Feasibility and Outcomes of a Multidisciplinary Care Pathway for Neurogenic Thoracic Outlet Syndrome

Citation for published version (APA):

Pesser, N., Goeteyn, J., van der Sanden, L., Houterman, S., van Alfen, N., van Sambeek, M. R. H. M., van Nuenen, B. F. L., & Teijink, J. A. W. (2021). Feasibility and Outcomes of a Multidisciplinary Care Pathway for Neurogenic Thoracic Outlet Syndrome: A Prospective Observational Cohort Study. *European Journal of Vascular and Endovascular Surgery*, 61(6), 1017-1024. <https://doi.org/10.1016/j.ejvs.2021.02.048>

Document status and date:

Published: 01/06/2021

DOI:

[10.1016/j.ejvs.2021.02.048](https://doi.org/10.1016/j.ejvs.2021.02.048)

Document Version:

Publisher's PDF, also known as Version of record

Document license:

Taverne

Please check the document version of this publication:

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

www.umlib.nl/taverne-license

Take down policy

If you believe that this document breaches copyright please contact us at:

repository@maastrichtuniversity.nl

providing details and we will investigate your claim.

Download date: 26 Apr. 2023

Feasibility and Outcomes of a Multidisciplinary Care Pathway for Neurogenic Thoracic Outlet Syndrome: A Prospective Observational Cohort Study

Niels Pesser ^{a,f}, Jens Goeteyn ^{a,f}, Lieke van der Sanden ^a, Saskia Housterman ^b, Nens van Alfen ^c, Marc R.H.M. van Sambeek ^{a,d}, Bart F.L. van Nuenen ^e, Joep A.W. Teijink ^{a,f,*}

^a Department of Vascular Surgery, Catharina Hospital, Eindhoven, the Netherlands

^b Department of Education and Research, Catharina Hospital, the Netherlands

^c Department of Neurology, Donders Institute for Brain, Cognition and Behaviour, Radboudumc, Nijmegen, the Netherlands

^d Department of Biomedical Technology, University of Technology Eindhoven, Eindhoven, the Netherlands

^e Department of Neurology, Catharina Hospital, Eindhoven, the Netherlands

^f CAPHRI School for Public Health and Primary Care, Faculty of Health, Medicine and Life Sciences, Maastricht University, the Netherlands

WHAT THIS PAPER ADDS

This is the first single centre prospective cohort study to describe the implementation of a multidisciplinary diagnostic care pathway for patients with neurogenic thoracic outlet syndrome (NTOS), and evaluates diagnostic and treatment outcomes of patients with NTOS within the scope of the North American Society for Vascular Surgery reporting standards for NTOS. The results suggest a prominent role for multidisciplinary care pathways in NTOS diagnostics, underline the role of dedicated physiotherapy as the primary treatment, and show good to excellent short term treatment outcomes in the majority of the surgically treated NTOS patients following previous unsuccessful physiotherapy. The objective outcome measures of surgically treated patients allow for reliable comparison with future cohort studies.

Objective: The North American Society for Vascular Surgery (SVS) reporting standards for neurogenic thoracic outlet syndrome (NTOS) were published in 2016 to produce consistency in the diagnosis and treatment of NTOS, but outcomes resulting from following these standards are not yet available. The results of a standardised multidisciplinary care pathway for NTOS based on the North American SVS reporting standards for NTOS are reported.

Methods: Patients referred between August 2016 and December 2019 with suspected NTOS were evaluated in this single center prospective cohort study. Diagnosis and treatment were performed according to a care pathway based on the North American SVS reporting standards. The outcome of surgically treated patients was determined by the Derkash score, thoracic outlet syndrome disability scale (TDS), Cervical Brachial Score Questionnaire (CBSQ), Disability of the Arm Shoulder and Hands Dutch language version (DASH-DLV) and Short Form-12 (SF-12) at three, six, 12, and 24 months.

Results: Of 856 referred patients, 476 (55.6%) patients were diagnosed with NTOS. Dedicated physiotherapy was successful in 186 patients (39.1%). Surgical treatment was performed in 290 (60.9%) patients of whom 274 were included in the follow up. At a mean follow up of 16.9 ± 9.2 months, significant improvement ($p < .001$) in TDS, CBSQ, DASH-DLV, and SF-12 scores was seen in the surgical group between baseline and all follow up intervals. Derkash outcome after surgical intervention was excellent in 83 (30.3%), good in 114 (41.6%), fair in 43 (15.7%), and poor in 34 (12.4%) of the patients. Complications occurred in 16 (5.8%) patients, and 32 (10.4%) patients experienced recurrent or persistent NTOS complaints.

Conclusion: A multidisciplinary care pathway based on the North American SVS reporting standards for NTOS helped to confirm the diagnosis in 56% of patients referred, and guided the selection of patients who might benefit from thoracic outlet decompression surgery after unsuccessful dedicated physiotherapy. Intermediate follow up showed good outcomes in the majority of surgically treated patients.

