



Outcomes of venous bypass combined with thoracic outlet decompression for treatment of upper extremity central venous occlusion

Jeffrey B. Edwards, MD,^a James D. Brooks, MD,^a Mathew D. Wooster, MD,^b Blake Fernandez, MD,^a Kelli Summers, MD,^c and Karl A. Illig, MD,^d Tampa, Fla; Charleston and Orangeburg, SC; and New Orleans, La

ABSTRACT

Background: Upper extremity central venous stenosis results from a variety of environmental and anatomic conditions, including venous thoracic outlet syndrome, the presence of device leads or catheters, and the turbulence created by the presence of arteriovenous fistulas or grafts. In cases of total occlusion, especially at the bony costoclavicular junction, options for endovascular treatment and open venous reconstruction are limited and bypass grafting may be needed. We describe our experience with venous bypass combined with thoracic outlet decompression in a cohort of symptomatic patients with subclavian vein occlusion.

Methods: A prospectively collected database of patients was queried for patients treated for central venous obstructive disease with venous bypass in the setting of both symptomatic venous thoracic outlet syndrome and ipsilateral arteriovenous access from July 2012 to December 2017. All but one patient presented with arm swelling and had either failed to respond to or were unsuitable for endovenous therapy. One patient desired elective removal of a venous stent because of pain and anxiety. Operative procedures were performed at the discretion of the operating surgeon.

Results: Fourteen patients (eight men; average age, 42 years) underwent open thoracic outlet decompression with first rib resection (n = 11) or claviclectomy (n = 4). Indication for treatment was dialysis-associated venous outlet obstruction in five, effort thrombosis (Paget-Schroetter syndrome) in seven, presence of a venous implantable cardioverter-defibrillator lead in one, and patent but painful venous stent in situ with significant anxiety. Nine patients required first interspace sternotomy for exposure of the proximal subclavian vein. One patient with acute Paget-Schroetter syndrome had been treated with preoperative thrombolysis without resolution; all others were chronically occluded. Bypass conduit was jugular vein in one, bovine carotid artery graft in two, paneled great saphenous vein in two, femoral vein in eight, and polytetrafluoroethylene in one. Mean operative time was 187 (± 45) minutes, with mean estimated blood loss of 379 (± 209) mL. There were two early graft thromboses that were revised with jugular venous turndown and femoral vein bypass, respectively. All patients experienced immediate symptom relief. Morbidity included two graft thromboses, two instances of wound dehiscence, two operative site hematomas, non-ST elevation myocardial infarction, vein harvest site infection, polytetrafluoroethylene graft infection, and phrenic nerve injury. At a mean follow-up of 357 (± 303) days, primary assisted patency and secondary patency for the entire cohort were 71.4% and 85.7%, respectively, with 100% primary assisted patency among those with femoral vein conduit. At last follow-up, 13 of the 14 living patients (93%) remained symptom free.

Conclusions: In our experience, venous bypass combined with thoracic outlet decompression achieves symptomatic relief in approximately 90% of patients with symptomatic upper extremity central venous occlusion, with morbidity limited to the perioperative period. (*J Vasc Surg: Venous and Lym Dis* 2019;7:660-4.)

Keywords: Thoracic outlet syndrome; Subclavian vein thrombosis; Deep venous thrombosis; Paget-Schroetter syndrome

Obstruction of the subclavian vein in the region of the costoclavicular junction (CCJ) is believed to result from two issues: the anatomic “nutcracker” effect of the first rib and clavicle (Fig), present in all humans, and a separate, inciting environmental factor leading to vein injury.¹⁻⁵

Most such cases are primary and are labeled venous thoracic outlet syndrome (VTOS).^{1,6,7} Although no clear objective cause is found, there is often a history of repetitive overhead activity (which further narrows the CCJ), muscle development, dehydration, or other such factors. Device-associated obstruction can occur by chronic

From the Division of Vascular Surgery, Department of Surgery, University of South Florida, Tampa^a; the Division of Vascular Surgery, Department of Surgery, Medical University of South Carolina, Charleston^b; the Division of Vascular Surgery, Department of Surgery, Louisiana State University Health Sciences Center, New Orleans^c; and the Dialysis Access Institute, Orangeburg.^d

Author conflict of interest: none.

