Reliability and Validity of the Elevated Arm Stress Test in the Diagnosis of Neurogenic Thoracic Outlet Syndrome

Reliability and validity of the elevated arm stress test in the diagnosis of neurogenic thoracic outlet syndrome

Niels Pesser, MD,[a,b] Britt I. de Bruijn, MSc,[a,c] Jens Goeteyn, MD,[a,b] Saskia Houterman, MSc, PhD,[d] Marc R. H. M. van Sambeek, MD, PhD,[a,e] Robert W. Thompson, MD,[f] Joep A. W. Teijink, MD, PhD,[a,b] *and* Bart F. L. van Nuenen, MD, PhD,[g] *Eindhoven, Maastricht, Utrecht, The Netherlands; and St Louis, MO*

ABSTRACT

Objectives: The objective of this retrospective analysis of prospectively collected data was to assess the test-retest reliability and validity of the elevated arm stress test (EAST) as measured by the duration in a cohort of patients with suspected neurogenic thoracic outlet syndrome (NTOS).

Methods: Patients evaluated for NTOS between January 2017 and September 2018 were identified. Test-retest reliability by the intraclass correlation coefficient was determined for duration of the EAST. For the validity analysis, patients were classified in a proven NTOS group or a symptomatic control group without NTOS using the Society for Vascular Surgery reporting standards and the outcome of thoracic outlet decompression surgery. A receiver operating characteristic curve was made for the duration of EAST. The area under the curve, and positive and negative predictive values were calculated for the EAST.

Results: In total, 428 patients with suspected NTOS were retrospectively analyzed. Of these patients, 61 were excluded because no EAST data was available. Another 101 patients were excluded because of inconclusive reporting standards, arterial or venous TOS, or because thoracic outlet decompression surgery was not performed or had a negative result. The validity analysis in the remaining 266 patients showed an area under the curve for the duration of the EAST of 0.62 (95% confidence interval, 0.55-0.69). The positive predictive value of the duration ranged between 65% and 66%, and the negative predictive value between 53% and 58%. For the test-retest reliability analysis, 118 patients were excluded because they performed only one measurement in a 100-day time period. Analysis in the remaining 148 patients showed an intraclass correlation coefficient value of 0.65 (95% confidence interval, 0.55-0.74) for duration.

Conclusions: The EAST measured by the duration showed a moderate test-retest reliability, but the discriminative value was low in the diagnosis of NTOS. The outcome of the EAST measured by the duration should be used with caution. (J Vasc Surg 2022;76:814-20.)

Clinical Relevance: The elevated arm stress test (EAST) has an important role in the current Society for Vascular Surgery reporting standards for neurogenic thoracic outlet syndrome (NTOS), but the reliability and diagnostic value of the EAST is debated. This study shows the limitations of the conventional EAST in NTOS diagnostics and follow-up. The performance of the EAST measured by the duration showed a moderate test-retest reliability, but the discriminative value was low in the diagnosis of NTOS. This indicates that this provocation test should be used with caution in NTOS diagnostics.

Keywords: Elevated arm stress test; Neurogenic thoracic outlet syndrome; Pinch strength; Provocation test; Thoracic outlet syndrome; Upper extremity

Neurogenic thoracic outlet syndrome (NTOS) is a clinical entity caused by dynamic compression of the brachial plexus in the thoracic outlet.[1] Although described extensively in the literature for decades, NTOS remains a controversial diagnosis due to inconsistent definitions, the lack of a reliable "objective" diagnostic test, and varying treatment results.[2] In the absence of a single "gold standard" diagnostic test, multifactor or multi-component diagnostic criteria are used in current daily practice to establish a clinical diagnosis of NTOS.[1,3-6] The elevated arm stress test (EAST; also known as the Roos test or positive abduction and external

From the Department of Vascular Surgery, Catharina Hospital, Eindhoven[a]; the CAPHRI School for Public Health and Primary Care, Faculty of Health, Medicine and Life Sciences, Maastricht University, Maastricht[b]; Physical Therapy Sciences, Program in Clinical Health Sciences, University Medical Center Utrecht, Utrecht[c]; the Department of Education and Research, Catharina Hospital, Eindhoven[d]; the Department of Biomedical Technology, Eindhoven University of Technology, Eindhoven[e]; the Center for Thoracic Outlet Syndrome and the Section of Vascular Surgery, Department of Surgery, Washington University School of Medicine, St. Louis[f]; and the Department of Neurology, Catharina Hospital, Eindhoven.[g]

Author conflict of interest: none.

