Aggressive Costoclavicular Junction Decompression in Patients with Threatened AV Access

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Background: A substantial number of patients with threatened arteriovenous (AV) access are found to have stenoses at the costoclavicular junction (CCJ), which frequently are resistant to angioplasty and stenting. We believe that stenoses in this location will not resolve unless bony decompression is performed to relieve the extrinsic compression on the vein. This article describes our short- to medium-term results following such decompression in patients with failing fistulae.

Methods: We reviewed a prospectively maintained database to identify all patients with threatened AV access operated on for stenoses at the CCJ. Pre- and postoperative course along with long-term follow-up were analyzed.

Results: Between July 2012 and December 2013, 24 patients with threatened access were operated on for CCJ stenoses at our institution. Fifteen had highly dysfunctional AV fistulae otherwise felt to need ligation, 10 had significant arm and/or head swelling, and 3 required access but had no contralateral options. In 6 patients, the subclavian vein was occluded and 18 stenotic; 5 of these had stents in place through the CCJ. Decompression was performed via claviculectomy in 3 patients, 2 of whom underwent reconstruction (one jugular vein, one prosthetic bypass) and 1 was stented. The other 21 patients underwent first rib resection, 20 via an infraclavicular exposure and 1 via a supraclavicular rib resection. A variety of interventions were performed in the arm, including aneurysm plication, cephalic to deep bypass, one prophylactic distal revascularization interval ligation, and several primary fistulae. 30-Day mortality was minimal: there was one significant hematoma and one hemothorax in a patient who underwent on-table thrombolysis and there were no deaths or cardiac, neurologic, or other significant morbidity. Median length of stay was 2 days. At follow-up up to 20 (median 10) months, 4 patients died of unrelated causes and 1 patient undergoing central reconstruction with prosthetic bypass required excision of this for infection and ligation of his fistula. Two other fistulae failed. One-year assisted primary patency of the fistula was 85%, and of the central bypass, 89%. At last follow-up, the index arm continued to be used for access in 85% of patients, and overall survival was 68%. Virtually all patients experienced dramatic symptom relief.

Conclusions: In this group of high-risk patients whose access was judged otherwise nonsalvageable, excellent symptom relief and long-term fistula and ipsilateral arm use can be achieved with aggressive decompression of the bony CCJ followed by endovascular intervention as needed.

INTRODUCTION

As of 2011, approximately 10% of patients in the United States had some degree of chronic kidney disease, and 615,899 were maintained on hemodialysis, at a cost to the United States (Medicare part D only) of at least $1.7 billion yearly.[1] Despite varying levels of aggressive surveillance, both fistulae and grafts fail at an alarming rate. Although grafts

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commonly fail because of intimal hyperplastic stenosis at the venous anastomosis, the most common cause for failure overall remains stenosis and/or occlusion within the venous outflow tract. Although many such stenoses can be successfully treated using endovascular techniques, a substantial number of such problems occur at the junction of the clavicle and first rib (costoclavicular junction, CCJ) (Fig. 1). This area has been studied for decades in the context of venous thoracic outlet syndrome (VTOS), and despite varying protocols and beliefs, essentially all involved in the care of patients with VTOS agree that the subclavian vein is vulnerable to injury in this location, that its very rare that the vein will stay open if the bony compression remains untreated, and that stents in this area quickly fracture, causing more problems than if the vein was simply left alone.[3]

Several years ago in conjunction with a busy TOS practice, we developed the idea that the subclavian vein at the CCJ was prone to stenosis in patients with arteriovenous (AV) access. We further hypothesized that this vein will not be successfully treatable unless the extrinsic bony compression is removed. We began treating such patients with aggressive thoracic outlet decompression in 2008, and were able to salvage 80% of fistulae that were deemed otherwise unsalvageable.[4,5] Taking lessons learned from that experience and following relocation of the primary author (K.A.I.), we began aggressively treating such patients in the Tampa Bay region in 2012. This report describes our experience, focusing on operative outcomes and short- to mid-term results.