Presented as a quickshot oral presentation at the Thirtieth Annual Meeting of the American Venous Forum, Tucson, Ariz, February 20-23, 2018.

Correspondence: Jeffrey B. Edwards, MD, Division of Vascular Surgery, 2 Tampa General Circle, 7th Fl, Tampa, FL 33606 (e-mail: jeffreyedwards@health.usf.edu).

The editors and reviewers of this article have no relevant financial relationships to disclose per the Journal policy that requires reviewers to decline review of any manuscript for which they may have a conflict of interest.

2213-333X

Copyright © 2019 by the Society for Vascular Surgery. Published by Elsevier Inc. All rights reserved.

<https://doi.org/10.1016/j.jvsv.2019.03.016>

intimal injury in the subclavian vein due to the long-term presence of cardiac device leads, tunneled hemodialysis catheters, or indwelling ports or central lines. Finally, it is increasingly accepted that patients with ipsilateral arteriovenous (AV) access are prone to similar injury in this location, probably because of the very high flow (1 L or more) past this area. Of the almost half-million patients on hemodialysis in the United States, it is estimated that 15% to 20% of those will develop central venous stenosis.² Whereas most such patients undergo angioplasty (and occasionally stenting) of this area, it is our belief that these stenoses will not resolve without thoracic outlet decompression. This is based on more than a half-century of knowledge gained from treatment of VTOS combined with the fact that the underlying anatomy and extrinsic bone compression are the same in these patients.⁸⁻¹²

We have previously presented our results of thoracic outlet decompression combined with endovascular or open surgical intervention in a larger population of patients with varying degrees of stenosis and symptom status.¹³ Those patients with complete occlusion of the subclavian vein, however, are a unique group, requiring venous reconstruction often with complex exposure strategies for correction of the problem, and such intervention has been thought by some to be overly invasive, not worth the risks to the patient. The purpose of this study was to describe our experience with formal central venous bypass combined with thoracic outlet decompression in patients with subclavian vein occlusion and severe symptoms who cannot be otherwise managed.

METHODS

A prospectively collected database of patients treated with thoracic outlet decompression was queried for those patients who had undergone concomitant central venous bypass between July 2012 and December 2017. Informed consent was not required. The database comprised the experience of a single surgeon at two tertiary referral centers. Patients were included if the reconstruction included portions of the superior vena cava and innominate, subclavian, or proximal axillary veins due to a lesion at the CCJ. All patients had either failed to respond to or were unsuitable for endovenous therapy. Bypass type and conduit were performed at the discretion of the operating surgeon and were often determined on the basis of intraoperative findings, including conduit length, vein caliber, and specific patient factors (Table).

Thrombolysis was attempted preoperatively in the case of acute subclavian vein thromboses, and these patients were anticoagulated with vitamin K antagonist or direct oral anticoagulant for 3 months postoperatively. First rib resection was performed through the paraclavicular approach, and the incision was extended medially to accommodate a first interspace sternotomy if access to

ARTICLE HIGHLIGHTS

- **Type of Research:** Single-center retrospective cohort study
- **Key Findings:** Venous bypass combined with thoracic outlet decompression for treatment of central venous occlusion in 14 symptomatic patients achieved symptom relief in 90% of patients, with 1-year primary patency and secondary patency of 71.4% and 85.7%, respectively.
- **Take Home Message:** Central venous bypass is a suitable option for highly symptomatic patients with central venous occlusive disease who have failed to respond to or are not candidates for endovenous therapy.

the proximal subclavian or innominate vein was necessary.³ Claviclectomy alone was performed in select cases and was favored in the event that a malunion after prior clavicular fracture was thought to be the key contributing factor to venous compression. Bypass conduit was variable, but femoral vein was preferred as other conduit types were found to be inferior in our early experience. Doppler assessment and intraoperative venography were used to interrogate bypass grafts before wound closure. Postoperative surveillance was performed with duplex ultrasound at 1 month and 6 months postoperatively and then on an annual basis unless new symptoms suggested loss of patency.

