From the Southern Association for Vascular Surgery

Midterm and long-term follow-up in competitive athletes undergoing thoracic outlet decompression for neurogenic thoracic outlet syndrome

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ABSTRACT

Background: Neurogenic thoracic outlet syndrome (NTOS) results from compression of the brachial plexus by the clavicle, first rib, and scalene muscles and may develop secondary to repetitive motion of the upper extremity. Athletes routinely perform repetitive motions, and sports requiring significant arm and shoulder use may put the participant at increased risk for NTOS. Competitive athletes who develop NTOS may require first rib resection and scalenectomy (FRRS) for symptomatic relief. However, the effectiveness of FRRS has not previously been studied in this vulnerable population.

Methods: This is a cross-sectional study of competitive athletes with NTOS who received FRRS by the senior author between 2009 and 2014. Eligible patients were contacted by phone and invited to complete a nine-item survey assessing the long-term effects of FRRS on pain medication use, postoperative physical therapy duration, patient satisfaction, symptom relief, activities of daily living, athletic performance, time to return of athletic performance, and need for other operations. Multivariate analyses of the following risk factors were performed: age, pectoralis minor release, preoperative narcotic use, athletic shutdown, and involvement in a throwing sport.

Results: There were 232 competitive athletes who met the inclusion criteria, and 67 of these (age, 14-48 years; 35 male; 99% white) responded to the survey. The average time between surgery and survey completion was 3.9 years (range, 2.2-7.0 years). The most frequent sports conducted by this group were baseball and softball (n = 44 [66%]), volleyball (n = 7 [10%]), and cheerleading and gymnastics (n = 5 [7%]), ranging from high-school to professional levels. The survey results revealed that 96% were improved in pain medication use, 75% would undergo FRRS on the contralateral side if needed, 82% had resolution of symptoms, and 94% were able to perform activities of daily living without limitation; 70% returned to the same or better level of athletic activity after FRRS, and this occurred within 1 year in 50%. Multivariate regression analysis identified younger age as a predictor of the length of physical therapy and preoperative narcotics use as a predictor of symptom resolution.

Conclusions: At our center, >40% of patients requiring FRRS for NTOS are competitive athletes. The results of this study show that the majority of them are able to return to their precompetitive state after FRRS, and few experience limitations in their daily living activities. Half can return to competition at or exceeding their premorbid ability level within 6 months of surgery. The majority are pleased with their decision to undergo FRRS. Further investigation is needed to identify predictive factors for successful return to competitive athletics. (J Vasc Surg 2017;66:1798-805.)

Thoracic outlet syndrome (TOS) is manifested in three types, arterial, venous, and neurogenic, which correspond to the respective anatomic element affected.[1] The vascular (arterial and venous) types are much less common than the neurogenic type. Compression of the structures in the thoracic outlet by the clavicle, first rib, and scalene muscles leads to the secondary complications seen with this syndrome. In arterial TOS, patients may develop aneurysms or thrombosis with or without distal emboli. Venous TOS leads to arm swelling and deep venous thrombosis of the axillosubclavian vein. Patients with neurogenic TOS (NTOS) suffer from shoulder, neck, and arm pain and may develop upper extremity weakness.[2]

Each of the TOS types develops secondary to repetitive motion of the upper extremity. Athletes perform repetitive motion as a routine in their activities, and certain sports requiring significant arm and shoulder use may put the participant at increased risk for TOS.[3] Throwing athletes, in particular baseball pitchers, have been famously treated for arterial TOS.[4] Weightlifters and athletes who use resistance to train their upper

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extremities are well known to develop venous TOS; they respond well to thrombolysis and rib resection with or without venoplasty.[5] Similarly, athletes using repetitive arm and shoulder motion for their training and sport may develop NTOS.[6] Competitive athletes may require first rib resection and scalenectomy (FRRS) for symptomatic relief so that they can continue in their respective sports.[6]

Although NTOS is the most common form of TOS, the effectiveness of the FRRS procedure as a treatment for NTOS has not been extensively studied in this vulnerable population of competitive athletes, and many questions remain to be answered. For example, what types of athletes develop NTOS? How old are they? Does physical therapy benefit them? Are they able to return to their respective sports? How satisfied are they with the outcome? We proposed to review our experience with FRRS for treatment of NTOS in competitive athletes to better understand this population, the treatment outcomes, and the risk factors for poor outcomes or dissatisfaction.