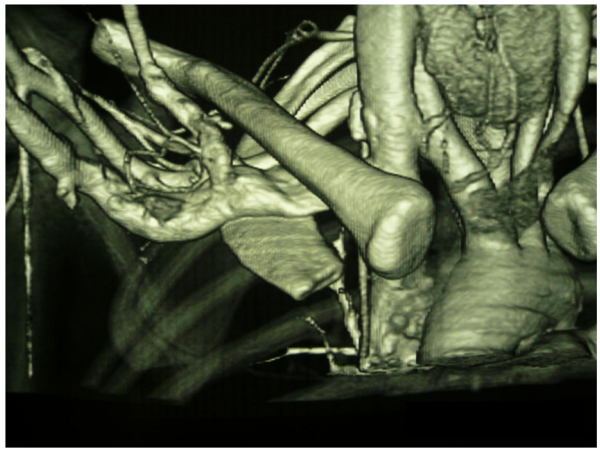

Fig. 1. Computed tomography scan of the right shoulder, viewed from an anterior projection, with soft tissues such as the subclavius muscle subtracted out. The right arm is elevated. Note compression of the subclavian vein as it passes between the clavicle and the first rib. Courtesy: Wallace Foster, MD, Brisbane, Australia. Reprinted from Glass.[2]

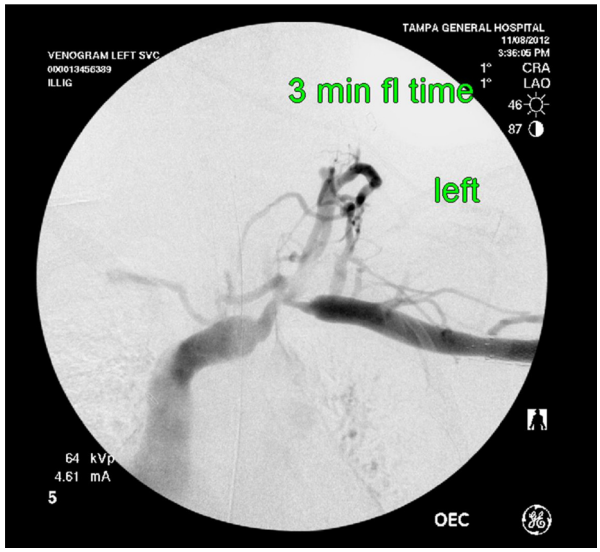

Fig. 2. Left arm fistulogram showing a high-grade stenosis at the costoclavicular junction with relatively normal vessels proximally and distally. Note the extensive collateralization, which is pathognomonic for a hemodynamically significant obstruction in this area.

METHODS

Patients are identified because of dysfunction of existing access (severe swelling, difficulties with cannulation, high venous pressures, shoulder pain with dialysis, excessive bleeding on decannulation), the presence of an existing stent within the CCJ, or documented stenosis ipsilateral to the only possible site for planned access. All patients undergo venography and ultrasonography to precisely delineate the relevant anatomy and confirm stenosis at the CCJ (Fig. 2). All patients undergo an unusually thorough informed consent process, and are provided with our previous work on this topic[4,5] with explanation, in layman's terms, of why we believe this procedure leads to better overall fistula function.

The specific technique used for each patient depends on the individual situation. In general, patients who require extensive venous reconstruction undergo claviculectomy, but most patients undergo preliminary venography/fistulography in the supine position followed by infraclavicular first rib excision, thorough mobilization of the vein, and thorough external venolysis. We then perform repeat imaging and definitively treat the stenosis before wound closure. In general, infraclavicular first rib excision allows removal of the anterior

half of the first rib, from posterior to the anterior scalene insertion site all the way to the sternum. The tendinocartilaginous tissue comprising the subclavius tendon and costoclavicular ligament can be completely removed, and the vein completely dissected free from the overlying tissues.

We recorded thorough perioperative records of these patients in a prospectively maintained database. After Institutional Review Board approval, this database was reviewed, and all sources of follow-up (University of South Florida outpatient records and Tampa Bay Vascular Center interventional information) were interrogated.