The study protocol was approved by the local Institutional Review Board. Informed consent waiver was granted for this retrospective review.

RESULTS

During the study period, 53 total patients underwent thoracic outlet decompression for VTOS or hemodialysis-associated CCJ stenosis; 13 had concomitant venous bypass for total occlusion and significant symptoms and 1 after removal of a patent stent for a total of 14 central vein bypasses. All procedures were performed by a single surgeon with assistance from vascular surgery residents or fellows. There were eight men, and the mean age was 42 (± 14) years. Patients presented with chronic obstruction and associated arm edema ($n = 11$), pain and anxiety related to an indwelling subclavian vein stent ($n = 1$), or effort-related acute subclavian vein thrombosis ($n = 2$). One patient also had symptoms of neurogenic thoracic outlet syndrome at the time of presentation. Both of these acutely symptomatic patients remained occluded despite preoperative thrombolysis, and intraoperative findings suggested acute-on-chronic venous disease (it is not our normal practice to bypass patients with acute effort-related thrombosis). Five patients had ipsilateral hemodialysis access, one patient had ipsilateral implantable



Fig. Three-dimensional reconstructed computed tomography venogram of the right venous thoracic outlet showing compression of the subclavian vein by the subclavius muscle (subtracted, *thick arrow*) underlying the clavicle and the clavicle and first rib (*thin arrows*), forming a "nutcracker" around the vein. (Reprinted with permission from Glass C. VTOS in the patient requiring chronic hemodialysis access. In: Illig KA, Thompson RW, Freischlag JA, Donahue DM, Jordan SE, Edgelow PI, editors. Thoracic outlet syndrome. London: Springer; 2013. p. 356. Original image courtesy Wallace Foster, MBBS, FRACS, Royal Brisbane and Women's Hospital, Brisbane, Australia.)

cardioverter-defibrillator leads, and the remaining eight patients had classic VTOS physiology. Six patients had previously placed subclavian vein stents, five of which were occluded. One patient had a patent stent removed. She had initially been treated for acute effort-related thrombosis with thrombolysis and subclavian vein stenting 1 year before our evaluation, but the presence of the stent was a significant cause of anxiety for her and she wished to have more definitive reconstruction and stent removal.

Three patients underwent claviclectomy alone, 1 patient underwent combined claviclectomy with first rib resection, and 10 patients underwent first rib resection alone. Nine of these required medial extension of the incision to accommodate a first interspace sternotomy for more medial venous exposure. Bypass conduits were eight femoral vein, two bovine xenograft, two great saphenous vein (one spiral graft), one polytetrafluoroethylene, and one jugular vein. Mean operative time was 187 (± 45) minutes, with average blood loss of 379 (± 209) mL. Thoracostomy tubes were not routinely placed, although one patient required placement for postoperative bleeding. All patients underwent completion venography, and none underwent adjunctive angioplasty or stenting during the index procedure. Patients remained hospitalized for an average of 8 (± 5) days postoperatively. Early morbidity included two graft thromboses, two instances of wound dehiscence, two operative site hematomas, non-ST elevation myocardial infarction, and vein harvest site infection. One graft thrombosis was

saphenous vein conduit converted to jugular venous turnout (reoccluded); the other was bovine xenograft conduit revised with femoral vein (patent at 3 months). Late morbidity included one polytetrafluoroethylene graft infection treated with serial washouts and eventual graft explantation without reconstruction and one phrenic nerve injury in a patient with prior neck irradiation that resulted in chronic dyspnea. There were no early deaths; one patient with a heart transplant died of myocardial infarction 5 months postoperatively.

