

Consensus Recommendations for Neurogenic Thoracic Outlet Syndrome from the INTOS Workgroup

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Background: There is significant variation in methods used for diagnosis and treatment of neurogenic thoracic outlet syndrome (NTOS). The lack of definitions and criteria for diagnosis as well as controversy in treatment options hampers standardized reporting of outcomes. In the orthopedic and plastic hand surgery literature, there are not standardized guidelines to direct evidence-based practice for hand surgeons relating to NTOS. Hence, expert consensus may provide guidance for clinical practice.

Methods: An international workgroup of 21 expert hand surgeons with cumulative experience of 5519 NTOS procedures was assembled. The Delphi method was used to arrive at consensus recommendations to guide diagnosis, treatment, surgery, and postoperative management of patients with NTOS.

Results: The workgroup achieved majority (greater than 75%) consensus with 17 statements. A modified version of the Society for Vascular Surgery clinical diagnostic criteria is recommended for diagnosis of NTOS. The elevated arm stress test and Tinel sign are recommended as provocative maneuvers. A cervical spine or chest radiograph should be routinely obtained preoperatively. Conservative management should be first line for NTOS, except in patients with significant muscle atrophy or weakness. An anterior supraclavicular approach is recommended for exposure of the supraclavicular brachial plexus, with the necessity for an additional infraclavicular approach or adjunctive surgeries indicated for specific patients.

Conclusions: Standardized consensus guidelines help guide management of NTOS by specialized hand surgeons, with an aim toward standardizing criteria for diagnosis and treatment of patients as well as measures and tools used for research and reporting of outcomes. (*Plast Reconstr Surg Glob Open* 2024; 12:e6107; doi: [10.1097/GOX.0000000000006107](https://doi.org/10.1097/GOX.0000000000006107); Published online 28 August 2024.)

INTRODUCTION

Thoracic outlet syndrome (TOS) encompasses a group of disorders caused by compression of neurovascular structures at the thoracic outlet. There are three distinct types of TOS, depending on the principal structures compressed and occasionally with overlap: neurogenic (NTOS), arterial (ATOS) and venous (VTOS). The prevalence of TOS has been estimated to range

from three to 80 per 1000,¹ with NTOS comprising over 90% of cases.²

Hand surgeons are predominantly involved in diagnosis and management of NTOS. NTOS is underdiagnosed, with presenting symptoms such as numbness; chronic pain; and weakness in the neck, shoulder, and upper extremity, which can also be caused by cervical spine disease, compressive neuropathies in the upper extremity, chronic pain, and psychological conditions. As a result, NTOS often becomes a diagnosis of exclusion after other conditions have been ruled out. The diagnosis of NTOS is highly variable among different providers, subjective and often controversial.³ Similarly, controversy is significant in

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management of NTOS, with an example being the necessity for first rib resection versus rib sparing scalenectomy as primary surgical treatment for NTOS.⁴

The lack of consensus on NTOS makes the interpretation of published literature difficult and research challenging. A Cochrane review focusing on treatment for TOS concluded that there was a lack of generally accepted diagnostic criteria for TOS. In addition, the review concluded that there was an urgent need for an agreed definition for diagnosis of TOS and agreed outcome measures.⁵ To address this need, expert consensus may help provide guidelines for clinicians diagnosing and treating NTOS. This article summarizes findings from an expert panel of orthopedic, plastic, and specialized hand surgeons, aiming to reach a consensus among hand surgeons regarding diagnosis and management of NTOS.

METHODS

Expert hand surgeons were identified and recruited to the International Neurogenic Thoracic Outlet Syndrome Hand Surgery (INTOS) Workgroup, consisting of 21 surgeons from North America, South America, Europe, and Asia. Where there were more than one surgeon managing patients with NTOS at a single center, only one surgeon was invited to participate in the panel. The level of expertise for all members of the panel qualified as level 4 (specialist-highly experienced) or 5 (expert) as defined by Tang and Giddins.⁶ The mean number of years in practice for the panel of experts was 21.7 ± 12.8 . The mean number of TOS procedures performed by each member of the panel was 262.8 ± 346.5 , with the panel having experience in a total of 5519 TOS procedures before this study.