ARTICLE HIGHLIGHTS

- **Type of Research:** Single-center retrospective review combined with a patient satisfaction survey
- **Take Home Message:** A nine-question survey of 67 (29%) of 232 competitive athletes who underwent first rib resection and scalenectomy for neurogenic thoracic outlet syndrome revealed that at a mean of 3.9 years (range, 2.2-7.0 years) later, 82% self-reported resolution of symptoms and 70% returned to the same or better athletic activity.
- **Recommendation:** This survey suggests that up to three-quarters of competitive athletes with neurogenic thoracic outlet syndrome can expect to return to at least their previous level of performance after surgical decompression.

METHODS

This is a cross-sectional study of competitive athletes who had undergone FRRS performed by the senior author (G.P.) in the past. The research protocol was approved by the Institutional Review Board of Baylor University Medical Center. Informed consent of the patients was not required for this retrospective collection of data. Potential study subjects were identified by reviewing our office records for all patients treated for TOS between July 2009 and May 2014. Demographic, historical, athletic, procedural, and follow-up data were entered into a study database. We then selected only the competitive athletes for review; recreational athletes and coaches were excluded. If patients participated in multiple sports, their primary, secondary, and tertiary sports were recorded in that order.

All FRRS procedures were performed through a supraclavicular approach with complete anterior and partial middle scalenectomy, brachial plexus neurolysis, and first rib resection with attention to identification and excision of fibrocartilaginous bands and scalenus minimus attachments if present. Patients were hospitalized for an average of 48 hours and quickly transitioned from intravenous pain medication to an oral medication regimen on which they were discharged. They were encouraged to use the ipsilateral extremity with avoidance of lifting, pushing, pulling, or repetitive activities and started on a course of supervised physical therapy at 1 week postoperatively, which would initially include active and passive range of motion and progress into a stretching and strengthening program. The postoperative therapy program was performed at a facility geographically convenient to the athlete or directed by the experienced training staff affiliated with the athlete's athletic department or professional organization on a case by case basis. For throwing athletes, a throwing program was initiated at 8 weeks, initially with short toss and progressing to a long toss program during 4 to 6 weeks, at which time pitchers may begin throwing from the pitching mound. Nonthrowing athletes would begin activities associated with the movements involved in their sport and progress into their full sport-related activities as tolerated under the supervision of trainers and coaches. Return to full unrestricted activity would be expected 3 to 12 months after the surgical procedure.

A nine-item survey (Table I) was constructed to assess the long-term effects of FRRS on pain medication use, postoperative physical therapy duration, patient satisfaction (willingness to undergo the operation again), symptom relief, effect on activities of daily living, athletic performance, time to return of athletic performance, and need for other operations (of the neck, shoulder, or arm). Items 1, 3, 4, 5, 6, and 9 were scored on a 5-point Likert scale. As part of an ongoing quality improvement process in our practice, all patients undergoing FRRS for TOS have been contacted by phone to complete the survey. Patients who could not be contacted by phone were sent a link to the online version of the survey by e-mail. All survey results were subsequently collected and entered into the study database.

Multivariate logistic regression was used to identify predictors for the most favorable response ("strongly agree") to survey items 1, 3, 4, 5, 6, 8, and 9. Independent risk factors considered included age, pectoralis minor release, preoperative narcotic use, athletic shutdown, and involvement in a throwing sport to identify risk factors for continued pain medication use, noncompliance with physical therapy, patient-centered outcome, and ability to return to athletic competition. For survey item 2, a multivariate linear model was considered, and the same predictors were assessed.