Presented at the 2021 Vascular Annual Meeting of the Society for Vascular Surgery, San Diego, CA, August 18-21, 2021.

Correspondence: Bart F. L. van Nuenen, MD, PhD, Neurologist, Department of Neurology, Catharina Hospital, Michelangelolaan 2, Postbus 1350, 6502 ZA Eindhoven, The Netherlands (e-mail: bart.v.nuenen@catharinaziekenhuis.nl).

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

0741-5214

https://doi.org/10.1016/j.jvs.2022.03.883

rotation position test) plays an important role in most of these diagnostic criteria.[1,3] The EAST is a positional provocation test that is thought to specifically reproduce symptoms of NTOS by increasing compression of the brachial plexus.[7] According to the 2016 Society for Vascular Surgery (SVS) reporting standards for NTOS, the EAST should be used during physical examination with the result characterized as positive when there is reproduction of the characteristic upper extremity symptoms of NTOS with inability to continue the examination beyond a 3-minute time period.[1] The duration of the EAST may be used as a correlate of the level or extent of disability in patients with NTOS, and the EAST is often used to determine the result of anterior and medial scalene muscle blocks with local anesthetic. The EAST may also be used to monitor the outcomes of treatment in patients with NTOS during follow-up office visits. Unfortunately, little is known about the clinimetric properties of the EAST; the available information is dated and inconsistent due to the use of different diagnostic criteria and varying control groups. Moreover, we presume that the outcome of the EAST as measured by the duration of the test can be influenced by differences in the instructions and support during the examination.[8] These factors would potentially explain the significant differences in sensitivity and specificity of the EAST as reported in literature.[6,9-12]

The aim of this study was to assess the diagnostic value of the performance of the EAST as measured by the duration of the test in a general cohort of patients with suspected NTOS, diagnosed and treated in accordance with the SVS reporting standards criteria. We determined the test-retest reliability and validity of the performance of the EAST in the diagnosis of patients with NTOS.

ARTICLE HIGHLIGHTS

- **Type of Research:** Retrospective analysis of prospectively collected data
- **Key Findings:** Evaluation of 266 patients with neurogenic thoracic outlet syndrome (NTOS) following the Society for Vascular Surgery reporting standards showed a validity of 0.62 (95% confidence interval (CI), 0.55-0.69) and test-retest reliability of 0.65 (95% CI, 0.55-0.74) of the elevated arm stress test (EAST) as measured by duration.
- **Take Home Message:** The EAST, measured by the duration, showed a moderate test-retest reliability, but the discriminative value was low in the diagnosis of neurogenic thoracic outlet syndrome. The outcome of the EAST measured by the duration should be used with caution.

METHODS

NTOS care pathway. Patients evaluated for the diagnosis of NTOS in the national TOS outpatient clinic of the Catharina Hospital in Eindhoven, The Netherlands, between January 2017 and September 2018, were identified from a prospectively collected database. The performance of the EAST measured by duration in seconds was retrospectively collected based on the database and the electronic health record of the referred patients. Patients were enrolled in our multidisciplinary diagnostic care pathway for NTOS based on the SVS reporting standards NTOS. The complete diagnostic algorithm and care pathway as used in this study is described in detail previously.[13] The vascular surgeon and/or neurologist performed an EAST at initial presentation. If patients were suspected to have NTOS, patients received a scalene muscle block for further diagnostics. In these patients, a pain anesthesiologist performed the EAST before and 1 hour after the scalene muscle block. After clinical evaluation, the patient was discussed in a multidisciplinary meeting with a TOS surgeon, neurologist, physiotherapist, pain anesthesiologist, orthopedic surgeon, and radiologist. The NTOS diagnosis was made by this team of physicians if a patients met at least three of the four main criteria of the SVS reporting standards.[1] If initial physiotherapy was not sufficient to alleviate the NTOS complaints, transaxillary thoracic outlet decompression (TOD) surgery was recommended.