A modified Delphi methodology⁷ was used to determine consensus for clinically relevant points relating to NTOS. Panel members participated in multiple rounds of surveys from November 2023 to February 2024. Members of the workgroup were blinded from their fellow panelists, with findings from the study between different rounds presented to the workgroup in an anonymous fashion.

Round 1

Round 1 consisted of 28 open-ended questions focused on the major subareas of diagnosis, treatment, surgery, and postoperative management for NTOS. (See table, **Supplemental Digital Content 1**, which displays the open-ended question. <http://links.lww.com/PRSGO/D460>.) Responses from this round of the survey were summarized and presented to the workgroup.

Round 2

Based on majority responses to the open-ended questions, statements were formulated and sent out to the workgroup in a second round of 22 questions aimed at achieving consensus. (See table, **Supplemental Digital Content 2**, which displays the consensus questions. <http://links.lww.com/PRSGO/D461>.) Round 2 similarly focused on major subareas of diagnosis, treatment, surgery, and postoperative management for NTOS. Respondents were given the option to agree, disagree, or request modifications to the statements. Replies were evaluated

Takeaways

Question: There is significant variation in methods used for diagnosis and treatment of neurogenic thoracic outlet syndrome (NTOS). Expert consensus may provide guidance for clinical practice.

Findings: The Delphi method was used to arrive at consensus recommendations to guide diagnosis, treatment, surgery, and postoperative management of patients with NTOS. The workgroup achieved majority (consensus >75%) with 17 statements.

Meaning: Standardized consensus guidelines help guide management of NTOS by specialized hand surgeons, with an aim toward standardizing criteria for diagnosis and treatment of patients as well as measures and tools used for research and reporting of outcomes.

to determine the level of agreement: complete (100%), majority (>75%), or partial (>50%).

Round 3

Round 3 consisted of modifications to two questions sent out in round 2 suggested by members of the workgroup (See table, **Supplemental Digital Content 3**, which displays consensus refinement questions. <http://links.lww.com/PRSGO/D462>.) Respondents were given the option to agree or disagree with the statements.

The median threshold recommended to be accepted as consensus for Delphi studies based on tendency for the remaining participants to shift towards consensus is 75%.⁸ Hence, statements achieving majority (>75%) agreement were adopted as consensus statements and recommendations from the workgroup. The panel was given a final opportunity to review the article and consensus statements before submission for publication.

RESULTS

Summary of Round 1 Findings

Diagnosis

Round 1 consisted of open-ended questions. The workgroup universally relied on a combination of neurological symptoms and signs for diagnosis of NTOS. The Roos/elevated arm stress test (EAST) was the most commonly used provocative test for diagnosis of NTOS. Other tests commonly used by the workgroup included a positive Tinel sign in the supraclavicular fossa and the upper limb tension test (ULTT)/Elvey test. Some members used scalene muscle blocks for diagnosis of NTOS. The use of screening questionnaires was not universal. A variety of questionnaires including the Disabilities of the Arm, Shoulder and Hand (DASH), Cervical Brachial Symptom Questionnaire, 12 item Short-Form Survey (SF-12), HandQ, visual analog scale, and other nonvalidated questionnaires were used by members of the workgroup.

Workup

The use of radiological imaging was not universal. Among the workgroup, imaging modalities used for

workup of NTOS included plain radiographs of the cervical spine, magnetic resonance imaging (MRI), computed tomography angiogram, and ultrasound. The most common imaging modality used was a plain cervical spine radiograph or chest radiograph to rule out a cervical rib.

The use of electrodiagnostic studies was not universal. When used, electrodiagnostic studies were used for diagnosis of NTOS or for ruling out other pathologies and distal nerve compression sites. In diagnosis of NTOS, decreased conduction velocity of the medial antebrachial cutaneous nerve was a common finding looked for. Some members used electrodiagnostic studies to rule out cubital tunnel syndrome.

The use of ultrasound was not universal. When used, ultrasound was used to rule out arterial and venous TOS. Some members used ultrasound to diagnose NTOS. The use of botulinum toxin injections, steroid injections, or nerve blocks was not universal. When nerve blocks were performed, this was most often with ultrasound guidance to the scalene muscles or pectoralis minor muscle. Classification systems for determining type or severity of NTOS were not universally used by the workgroup.

