclavicular (IC) patients.

decompression. Molina[8] first described the IC technique for VTOS in 1998 and noted in a subsequent publication[9] that recurrence of subclavian vein thrombosis was generally due to a residual anterior first rib stump or incomplete resection of the costoclavicular ligament and tendon of the subclavius muscle. The TA approach does not lend itself to the same excellent medial exposure as an IC approach. We think the addition of a supraclavicular incision for resection of the posterior first rib is unnecessary because unlike neurogenic or arterial thoracic outlet syndrome, venous stenosis is most commonly due to medial vein compression. The PC approach adds time and complexity to the operation.

Whereas our results found a nonsignificant, slightly higher primary patency for the PC approach in midterm follow-up, the number of patients in the PC group was small (11), and none of the recurrent stenoses were due to compression of a retained upper posterior rib segment, which is removed in the PC approach. Moreover, overall assisted patency rates were 100% at 60-month follow-up. Longer follow-up data are needed to further validate this finding.

Samoila et al[15] recently reported a literature review of all published series using the IC approach for VTOS. To date, only 268 IC cases have been reported in the literature, including 7 from our previous report.[3] The majority have been reported by Molina et al, but our current

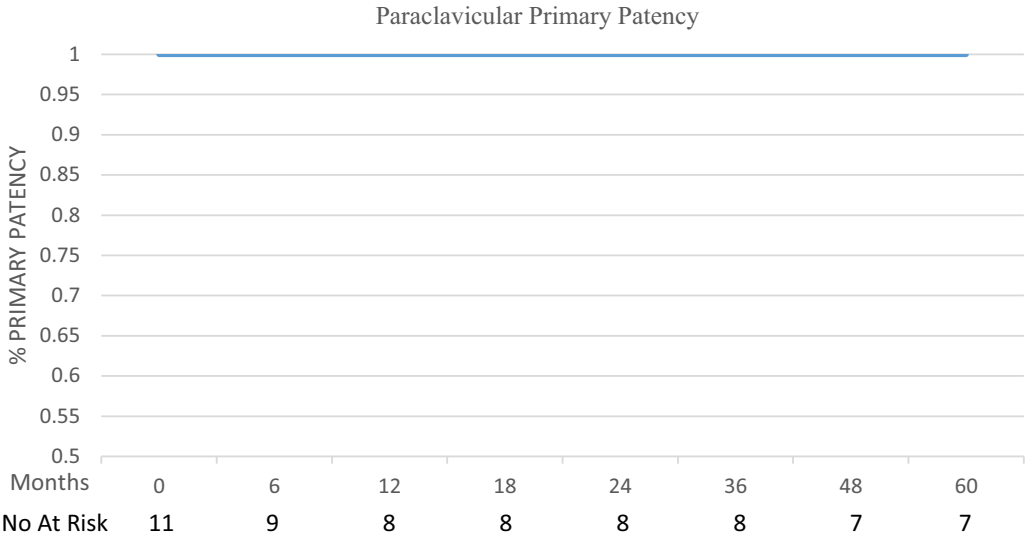

Fig 2. Primary subclavian vein patency for paraclavicular (PC) group (N = 11).

