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Clinical Research

Successful Return to Active Duty after First Rib Resection for Thoracic Outlet Syndrome

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Background: The optimal surgical approach and treatment algorithm for thoracic outlet syndrome (TOS) remain controversial. We sought to examine the outcomes of patients treated at a military medical treatment facility (MTF) for TOS.

Methods: A retrospective review was performed on all patients who had a first rib resection (FRR) for TOS over a 9-year period at a single MTF. Patient demographics, perioperative details, and patient outcomes were examined. Active duty (AD) status and return to AD were reviewed.

Results: From 2008 to 2016, 33 FRRs were performed in 32 patients. Of these, 30 patients were on AD with a mean age of 27 years (range, 19−44). The 29 male and 4 female patients were treated for symptoms of venous (23), neurogenic (6), or arterial (4) TOS. The mean time from onset of symptoms was 11 months (range, 1 to 120). The FRR was performed via a transaxillary (13), supraclavicular (12), or paraclavicular (8) approach. Of 21 AD patients with venous TOS, 16 (76%) underwent preoperative thrombolysis. A postoperative venogram or ultrasound was performed in 20 patients, documenting vein patency in 18 (90%). Nine patients underwent subsequent venoplasty or stent placement. Most patients (15) were placed on anticoagulation for 1−6 months. Two AD patients had perioperative complications including a lymph leak and brachial plexus palsy. Twenty-four (89%) patients returned to AD status. One recruit never returned to AD after successful FRR, and two other patients did not return for medical reasons unrelated to the FRR.

Conclusions: Despite a variety of surgical approaches and often delayed presentation, we identified a high percentage of postoperative vein patency and return to AD status in our population. The debate over surgical approach remains; however, a multimodal approach individualized to the patient's presentation and meticulous surgical technique led to successful outcomes in our healthy military population.

INTRODUCTION

Thoracic outlet syndrome (TOS) is a complex medical condition. Rather than one entity, it is instead three different processes each causing external compression on either the subclavian artery, subclavian vein, and/or the brachial plexus. Neurogenic (nTOS) is the most common (80%), followed by venous (vTOS; 20%) and arterial (aTOS; <1%). While surgery is frequently not the initial treatment for nTOS, first rib resection (FRR) is the standard therapy for arterial and venous TOS.

The views expressed in this presentation are those of the author and do not necessarily reflect the official policy or position of the Department of the Navy, Department of Defense, nor the US Government.

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The most commonly identified and treated population for TOS is young athletes. Significant research has focused on this population, often with an emphasis on vTOS, also known as Paget-Schroetter Syndrome.[1] The repetitive use of the upper extremity in high-performance athletes is thought to predispose them to repetitive endothelial trauma which may lead to narrowing and eventual thrombosis. With the appropriate intervention, competitive athletes can return to full activity at a presurgical performance level.[2,3]

The US military population consists of a significant portion of young, healthy active males. Soldiers and sailors frequently train for and have jobs that have physical requirements comparable to those of a high-performance athlete. Despite this, TOS in the AD population has been understudied.[4] The aim of this study was to review the experience with TOS at a single military medical treatment facility (MTF) and the outcomes, primarily rate of return to duty (RTD), in those patients who underwent surgical treatment.

METHODS

This study was a retrospective analysis of all patients who underwent an FRR for TOS from 2008 to 2016 at the Naval Medical Center San Diego (NMCSD). NMCSD is the largest MTF on the West Coast and also receives patients from the Western Pacific Naval Fleet. Data were obtained by direct chart abstraction. This project was approved by the institutional review board at the NMCSD.

Basic demographics were reviewed and can be found in Table I. Patients were divided into active duty (AD) or not AD (retired or dependent). AD members were then categorized into officer or enlisted and by their military job (Fig. 1). These were reviewed so as to examine the ability to return to their position and included high-performance athlete-equivalent (HPAE), surface warfare/intel, medical, mechanic/technician (so-called ''industrial athlete''), and other enlisted/officer. HPAE included Basic Underwater Demolition/Seal Trainees, Survival/Evasion, Resistance, and Escape school participants, rescue swimmers, and Marine Corps Recruits.

A total of four operating surgeons were included in this study. Surgical procedures were identified by surgical case logs and confirmed by Current Procedural Terminology (CPT) codes (21615; 21705). The surgical approach was at the discretion of the surgeon, based on their training, experience, and best plan for the specific patient. The benefits and drawbacks to each type of procedure are greatly debated. The transaxillary approach is hindered by a limited view and exposure. The supraclavicular approach can result in inadequate removal of the medial portion of the first rib. The paraclavicular approach is performed to address this concern but requires an additional incision.