Treatment

The majority of the workgroup recommended surgery after failure of conservative management. Three to six months of conservative management or physical therapy before consideration of surgery was the period of time recommended by the majority of the workgroup. Some participants recommended surgery as first line treatment if there was muscle atrophy or weakness or sustained sensory deficits on physical examination. The presence of a structural abnormality (cervical rib, scalene minimus, vascular compression) was also stated by some members as an indication for surgery without a prior trial of conservative treatment.

Nonsurgical modalities for NTOS used by the workgroup included nerve gliding exercises, postural exercises, muscle strengthening and elongation exercises, trigger point therapy, scalene stretching, scapular retraction, and stabilization. Lifestyle modification by avoiding activities causing shoulder drooping was recommended. Therapeutic injections to the scalene muscles (some members using ultrasound guidance) with local anesthesia or steroids, botulinum toxin injections and medications such as gabapentin or pregabalin were used by some members of the workgroup. Multidisciplinary teams were commonly but not universally used in management of NTOS.

Surgery

The workgroup almost universally used an anterior supraclavicular approach to the brachial plexus for surgical treatment of NTOS. Two members routinely used an endoscope assisted transaxillary or subclavicular approach for surgery on the supraclavicular brachial plexus. There was no consensus on the necessity for routine first rib resection. Thirteen members (61.9%) did not routinely remove the first rib, whereas eight members (38.1%) routinely resected the first rib. An intraoperative EAST or dynamic overhead abduction test was used by some

members to assess for tethering of the T1 root over the first rib and necessity for first rib resection.

The workgroup most often used a direct infraclavicular approach to the brachial plexus through a deltopectoral incision for treatment of pectoralis minor syndrome. An axillary, transpectoral or endoscopic-assisted subclavicular approach was also used by some members. Decompression of the infraclavicular brachial plexus was not universally performed by the workgroup on a routine basis. Indications for infraclavicular surgery used by the workgroup included positive findings on physical examination or imaging as well as relief of symptoms following diagnostic injections. Physical examination findings used included a positive Tinel sign and tenderness over the pectoralis minor. Some members used the presence of scapular dyskinesia as an indication for infraclavicular surgery.

Adjunctive procedures for NTOS were not universally performed. When performed, these included distal nerve decompression and distal nerve or tendon transfer. These procedures were performed at the time of the primary surgery, before, or afterwards in a delayed fashion, by different members of the workgroup.

Postoperative

Success after surgery for NTOS was variably defined by the workgroup as the following: (1) subjective improvement in symptoms; (2) improvement in range of motion, strength, scapular tracking, or resolution of provocative tests; (3) improvement in pain scores; (4) improvement in quality of life/satisfaction scores; (5) improvement as assessed through patient-reported outcome measures.

The workgroup had varying practices regarding postoperative hospitalization after surgery for NTOS. One-third ($n = 7$) routinely performed surgery as an outpatient, one-third observed patients overnight, and one-third kept patients in the hospital for a few days after surgery. Postoperative rehabilitation protocols used by members of the workgroup included the following components: nerve gliding, scar release, shoulder girdle strengthening, range of motion exercises.

Research

The workgroup was queried on future research directions for NTOS. A summary of proposed research areas is provided in [Table 1](#).

Summary of Round 2 and Round 3 Findings

Consensus Summary

Of 22 statements presented to the workgroup, one reached complete agreement (100%), 17 reached majority agreement (75%), and 21 reached partial agreement (>50%). Statements reaching greater than 75% agreement were adopted as consensus recommendations from the workgroup and are summarized in [Table 2](#). The modified version of the clinical diagnostic criteria (CDC) of the Society for Vascular Surgery (SVS)³ recommended by the workgroup for use by hand surgeons in diagnosis of NTOS, with majority consensus, is presented in [Table 3](#). The CDC proposed by the Consortium for Research and Education on Thoracic Outlet Syndrome (CORE-TOS),⁹