Performance of the elevated arm stress test. The EAST was performed seated or standing with both arms in 90-degree abduction, external rotation, and elbows flexed to 90 degrees as described in the original publication of the EAST by Roos et al.[7] After correct positioning, the patient was instructed to alternately open and close both hands once per second for 3 minutes. The total duration of the EAST measured in seconds was noted in the electronic health record. The inability to complete the test because of reproduction of symptoms (<180 seconds) is considered a positive EAST and suggestive of a diagnosis of NTOS.[1] Patients who are able to complete the test for at least 180 seconds are considered as having a negative EAST. All raters were experienced members of the TOS team and familiar with the performance of the EAST as described. Therefore, no formal training in the performance of the EAST was given before the prospective database was started. Although the rater was always a member of the TOS team, both EAST measurements were not always performed by the same clinician.

Group formation for analysis. Patients were divided into groups for the test-retest and validity analysis based on the diagnosis after completion of the diagnostic care pathway and outcome of TOD surgery. Two groups were formed for the validity and test-retest analysis: the proven NTOS group and the symptomatic

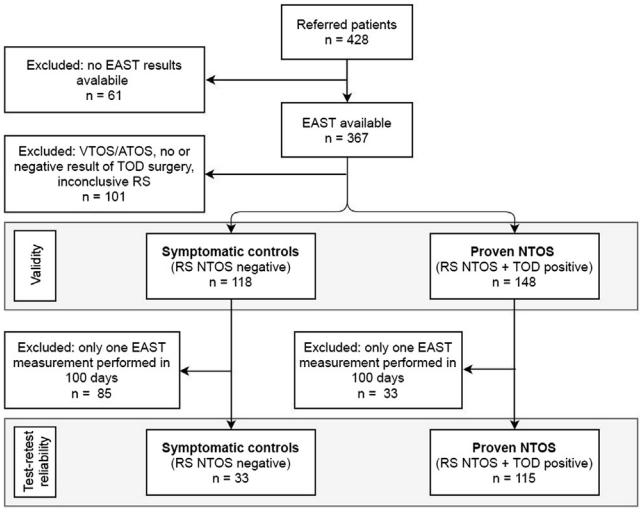

Fig 1. Flowchart of the validity and test-retest analysis. *ATOS*, Arterial thoracic outlet syndrome; *EAST*, elevated arm stress test; *NTOS*, neurogenic thoracic outlet syndrome; *RS*, Society for Vascular Surgery reporting standards for TOS; *TOD*, thoracic outlet decompression; *TOS*, thoracic outlet syndrome; *VTOS*, venous thoracic outlet syndrome.

control group. The proven NTOS group consisted of patients who met at least three of the four main criteria of the SVS reporting standards for NTOS and reported a positive response after treatment with TOD surgery. The criteria of the SVS reporting standards were defined as follows: local findings at the thoracic outlet consistent with NTOS, peripheral findings in the affected upper extremity, absence of possible differential diagnosis, and a positive test injection. The response after TOD was determined by the Derkash score, the cervical brachial score questionnaire, and the disability of the arm, shoulder, and hand (Dutch language version) score. An excellent or good Derkash classification or a fair classification with improvement in the disability of the arm, shoulder, and hand (Dutch language version) score and cervical brachial score questionnaire after surgery was defined as a positive TOD response. Symptomatic patients who did not meet the reporting standards for NTOS were included in the symptomatic control group. Patients with incomplete EAST data, an incomplete diagnostic care pathway, coexisting arterial TOS or venous TOS symptoms, or a negative or unknown response on TOD surgery were excluded from this analysis. The study (data collection and retrospective analysis) was approved by the medical ethical committee of the Catharina Hospital.