Keywords: Brachial plexus, Physiotherapy, Reporting standards, Surgical treatment, Thoracic outlet decompression, Thoracic outlet syndrome, TOS

Article history: Received 17 November 2020, Accepted 22 February 2021, Available online 31 March 2021

© 2021 European Society for Vascular Surgery. Published by Elsevier B.V. All rights reserved.

* Corresponding author. Department of Vascular Surgery, Catharina Hospital, Michelangelolaan 2, 5623 EJ Eindhoven, P.O. Box 1350, 5602 ZA, Eindhoven, the Netherlands.

E-mail address: joep.teijink@catharinaziekenhuis.nl (Joep A.W. Teijink).
1078-5884/© 2021 European Society for Vascular Surgery. Published by Elsevier B.V. All rights reserved.

<https://doi.org/10.1016/j.ejvs.2021.02.048>

INTRODUCTION

Neurogenic thoracic outlet syndrome (NTOS) is considered a controversial condition, caused by compression of the brachial plexus in the thoracic outlet. Patients present with a variety of symptoms mostly characterised by pain,

paraesthesia, and numbness or muscle weakness in the neck, shoulder, arm, and/or hand. The diagnosis of NTOS can be difficult owing to the lack of consensus on pathophysiology, inconsistent definitions, non-specific symptoms, potential overlap with other neurological disorders, and limited applicability of adequate diagnostic testing procedures.^{1,2} To address these shortcomings, the North American Society for Vascular Surgery (SVS) published the reporting standards for thoracic outlet syndrome (TOS) in 2016 in an effort to produce more consistency in the diagnosis and subsequent treatment of NTOS.²

Current treatment of NTOS is based on mainly retrospective cohort series that describe subjective and varying diagnostic criteria.¹ More recent prospective observational studies have reported treatment outcomes after using the consortium for research and education on thoracic outlet syndrome (CORE-TOS) criteria.^{3,4} In the absence of diagnostic (imaging) techniques with high sensitivity and specificity for NTOS, a combination of diagnostic criteria is considered as the near best option to define the diagnosis.^{2,4} A multidisciplinary care pathway based on the North American SVS reporting standards for NTOS was developed to standardise the diagnosis and treatment of all referred patients suspected of having NTOS. The outcomes of multidisciplinary care pathways based on the North American SVS reporting standards of NTOS are not yet available. In this prospective cohort study, the results of this NTOS care pathway are reported, in order to evaluate the results of a standardised treatment algorithm based on the North American SVS reporting standards for NTOS.

MATERIALS AND METHODS

Diagnostic algorithm

All patients referred to the TOS outpatient clinic (Catharina Hospital, Eindhoven, the Netherlands) from 1 August 2016 to 31 December 2019 suspected of having NTOS were evaluated. The TOS clinic is the combined effort of the vascular surgery, neurology, orthopaedic, pain anaesthetics, radiology, and physiotherapy departments, and a nationwide tertiary referral centre for all types of TOS. Before clinical evaluation, the patient's medical records, including previously performed imaging and treatment, were assessed by the neurologist. Thereafter, patients were evaluated following a multidisciplinary diagnostic care pathway based on the North American SVS reporting standards for NTOS.² In advance of the first visit, a combined questionnaire consisting of the TOS disability scale, Cervical Brachial Symptom Questionnaire (CBSQ), Disabilities of the Arm, Shoulder and Hand Dutch Language Version (DASH-DLV), and the 12 item Short Form survey (SF-12) was distributed to patients.⁵ Initial clinical evaluation of all patients was performed by a nurse practitioner, a vascular (TOS) surgeon, a neurologist, and a physiotherapist. Additionally, colour Doppler of the subclavian artery in adduction, 90 degree abduction, and military attitude position was obtained, followed by a standardised elevated arm stress test (EAST) measurement.⁶ Lastly, an Xray of the

superior thoracic aperture was conducted. After this first clinical evaluation, the patient was discussed in a weekly multidisciplinary meeting attended by a TOS surgeon, a neurologist, a radiologist, physiotherapists, a pain anaesthetist, and an orthopaedic surgeon with a special interest in shoulder pathology.