Table 1. Future Research Directions for NTOS

Basic science research on etiology of NTOS
Regenerative medicine
Refined, standardized, objective diagnostic criteria for NTOS
Defining objective radiological findings diagnostic of NTOS
Role of psychological factors in response to treatment for NTOS
Improved imaging modalities for preoperative assessment—ultrasound, MRI, dynamic radiologic studies
Role of abnormal NCS with MABC in diagnosis of NTOS with electrodiagnostic studies
Dedicated NCS for assessment of pathology in brachial plexus
Correlation of response to diagnostic injections with improvement after surgery
Treatment for traction type TOS
Role of cervical rib in symptoms
Improvements in nonoperative physical therapy protocol
Long term follow-up of efficacy of nonoperative treatment for NTOS
Role of botox injections in treatment of NTOS
Individualized surgical approaches for each patient
Role of intraoperative NCS to determine exact level of compression
Efficacy of rib sparing scalenectomy versus routine first rib resection
Robotic surgery for NTOS
Sham surgery study for NTOS
Standardized outcome measures to assess improvement/ change following treatment for NTOS
Optimizing postoperative rehabilitation protocols
NCS: nerve conduction studies; MABC: medial antebrachial cutaneous nerve.

recommended with majority consensus for use by hand surgeons in diagnosis of NTOS, is presented in [Table 4](#). (See [table, Supplemental Digital Content 4](#), which displays a summary of the level of agreement for each proposed statement presented to the workgroup. <http://links.lww.com/PRSGO/D463>).

DISCUSSION

In the United States, the majority of surgery for TOS is performed by vascular surgeons, ranging from 87% to 90% of all cases.^{10,11} This is followed, in predominance, by thoracic surgeons and general surgeons. Orthopedic and plastic hand surgeons perform only 1.8% of all TOS cases.¹¹ This is an interesting trend, as the majority of cases of TOS (90%) are neurogenic in nature.² This trend is particularly interesting given the majority involvement of orthopedic and plastic hand surgeons in all aspects of brachial plexus injuries, including reconstruction for traumatic and obstetric cases.

A significant development within the vascular surgery community focused on treatment of TOS was the development and adoption of standardized diagnostic criteria. These include the SVS³ and CORE-TOS⁹ criteria, which also have been adopted in modified form by this workgroup. Similarly, the neurosurgical community, through the section of peripheral nerve surgery of the European Association of Neurosurgical Societies recently adopted consensus statements focused on anatomy, diagnosis and classification of TOS.¹² A follow-up publication provided consensus recommendations for management of NTOS.¹³ Within the orthopedic and plastic hand surgery community, however, there remains a significant variation in clinical practice ranging in all aspects from tools used for

Table 2. Consensus Recommendations from the INTOS Workgroup

Diagnosis
1. Criteria of the SVS ³ are recommended for diagnosis of NTOS, with the following modifications:
a) 1b. Addition of: positive Tinel's on palpation of the affected area
b) 3. Addition of this statement: This does not rule out other diagnoses co-existing with NTOS
c) Criteria 4 was removed
d) 3. Addition of this statement: NTOS can be diagnosed with <6 months of symptoms in some cases
2. The CDC proposed by the Consortium for Research and Education on Thoracic Outlet Syndrome (CORE-TOS) ⁹ are recommended for diagnosis of NTOS.
3. History and physical examination is most important in diagnosis of NTOS.
4. The Roos/EAST is recommended as a provocative test for diagnosis of NTOS.
5. Tinel's sign at the supraclavicular fossa/Morley test is recommended as a provocative test for diagnosis of NTOS.
6. A cervical spine XR or chest XR should be routinely obtained in workup of patients with NTOS to rule out a cervical rib.
7. MRI may be useful in diagnosis of NTOS or to rule out other pathology in the cervical spine.
8. Electrodiagnostic studies may be useful in diagnosis of NTOS or to rule out other pathology and distal compression sites.
9. Ultrasound may be useful in diagnosis of NTOS or to rule out arterial and venous TOS.
Treatment
1. Generally, conservative management is the first line treatment for NTOS.
Generally, conservative treatment should be offered for 3–6 months before considering surgery.
3. With muscle atrophy or weakness, surgery should be offered as the first line treatment for NTOS.
Surgery
1. An anterior supraclavicular approach is recommended for surgical exposure of the supraclavicular brachial plexus.
2. Findings on physical examination or imaging may suggest the necessity for an infraclavicular approach and pectoralis minor tenotomy.
3. Adjunctive surgeries for NTOS (distal nerve decompression, nerve or tendon transfer) may be beneficial.
Postoperative
1. Resolution of preoperative symptoms is most important in determining success after surgery for NTOS.
2. Postoperative rehabilitation is useful after surgery for NTOS.
INTOS: International Neurogenic Thoracic Outlet Syndrome Hand Surgery Workgroup; NTOS: neurogenic thoracic outlet syndrome; XR: x-ray.