All patients with two complete EAST measurements within 100 days were used for the test-retest reliability analysis. The EAST measurement of the initial presentation was compared with the EAST measurement before the scalene muscle block. Analysis was performed using the proven NTOS group and the symptomatic control group. The formation of all groups and their contribution to each analysis is summarized in a flowchart in Fig 1.

Statistical analysis. Descriptive statistics were used to compare baseline characteristics. The intraclass correlation coefficient (ICC) estimate with 95% confidence interval (CI) was used to determine test-retest reliability. The ICC value shows the reproducibility of the EAST when measured at different time intervals. A higher ICC value indicates more similarity in the data and suggests that a test is reliable and reproducible at different time intervals. The ICC is calculated based on a single rating, absolute agreement, two-way mixed-effects model. Additionally, sub-group analysis of the ICC values was performed based on diagnosis (symptomatic controls and proven NTOS groups) and on the time between both EAST measurements. Patients who performed both EAST measurements within 30 days were compared with patients with >30 days in between both EAST measurements.

The validity analysis was used to determine the diagnostic value of the EAST. This analysis tested if the EAST can discriminate between the proven NTOS group and the symptomatic control group. To determine the validity, the area under the curve (AUC) of the receiver operating characteristic (ROC) curve was calculated for the duration of the EAST measurement. The cutoff value for performance of the EAST measured by duration was determined using the ROC curve, comparing participants with proven NTOS with symptomatic controls. The minimally acceptable AUC considered for a diagnostic test is 0.70.[14] Because the AUC was smaller than 0.70, no optimal threshold with both an acceptable sensitivity and specificity rate could be determined. Therefore, two cutoff values for daily care practice at 70% sensitivity or 70% specificity were determined based on previously reported mean sensitivity and specificity rates of provocative tests in patients with TOS.[11,13] Based on the 70% sensitivity or 70% specificity cutoff value, the true positives, true negatives, false positives, and false negatives were determined, and the positive and negative predictive value were calculated.[15] The significance level was set at $P < .05$. Analysis was performed in RStudio version 1.2.5033.

RESULTS

We identified and retrospectively analyzed 428 patients with suspected NTOS. A total of 61 patients were excluded because no EAST data was available. Another 101 patients were excluded after retrospective analysis because coexisting venous or arterial TOS symptoms were present, TOD surgery was not performed, or had a negative result, or the SVS reporting standards were inconclusive (Fig 1). The remaining 266 patients were included for the validity analysis of duration of the EAST. This group consisted of 148 patients with proven

Table I. Participant characteristics for determining validity

Variable	Total	Sub-analysis groups	
		Proven NTOS group	Symptomatic control group
Number of participants (female/male)	266 (179/87)	148 (117/31)	118 (62/56)
Median age, years (IQR)	42 (34-51)	40 (33-48)	45 (35-53)
Dominant hand (R/L)	213/53	120/28	94/24
Affected side used for analysis (R/L)	168/98	90/58	77/41
Complications after surgical intervention (n = 200)	12	9	
Hematoma formation	3	2	
Pneumothorax	2	1	
Wound infection	1	1	
Phrenic nerve palsy	1	1	
Horner's syndrome	3	2	
Pulmonary embolism	1	1	
Long thoracic nerve palsy	1	1	

IQR, Interquartile range; *L*, left; *NTOS*, neurogenic thoracic outlet syndrome; *R*, right.