The type of TOS and duration of preoperative symptoms were reviewed. Venous TOS was divided into acute (<14 days) and subacute/chronic (>14 days) based on the duration of symptoms. All patients with acute vTOS underwent thrombolysis followed by surgical decompression. Some patients with subacute/chronic vTOS underwent preoperative thrombolysis, and all underwent surgical decompression. All patients with aTOS underwent surgical decompression with or without reconstruction of the artery. Only a minority of patients with neurogenic TOS underwent FRR, although no formal algorithm existed for this population during the study period.

Follow-up was individualized but consisted of immediate postoperative follow-up and at least one additional clinic visit. Type and duration of postoperative anticoagulation was left to the discretion of the

Table I. Patient demographics for TOS in 33 patients

FRR for TOS	Male: *n* (%)	AD: *n* (%)	Enlisted: *n* (%)	AD acute vTOS sxs: *n* (%)	AD chronic vTOS sxs: *n* (%)	AD RTFD: *n* (%)	AD, vein patent at last follow-up
Total							
33	29 (88%)	30 (91%)					
aTOS							
4	4 (100%)	4	4 (100%)	N/A	N/A	3 (75%)	N/A
nTOS							
5 (bilateral, 1)	4 (80%)	5	1 (20%)	N/A	N/A	4 (80%)	N/A
vTOS							
23	20 (87%)	21 (91%)	13 (62%)	13 (62%)	8 (38%)	19 (90%)	19 (90%)

RTFD, return to full duty; sxs, symptoms.

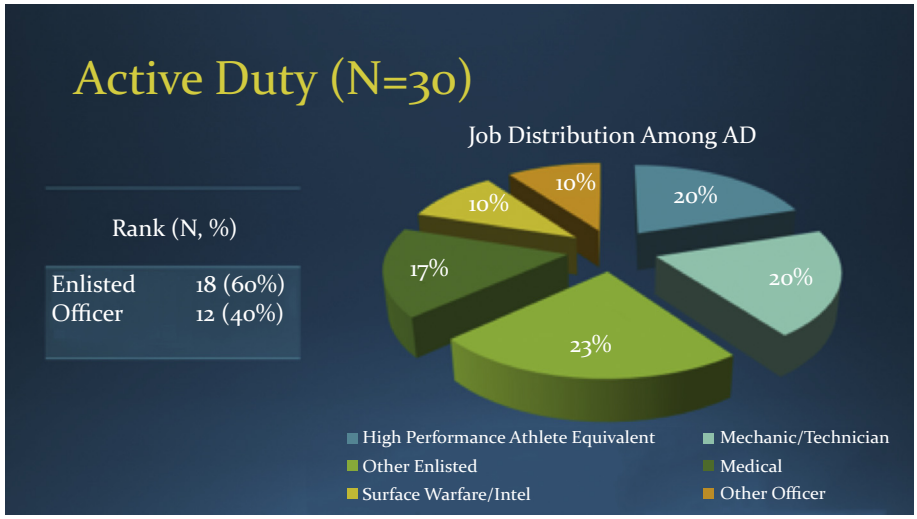

Fig. 1. Job distribution among active duty military personnel treated with a first rib resection for thoracic outlet syndrome.

operating surgeon. Postoperative imaging, including venous ultrasound or venogram, was not standardized and was often dependent on patient symptoms. Finally, the decision to place a stent was at the discretion of the primary surgeon and was seen more commonly in the earlier years of the study. Because of the transient nature of the military, long-term follow-up by the operating surgeon was not always possible. However, the military electronic medical record allowed for long-term chart review both in the continental United States and abroad.

The primary outcome was RTD. AD military members must be able to perform duties of their position and successfully complete the biannual physical readiness test (PRT) to return to full duty and AD. The PRT is a three-segment conditioning test and consists of 1.5-mile run and 2 minutes of both push-ups and sit-ups. Passing scores are dependent on both age and gender. Secondary outcomes included vein patency, return of symptoms, and complications.

Data analysis was performed using standard statistical methods including Fisher's exact, one-way analysis of variance, and Kruskal-Wallis as appropriate. Kaplan-Meier survival curves were used to demonstrate the duration of symptom-free follow-up.