diagnosis of NTOS to indications and techniques for surgical management of NTOS.

Most hand surgeons will not treat a significant volume of NTOS, unless an individual surgeon or group has an interest in brachial plexus and peripheral nerve surgery, or regional referral patterns direct patients with NTOS toward hand surgeons for evaluation and management. However, structured guidelines for diagnosis and management of NTOS within the hand surgery community will help to improve decision-making and direct appropriate referral for specialized care by general hand surgeons and physicians from other specialties. This will likely lead secondarily to an increase in the overall number of NTOS patients treated by hand surgeons. In addition,

Table 3. Modified Version of the SVS Criteria Recommended by the Workgroup for Diagnosis of NTOS

NTOS should be defined by the presence of all three of the following criteria.

1. Local Findings

- a. History: symptoms consistent with irritation or inflammation at the site of compression—scalene triangle in the case of NTOS and pectoralis insertion site in the case of NPMS—along with symptoms due to referred pain in the areas near the thoracic outlet. Patients may complain of pain in the chest wall, axilla, upper back, shoulder, trapezius region, neck, or head (including headache).
- b. Examination: positive Tinel sign or pain on palpation of the affected area

2. Peripheral Findings

- a. History: arm or hand symptoms consistent with central nerve compression. Such symptoms can include numbness, pain, paresthesias, vasomotor changes, and weakness (with muscle wasting in extreme cases).
 - i. These peripheral symptoms are often exacerbated by maneuvers that either narrow the thoracic outlet (lifting the arms overhead) or stretch the brachial plexus (dangling; often driving or walking/running).
- b. Examination: palpation of the affected area (scalene triangle or pectoralis minor insertion site) often reproduces the peripheral symptoms.
 - i. Peripheral symptoms are often produced or worsened by provocative maneuvers that are believed to narrow the scalene triangle (EAST) or to stretch the brachial plexus (ULTT).

3. Absence of Other Reasonably Likely Diagnoses (cervical disk disease, shoulder disease, carpal tunnel syndrome, chronic regional pain syndrome, brachial neuritis) that might explain the majority of symptoms. This does not rule out other diagnoses co-existing with NTOS.

In addition, most patients have prolonged symptoms (>6 mo), deteriorate over time, and have a history of trauma, although these factors are not required for diagnosis and NTOS could be diagnosed with <6 mo of symptoms in some cases.

standardized consensus guidelines help to guide management of NTOS by hand surgeons treating NTOS, with an aim towards standardizing criteria for diagnosis and treatment of patients as well as measures and tools used for research and reporting of outcomes.

The consensus statements recommended by this workgroup show similar trends to those adopted by our vascular and neurosurgical colleagues. Diagnosis of NTOS relies heavily on history and physical examination.^{14,15} This was a point that achieved complete consensus within the workgroup. Similar to the SVS,³ CORE-TOS⁹ and neurosurgical consensus criteria¹² for diagnosis of TOS, the Roos test/EAST, and Tinel sign were considered important provocative maneuvers by this workgroup. However, the ULTT as a diagnostic tool (adopted in the SVS, CORE-TOS and neurosurgical consensus criteria) did not reach majority agreement within the workgroup. The only imaging modality where majority agreement was reached for routine preoperative use was a plain radiograph of the cervical spine or chest, to rule out a cervical rib and other bony abnormalities. The importance of a plain radiograph in preoperative assessment of TOS has previously been emphasized.¹⁴ Other imaging modalities,¹⁶ such as MRI and ultrasound as well as electrodiagnostic studies,

Table 4. CDC Proposed by the Consortium for Research and Education on Thoracic Outlet Syndrome (CORE-TOS)⁹ for Diagnosis of NTOS

Upper Extremity Symptoms Extending Beyond the Distribution of a Single Cervical Nerve Root or Peripheral Nerve, Present for at least 12 wk, Not Satisfactorily Explained by Another Condition, and Meeting at Least One Criterion in at Least Four of the Following Five Categories

Principal Symptoms

- 1A: Pain in the neck, upper back, shoulder, arm, and/or hand.
- 1B: Numbness, paresthesia, and/or weakness in the arm, hand, or digits.