Early symptom relief of arm edema was experienced by 100% of patients. Function was preserved in all dialysis accesses for the duration of the follow-up period, and the patient with obstructing automatic implantable cardioverter-defibrillator leads did not require any modifications to maintain function of the device. At a mean follow-up of 357 (± 303) days, primary assisted patency and secondary patency were 71.4% and 85.7%, respectively. Primary assisted patency was 100% among those patients with femoral vein conduit. Three patients underwent percutaneous balloon angioplasty during the follow-up period. One patient had limb swelling after femoral vein harvest. Thirteen patients (93%) remained symptom free at last follow-up, and the one patient whose symptoms returned deferred additional therapy and was subsequently lost to follow-up.

DISCUSSION

Central venous obstruction is a cause of significant morbidity among affected patients. In those with hemodialysis-associated VTOS, it can lead to loss of vascular access in the affected arm. Although many patients are treated initially with less invasive means, there is a cohort that will require more aggressive therapies with decompression of the thoracic inlet with venous reconstruction or bypass, notably those with total occlusions that cannot be crossed with a wire.^{2,4,14-16}

With the exception of the patient with psychological distress and local pain secondary to a previously placed CCJ stent, our cohort of patients presented with symptoms consistent with upper extremity venous insufficiency. Such symptoms were primarily arm edema, occasionally with resultant pain secondary to venous hypertension, although some patients had chest or facial edema, depending on the exact location of the obstruction, amount of flow, and anatomy of collaterals.

Our results show that morbidity, although not insignificant, was limited to the perioperative period. Of the 14 patients, 13 experienced symptom relief, and all AV accesses were preserved during follow-up (patients with an ipsilateral fistula had a higher secondary patency than those without a fistula, although small numbers preclude any definitive statements).

Based on our experience, we submit that aggressive surgical treatment of patients with total subclavian vein occlusion that cannot be treated with endovascular

Table. Operative details

Age, years/ sex	Pathophysiology	Prior stent	Operative details (relevant history)	Conduit	Complications
57/M	HD	No	Claviclectomy, SCV to proximal innominate vein bypass, stage I basilic transposition (prior heart transplantation)	JV	None
57/M	HD	No	Claviclectomy, FRR, SCV interposition bypass, thrombectomy of existing brachial-axillary AVG	PTFE	Hematoma, graft infection
48/M	HD	No	FRR, SCV-proximal innominate vein bypass through first interspace sternotomy	CFV	None
54/M	HD	Yes	Claviclectomy, innominate reconstruction with panel graft	Bovine xenograft	NSTEMI
70/F	VTOS	No	FRR, SCV interposition bypass through first interspace sternotomy	GSV (spiral)	Wound dehiscence
26/M	VTOS	No	FRR, SCV interposition bypass, early revision to jugular turndown	GSV	Wound dehiscence
45/F	VTOS	Yes	FRR, innominate venoplasty, and SCV-innominate bypass through first interspace sternotomy; early revision to femoral vein conduit	Bovine xenograft	Thrombosed POD 2
30/F	Device lead associated	Yes	FRR, SCV interposition bypass	CFV	Postoperative bleeding, tube thoracostomy
41/F	VTOS	No	Claviclectomy, SCV-innominate vein bypass	CFV	Vein harvest site hematoma
30/M	VTOS	Yes	FRR, axillary-SCV bypass through first interspace sternotomy	CFV	None
38/F	NTOS/VTOS	No	FRR, SCV interposition bypass (redo operation, irradiated surgical field)	CFV	Vein harvest SSI
36/M	VTOS	Yes	FRR, axillary-innominate vein bypass through first interspace sternotomy (history of sternotomy, neck irradiation)	CFV	Phrenic nerve injury
31/M	VTOS	No	FRR, SCV interposition bypass through first interspace sternotomy	CFV	None
23/F	VTOS	Yes	Redo FRR, SCV interposition bypass through first interspace sternotomy	CFV	None