If a patient was suspected of having NTOS by both the TOS surgeon and the neurologist, a local anaesthetic muscle block with two mL bupivacaine 0.5% per muscle was performed under ultrasound guidance in the anterior and medial scalene muscle. The results of the EAST before and one hour after the test were obtained using a standardised EAST meter.⁶ The scalene muscle block was considered positive if EAST time improved $\geq 50\%$ vs. the pre-test measurement. Patients diagnosed with a Gilliatt-Sumner hand or co-existing venous TOS (VTOS) or arterial TOS (ATOS) did not undergo a scalene muscle block because these patients already had an indication for thoracic outlet decompression (TOD) surgery. If necessary, as decided by the multidisciplinary meeting, additional nerve conduction studies, magnetic resonance imaging, consultation with an orthopaedic surgeon, and/or bilateral high resolution ultrasound of the brachial plexus were performed to exclude differential diagnoses. After completing the scalene muscle block and additional diagnostics, the patient was evaluated again in a multidisciplinary meeting. The team of physicians made the NTOS diagnosis if at least three of the four criteria of the North American SVS reporting standards were present: (1) local findings at the thoracic outlet consistent with NTOS; (2) peripheral findings in the affected upper extremity; (3) absence of possible differential diagnosis; and (4) a positive test injection. The diagnostic care pathway is summarised in Fig. 1.

Treatment algorithm

All patients with NTOS underwent physiotherapy as the primary treatment. This was initiated by one of three experienced TOS physiotherapists participating in the care pathway. The TOS physiotherapist instructed a specialised physiotherapist in the patient's community who was affiliated with the Dutch shoulder network ("Schoudernetwerk Nederland"). The exercise programme consisted of posture evaluation and improvement, shoulder girdle therapy, and focused scapular mobility therapy. After a minimum of six and a maximum of 12 weeks of supervised (at least once a week) physiotherapy and daily unsupervised training, changes in complaints were discussed by the physiotherapist in the weekly multidisciplinary meeting. Physiotherapy was continued in patients with sufficient improvement.

All patients with NTOS with a significant level of disability and insufficient improvement in symptoms with physiotherapy were considered for TOD surgery. After an appointment with the TOS surgeon, who explains the pros and cons of TOD surgery (shared decision making), the decision of whether or not to undergo surgical intervention was made. TOD surgery without 6 – 12 weeks of physiotherapy was only considered in patients with a Gilliatt-

Sumner hand, or in patients who had already undergone an adequate physiotherapy programme, as decided at the discretion of the TOS physiotherapist and discussed in the TOS meeting.

All patients with written informed consent at intake were eligible for inclusion. Patients aged < 18 years, unable to complete the questionnaires owing to illiteracy or lack of sufficient Dutch language skills, or who did not provide informed consent were excluded. Data were obtained from the electronic health record and included all criteria as defined in the North American SVS reporting standards for NTOS. Moreover, the results of baseline TOS disability score, CBSQ, DASH-DLV, and SF-12 Physical Composite Scale (SF-12 PCS) and SF-12 Mental Component Summary (SF-12 MCS) were collected prospectively. The study was approved by the medical ethical committee of the Catharina Hospital.

Surgical treatment

In all patients transaxillary TOD (TA-TOD) consisted of a partial anterior and medial (minimum if applicable) 1–2 cm scalenectomy (caudal part), a complete first rib resection medial to the subclavian vein (near or in the sternocostochondral junction) just beyond its articulation with the vertebral body's transverse process (leaving only the neck of the first rib *in situ*), and a thorough neurolysis of the

branches of the lower brachial plexus (C8–T1), including if possible C7. Additionally, a pectoralis minor tenectomy of approximately 4–5 cm was performed if pressure over the pectoralis minor muscle provoked symptoms during clinical examination. If present, resection of a (partial) cervical rib and/or fibrous band was performed in the same procedure. In the case of a parietal defect, sometimes made intentionally for drainage of wound fluid, a pleural catheter (8 F; Rucomed, The Hague, the Netherlands) was inserted. This catheter was removed after control chest X-ray, most often one day after surgery. In patients with morbid obesity (body mass index > 40), TOD surgery was performed through a supraclavicular approach (SC-TOD), which was performed following the same principles as described for primary TA-TOD surgery.

A hospital physiotherapist visited all patients the day before and after surgery to explain exercises and daily limitations for the immediate three week post-operative period. Moreover, a three month instruction and exercise programme was given to provide a structured rehabilitation programme. As the majority of patients reside at a distance from the hospital, most were treated by a shoulder physiotherapist from the Dutch shoulder network who received written instructions and the option to contact one of four TOS physiotherapists if deemed necessary. Hospital stay, use of chest drainage, post-operative pain control method, peri-

and post-operative complications, and re-admissions within 30 days were recorded in a prospectively maintained database.

Follow up

All patients were seen six weeks after TA-TOD by the TOS surgeon who performed the surgery (J.T.). All patients were evaluated by one of two neurologists three months after surgery and then yearly for two years. The neurologist specifically reported neuropathies and treatment outcome by Derkash score (Table 1). Treatment outcomes and post-operative complications were included in the prospective database based on the reports of the neurologist and follow up questionnaires, independent from the TOS surgeon. Follow up TOS disability scale, CBSQ, DASH-DLV, and SF-12 scores were obtained online (Research Manager, Deventer, the Netherlands) at three, six, 12, and 24 months or by postal questionnaires if patients were unable to use online questionnaires. Patients were contacted by telephone if they did not complete the questionnaires on time. Patients who did not complete the three and six month questionnaire within one month after contact or the 12 and 24 month questionnaire within three months after contact were excluded for that particular follow up interval. Patients who were treated by physiotherapy alone had no control appointments and were not included in the follow up.