Symptom Characteristics

- 2A: Pain/paresthesia/weakness exacerbated by elevated arm positions.
- 2B: Pain/paresthesia/weakness exacerbated by prolonged or repetitive arm/hand use, including prolonged work on a keyboard or other repetitive strain tasks.
- 2C: Pain/paresthesia radiate down the arm from the supraclavicular or infraclavicular spaces.

Clinical History

- 3A: Symptoms began after occupational, recreational, or accidental injury of the head, neck, or upper extremity, including repetitive upper extremity strain or overuse.
- 3B: Previous ipsilateral clavicle or first rib fracture, or known cervical rib.
- 3C: Previous cervical spine or ipsilateral peripheral nerve surgery without sustained improvement in symptoms.
- 3D: Previous conservative or surgical treatment for ipsilateral TOS.

Physical Examination

- 4A: Local tenderness on palpation over the scalene triangle and/or subcoracoid space.
- 4B: Arm/hand/digit paresthesia on palpation over the scalene triangle and/or subcoracoid space.
- 4C: Objectively weak handgrip, intrinsic muscles, or digit 5, or thenar/hypothenar atrophy.

Provocative Maneuvers

- 5A: Positive upper limb tension test (ULTT).
- 5B: Positive 3-min elevated arm stress test (EAST).

showed significant variation in use and indication within the workgroup. This likely relates also to variation in availability of advanced radiological protocols and expertise for imaging of the brachial plexus between different centers.

An initial conservative approach towards management of NTOS was a point that reached majority consensus within the workgroup. This is consistent with conventional practice^{17,18} as well as recommendations from neurosurgical consensus guidelines.¹³ The workgroup reached majority agreement that muscle atrophy or weakness was an indication for surgery as first line treatment for NTOS. This is similar to the neurosurgical consensus guidelines,¹³ which also state that surgery may be offered to patients with sensory deficits or structural abnormalities after failure of conservative treatment, with symptoms in a position-dependent manner or after exclusion of other pathologies. A partial consensus (50%) was not reached within the workgroup that surgery should be offered for patients with only structural abnormalities, indicating that the majority of the workgroup would pursue conservative treatment first.

Regarding specific surgical details, the majority of the workgroup used an anterior supraclavicular approach for

exposure of the supraclavicular brachial plexus, with an infraclavicular approach and adjunctive procedures for select patients. An anterior supraclavicular approach is also the preferred surgical approach by the neurosurgical consensus group.^{13,19} The transaxillary approach^{20–22} remains uncommonly used by hand surgeons in general, though two members of the workgroup used this as the first line approach to the supraclavicular brachial plexus. This may reflect region-specific surgical preferences.

The necessity for routine first rib resection in surgical treatment of primary NTOS remains an issue of controversy. The workgroup had varying practice patterns, with strong individual preferences.^{23–28} Further high-quality evidence-based research will be required to determine the best treatment option in primary NTOS.

Majority agreement was reached within the workgroup that the success of surgery was best assessed through resolution of preoperative symptoms. In addition, the necessity for postoperative rehabilitation after surgery for NTOS was a point that reached majority consensus. The importance of rehabilitation in all aspects of treatment relating to TOS has previously been emphasized.²⁹

CONCLUSIONS

In the absence of high-quality evidence to guide diagnosis and management of NTOS, as well as significant variation in practices among surgeons, this article provides consensus guidelines for hand surgeons based on consensus within an international expert panel of hand surgeons with cumulative experience to date of surgery in more than 5500 NTOS patients. A point that should be highlighted is that the treatment of NTOS may be done equally well by any specialty provided that they have adequate training and expertise in surgery around the brachial plexus.

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DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

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