RESULTS

Between July 2012 and December 2013, we operated on 24 patients with threatened AV access and CCJ stenoses as described above. Indications for surgery, procedures performed, and short-term complications are shown in Table I. Fifteen patients had dysfunctional access, most commonly excessive decannulation bleeding, venous hypertension, or pain in the shoulder region with access; 10 had significant arm and/or head swelling, at times enough to interfere with access; and 5 patients, 4 of them symptomatic, had stents in place through the CCJ (another 2 had stents at the cephalic arch). In 6 patients, the subclavian vein was occluded, while the other 18 had stenotic or recently stented CCJs. Thirteen patients had undergone up to 8 prior interventions (mean 3.4 and median 3 per patient). Two patients had prior fistula or graft thrombosis with recent declotting. Two patients had existing AV grafts, 20 existing AV fistulae, and in 2 patients AV fistulae were constructed at the time of the procedure. One patient had ipsilateral pacemaker/defibrillator leads through a highly stenotic CCJ.

Three patients underwent medial claviculectomy, 2 of whom required subclavian vein bypass and 1 was subsequently stented. One patient underwent supraclavicular rib resection for a high-lying vein, while the remaining 20 underwent infraclavicular first rib excision as described. One patient underwent prophylactic distal revascularization interval ligation and 7 patients underwent revision (aneurysm repair, correction of stenoses, and/or superficialization) of their existing AV fistulae.

Two patients were operated on for acute access thrombosis. One patient (forearm loop graft) underwent surgical declotting with CCJ decompression, but the other had thrombosed his brachiocephalic fistula up to and including the CCJ because of a cephalic arch stent occluding both the cephalic and deep systems. This patient underwent on-table pharmacomechanical thrombolysis followed by successful first rib excision, but developed an acute hemothorax requiring thoracoscopic drainage. One other (immunocompromised) patient who underwent claviculectomy and prosthetic bypass of an occluded SVC required drainage of a hematoma, developed a wound infection requiring several trips to the operating room, and ultimately lost his subclavian vein graft and fistula. There were no deaths within 30 days. Median length of stay was 2 days (range 1–4 days); subjectively, these patients seem to have much less pain than a typical thoracic outlet patient.

Table I. Indications for operation and short-term outcomes

Indications[a]	
Access dysfunction	15
Arm/head swelling	10
CCJ stent in situ	5
SCV occlusion	6
Stenosis or stent	18
Procedures	
Infraclavicular FRR	20
Medial claviculectomy	3
Supraclavicular FRR	1
Complications	
Uneventful	21
Hemothorax	1 (reconstruction and fistula did well)
Infection, excision	1
AVF thrombosis	1
30-day success	22

AVF, arteriovenous fistula; FRR, first rib resection; SCV, subclavian vein.
[a]Includes patients with more than one indication.

One patient occluded her fistula (despite an open CCJ repair) on the first postoperative day, while the patient described above lost his central graft and had his fistula ligated within 30 days. Our 30-day technical success rates for both fistula salvage/patency and patency of our CCJ decompressions were thus 23 of 24, or 96%. At a median follow-up of 5 months, assisted primary patency of the fistula was 88% and of the central bypass 78%. The index arm continued to be used in 21 of the surviving 23 patients (88%). Virtually all patients with shoulder discomfort from previously placed stents report full resolution of pain.

Mean follow-up extends to 10 months, ranging from 1 to 20 months. During this interval, 7 fistulae have required venoplasty with or without stenting, 2 have been ligated, and 1 occluded. Two pseudoaneurysms have been repaired. One-year assisted

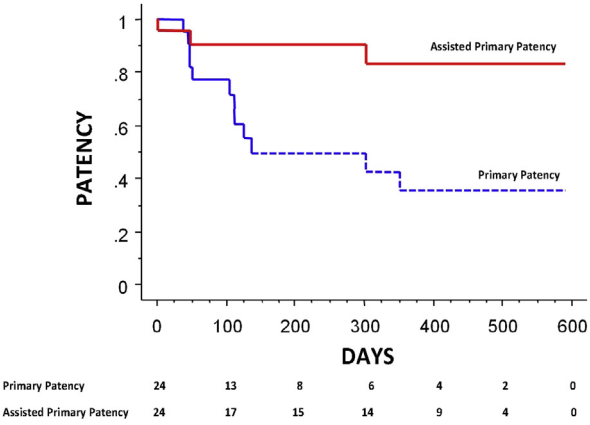

Fig. 3. Primary (blue) and assisted primary (red) patency rates for the fistula. Numbers at risk at the beginning of each interval are reported below the *x*-axis. Dotted line indicates a standard error of >10.