Table I. Elements of the nine-question survey instrument used to query competitive athletes with neurogenic thoracic outlet syndrome (NTOS) after first rib resection and scalenectomy (FRRS)

1. I am taking less pain medication now than just before the surgery.
2. How long did you attend supervised physical therapy after your surgical procedure?
3. In the future, if I develop TOS symptoms on the opposite side, I would undergo surgery.
4. Overall, my symptoms related to TOS have fully resolved.
5. I am able to perform my activities of daily living (clean, drive, child care, work) without limitations related to my previous TOS symptoms.
6. My athletic performance after TOS surgery is (was) the same as or better than before I developed TOS symptoms.
7. My athletic performance after surgery returned to normal at: 3 months, 6 months, 9 months, 1 year, or never returned to baseline.
8. Have you had any other surgery on your neck or the same shoulder or arm since your rib was removed?
9. Having my rib removed was the right decision.

TOS, Thoracic outlet syndrome.

Data were analyzed using SAS version 9.4 (SAS Institute, Cary, NC), with two-tailed *P* values $< .05$ considered statistically significant.

RESULTS

During the study period, 564 patients had FRRS for NTOS, 232 of whom were identified as competitive athletes (113 male, 119 female) with an average (range) age of 19 (13-67) years. The majority of these athletes (n = 223 [96%]) were white. This cohort consisted of athletes in the following sports: baseball and softball (146), volleyball (23), band and musician (8), cheerleading and gymnastics (10), diving (2), football (5), swimming (8), basketball (6), tennis (5), training and fitness (3), golf (2), track and field (7), wrestling (2), soccer (1), crew (1), other (2), and unknown (2); they performed at the high-school (121), collegiate (76), and professional (26) levels. Thirty-two patients participated in multiple sports. There were bilateral FRRS procedures in 17 patients (7%), and 5 patients (2%) were treated for recurrent TOS. The right side was operated on in 166 (71%) and the left in 67 (29%) cases. The average length of stay in the hospital was 2 days (range, 1-6 days), with 226 (97%) patients being discharged by postoperative day 5. Discharge was delayed in seven patients until satisfactory pain control had been achieved. Complications were infrequent and consisted of hematoma (6), pneumothorax (5), atelectasis (2), and lymphorrhea (2). Twenty patients were readmitted within 30 days after surgery, 4 for pain control and 16 for pulmonary reasons due to atelectasis and sympathetic ipsilateral pleural effusion that was caused by splinting by the patient.

Responding to the survey were 67 (29%) competitive athletes (35 male, 32 female) who were similar in age (average [range], 19 [14-48] years), race (99% white), and other characteristics to the entire cohort (Table II). The distribution of sports conducted by the respondents was also similar to the entire cohort: baseball and softball (44), volleyball (7), cheerleading and gymnastics (5), band and musician (3), basketball (2), diving (1), football (1), swimming (1), running (1), and unspecified (2); they performed at the high-school (36), collegiate (24), and professional (7) levels. Seven patients participated in multiple sports. There were bilateral procedures in seven (10%) patients, and one patient was treated for recurrent TOS. The average time between surgery and survey completion was 3.9 years (range, 2.2-7.0 years), indicating that all of the respondents had completed the postsurgical recovery period.

The survey results (Table III) demonstrated that 96% were improved in pain medication use, 75% would undergo FRRS on the contralateral side if needed, 82% had resolution of TOS symptoms, and 94% were able to perform activities of daily living without limitation; 70% returned to at least the same or better premorbid level of athletic activity, and this occurred within 1 year in 50%. Additional procedures (unrelated to NTOS) on the ipsilateral shoulder or arm were performed in 34% of respondents, but overwhelmingly 94% thought that they had made the right decision. As can be seen in Table III, all survey items that were measured on a Likert rating scale showed results that were skewed toward the "favorable" end of that scale.

Multivariable regression analysis (Table IV) found few of the investigated risk factors to be predictive. Only age at the time of surgery and the use of preoperative narcotics were found to be associated with the survey responses of the patients. For question 2, younger age was strongly associated with postoperative physical therapy duration, and the use of preoperative narcotics was strongly associated with complete relief of NTOS symptoms postoperatively (item 4). None of the other risk factors or survey questions were found to have a significant association.