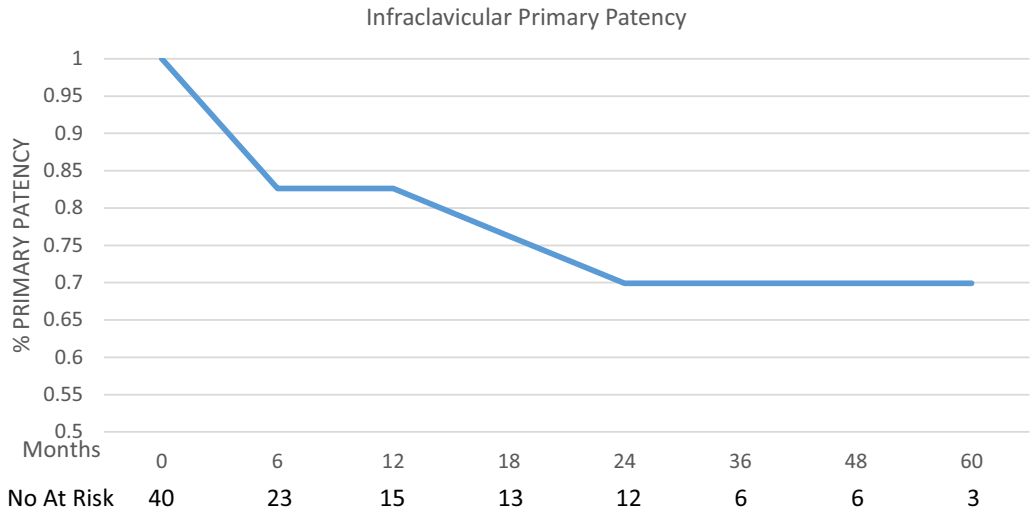

Fig 3. Primary subclavian vein patency for infraclavicular (IC) group (N = 41).

report using the IC approach in 40 patients is one of the largest series to date using the IC technique. Of the six studies reported, all noted a low complication rate, 100% symptom resolution, and pooled secondary patency rate of 98.5%.[15]

Controversy about the optimal approach remains.[16,17] Molina generally incorporated a subclavian vein reconstruction (most frequently vein patch) at the time of thoracic outlet decompression. We believe this strategy adds time and complexity to the procedure and is unnecessary in an era when endovascular interventions, such as balloon angioplasty, provide outstanding patency rates in the majority of VTOS cases. In our series, we had no complications specific to our endovascular interventions, similar to a previous report by Siracuse et al,[10] who also adopted an endovascular protocol for management of VTOS patients at the time of surgical decompression. After removal of the rib, the subclavian vein is no longer subject to extrinsic compression after balloon angioplasty and yields excellent patency rates as reported in this series. Nonetheless, we agree that a few selected patients may require venous endarterectomy with patching or replacement (or venous stenting) for persistent severe venous stenosis despite aggressive balloon angioplasty. Our practice in general is to accept up to a 30% residual stenosis as these patients typically remain patent and symptom free in follow-up. This estimation is based on venography with and without abduction of the arm. As seen with our reinterventions, the placement of a stent is not without the risk of stent thrombosis and need for further interventions. In addition, routine venous reconstruction as proposed by Molina may necessitate a more extensive operation in that partial sternotomy is sometimes required. The role of other adjuncts, such as intravascular ultrasound, has yet to be defined but may aid in this decision-making.

Our other strategies have evolved as a result our personal experience and that reported by others. We routinely perform rib excision during the same hospitalization as venous thrombolysis to avoid recurrent venous thrombosis. We have found mechanical thrombectomy superior to CDT alone. We also currently employ ipsilateral low-dose heparin infusion, an upper extremity antithrombotic pump, and 6 weeks of clopidogrel and 6 months of oral anticoagulation to prevent recurrent venous thrombosis. Whether this long a course of postoperative anticoagulation is necessary is unclear, given that these thromboses are provoked by a mechanical problem that is addressed with thoracic outlet decompression, but this has not been well studied to date. It is therefore our practice to treat this as an acute deep venous thrombosis, with 6 months of anticoagulation being our norm.

CONCLUSIONS

TA and PC approaches have been the historic standards for thoracic outlet decompression for acute VTOS. We believe an IC approach with adjunctive balloon angioplasty at the time of decompression along with the other strategies listed in this report offers an attractive alternative. The IC approach is safe, allows shorter operative times, is technically less challenging, and offers comparable outcomes to the traditional surgical approaches for acute VTOS.

AUTHOR CONTRIBUTIONS

Conception and design: NM, KC, MD, KM, DT
Analysis and interpretation: NM, KC
Data collection: NM, KC
Writing the article: NM, KC
Critical revision of the article: NM, KC, MD, KM, DT
Final approval of the article: NM, KC, MD, KM, DT

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Overall responsibility: NM

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