Patients with persistent symptoms (TOD surgery did not reduce the complaints at all) or recurrent symptoms (complaints returned after a period of no/minimal complaints) were evaluated by the neurologist and TOD surgeon. Thereafter, these patients were discussed in the multidisciplinary meeting and treatment options were reviewed. If a patient experienced sequelae with severe impact on daily activities and quality of life more than one year after initial TA-TOD, especially after an initial period of relief of complaints, and conservative therapy was insufficient, a SC-TOD was considered. If, after shared decision

making, the limiting complaints outweighed the possible disadvantages of re-intervention, a SC-TOD with complete anterior and medial scalenectomy followed by complete brachial plexus neurolysis was performed.

Statistical analysis

Continuous data are presented as mean $\pm$ standard deviation or as median $\pm$ interquartile range (IQR) (25th and 75th percentiles), depending on normality. Categorical data are presented as frequency (%). One group comparisons over time were performed using a paired samples *t* test. For two group comparisons, an independent samples *t* test was performed. Multiple group comparison was performed using a one way analysis of variance. For non-normally distributed data, comparable non-parametric tests were used. All confidence intervals of the follow up scores were determined using the standard error of the mean to compare differences between means. The follow up index (FUI) was calculated using the last known follow up interval divided by the last possible follow up interval.⁷ A *p* value < .05 was considered to be statistically significant. Statistical analysis was performed using SPSS 25 software (IBM, Armonk, NY, USA).

RESULTS

During the study period, 856 patients were referred as possibly having NTOS. Of these patients, 476 (55.6%) met the North American SVS reporting standards and were diagnosed with NTOS, of whom 186 (39.1%) were successfully treated by a dedicated physiotherapy programme. However, previous or initiated physiotherapy appeared to be insufficient in relieving the complaints of 290 (60.9%) patients and surgical treatment was offered. Bilateral NTOS in 39 patients resulted in a total of 329 TOD procedures for NTOS during the study period. In total, 376 TOD procedures were performed: 329 for NTOS (87.5%); 41 for VTOS

Table 1. Patient reported outcomes by Derkash score during the follow up of 290 patients treated surgically for neurogenic thoracic outlet syndrome

Classification by Derkash outcome	Complaints	Return to work	Daily activities	Latest reported Derkash outcome (n = 274)	Latest reported Derkash outcome excluding re-interventions (n = 258)	Highest reported Derkash outcome at any post-TOD moment (n = 274)
Excellent	None	Without limitations	Without limitations	83 (30.3)	81 (31.4)	95 (34.7)
Good	No major symptoms	Without limitations, minor sequelae	Without limitations, minor sequelae	114 (41.6)	106 (41.1)	128 (46.7)
Fair	Relief of some complaints	With limitations, and/or sequelae	With limitations and/or sequelae	43 (15.7)	41 (15.9)	30 (10.9)
Poor	No relief of complaints	No return	Severely limited	34 (12.4)	30 (11.6)	21 (7.7)

TOD = thoracic outlet decompression.

(10.9%); and six for ATOS (1.6%). Of the 290 surgically treated patients with NTOS, 274 (94.5%) patients gave written informed consent and were included in the database (307 TOD procedures). The median duration of complaints was 3.0 years (IQR 1.2 – 7.0 years) and 199 (72.6%) patients had previously undergone a variety of treatments (range 1 – 12 treatments) before being presented to the authors' institution. Daily opioid and/or tricyclic antidepressant use was present in 68 (24.8%) patients. A scalene muscle block was performed in 256 (93.4%) patients. All patient characteristics following the North American SVS reporting standards for NTOS are presented in Table 2.

In the surgical group of 274 patients, 17 were treated for bilateral NTOS and 16 for recurrent NTOS after initial TOD surgery, totalling "307 arms" treated by TOD surgery. All primary TA-TOD procedures were performed by one TOS surgeon (J.T.). Primary TA-TOD was performed in 272 arms and primary SC-TOD in two arms. For recurrent or persistent symptoms after TOD in another centre, TA-TOD was performed in four arms and SC-TOD in 13 arms. Recurrent symptoms after TA-TOD were treated by a SC-TOD in 16 arms. The initial TA-TOD or SC-TOD was combined with pectoralis minor tenectomy in 186 arms (60.6%). A cervical rib (type I – IV) was removed in 34 patients (11.1%). No intra-operative complications occurred. Post-operative complications occurred in 16 patients (5.2%) and are summarised in Table 3 along with all surgical data. Re-admission within 30 days was required in three patients (1.1%) for wound infection, haematoma formation with re-exploration, and pneumothorax. Neurapraxia of the second intercostobrachial nerve related to surgical traction and treated with medication was seen in 35 patients (11.4%) and was transient in 18 of 28 patients (64.3%) with at least one year follow up after TOD surgery. Mean length of hospital stay was 1.3 ± 0.59 days.