DISCUSSION

We described the level and variety of athletes affected by NTOS. The type and distribution of sports match those of other reports, and overhead throwing athletes are the type most commonly seen for NTOS.[6] However, other sporting activities can lead to NTOS, such as volleyball,

Table II. Comparison of demographic characteristics, preoperative factors, and outcomes for neurogenic thoracic outlet syndrome (NTOS) patients between survey responders and nonresponders

	Survey responders (n = 67)	Nonresponders (n = 150)	*P* value
Demographics			
Age, years	19.1 ± 5.1	19.4 ± 6.3	.73[a]
Female sex	32 (47.8)	75 (50.0)	.76
White race	50 (74.6)	119 (79.3)	.44
Athletic level			
Collegiate	24 (35.8)	50 (33.3)	.87
High school	36 (53.7)	81 (54.0)	
Professional	7 (10.4)	19 (12.7)	
Throwing sports	45 (67.2)	94 (62.7)	.52
Preoperative factors			
Pectoralis minor release	10 (14.9)	38 (25.3)	.09
Previous surgery	16 (23.9)	37 (24.7)	.90
Preoperative narcotics	12 (17.9)	12 (8.0)	.03
Preoperative physical therapy	62 (92.5)	134 (89.3)	.46
Preoperative physical therapy TOS	39 (58.2)	76 (50.7)	.31
Preoperative rest	43 (64.2)	85 (56.7)	.30
Outcomes			
Hospital length of stay, days	2.2 ± 0.8	2.4 ± 0.9	.13[a]
Any complications (eg, bleeding, hematoma, atelectasis, lymph leak, prolonged hospital stay, pain, reoperation, readmission)	8 (11.9)	20 (13.3)	.78

TOS, Thoracic outlet syndrome.
Categorical variables are presented as number (%). Continuous variables are presented as mean ± standard deviation.
There were 10 coaches and 5 recurrent patients in the nonresponder group omitted from this analysis.
[a]*P* value based on *t*-test. Other *P* values are based on χ^2 test.

swimming and diving, cheerleading and gymnastics, football, and playing a musical instrument.[7,8] This condition can even develop at a young age, such that the majority of our patients were younger and competed at the high-school level.[9] Similar to other studies, we had an equal predominance of male and female patients.[6]

Athletes in sports requiring vigorous and repetitive upper extremity motion are particularly at risk for TOS.[6] Venous thrombosis from TOS (Pagett-Schroetter syndrome or effort thrombosis) has been well described in weightlifters.[5] Arterial TOS devastated an All-Star Major League pitcher by causing a posterior circulation stroke.[4] Although TOS typically results from compression of the neurovascular structures between the anterior scalene muscle, first rib, and clavicle, anomalous entities such as cervical ribs, first ribs, and fibrous bands can also be sources of compression. The brachial plexus and subclavian artery and vein can be affected, resulting in NTOS, arterial TOS, or venous TOS, respectively. The NTOS form is the most common, and because of lack of clear-cut diagnostic testing for this condition, it was slow to be accepted as a valid medical condition.[10]

Recently, it has been recognized that research should be focused on the needs and concerns of the patient and that it is important to have relevant information and data that patients can then use to make appropriate individualized decisions about treatment.[11] Until now, we have not had that information for competitive athletes with NTOS, and as mentioned before, the decision for an athlete to undergo reparative surgery has the added worry of any treatment's impact on the athlete's sporting career. The most useful available surveys for evaluating this population are the Disabilities of the Arm, Shoulder, and Hand (DASH) and its shortened version, the QuickDASH.[12,13] Whereas these are useful quality of life instruments, the four questions specifically related to sports are an additional module, and they do not necessarily produce the information that an athlete considering FRRS would want to know. We designed our survey with this in mind and not with the intention of replacing the DASH or QuickDASH.

Encouragingly, we found very good results in treating competitive athletes with NTOS with FRRS; 96% of the respondents reported that they were taking less pain medication. Similar to others,[6] we found that 82% were relieved of their symptoms, and nearly 94% were able to perform activities of daily living without limitation. For athletes, however, the main focus is returning to their sport. We found that about 70% were able to return to competition at the same level or higher in their sport. This is similar but slightly less than the "return to competition" rates of 77% and 81% identified by other investigators.[6,14] This discrepancy is related to our survey, which queried return to competition level, whereas the other reports documented solely competition resumption.