RESULTS

During the study period, 33 FRRs were performed for TOS in 32 patients. The mean age of the population was 28 years (range, 19–64). Most patients were male (88%) and AD military members (91%). Eighteen AD members were in the Navy, eleven were in the Marine Corps, and one was in the Air Force. Two patients were military dependents, and one was retired. Sixty percent of AD members were enlisted, and the remaining 40% were officers. HPAE accounted for 20% of the AD cohort, and an additional 20% were considered ''industrial-athletes''—mechanics or technicians. The remaining military positions included other enlisted (23%), medical (17%), surface warfare/intel (10%), and other officers (10%).

The indications of FRR were vTOS in twenty-three (70%) patients, nTOS in 6 (21%; one bilateral), and aTOS in 4 (9%) patients. Twenty-one (91%) of the vTOS patients were in AD and were the focus of much of the analysis. Thirteen (62%) were treated for acute symptoms with a median duration of 5 (1–19) days. Eight patients (38%) were treated for chronic symptoms with a median duration of 140 (30–1,095) days.

The surgical approach was evenly divided. Thirteen (39%) FRRs were performed via a transaxillary approach. Twelve (36%) were performed via a supraclavicular approach. Eight (24%) were performed via a paraclavicular approach, and a majority of these were performed in the latter part of the study period. When the procedure was performed for vTOS, circumferential external venolysis was performed in a standard fashion. No veins had to be reconstructed, and no intraoperative venoplasties were performed.

Nine AD patients were treated for nTOS[5] and aTOS.[5] The duration of preoperative symptoms was dependent on the type of TOS. The median time to presentation among 5 AD patients with

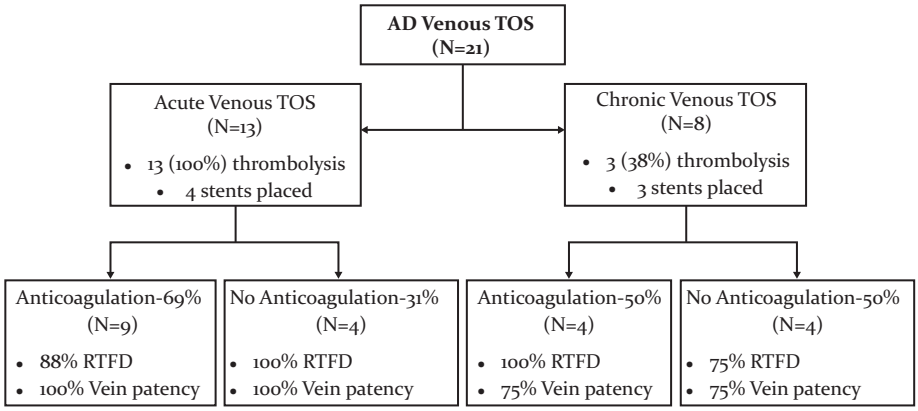

Fig. 2. Outcomes, return to full duty, and vein patency of patients in active duty with venous TOS, who underwent FRR after evaluation of preoperative thrombolysis, stent placement, and postoperative anticoagulation.

neurogenic TOS was 365 days (126–1,095). Four patients RTD after FRR. One patient who underwent bilateral FRR for nTOS was subsequently diagnosed with multiple sclerosis and underwent a medical board assessment and separation. Four patients were treated for arterial TOS, confirmed by ischemic symptoms and radiographic imaging. One patient had a prior penetrating trauma which contributed to the abnormal arterial compression and subsequent aneurysmal dilatation of the vessel wall. All four patients underwent surgical decompression. Two patients had a concomitant arterial bypass. Only one had follow-up imaging which confirmed patency of the bypass. Three patients RTD without limitation; the final patient was unable to RTD secondary to concomitant injuries.

There were 21 AD patients treated for vTOS, and a closer examination of this group was performed. The median duration from surgery to last follow-up among the AD cohort was 9.6 months (range, 1.4–48.5). The median time from surgery to last imaging study (ultrasound or venogram) was 5.3 months (0.4–47.3). The overall RTD for this group was 89%, and the overall vein patency was 90%.

Thirteen patients presented with acute onset of symptoms and underwent immediate thrombolysis followed by surgical FRR. The average time from lysis to surgery was twelve days. Nine patients (69%) received postoperative anticoagulation for a median of 90 days (7–180). The RTD rate was 88%, and vein patency was 100%. Four patients received no anticoagulation. The RTD rate was 100%, and vein patency was 100%. Four patients required a stent placement during the follow-up period for vein restenosis (Fig. 2).