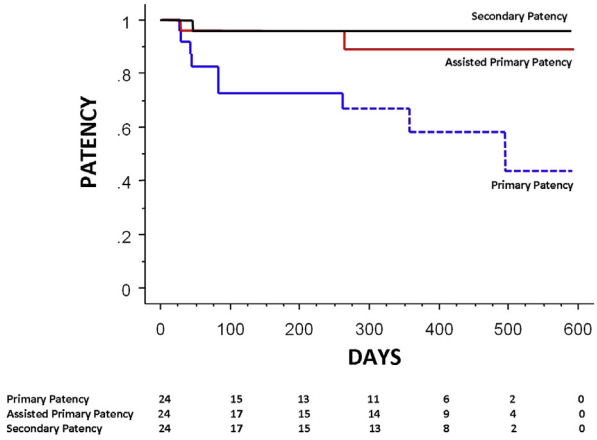

Fig. 4. Primary (blue), assisted primary (red), and secondary (black) patency rates for the subclavian vein at the decompressed costoclavicular junction. Numbers at risk at the beginning of each interval are reported below the *x*-axis. Dotted line indicates a standard error of >10.

primary patency of the fistula is 85% (Fig. 3). Nine of our central reconstructions have required intervention, but only 2 ultimately failed; one-year assisted primary patency of the CCJ segment is 89% (Fig. 4). Four patients have died, all from problems unrelated to access. Finally, at 1 year, the index arm continues to be used for access in 85% of the patients (Fig. 5).

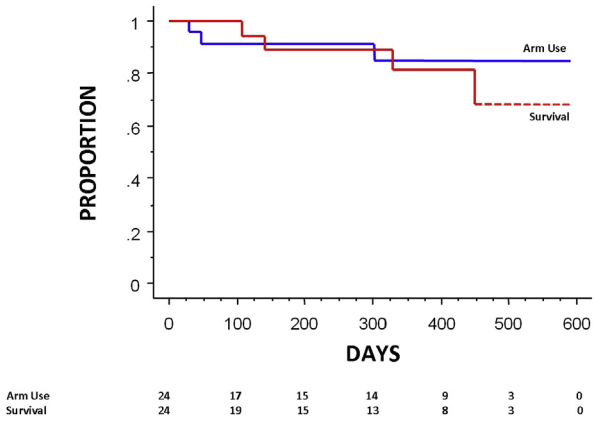

Fig. 5. Ipsilateral arm use for access (blue) and overall survival (red) following costoclavicular decompression. Numbers at risk at the beginning of each interval are reported below the *x*-axis. Dotted line indicates a standard error of >10.

DISCUSSION

Our results show that surgical decompression of the CCJ in patients with threatened AV access is feasible, is well tolerated in the short term, and leads to maintained symptom-free access use in a large majority of patients.

To our knowledge, this problem (or, at least, the concept that stenosis in this area is different from stenosis elsewhere) has not been previously recognized. The images obtained in patients with this problem (Fig. 2) are immediately recognized as classic VTOS by surgeons who concentrate on thoracic outlet syndrome. It is rare that a single surgeon concentrates on both thoracic outlet syndrome and AV access, which may be why this issue has not previously been addressed. Although many dialysis patients with stenoses at the CCJ obviously maintain their access, at best this requires repeated endovascular intervention until this area is stented, after which the vein quickly occludes.[6,7] At worst, such patients very often undergo early ligation of their access, removing this arm from future consideration and likely shortening their lifespan.