The recovery time and rehabilitation time required are important issues for athletes because they have only a limited "age window" in which to compete. Longer recovery times detract from this time limitation, and it is helpful to give these athletes realistic answers to the "how long" question. The return to sport after rotator cuff surgery varies, but a meta-analysis has found that for elite pitchers (of which only 68% return to competition), the mean period is approximately 12 months (range, 9-17 months).[15] For ulnar collateral ligament

Table III. Descriptive statistics of responses to survey items for competitive athletes who underwent first rib resection and scalenectomy (FRRS) for neurogenic thoracic outlet syndrome (NTOS)

Q1. I am taking less pain medication now than just before the surgery.	Statistics
Strongly agree	58 (86.5)
Somewhat agree	1 (1.5)
Neutral/no opinion	5 (7.5)
Somewhat disagree	2 (3.0)
Strongly disagree	1 (1.5)
Q2. How long did you attend supervised physical therapy after your surgical procedure? median (IQR), weeks	12.0 (6.0-26)
Q3. In the future, if I develop TOS symptoms on the opposite side, I would undergo surgery.	
Strongly agree	35 (52.2)
Somewhat agree	11 (16.4)
Neutral/no opinion	4 (6.0)
Somewhat disagree	10 (15.0)
Strongly disagree	7 (10.4)
Q4. Overall, my symptoms related to TOS have fully resolved.	
Strongly agree	26 (38.8)
Somewhat agree	24 (35.8)
Neutral/no opinion	5 (7.5)
Somewhat disagree	7 (10.4)
Strongly disagree	5 (7.5)
Q5. I am able to perform my activities of daily living without limitations related to my previous TOS symptoms.	
Strongly agree	54 (80.6)
Somewhat agree	7 (10.4)
Neutral/no opinion	2 (3.0)
Somewhat disagree	3 (4.5)
Strongly disagree	1 (1.5)
Q6. My athletic performance after TOS surgery is (was) the same as or better than before I developed TOS symptoms.	
Strongly agree	37 (55.2)
Somewhat agree	6 (9.0)
Neutral/no opinion	4 (6.0)
Somewhat disagree	6 (9.0)
Strongly disagree	11 (16.4)
Not answered	3 (4.5)
Q7. My athletic performance after surgery returned to normal at:	
3 months	13 (19.4)
6 months	16 (23.9)
9 months	5 (7.5)
1 year	10 (14.9)
Never returned	13 (19.4)
Not answered	10 (14.9)
Q8. Have you had any other surgery on your neck or the same shoulder or arm since your rib was removed?	
Yes	23 (34.3)
No	44 (65.7)
Q9. Having my rib removed was the right decision.	
Strongly agree	52 (77.6)
Somewhat agree	6 (9.0)
Neutral/no opinion	5 (7.5)
Somewhat disagree	1 (1.5)
Strongly disagree	2 (3.0)
Not answered	1 (1.5)

IQR, Interquartile range; *TOS*, thoracic outlet syndrome.

reconstruction (Tommy John surgery), this period is also 1 year.[16] In this study, we found that almost half of the athletes were able to return within 6 months and the remainder within 1 year. Others have reported a mean recovery period of 4.4 months for NTOS athletes, which is slightly shorter than ours, but it is unclear if the time stated is when the patient resumed training and rehabilitation or actual competition.[6] Another report focusing on a small cohort of Major League Baseball pitchers found that the mean postoperative duration until return to competitive play was 11 months.[14] Based on our results and those of others, it appears safe to presume that the time to resumption of competition will depend on the sport and the level of competition and will be between 3 months and 1 year.

We performed a multivariate analysis to identify potential risk factors for the answers on our survey. We sought to identify risk factors for continued pain medication use, noncompliance with physical therapy, patient-centered outcome, and ability to return to athletic competition.