Eight AD patients underwent FRR for chronic vTOS. Three patients received preoperative thrombolysis. Four patients were placed on anticoagulation after surgery for a median 90 days (90–150). The RTD rate was 100%, and vein patency was 75%. Four patients did not receive postoperative anticoagulation. The RTD rate was 75%, and the vein patency was 75%. Three patients required a stent placement during the follow-up period.

The RTD and vein patency rates among AD patients with vTOS were 90%. One patient with acute vTOS did not RTD secondary to the brachial plexus palsy which prevented him from completing marine recruit training. The patient with chronic vTOS did not RTD for reasons unrelated to TOS. There were two cases of postoperative vein occlusion, one was chronically occluded and the other was secondary to stent thrombosis.

Finally, the postoperative duration of anticoagulation was quite variable, ranging from 7 to 269 days. Although no statistical significance could be identified, the RTD was almost 3 times faster among those who received anticoagulation for less than 90 days (median, 42 days; 7–42) than among those who received anticoagulation for $\geq$90 days (median, 119 days; 53–269).

Eighty-eight percent of the AD patients remained symptom-free during the follow-up period (Fig. 3). Three patients had return of symptoms. One patient's symptoms recurred after stent thrombosis, and two patients had no identifiable cause for symptom recurrence. The complication rate was 15% for the entire cohort. Complications included a lymphocele requiring evacuation, a hematoma which required discontinuation of anticoagulation and subsequent stent placement, and a hemothorax requiring video-assisted thoracoscopy and drainage. The patient who sustained a stent thrombosis at 3 weeks postoperatively was treated with

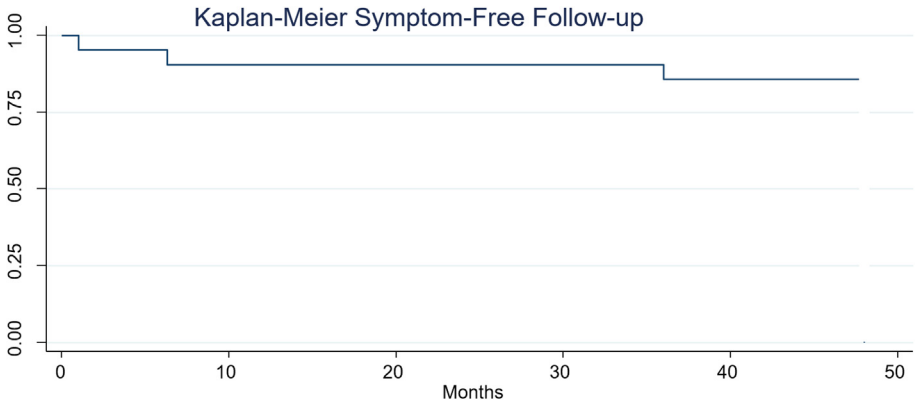

Fig. 3. Kaplan-Meier analysis of patients in active duty after first rib resection for venous thoracic outlet syndrome.

thrombolysis and venoplasty without further events. One patient incurred a brachial plexus palsy which resolved with physical therapy. There were 9 (27%) pleural violations which were treated with intraoperative Valsalva and red rubber suction or temporary chest tube placement.

DISCUSSION

The treatment algorithm for TOS has been the subject of much debate, including the best operative approach, best surgical candidate (nTOS), and the optimal long-term treatment of the vein (vTOS).[5–7] At NMCSD, there have been four surgeons who performed all the FRRs during the past decade. Each trained at different institutions and thus have different surgical approaches to removing the first rib and performing an anterior scalenectomy. In addition, the concept of ''institutional memory'' can be challenging at a military MTF because of multiple deployments and increased turnover of the medical community based on the needs of the military. Unlike many academic centers with a large number of patients with TOS, there is no standardized algorithm at NMCSD for the treatment of TOS.

Nevertheless, to our knowledge, this represents the largest cohort of FRRs in a military population. The large majority of our population was young AD males, and at least 40% of the study population can be considered equivalent to high-performance athletes, a well-studied TOS population.

Because most of the population were in AD military, RTD was an important objective endpoint for the vTOS population, unique from other studies. AD members must meet several requirements to remain on AD status. There was a high rate of RTD in the vTOS (89%), despite a frequently delayed presentation. Patients with subacute and chronic vTOS presented a median of 140 days after symptoms began. We surmise that many of these patients may have been deployed on naval ships or in combat theater and may represent the reason for a delayed presentation and diagnosis. Education of the forward deployed and primary care providers may aid in earlier recognition and decrease the rate of chronic vTOS. Nevertheless, 88% of these patients RTD, and 75% had patent veins through follow-up.

