Diagnostic Accuracy of Clinical Tests for Neurogenic and Vascular Thoracic Outlet Syndrome: A Systematic Review

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ABSTRACT

Objective: To summarize the evidence on the accuracy of clinical tests to help confirm or refute a diagnosis of thoracic outlet syndrome (TOS).

Methods: We searched 10 databases (January 1990 to February 2016) using relevant key words and medical subject headings terms. We considered diagnostic test accuracy studies comparing clinical tests for the diagnosis of TOS against a reference test. Cross-sectional, cohort, and case-control studies and randomized controlled trials were included. Risk of bias was appraised using QUADAS-2 and the Quality Appraisal of Reliability Studies checklist. We performed a qualitative synthesis of scientifically admissible studies. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses guideline was used to report findings.

Results: A total of 3932 articles were retrieved. After removal of duplicates, 1767 articles were screened for titles and abstract, leaving 494 articles for full-text review. Ten studies met the eligibility criteria and were assessed for risk of bias, 4 of which were included in the review. None of the included studies used the same index tests when comparing with a gold standard, and quality was poor. High clinical heterogeneity and the use of different comparators prevented from pooling results. Findings suggest that prescribing magnetic resonance imaging during provocative positioning to confirm a diagnosis of TOS may be useful. However, this is associated with a high false-positive rate of venous compression.

Conclusion: Little evidence currently supports the validity of clinical tests for the diagnosis of TOS. Future diagnostic accuracy studies should aim to use established methodological criteria and appropriate reporting guidelines to help validate clinical tests for diagnosing patients with TOS. (J Manipulative Physiol Ther 2018;41:789-799)

Key Indexing Terms: *Thoracic Outlet Syndrome; Diagnosis; Physical Examination; Diagnostic Imaging*

INTRODUCTION

Although the term *thoracic outlet syndrome* (TOS) first was coined in 1956,[1] this remains a controversial clinical entity.[2] Complaints in the arm, hand, and neck are very common, with an estimated annual prevalence of 57% in workers.[3] In contrast, the prevalence of symptomatic TOS in the general population is estimated at 1 in 10 000.[4,5]

Thoracic outlet syndrome is defined as a neurovascular syndrome associated with compression of the brachial bundle (brachial plexus and/or subclavian vessels). Compression of the thoracic outlet may be caused by several anatomical structures (cervical rib, anomalous facial bands, fibrous bands, abnormalities of the anterior or medial scalene muscles, abnormalities of the pectoralis minor muscle, hypertrophy of C7 transverse process) in 1 or more of these 3 compartments (interscalene triangle, costoclavicular space, retropectoralis minor space).[6] However, using Roos' classification of abnormal anatomy in the upper thoracic outlet,[6-8] a cadaveric study of 50 randomly selected specimens concluded that only 5 (10%) specimens had a "normal" anatomy of the thoracic outlet bilaterally.[9]

Thoracic outlet syndrome complaints are associated with high levels of disability and health care costs.[10,11] Thoracic outlet syndrome represents a spectrum of disorders encompassing 4 related types: compression of the brachial plexus

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(neurogenic TOS), compression of the subclavian artery (arterial TOS), compression of the subclavian vein (venous TOS), and an often-disputed nonspecific type of TOS (disputed neurogenic TOS). Reported clinical features include neurological symptoms (paresthesia, numbness, tingling, progressive weakness, loss of dexterity, pain, atrophy), arterial symptoms (ischemia, pallor, coolness, fatigability, pain, muscle cramp, absence of pulse), and venous symptoms (edema, cyanosis, fatigue, heaviness, thrombosis).[2,6,8] Disputed neurogenic TOS has been described as a subcategory of the "true neurogenic TOS" but without the same objective diagnostic findings.[12] Patients may have a compression of 1 structure or a combination of neurovascular symptoms, which can complicate the diagnosis.[6] Based on the clinical presentation, the clinician often performs selected provocative tests to identify the site of compression of the brachial bundle specific to a type of TOS to confirm the syndrome and propose a management plan. Unfortunately, symptoms may not always match established patterns of typical peripheral entrapment neuropathies.[13] For example, neurogenic TOS may lack definitive findings in electrodiagnostic studies and has been referred to as "disputed neurogenic TOS."[12] As a consequence, many patients with TOS symptoms may present minimal sensory deficits and lack demonstrable muscle weakness.[14] Owing to the lack of accepted criteria for the diagnosis of TOS, test results may be unable to confirm or rule out the presence of the syndrome.[2] This has important implications for the generalization of results relating to test performance and related treatments. Nonspecific TOS with neurological symptoms accounts for over 90% of all TOS surgeries in the United States.[4]

To our knowledge, no systematic review has been conducted on the diagnostic accuracy of clinical tests to help confirm or refute a diagnosis of TOS. A better understanding of the validity of these tests should improve the clinical diagnosis and help define a clear plan of management. The aim of this review was to summarize the existing literature on the diagnostic accuracy of clinical tests used to identify patients with possible TOS compared with a control group, using a reference standard as a diagnostic tool to confirm or refute the diagnosis.