Follow up results

The mean follow up was 16.9 ± 9.2 months. At the time of writing, follow up was completed in 61% patients at three months, 65% at six months, 77% at 12 months, and in 83% of patients at the 24 month interval (FUI 0.82 ± 0.34). In total, 239 patients (87.2%) completed at least one of the follow up questionnaires. No follow up data were available for the remaining 35 (12.8%) patients owing to some returning incomplete questionnaires or some who did not respond to any of the follow up questionnaires. The significant decline in mean scores of the TOS disability scale, CBSQ, DASH-DLV, SF-12 PCS and SF-12 MCS is presented in Fig. 2. The overall latest reported Derkash, Derkash excluding re-interventions and highest Derkash at any post-operative interval are summarised in Table 1.

In total, 14 patients (5.1%) experienced persisting complaints after TOD surgery without any improvement during follow up. Recurrent symptoms after a period of good or excellent results occurred in 18 patients, yielding a total of 32 (10.4%) patients with NTOS complaints at the same level as before TOD surgery. A re-intervention was performed by

Table 2. Patient characteristics following the North American Society for Vascular Surgery reporting standards for thoracic outlet syndrome (TOS) of patients treated by thoracic outlet decompression surgery for neurogenic TOS (NTOS)

Patient characteristics	Patients (n = 274)
Female sex	211 (77.0)
Age – y	41.6 $\pm$ 12.01
Time with complaints – y	3.0 (1.2–7.0)
<i>Symptomatic side</i>	
Right side	104 (38.0)
Left side	93 (33.9)
Both sides	77 (28.1)
<i>Dominant side</i>	
Right hand side	229 (83.6)
Left hand side	36 (13.1)
Unknown	9 (3.3)
<i>NTOS diagnosis</i>	
Unilateral	257 (93.8)
Bilateral	17 (6.2)
<i>Type of NTOS</i>	
Persisting	259 (94.5)
Recurrent	15 (5.5)
<i>Symptoms</i>	
Pain	247 (90.1)
Numbness	116 (42.3)
Paraesthesia	217 (79.2)
Muscle weakness	140 (51.1)
<i>Distribution</i>	
To the neck and/or head	100 (36.5)
To the shoulder	189 (69.0)
To the arm	252 (92.0)
To the hand and/or fingers	251 (91.6)
<i>Pain pattern</i>	
Continuous pain level	236 (86.1)
Undulating pain	38 (13.9)
Problems with sleeping	134 (48.9)
Arm related intervention in history	100 (36.5)
<i>Trauma in history</i>	155 (56.6)
Single episode	151 (97.4)
Direct impact on the arm	13 (8.6)
Fall from height	77 (51.0)
Whiplash trauma	46 (30.5)
Other	15 (9.9)
Repetitive motion injury	4 (2.6)
Occupation relevant for NTOS for repetitive motion, arms overhead	105 (38.3)
Incapacitated for work due to complaints	113 (41.2)
Underwent physiotherapy prior to presentation	227 (82.8)
Underwent therapy other than physiotherapy	199 (72.6)
Daily use of opioids and/or tricyclic antidepressants	68 (24.8)
Signs of a Gilliatt-Sumner hand	14 (5.1)
Tinel's sign over MSA/MSM positive	206 (75.2)
Tenderness over scalene muscle	241 (88.0)
Tenderness over pectoral minor muscle	163 (59.5)
EAST positive	223 (81.4)
ULTT positive	234 (85.4)
<i>Scalene test muscle block</i>	
Positive	187 (68.2)
Negative	69 (25.2)
Not performed for Gilliatt-Sumner hand, ATOS, VTOS	18 (6.6)
<i>Scalene muscle block patient reported outcome[†]</i>	
Positive response	232 (90.6)
Negative response	24 (9.4)

Continued

Table 2-continued

Patient characteristics	Patients (n = 274)
Baseline scores	
TOS disability scale	6.34 ± 2.08
CBSQ	75.65 ± 24.07
DASH	53.15 ± 17.72
SF-12 PCS	33.67 ± 7.83
SF-12 MCS	42.65 ± 11.74

Data are presented as n (%), mean ± standard deviation or median (interquartile range). MSA = scalenus anterior muscle; MSM = scalenus medius muscle; EAST = elevated arm stress test; ULTT = upper limb tension test; ATOS = arterial thoracic outlet syndrome; VTOS = venous thoracic outlet syndrome; CBSQ = Cervical Brachial Symptom Questionnaire; DASH = Disabilities of the Arm, Shoulder and Hands; SF-12 = 12 item Short Form; PCS = Physical Composite Scale; MCS = Mental Component Summary.