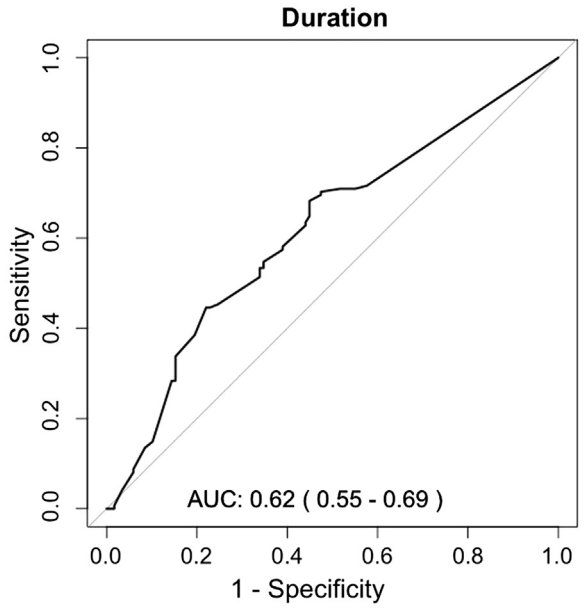

Fig 2. Receiver operating characteristic (ROC) curve for neurogenic thoracic outlet syndrome (NTOS) vs symptomatic control. AUC, Area under the curve.

NTOS and 118 symptomatic controls, of which the baseline characteristics are summarized in Table I. A ROC curve comparing patients with proven NTOS with symptomatic controls was created for duration (Fig 2). The AUC value of duration was 0.62 (95% CI, 0.55-0.69), meaning duration had a 62% chance to distinguish patients with proven NTOS from symptomatic controls based on the outcomes of duration of the EAST. A cutoff value at 70% sensitivity was determined for duration followed by a cutoff value at 70% specificity because the ROC curve of duration resulted in an AUC <0.70. If a 70% sensitivity cutoff value for duration is chosen, the positive predictive value is 65%, and the negative predictive value is 58%, respectively. On the other hand, if a 70% specificity cutoff is preferred, the positive predictive value is 66%, and the negative predictive value is 53%. The true positives, false positives, true negatives, and false negatives based on the cutoff value at 70% sensitivity or 70% specificity are presented in Table II.

The analysis of the test-retest reliability was performed with 148 patients who performed two EAST measurements (115 in the proven NTOS group, 33 in the symptomatic group). The remaining 118 patients did not perform two EAST measurements within 100 days and were therefore excluded for the test-retest reliability analysis. The baseline characteristics, the EAST duration times, and the median time in between the tests of the patients included in the test-retest analysis are summarized in Tables III and IV. Analysis showed a moderate test-retest reliability with an ICC value of 0.66 (95% CI, 0.58-0.73) for the total group (n = 148) (Table V).

DISCUSSION

The outcome of a diagnostic test can be investigated in terms of reliability, validity, and responsiveness. In this study, we assessed both the test-retest reliability and the validity of the performance of the EAST as measured by the duration of the test in a series of patients with suspected NTOS. In general, test-retest reliability with an ICC value of 0.75 is considered good for diagnostic tests.[16] The results of this study show that the test-retest reliability for the duration of the EAST is moderate (ICC = 0.65), which indicates that multiple practitioners are not likely to obtain similar results. Therefore, outcomes defined solely by the duration of the EAST should

Table II. Cutoff value for duration and the corresponding positive and negative predictive value determined by comparing participants with proven NTOS to symptomatic controls

Parameter	Cutoff point	Cutoff value, seconds	TP, No.	FP, No.	TN, No.	FN, No.	Total, No,	PPV, %	NPV, %
Duration	70% sensitivity	117.5	104	56	62	44	266	65	58
	70% specificity	77.5	81	41	77	67	266	66	53

FN, False negatives; *FP*, false positives; *NPV*, negative predictive value; *PPV*, positive predictive value; *TN*, true negatives; *TP*, true positives.

Table III. Participant characteristics for determining test-retest reliability

Variable	Total	Subanalysis groups		Subanalysis time	
		Proven NTOS group	Non-NTOS group	Total ≤30 days between measurements	Total >30 days between measurements
Number of participants (female/male)	148 (111/37)	115 (91/24)	33 (20/13)	65 (48/17)	83 (63/20)
Median age (IQR), years	40 (33-49)	40 (33-48)	41 (34-53)	42 (33-53)	40 (34-48)
Dominant hand (R/L)	117/31	90/25	27/6	52/13	65/18
Affected side used for analysis (R/L)	87/61	66/49	22/11	45/20	42/41
Median days between measurements (IQR)	36 (20-56)	36 (15-56)	39 (25-56)	15 (8-25)	56 (48-69)

IQR, Interquartile range; *L*, left; *NTOS*, neurogenic thoracic outlet syndrome; *R*, right.

be used with caution in daily clinical practice. The moderate test-retest reliability especially affects the applicability of the duration of the EAST as an outcome measure for multiple assessments in patients with NTOS (for example, to determine the before-after result of a scalene muscle block). In this case, differences in the duration of the EAST cannot only be attributed to the effect of the muscle block but are also influenced by differences in performance of the EAST at different times. Substantial improvement in the test-retest reliability of the EAST (ICC >0.75) is necessary before it can be used as a reliable outcome measure or diagnostic test in patients with NTOS.