AVG, Arteriovenous graft; CFV, common femoral vein; FRR, first rib resection; GSV, great saphenous vein; HD, hemodialysis associated; JV, jugular vein; NSTEMI, non-ST elevation myocardial infarction; NTOS, neurogenic thoracic outlet syndrome; POD, postoperative day; PTFE, polytetrafluoroethylene; SCV, subclavian vein; SSI, surgical site infection; VTOS, venous thoracic outlet syndrome.

techniques is a reasonable option to consider. Our preferred conduit is femoral vein as we found saphenous vein graft and prosthetic conduits to be prone to early thrombosis. Molina⁵ presented his initial experience with first rib resection with central venous intervention through limited first interspace sternotomy in the 1990s. This small series of eight patients demonstrated feasibility of this useful surgical technique and conveyed good results out to 14 months, with all reconstructed segments remaining patent. None of these patients had ipsilateral fistulas, and the conduit of choice was aortic homograft for those patients requiring vein replacement. Overall, there is little precedent established for the optimal management of chronic central venous obstruction, but several isolated case reports describe good results with central venous bypass or surgical

reconstruction after failure of endovenous therapy.¹⁵⁻¹⁸ Although this study is limited by its small sample size and limited follow-up, we have found similarly good results in a cohort of patients who have failed to respond to or were not candidates for less invasive therapies.

Others have recommended a more conservative approach as definitive therapy.^{8,14,16,19-23} de León et al²⁰ have reported that the subclavian vein may recanalize with the use of anticoagulation after first rib resection (studying patients with classic VTOS only). As mentioned earlier, we agree that there is a subset of patients who may improve with decompression alone, but in the case of severe symptoms, especially with a clinical situation and intraoperative findings suggestive of a chronic occluded vein, we would recommend more aggressive treatment to restore venous outflow.

CONCLUSIONS

Total obstruction of the subclavian vein in the region of the CCJ, although at times asymptomatic, can be a significant cause of morbidity among patients with VTOS, especially those without pre-existing collaterals or those with ipsilateral AV access. Whereas morbidity of aggressive exposure and reconstruction in these patients is not zero, problems are generally easily managed and limited to the perioperative period; 93% of our patients experienced significant symptom relief, and all AV accesses were preserved. We recommend that when endovascular options fail in a patient with an occluded subclavian vein and significant symptoms, thoracic outlet decompression with primary venous bypass should be considered.