* Total of 155 patients for single episode, other, and repetitive motion injury, and 151 for direct impact, fall, and whiplash.

† Total of 256 patients for scalene muscle block patient reported outcomes.

SC-TOD in 16 (50.0%) of these patients leading to excellent Derkash results in two, good in six, fair in three, and poor in five patients after a mean follow up of 8.5 ± 5.74 months.

DISCUSSION

Surgical outcomes for a large group of patients with NTOS seen in a multidisciplinary care pathway within the scope of the North American SVS reporting standards have been reported. Using this care pathway, a significant proportion of patients with NTOS responded successfully to dedicated physiotherapy. For the remaining majority, good functional outcomes of TOD surgery were found with a significant

improvement in TOS disability scale, CBSQ, and DASH-DLV score after a mean follow up of 16.9 ± 9.2 months. Moreover, quality of life, as measured by SF-12 PCS and SF-12 MCS scores, improved significantly after TOD. As shown by others, TOD surgery was safe, brachial plexus or major vessel injury did not occur, and the mean hospital stay was short.^{8,9} Comparably low complication rates and short lengths of hospital stay have been reported from high volume (> 15 cases a year) teaching hospitals.¹⁰

Varying diagnostic criteria and outcome measures in the TOS literature makes comparison of the results difficult. The diagnosis and treatment outcomes of this cohort suggest a more prominent role for multidisciplinary care pathways in NTOS diagnostics, underlines the role of dedicated physiotherapy as the primary treatment, and shows good to excellent treatment outcomes in the majority of the surgically treated patients with NTOS following previous unsuccessful physiotherapy. Following the North American SVS reporting standards in a multidisciplinary care pathway setting provides good guidance on both diagnostics and treatment of a NTOS population, and makes reliable comparison between centres, surgeons, and surgical approaches possible. The first results, as described in this study, allow for reliable comparison with future cohort studies. This will potentially help to reduce some of the controversy surrounding NTOS and help to reduce the diagnostic and treatment delay in patients with NTOS.

In the absence of level 1 evidence the optimal surgical approach is generally based on surgeon preference.¹ There are multiple surgical approaches for TOD surgery, of which the transaxillary (TA) and supraclavicular (SC) approaches are those most commonly used in patients with NTOS.⁹ Both approaches allow for complete first rib resection from the costochondral junction to the articulation with the vertebral body's transverse process (if necessary, combined with cervical rib resection). Therefore, they minimise the risk of residual rib stumps, which is important to prevent regrowth with consequent persistent or recurrent NTOS complaints.^{11–13} A TA approach is preferred by the authors as the first option because this approach can easily be combined with a pectoralis minor tenectomy. This makes the TA approach favourable for cosmetic effects, certainly when compared with a SC approach combined with a second incision for a pectoralis minor tenectomy.¹⁴ Using the TA approach as the primary approach also leaves an "untouched" SC approach for a secondary intervention, with the further advantage of a preserved fat pad that can be split at the level of the omohyoid muscle and so be used as a boundary between the apex of the lung, as well as the subcutis, protecting the brachial plexus. The SC approach is therefore used for cases with recurrent symptoms or persistent NTOS symptoms. In these cases, the SC approach allows for a complete resection of the scalene muscle remnants, any residual first rib stumps, anomalous fibrous bands, and a thorough complete brachial plexus neurolysis.

Some favour the TA approach because it has a potentially lower risk of peripheral nerve complications than the SC approach.¹ However, the literature does not support this

Table 3. Surgical data of all thoracic outlet decompression (TOD) procedures for neurogenic thoracic outlet syndrome

Surgical data	Arms (n = 307)
First intervention	274 (89.3)
Re-intervention after TOD in another institution	17 (5.5)
Re-intervention after TOD in our institution	16 (5.2)
Pectoralis minor muscle tenectomy performed	186 (60.6)
Intra-operative use of pleural catheter	99 (32.2)
Time of pleural catheter in situ – d	1.1 ± 0.44
Length of stay – d	1.3 ± 0.59
Readmission within 30 days	3 (1.0)
Complications	
Haematoma formation*	3 (1.0)
Pneumothorax (1 week post-procedure)	1 (0.3)
Superficial wound infection	2 (0.7)
Long thoracic nerve palsy	2 (0.7)
Phrenic nerve palsy	3 (1.0)
Horner's syndrome	2 (0.7)
Pulmonary embolism	1 (0.3)
Pneumonia	1 (0.3)
Brachial vein thrombosis	1 (0.3)

Data are presented as n (%) or mean ± standard deviation. TOD = thoracic outlet decompression.