The EAST has a prominent role in the SVS reporting standards for NTOS, but the reliability and diagnostic value of the EAST in daily clinical practice remains unclear.[1,10,11] Several studies report sensitivity rates higher than 80%.[9,12,17] Evaluation of the optimal threshold for EAST duration was done by using the 70% sensitivity and 70% specificity cutoff values. This approach differs considerably from other studies and does not represent a valuable diagnostic test for daily clinical practice.[18] However, a higher sensitivity cutoff value sacrifices the specificity, and vice versa. Considering the AUC <0.70 of the EAST, the cutoff values as used in this study are as close as possible to an optimal threshold for both sensitivity and specificity and correspond to the mean diagnostic value of diagnostic tests in patients with NTOS.[12,17] Overall, the validity analysis showed that the discriminative value of the EAST in daily clinical practice is poor when used in isolation. These results indicate that, when used alone, the EAST is not useful to reliably discriminate patients with NTOS from symptomatic controls. This can be explained by the finding that a significant proportion (58%) of patients with symptoms of the upper extremity, other than NTOS, are not able to complete the test. Although the EAST seems to be of low diagnostic value, some may use the EAST as a quick screening test for patients with upper extremity symptoms. This can be useful to distinguish patients with NTOS from those without upper extremity complaints. However, the false-positive rate based on a 70% sensitivity or 70% specificity cutoff value in this study demonstrates that screening with the EAST in patients already suspected to have NTOS is not of additional value. The low discriminative value of the EAST is endorsed by others, although these studies compared subjective complaints during the EAST rather than the measured duration of the test in patients with NTOS and symptomatic controls (eg, patients with carpal tunnel syndrome).[19] Considering the low discriminative value, the diagnosis of NTOS should not be based solely on a positive result of the duration of the EAST.

Debate exists about the performance and interpretation of the EAST, with two different methods described in the literature to indicate what constitutes a positive test result. The SVS reporting standards describe a 3-minute EAST measurement with both time to the onset of complaints and the duration to which the patient is unable to continue used as endpoints.[1] Roos and Owens described the EAST with reproduction of symptoms as the primary endpoint.[7] In line with this first description of the EAST, some clinicians prefer a 1-minute EAST with an endpoint of symptom reproduction.[20]

Table IV. Duration in seconds of the elevated arm stress test at both measurement intervals for the test-retest reliability

Parameter	Total	Proven NTOS group	Non-NTOS Group	Total <30 days in between group	Total >30 days in between (women)
Duration at intake, seconds	90 ± 62	84 ± 62	112 ± 58	77 ± 58	100 ± 63
Duration before test injection, seconds	98 ± 59	96 ± 60	105 ± 54	90 ± 58	104 ± 59

NTOS, Neurogenic thoracic outlet syndrome.
Data are presented as mean ± standard deviation.

Table V. The intraclass correlation coefficient (ICC) estimates with their 95% confidence intervals (CIs) of the elevated arm stress test (EAST) measurement parameters

		Subanalysis groups		Subanalysis time	
Parameter	Total	Proven NTOS group	Non-NTOS group	Total, ≤ 30 days between measurements	Total, > 30 days between measurements
Duration, seconds	0.65 (0.55-0.74)	0.61 (0.47-0.71)	0.83 (0.68-0.91)	0.63 (0.46-0.76)	0.65 (0.51-0.76)

NTOS, Neurogenic thoracic outlet syndrome.
Data are presented as ICC estimate with 95% CIs.