Younger age has previously been demonstrated to be a beneficial characteristic.[9] Awareness of the role of compression of the brachial plexus by the pectoralis minor tendon has been revived by Sanders and Rao[17] and further investigated by Thompson et al.[18] Preoperative narcotic use has been demonstrated to be a negative predictor.[19] In many sports-related injuries, a period of rest or shutdown is used in an attempt to avoid surgery with a prolonged recovery period, with the goal of permitting the athlete to return to competition sooner. Yet, longer duration of symptoms has been mentioned as a risk factor that reduces the success rates of surgical decompression.[20,21] This variable has not been explored in regard to NTOS and competitive athletes, and we opined that this variable deserved exploring as a potential predictor. Last, although the ultimate mechanism for NTOS is the same for all of the athletes affected, the physicomechanics are different for overhand throwing

Table IV. Multivariable logistic regression and linear regression models assessing factors influencing patients' responses to survey item outcomes for first rib resection and scalenectomy (FRRS) for neurogenic thoracic outlet syndrome (NTOS)

Survey item	Effect	OR (95% CI)[a]	*P* value
Q1. I am taking less pain medication now than just before the surgery.	Age at surgery	1.01 (0.88-1.17)	.85
	Pectoralis minor release	1.50 (0.16-14.05)	.72
	Preoperative narcotics	0.35 (0.07-1.74)	.20
	Shutdown rest	0.48 (0.08-2.78)	.42
	Throwing sports	0.93 (0.19-4.61)	.92
Q3. In the future, if I develop TOS symptoms on the opposite side, I would undergo surgery.	Age at surgery	1.01 (0.92-1.12)	.78
	Pectoralis minor release	0.53 (0.15-1.92)	.33
	Preoperative narcotics	1.60 (0.43-5.91)	.48
	Shutdown rest	0.57 (0.20-1.64)	.30
	Throwing sports	0.35 (0.12-1.03)	.06
Q4. Overall, my symptoms related to TOS have fully resolved.	Age at surgery	0.96 (0.87-1.05)	.34
	Pectoralis minor release	0.49 (0.14-1.80)	.28
	Preoperative narcotics	4.13 (1.06-16.15)	.04
	Shutdown rest	0.60 (0.21-1.68)	.33
	Throwing sports	1.41 (0.51-3.88)	.51
Q5. I am able to perform my activities of daily living without limitations related to my previous TOS symptoms.	Age at surgery	0.91 (0.81-1.01)	.07
	Pectoralis minor release	0.95 (0.17-5.28)	.96
	Preoperative narcotics	0.99 (0.20-4.98)	.99
	Shutdown rest	0.25 (0.04-1.44)	.12
	Throwing sports	2.69 (0.68-10.72)	.16
Q6. My athletic performance after TOS surgery is (was) the same as or better than before I developed TOS symptoms.	Age at surgery	0.97 (0.88-1.07)	.55
	Pectoralis minor release	1.53 (0.37-6.39)	.56
	Preoperative narcotics	0.67 (0.19-2.29)	.52
	Shutdown rest	0.74 (0.25-2.18)	.59
	Throwing sports	0.84 (0.29-2.46)	.75
Q7. My athletic performance after surgery returned to normal at:	Age at surgery	0.88 (0.76-1.01)	.07
	Pectoralis minor release	1.25 (0.31-5.03)	.76
	Preoperative narcotics	3.20 (0.75-13.76)	.12
	Shutdown rest	0.79 (0.28-2.23)	.65
	Throwing sports	0.64 (0.21-1.93)	.42
Q8. Have you had any other surgery on your neck or the same shoulder or arm since your rib was removed?	Age at surgery	1.03 (0.93-1.15)	.57
	Pectoralis minor release	0.63 (0.14-2.97)	.56
	Preoperative narcotics	0.51 (0.11-2.25)	.37
	Shutdown rest	1.45 (0.46-4.62)	.53
	Throwing sports	1.02 (0.32-3.23)	.97
Q9. Having my rib removed was the right decision.	Age at surgery	0.94 (0.85-1.04)	.23
	Pectoralis minor release	0.87 (0.17-4.44)	.87
	Preoperative narcotics	0.52 (0.12-2.26)	.38
	Shutdown rest	0.51 (0.12-2.27)	.38
	Throwing sports	0.67 (0.16-2.78)	.58
		Regression estimate (SE)[b]	

(Continued on next page)

Table IV. Continued.