AUTHOR CONTRIBUTIONS

Conception and design: JE, JB, MW, BF, KS, KI

Analysis and interpretation: JE, JB, MW, KI

Data collection: BF, KS

Writing the article: JE, JB, KI

Critical revision of the article: JE, JB, MW, BF, KS, KI

Final approval of the article: JE, JB, MW, BF, KS, KI

Statistical analysis: JE, KI

Obtained funding: Not applicable

Overall responsibility: JE

REFERENCES

- Illig KA, Doyle AJ. A comprehensive review of Paget-Schroetter syndrome. *J Vasc Surg* 2010;51:1538-47.
- Illig KA. Management of central vein stenoses and occlusions: the critical importance of the costoclavicular junction. *Semin Vasc Surg* 2011;24:113-8.
- Molina JE. A new surgical approach to the innominate and subclavian vein. *J Vasc Surg* 1998;27:576-81.
- Beygui RE, Olcott C, Dalman RL. Subclavian vein thrombosis: outcome analysis based on etiology and modality of treatment. *Ann Vasc Surg* 1997;11:247-55.
- Illig KA, Donahue D, Duncan A, Freischlag J, Gelabert H, Johansen K, et al. Reporting standards of the Society for Vascular Surgery for thoracic outlet syndrome. *J Vasc Surg* 2016;64:e23-35.
- Doyle A, Wolford HY, Davies MG, Adams JT, Singh MJ, Saad W, et al. Management of effort thrombosis of the subclavian vein: today's treatment. *Ann Vasc Surg* 2007;21:723-9.
- Thompson RW. Comprehensive management of subclavian vein effort thrombosis. *Semin Intervent Radiol* 2012;29:44-51.
- Wisselink W, Money SR, Becker MO, Rice KL, Ramee SR, White CJ, et al. Comparison of operative reconstruction and percutaneous balloon dilatation for central venous obstruction. *Am J Surg* 1993;166:200-4; discussion: 204-5.
- Illig KA, Gabbard W, Calero A, Bailey C, Shames M, Armstrong P, et al. Aggressive costoclavicular junction decompression in patients with threatened AV access. *Ann Vasc Surg* 2015;29:698-703.
- Williams ME. Venous thoracic outlet syndrome simulating subclavian stenosis in a hemodialysis patient. *Am J Nephrol* 1998;18:562-4.
- Maintz D, Landwehr P, Gawenda M, Lackner K. Failure of Wallstents in the subclavian vein due to stent damage. *Clin Imaging* 2001;25:133-7.
- Schneider DB, Dimuzio PJ, Martin ND, Gordon RL, Wilson MW, Laberge JM, et al. Combination treatment of venous thoracic outlet syndrome: open surgical decompression and intraoperative angioplasty. *J Vasc Surg* 2004;40:599-603.
- Wooster M, Fernandez B, Summers KL, Illig KA. Methods and outcomes of surgical and endovascular central venous reconstruction combined with thoracic outlet decompression. *J Vasc Surg* 2017;65(Suppl):7S.
- Surowiec SM, Fegley AJ, Tanski WJ, Sivamurthy N, Illig KA, Lee DE, et al. Endovascular management of central venous stenoses in the hemodialysis patient: results of percutaneous therapy. *Vasc Endovascular Surg* 2004;38:349-54.
- Suliman A, Greenberg JI, Angle N. Surgical bypass of symptomatic central venous obstruction for arteriovenous fistula salvage in hemodialysis patients. *Ann Vasc Surg* 2008;22:203-9.
- Bhatia DS, Money SR, Ochsner JL, Crockett DE, Chatman D, Dharamsey SA, et al. Comparison of surgical bypass and percutaneous balloon dilatation with primary stent placement in the treatment of central venous obstruction in the dialysis patient: one-year follow-up. *Ann Vasc Surg* 1996;10:452-5.
- Aciri I, Carmignani A, Vazzana G, Massara M, Aciri E, Lentini S, et al. Ipsilateral jugular to distal subclavian vein transposition to relieve central venous hypertension in rescue vascular access surgery: a surgical report of 3 cases. *Ann Thorac Cardiovasc Surg* 2013;19:55-9.
- Urschel HC, Patel AN. Surgery remains the most effective treatment for Paget-Schroetter syndrome: 50 years' experience. *Ann Thorac Surg* 2008;86:254-60; discussion: 260.
- Lee WA, Hill BB, Harris EJ Jr, Semba CP, Olcott CIV. Surgical intervention is not required for all patients with subclavian vein thrombosis. *J Vasc Surg* 2000;32:57-67.
- de León R, Chang DC, Busse C, Call D, Freischlag JA. First rib resection and scalenectomy for chronically occluded subclavian veins: what does it really do? *Ann Vasc Surg* 2008;22:395-401.
- Onozawa S, Tajima H, Murata S, Nakazawa K, Fukunaga T. Clinical usefulness of hybrid intervention for the treatment of primary thrombosis of axillary-subclavian vein. *Ann Vasc Dis* 2009;2:62-5.
- Lugo J, Tanious A, Armstrong P, Back M, Johnson B, Shames M, et al. Acute Paget-Schroetter syndrome: does the first rib routinely need to be removed after thrombolysis? *Ann Vasc Surg* 2015;29:1073-7.
- Bakken AM, Protack CD, Saad WE, Lee DE, Waldman DL, Davies MG. Long-term outcomes of primary angioplasty and primary stenting of central venous stenosis in hemodialysis patients. *J Vasc Surg* 2007;45:776-83.

Submitted Oct 27, 2018; accepted Mar 28, 2019.