Although there is little supportive literature, this 1-minute variant is advocated because the majority of patients with NTOS will have complaints within seconds and patients with a different diagnosis (eg, complex regional pain syndrome) may experience many days of delayed onset muscular pain after a 3-minute test.[21] However, 55% of the "proven NTOS" patients in this study were able to perform the EAST for 60 seconds or more. If the maximum duration of the test was 1 minute, comparison before and after a scalene muscle block would not be possible in these patients. The 3-minute EAST is based on the initial description of the EAST and some studies that suggested a 3-minute cutoff point for duration. However, solid evidence for this cutoff point is lacking. This study shows that an optimal cutoff point within these 3 minutes with high sensitivity and specificity does not exist. As evidenced by our data, most of the patients with NTOS are not able to complete the 3-minute EAST. Therefore, longer EAST duration times are not likely to improve the diagnostic accuracy of the EAST, and a maximum time of 3 minutes seems sufficient. In addition to the duration of the EAST, the location and the degree of symptoms are used to discriminate patients with NTOS from patients with other conditions. In our view, measurement of the reproduction of symptoms is more subjective in nature because the symptoms of NTOS can vary significantly between patients.[22] The pattern and location of symptoms is also diverse and cannot always be reliably distinguished from conditions with similar or overlapping symptoms. As a result, reliable determination of the test-retest reliability and validity of these more subjective complaints is difficult, and therefore, we chose not to include specific patterns of symptoms in our analysis. We advocate the use of a 3-minute test with the duration until the patient is unable to continue as the primary endpoint to make the EAST as objective as possible and a useful endpoint for comparisons.

This cohort study suffers from several limitations. First, all analyses are based on the EAST duration measurement as documented in the electronic patient file. A total of 61 patients were excluded because the duration of the EAST was not noted, and 62 patients did not meet the criteria for the NTOS diagnosis. The retrospective nature of this study may therefore result in selection bias. However, the 266 included patients do represent a general NTOS population as defined by the SVS reporting standards criteria. Second, we defined a positive response after TOD surgery in patients with a diagnosis of NTOS based on the SVS reporting standards criteria as "proven NTOS" patients. This selection of patients also has its downsides and potentially leads to selection bias in the validity analysis. Nevertheless, we consider this to be the best method to define a group of patients with confirmed NTOS considering the absence of a gold standard diagnostic test or imaging technique. Third, we excluded patients with multiple measurements in a time period of more than 100 days. Because literature is lacking, the 100-day time period is an arbitrary line. We chose to include this time period to exclude patients who might have different EAST duration times based on a progression of NTOS symptoms. The 100-day time interval was based on the mean time between presentation and completion of the diagnostic care pathway. Using this exclusion criterion, we expected to find a more accurate EAST duration test-retest reliability. Fourth, the EAST was not performed in all patients under the same conditions. Although the EAST is explained and performed by all members of the multidisciplinary team following the same principles, the posture and duration measurement of the EAST could differ between physicians and examinations. This could potentially lead to lower inter- and

intra-rater reliability than expected with a more standardized protocol for both posture and duration measurement. However, the performance in this study mimics the EAST as used in daily clinical practice, and as described, we consider the variability of the posture and EAST measurement as major limitations. Future studies should therefore focus on standardization of the EAST measurements to improve the test-retest reliability and validity in the diagnosis of NTOS.

The authors thank Mandy Swinkels (nurse practitioner) and Marieke Smelt (physician assistant) for the daily coordination of our TOS care pathway and their contribution to the data collection. The authors also thank Dyanne Verhoeven (secretary TOS expert center) for her contribution in the logistics and planning all patients with NTOS.