Survey item	Effect	OR (95% CI)[a]	*P* value
Q2. How long did you attend supervised physical therapy after your surgical procedure?	Age at surgery	2.17 (0.62)	<.0001
	Pectoralis minor release	0.16 (9.11)	.99
	Preoperative narcotics	−6.32 (8.54)	.46
	Shutdown rest	10.86 (6.90)	.12
	Throwing sports	2.41 (6.96)	.73

CI, Confidence interval; *OR*, odds ratio; *SE*, standard error; *TOS*, thoracic outlet syndrome.
[a]From logistic regression model.
[b]From linear regression model.

athletes compared with the other types of athletes, and we sought to identify whether this made a difference.

The multivariate analysis demonstrated that younger age was predictive of better compliance with the postoperative supervised physical therapy program and the ability to perform activities of daily living without limitation. It was also predictive of return to competition at a similar or better level, but this did not reach statistical numbers, and a larger population of respondents may have clarified this further. Pectoralis minor release (or tenotomy) did not demonstrate an impact on any of the questions in our survey. As others have stated, there is a definite role for pectoralis minor release in addition to FRRS when there is infraclavicular compression, but its exact role is still being determined.[18] None of the outcomes that the survey looked at were affected positively or negatively by a period of sporting activity shutdown, suggesting that this approach is not necessarily helpful in NTOS athletes but certainly not harmful. Last, the competitive athletes in throwing sports were positively associated with patient satisfaction (question 3) but otherwise were not statistically different from the other athletes in continued pain medication use, noncompliance with physical therapy, and ability to return to athletic competition.

Despite being the largest study of competitive athletes with NTOS, this investigation suffers from several limitations. Only 30% of the overall study group responded to the survey, and it is possible that including the remaining 70% could have changed the findings. The survey format also can lead to flawed data because of impaired recall by the respondents. The recently published guidelines from the Society for Vascular Surgery regarding reporting standards for TOS recommend using the DASH quality of life survey in evaluating results, and we can certainly be faulted for omitting that.[22,23] However, the DASH survey is most valuable as a tool when the survey is given preoperatively and at variable times postopereatively.[12] Similar to others, in the past we have not incorporated the DASH instrument in our treatment protocols[9,19] and did not think that obtaining only the postoperative DASH score would be useful. In addition, the questions that we proposed to answer are not specifically addressed by the DASH instrument.[14] Therefore, we created a survey designed for the purposes of this study.

Although there was a low survey response rate, we think that this is an adequate number of patients to analyze, acknowledging the limitations due to possible sampling errors. It has been noted that survey response rates are in steep decline, and although there is no scientifically proven minimally acceptable response rate, there is increasing recognition that the degree to which the respondents differ from the survey population as a whole is central to evaluating the representativeness of the survey.[24] Our analysis comparing the survey responders and nonresponders (Table II) demonstrates that the survey responders group is comparable to the nonresponders group.

The multivariate analysis provides interesting insights in regard to the variables evaluated that can immediately be translated into clinical practice and stimulate thoughtful future investigations into why these risk factors were or were not associated with the outcomes being evaluated.

CONCLUSIONS

More than 40% of patients requiring FRRS for NTOS are competitive athletes. The results of this study show that the majority are able to return to their precompetitive state after FRRS, and few have limitations in their activities of daily living. Whereas additional, sports-related but non-TOS procedures are necessary in more than a third of these patients, almost half return to competition by 6 months and the majority within 1 year. The majority are pleased with their decision to have FRRS and would do it again. Further investigation remains to be done for predictive factors for successful return to competitive athletics in this population.

AUTHOR CONTRIBUTIONS

Conception and design: WS, GP
Analysis and interpretation: WS, GO, GP
Data collection: WS, BR, AY, KT, AD, RS
Writing the article: WS, GP
Critical revision of the article: WS, GO, GP, BR, AY, KT, AD, RS
Final approval of the article: WS, GO, GP, BR, AY, KT, AD, RS

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Overall responsibility: WS

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