The recommended duration of anticoagulation can range from days to six months, and no large study exists to support a formal recommendation. Individual institutional algorithms for management vary widely. Bamford et al. used an algorithm that used postoperative anticoagulation only when residual thrombosis was identified after repeat venoplasty.[8] Less than half of the cohort required anticoagulation. The remainder were discharged with baby aspirin and remained asymptomatic for 2 years, suggesting that routine anticoagulation may not be necessary.[8] In our study population, there was a broad range, likely secondary to surgeon preference. There was a trend toward shorter RTD among AD members who were treated with a shorter duration. While this did not reach statistical significance, this is due to the small sample size. This did not appear to compromise vein patency as the long-term rates were not different. Further studies should focus on the optimal type and duration of postoperative anticoagulation.

Seven patients with subacute or chronic vTOS symptoms had full RTD after FRR with or without preoperative thrombolysis. Four of the patients ultimately required stent placement to maintain patency (Fig. 3). Seventy-five percent of the stents remained patent at the end of the study period. Patients with delayed presentation now undergoing FRR still have a high rate of postoperative occlusion requiring venoplasty or long-term anticoagulation.

The vein may recannulate on anticoagulation as described by de Leon et al., who had similar outcomes in the civilian population.[9] A significant number of their chronically occluded population required venoplasty, anticoagulation, or both.

The best imaging modality and timing to examine vein patency is debated.[10] Our institution had no formal algorithm for postoperative evaluation of the vein, although this is currently being considered. During the decade these patients were treated, imaging studies (7 venograms and 14 duplex ultrasounds) were performed on 20 of the 21 patients with vTOS. Given the higher rates of postoperative occlusion in chronic vTOS cases, most support routine imaging with either repeat venography or duplex ultrasound. The Johns Hopkins group reported their experience performing routine venography in 84 patients after FRR. They found that 47 patients had recurrent restenosis and 16 patients had complete vein occlusions. Fourteen of the patients with occluded veins eventually recanalized with anticoagulation alone.[11] Patients who present in a delayed fashion or with occlusion after FRR warrant close and attentive follow-up and evaluation.

Civilian studies have argued that patients should be sent to larger referral centers with surgeons who perform many FRRs per month.[12] However, in the military, and perhaps also in smaller communities, this may not be a viable option. Our institution had four surgeons with different surgical approaches learned during training. We also had fewer cases performed during the study period yet our RTD rates were not different from those of larger cohorts from tertiary academic centers for vTOS. Military physician training should include a focus on early recognition of vTOS, especially on ships and international billets where delayed recognition leads to chronic symptoms. We argue that focused studies should examine the optimal length for postoperative anticoagulation to hasten RTD and unrestricted activity in the civilian population.

There are several points that warrant consideration in this treatment group. The variability in treatment patterns in this cohort argues that even smaller institutions should have algorithms when treating vTOS. Venous stents are identified with lower patency rates than venoplasty alone,[13] yet four of these were placed early in the study period. This is likely due to involvement of interventionalists early in the study period, as no stent was placed in the final 7 years of the study. The length of anticoagulation and postoperative imaging protocols should also be further examined and standardized. The surgical approach was varied, especially in the surgical approach to vTOS. This is likely based on surgical training, and there was a clear trend from transaxillary to supraclavicular and subsequently paraclavicular over the course of the study. Our cohort was too small to make any correlation toward vein patency or outcomes with respect to surgical approach. Finally, the Society for Vascular Surgery recommends 24 months of follow-up with adequate documentation of vessel patency and disability evaluation. This is not always possible in the military, give the transient nature of the population, but we do not believe this should preclude the treatment of these patients in military MTFs.[14]

Limitations of this study include the retrospective design, small study size, and variation in management of each patient secondary to provider preference. This limits the strong conclusions that can be drawn and applied to future patients. However, it emphasizes that AD military members, similar to high-performance athletes, can be expected to RTD after surgical treatment for TOS.

CONCLUSION

AD military members should be considered and treated like high-performance athletes. They can expect to RTD with low rates of symptom recurrence after FRR for TOS. Despite a significant number of patients presenting with chronic symptoms in a delayed fashion, we achieved successful RTD rates. We observed shorter anticoagulation times led to earlier RTD without an increase in thrombotic events or symptom recurrence. However, a larger cohort should be examined before a conclusive recommendation can be made about postoperative anticoagulation protocols. Even smaller institutions, both military and civilian, should work toward creating a formal algorithm in treatment of vTOS.

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