* Re-exploration was needed for one patient.

theory and the complication rates of both the TA and SC approach are comparable.^{1,3,15–19} The complication rate in this study (5.2%) is comparable to other cohorts, using either approach.^{3,9,18,19} Although the complication rates are comparable, the mean length of hospital stay of 1.3 ± 0.59 days in this cohort is relatively short compared with most other studies, which report a range of 2 – 5 days in hospital.^{3,9,16,19} In addition, the 30 day re-admission rate of 1% is lower than the range of 3% – 5% reported in several other surgical cohorts.^{9,20} This may suggest that most patients can be discharged after one day of hospitalisation without an increased risk of re-admission after TA-TOD surgery.

This study has several limitations. First, as a tertiary referral centre for NTOS complaints, patients in the presented cohort are likely to suffer from a greater degree of disability at presentation than patients in more general practice settings. Patients in general practice settings may have an even higher chance of improving with physiotherapy without the need for TOD surgery, because the majority of patients presenting in the authors' clinic have long lasting complaints (median three years) and had undergone extensive previous physiotherapy. This potentially underestimates the success rate of conservative therapy in

the cohort. Second, history of trauma, age, duration of complaints, socio-economic status, chronic pain syndromes, and response to scalene or pectoralis minor muscle blocks have been correlated with outcome after TOD surgery.^{3,15,16,19,21–26} In this study, the relationship between patient characteristics and surgical outcome was not assessed because reliable decision making based on patient characteristics requires more research with internal and external validation of a prediction model. Moreover, long term results must be awaited to show the predictive value of patient characteristics on the durability of surgical outcome. Future studies should therefore focus on delivering sound evidence for the long term durability of surgical treatment after using the North American SVS reporting standards. At this time, excluding patients with “negative” patient characteristics for TOD surgery potentially results in undertreatment of patients with NTOS.

DATA SHARING STATEMENT

De-identified participant data will be made available on request by the corresponding author on the condition of a signed data access agreement. Requests for data can be sent to the corresponding author: joep.teijink@catharinaziekenhuis.nl.

CONFLICTS OF INTEREST

Dr N. van Alfen works as an ultrasound consultant for Dynacure; fee payment goes to her employer.

FUNDING

None.

ACKNOWLEDGEMENTS

The authors thank Mandy Swinkels (nurse practitioner) and Marieke Smelt (physician assistant) for the daily coordination of the thoracic outlet syndrome (TOS) care pathway and their contribution to data collection. The authors also thank the following members of the multidisciplinary team for their contributions to the diagnosis and treatment of the patients with neurogenic thoracic outlet syndrome: Niek Schepel (orthopaedic surgeon); Rob Gons (neurologist); Joris Hendriks, Lonneke Yo, and Menno Krietemeijer (radiologists); Marieke Slegers, Bernice van der Pompe, and Wouter Oomen (TOS physiotherapists); and Hans van Suijlekom, Antal van der Gaag, Dries Oubaha, Walter ter Woerds, and Jurgen Koster (anaesthetists/pain specialists). The authors thank Lisanne Passier, Sanne Plat, and Yvonne Maassen (vascular laboratory technicians for the standardised elevated arm stress test [EAST]) for implementing the standardised EAST in daily care practice and all measurements. The authors thank Kimberly Vervaart (clinical neurophysiologist technician) for performing the nerve conduction studies and high resolution ultrasounds of the brachial plexus; Stijn Teijink (medical student) for the contribution to the data collection; and Dyanne Verhoeven (secretary TOS expert centre) for the contribution to the logistics of the questionnaires, follow up, and data collection for all the patients with NTOS.