AUTHOR CONTRIBUTIONS

Conception and design: NP, BD, MS, RT, JT, BN
Analysis and interpretation: NP, BD, SH, BN
Data collection: NP, BD, JG
Writing the article: NP, BD
Critical revision of the article: JG, SH, MS, RT, JT, BN
Final approval of the article: NP, BD, JG, SH, MS, RT, JT, BN
Statistical analysis: NP, BD
Obtained funding: Not applicable
Overall responsibility: BN

REFERENCES

1. 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.
2. Povlsen B, Hansson T, Povlsen SD. Treatment for thoracic outlet syndrome. Cochrane Database Syst Rev 2014;11:CD007218.
3. Weaver ML, Lum YW. New diagnostic and treatment modalities for neurogenic thoracic outlet syndrome. Diagn Basel Switz 2017;7:28.
4. 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.
5. Thompson RW. Diagnosis of neurogenic thoracic outlet syndrome: 2016 consensus guidelines and other strategies. In: Illig KA, Thompson RW, Freischlag JA, Donahue DM, Jordan SE, Lum YWet al., editors. Thoracic outlet syndrome. Second Edition. Springer Nature; 2021. p. 67-97.
6. 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.e2.
7. Roos DB, Owens JC. Thoracic outlet syndrome. Arch Surg 1966;93:71-4.
8. 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 YWet al., editors. Thoracic oulet syndrome. Second edition. Springer; 2020. chapter 10.
9. Sanders RJ, Hammond SL, Rao NM. Diagnosis of thoracic outlet syndrome. J Vasc Surg 2007;46:601-4.
10. Plewa MC, Delinger M. The false-positive rate of thoracic outlet syndrome shoulder maneuvers in healthy subjects. Acad Emerg Med 1998;5:337-42.
11. Dessureault-Dober I, Bronchti G, Bussières A. Diagnostic accuracy of clinical tests for neurogenic and vascular thoracic outlet syndrome: a systematic review. J Manipulative Physiol Ther 2018;41:789-99.
12. Gillard J, Pérez-Cousin M, Hachulla É, Remy J, Hurtevent J-F, Vinckier L, et al. Diagnosing thoracic outlet syndrome: contribution of provocative tests, ultrasonography, electrophysiology, and helical computed tomography in 48 patients. Jt Bone Spine 2001;68:416-24.
13. Pesser N, Goeteyn J, van der Sanden L, Houterman S, van Alfen N, van Sambeek MRHM, et al. Feasibility and outcomes of a multidisciplinary care pathway for neurogenic thoracic outlet syndrome: a prospective observational cohort study. Eur J Vasc Endovasc Surg 2021;61:1017-24.
14. Hosmer DW, Lemeshow S. Applied Logistic Regression. 2nd Ed. John Wiley and Sons; 2000. p. 160-4. Chapter 5.
15. Trevethan R. Sensitivity, specificity, and predictive values: foundations, pliabilities, and pitfalls in research and practice. Front Public Health 2017;5:307.
16. Koo TK, Li MY. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. J Chiropr Med 2016;15:155-63.
17. Sadeghi-Azandaryani M, Bürklein D, Ozimek A, Geiger C, Mendl N, Steckmeier B, et al. Thoracic outlet syndrome: do we have clinical tests as predictors for the outcome after surgery? Eur J Med Res 2009;14:443-6.
18. Power M, Fell G, Wright M. Principles for high-quality, high-value testing. Evid Based Med 2013;18:5-10.
19. Nord KM, Kapoor P, Fisher J, Thomas G, Sundaram A, Scott K, et al. False positive rate of thoracic outlet syndrome diagnostic maneuvers. Electromyogr Clin Neurophysiol 2008;48:67-74.
20. Illig KA, Thompson RW, Freischlag JA, Donahue DM, Jordan SE, Edgelow PI. Clinical incidence and prevalence: basic data on the current scope of the problem. In: Thoracic outlet syndrome. Springer; 2013. p. 25-8.
21. Illig KA, Thompson RW, Freischlag JA, Donahue DM, Jordan SE, Edgelow PI. NTOS for the primary care team: when to consider the diagnosis. In: Thoracic outlet syndrome. Springer; 2013. p. 31-47.
22. Ferrante MA, Ferrante ND. The thoracic outlet syndromes: part 2. The arterial, venous, neurovascular, and disputed thoracic outlet syndromes. Muscle Nerve 2017;56:663-73.

Submitted Jul 12, 2021; accepted Mar 23, 2022.