This area is qualitatively different from the rest of the venous inflow circuit. The clavicle and the first rib are both securely anchored to the sternum and each other anteriorly, not only by their specific attachments to the sternum but also by a combination of subclavius muscle and tendon and the cartilaginous costoclavicular ligament. Infraclavicular first rib exposure clearly displays this fulcrum, which is very difficult to cut even with scissors. Although movement is slight, leverage is impressive and it is surprising that more people do not have this problem (Fig. 1).

The inciting factor in patients with venous TOS is felt to be hypertrophy of the muscles and/or

prolonged shoulder abduction in otherwise healthy athletic patients (''effort thrombosis''). Our AVF patients do not seem to fit into this category. We hypothesize rather that the forces that exist within this area produce some degree of subtle stenosis in some patients. Because of the extremely high flow through this area, there is created a localized area of relatively increased turbulence. This, in turn, acts as a stimulus for intimal hyperplasia, which worsens the stenosis. These patients thus develop a positive feedback loop, creating worsening stenosis in this area.

Why is bony decompression required? We do not have a control group to compare our results within the series, but by extrapolation from decades worth of experience with VTOS, we strongly believe that the problem (extrinsic compression by the bones) must be eliminated for the vein to recover. It is well known from this point that stents in this area performed very poorly[6,7] as the forces created by the bones overwhelm even the strongest stent. In fact, in this situation stents often fragment, creating irreversible thrombosis of the vein. As our experience matures, we are becoming more and more aggressive with decompression in asymptomatic patients who have had stents previously placed in this location to forestall future problems.

When we have discussed our preliminary results, we have been struck by surgeons' reticence to approach this area in this situation. In approximately 65 cases performed thus far, we have had absolutely no sense that pressure and/or bleeding problems are any different from those during any other operation. We have had only one hematoma requiring reoperation, and the one other significant bleeding complication (hemothorax) occurred in a patient who underwent on-table thrombolysis at the time of surgery. It may simply be that surgeons who concentrate on AV access are not comfortable in the thoracic outlet. Our message in the situation is to ask an experienced ''thoracic outlet surgeon'' to be part of the AV access salvage team.

Our technique has evolved over the past few years, and we have learned some lessons. First, we believe that infraclavicular first rib excision is the preferred approach in this situation, as it allows supine patient positioning for concomitant endovascular intervention, allows resection of all relevant ribs, allows excision of subclavius muscle and tendon and costoclavicular ligament, and provides excellent venous exposure for venolysis. If greater exposure for clamping and repair is necessary, while claviculectomy is an option, we increasingly prefer cephalad sternoclavicular rotation.[8] Second, we have been increasingly aggressive with stent placement in the ''decompressed'' thoracic outlet. Although the majority of experts feel that a stenotic vein in a patient with venous TOS will remodel after bony decompression, our fear in this situation is that the flow is so high that an untreated stenosis in this area will continue to worsen. Third, we leave the wound open during endovascular intervention. In the unlikely event that bleeding occurs after aggressive balloon venoplasty, this can immediately be identified and repaired. Finally, we wish to point out not only that surgery is relatively expeditious, but that this operation is extremely well tolerated. Again, these patients seem to have less pain and a quicker recovery then do our classic thoracic outlet patients.

The major drawback to this report is obviously the lack of a control group. These patients were all selected after multiple failures of conventional treatment, but we have no proof that we could not obtain the same results without surgical decompression. We have a fairly large number of patients who refused consultation and/or treatment, but follow-up has been extremely difficult in this group. As our experience matures (and selection criteria become more liberal), we plan on making an effort to track down such patients, trying to standardize or pair patients based on presenting symptomatology, and thus getting a better sense as to what difference, if any, we are making. Assuming there is a difference, obviously a prospective randomized trial should follow.

CONCLUSION

The present series documents that patients with threatened AV access because of stenoses at the CCJ can undergo bony decompression with minimal morbidity and mortality. Overall long-term fistula salvage rate is approximately 90%, and, assuming that these patients may continue to have problems without such intervention, short- to medium-term patency rates seem good. We are currently increasingly aggressive with this technique as part of an overall ''fistula rehabilitation'' strategy, but definitive proof will require standardization of patients and subsequent comparison of outcomes with and without bony decompression.

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