REFERENCES

- Povlsen B, Hansson T, Povlsen SD. Treatment for thoracic outlet syndrome. *Cochrane Database Syst Rev* 2014;CD007218.
- 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.
- Balderman J, Abuirqeba AA, Eichaker L, Pate C, Earley JA, Bottros MM, et al. Physical therapy management, surgical treatment, and patient-reported outcomes measures in a prospective observational cohort of patients with neurogenic thoracic outlet syndrome. *J Vasc Surg* 2019;**70**:832–41.
- Balderman J, Holzem K, Field BJ, Bottros MM, Abuirqeba AA, Vemuri C, et al. Associations between clinical diagnostic criteria and pretreatment patient-reported outcomes measures in a prospective observational cohort of patients with neurogenic thoracic outlet syndrome. *J Vasc Surg* 2017;**66**:533–44.
- Veehof MM, Slegers EJA, van Veldhoven NHMJ, Schuurman AH, van Meeteren NLU. Psychometric qualities of the Dutch language version of the Disabilities of the Arm, Shoulder, and Hand questionnaire (DASH-DLV). *J Hand Ther* 2002;**15**:347–54.
- Pesser N, Boidin S, Van Sambeek MRHM, Van Nuenen BFL, Teijink JAW. Increasing objectivity in the diagnosis of NTOS: the standardized EAST-Meter. In: Illig KA, Thomson RW, Freischlag JA, Donahue D, Jordan SE, Lum YW, Gelabert HA, editors. *Thoracic Outlet Syndrome*. 2nd edn. Berlin: Springer; 2021. Chapter 10.
- Allmen RS von, Weiss S, Tevaearai HT, Kuemmerli C, Tinner C, Carrel TP, et al. Completeness of follow-up determines validity of study findings: results of a prospective repeated measures cohort study. *PLoS One* 2015;**10**:e0140817.
- Yin ZG, Gong KT, Zhang JB. Outcomes of surgical management of neurogenic thoracic outlet syndrome: a systematic review and Bayesian perspective. *J Hand Surg* 2019;**44**:416.
- Rinehardt EK, Scarborough JE, Bennett KM. Current practice of thoracic outlet decompression surgery in the United States. *J Vasc Surg* 2017;**66**:858–65.
- Chang DC, Lidor AO, Matsen SL, Freischlag JA. Reported in-hospital complications following rib resections for neurogenic thoracic outlet syndrome. *Ann Vasc Surg* 2007;**21**:564–70.
- Likes K, Dapash T, Rochlin DH, Freischlag JA. Remaining or residual first ribs are the cause of recurrent thoracic outlet syndrome. *Ann Vasc Surg* 2014;**28**:939–45.
- Jayaraj A, Duncan AA, Kalra M, Bower TC, Gloviczki P. Outcomes of transaxillary approach to cervical and first-rib resection for neurogenic thoracic outlet syndrome. *Ann Vasc Surg* 2018;**51**:147–9.
- Ambrad-Chalela E, Thomas GI, Johansen KH. Recurrent neurogenic thoracic outlet syndrome. *Am J Surg* 2004;**187**:505–10.
- Roos DB. Transaxillary approach for first rib resection to relieve thoracic outlet syndrome. *Ann Surg* 1966;**163**:354–8.
- Altobelli GG, Kudo T, Haas BT, Chandra FA, Moy JL, Ahn SS. Thoracic outlet syndrome: pattern of clinical success after operative decompression. *J Vasc Surg* 2005;**42**:122–8.
- Caputo FJ, Wittenberg AM, Vemuri C, Driskill MR, Earley JA, Rastogi R, et al. Supraclavicular decompression for neurogenic thoracic outlet syndrome in adolescent and adult populations. *J Vasc Surg* 2013;**57**:149–57.
- Axelrod DA, Proctor MC, Geisser ME, Roth RS, Greenfield LJ. Outcomes after surgery for thoracic outlet syndrome. *J Vasc Surg* 2001;**33**:1220–5.
- Orlando MS, Likes KC, Mirza S, Cao Y, Cohen A, Lum YW, et al. A decade of excellent outcomes after surgical intervention in 538 patients with thoracic outlet syndrome. *J Am Coll Surg* 2015;**220**:934–9.
- Gelabert HA, Rigberg DA, O'Connell JB, Jabori S, Jimenez JC, Farley S. Transaxillary decompression of thoracic outlet syndrome patients presenting with cervical ribs. *J Vasc Surg* 2018;**68**:1143–9.
- Maqbool T, Novak CB, Jackson T, Baltzer HL. Thirty-day outcomes following surgical decompression of thoracic outlet syndrome. *Hand N Y N* 2019;**14**:107–13.
- Franklin GM, Fulton-Kehoe D, Bradley C, Smith-Weller T. Outcome of surgery for thoracic outlet syndrome in Washington state workers' compensation. *Neurology* 2000;**54**:1252–7.
- Cheng SW, Reilly LM, Nelken NA, Ellis WV, Stoney RJ. Neurogenic thoracic outlet decompression: rationale for sparing the first rib. *Cardiovasc Surg* 1995;**3**:617–24.
- Jordan SE, Machleder HI. Diagnosis of thoracic outlet syndrome using electrophysiologically guided anterior scalene blocks. *Ann Vasc Surg* 1998;**12**:260–4.
- Lum YW, Brooke BS, Likes K, Modi M, Grunebach H, Christo PJ, et al. Impact of anterior scalene lidocaine blocks on predicting surgical success in older patients with neurogenic thoracic outlet syndrome. *J Vasc Surg* 2012;**55**:1370–5.
- Hong J, Pisapia JM, Ali ZS, Heuer AJ, Alexander E, Heuer GG, et al. Long-term outcomes after surgical treatment of pediatric neurogenic thoracic outlet syndrome. *J Neurosurg Pediatr* 2018;**21**:54–64.
- Scali S, Stone D, Bjerke A, Chang C, Rzucidlo E, Goodney P, et al. Long-term functional results for the surgical management of neurogenic thoracic outlet syndrome. *Vasc Endovascular Surg* 2010;**44**:550–5.