Methods

Ethics

Because no novel human participant intervention was required and secondary analysis was considered, the research presented in this guideline was exempt from institutional ethics review board approval.

We reported this review according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement.[15] The protocol was submitted to the International Prospective Register of Systematic Reviews for registration, but were too far advanced in the data extraction process for approval.

Search Strategy

The literature search aimed to systematically identify publications on the diagnostic accuracy of TOS from January 1, 1990 to February 5, 2016. Only articles published after January 1990 were retrieved to ensure a minimum of quality and an acceptable reference standard (eg, magnetic resonance imaging [MRI]).[16-20]

Searches were conducted between November 29 and December 11, 2013, in 10 databases: Medline, CINAHL, MANTIS, Scopus, Web of Science, Cochrane, Embase, ProQuest, Index to Chiropractic Literature, and SCHOLAR. The search first was created in Medline without language limitation and adapted to other databases using a combination of medical subject headings terms and key terms for targeted condition, index test, and clinical diagnosis. The search was updated from December 12, 2013, and February 5, 2016, in Medline, Embase, Web of Science, and MANTIS (Appendices 1-3). The bibliographies of the identified articles were reviewed for additional studies.

Selection Criteria

The primary author (D.D.I.) screened the titles and abstracts for relevance. A second reviewer independently screened 10% (n = 160) of the randomly selected articles in a blinded fashion to ensure reliability (κ = 0.76). The procedure was repeated for full-text eligibility, with D.D.I. screening full-text articles and the second reviewer independently screening 10% (n = 50) of the randomly selected articles (κ = 0.79). Articles in English or French meeting the following criteria were included.

Study Design. We considered diagnostic test accuracy studies using the following designs: cross-sectional, cohort (retrospective or prospective), or case-control studies and randomized controlled trials.

Participants and Target Condition. We considered studies assessing diagnostic accuracy of physical examination in patients with neck and arm complaints and participants suspected of having a TOS condition, and finally, these were compared with a control group.

Study Setting. We considered diagnostic test accuracy studies that directly compared the accuracy of 1 or more index tests for TOS against a reference test in the primary or secondary care settings.

Index Tests (Clinical Tests). Index (clinical) tests must be described and evaluate the reproduction of symptoms or absence of radial pulse. Index tests considered for this review were "Adson's test" and "modified Adson's or Halstead's test," both intended to identify a compression in the interscalene triangle or costoclavicular space[21,22]; "Allen's test," intended to identify a compression in the interscalene triangle or costoclavicular space[23]; "Roos or EAST test," intended to identify any type of compression in the thoracic outlet[6]; "hyperabduction or Wright's test," intended to identify a compression caused by the pectoralis minor muscle[24];

"military or costoclavicular or Eden's test," intended to identify a compression in the costoclavicular space[25,26]; and "Tinel sign or supraclavicular fossa pressure," intended to identify pain in the thoracic outlet region.[23] Appendix 3 (available online) presents a description of common TOS tests.

Reference Standards. We included studies for which the results of a physical examination were compared to 1 or more of the primary diagnostic tools: MRI, computed tomography (CT), neurography, ultrasonography, electrophysiology, and angiography. Findings from secondary diagnostic tools such as radiography and at surgery had to be combined with 1 or more of the primary diagnostic tools.

Articles were excluded if the population was mainly pediatric patients; the study reported on causes of neck and arm pain not related to a TOS (eg, infection, tumor, severe osteoarthritis, carpal tunnel syndrome, severe trauma, herniated disc syndrome, or fractures), and diagnostic testing was aimed at identifying these conditions; or a clinical diagnosis (some unknown combination of history and physical examination) was compared with the results of a reference standard.

Outcomes

Measurements for the reference standards were as follows:

- Magnetic resonance imaging/CT scan/angiography: any type of compression of the neurovascular bundle in the thoracic outlet in neutral position or arm. Positive findings defined as having over 50% arterial compression (30% on CT scan) or over 70% venous compression or loss of fat surrounding the brachial plexus.
- Doppler: Change in blood flow for the radial artery during arm position similar to an index test or compression of over 50% of the subclavian artery or over 70% for the subclavian vein during arm positioning (similar to index test).
- Neurography: Compression of the plexus in the thoracic outlet during different arm positions seen on radiography after injection of the brachial plexus.
- Electrophysiology: Abnormal or diminished signals indicating a compression of the brachial plexus in neutral position or arm abduction.

Quality Assessment and Appraisal of Reliability

We used the QUADAS-2 tool to assess the methodological quality of diagnostic accuracy studies[27] and the Quality Appraisal of Reliability Studies checklist to assess diagnostic reliability of the eligible studies that had a high to unclear risk of bias.[28]

Data Extraction

The lead author (D.D.I.) independently extracted the data. Findings were verified by a second reviewer (B.A.) and any discrepancies resolved by consensus. Missing data were requested from study authors if necessary. Sensitivity, specificity, true positive, false positive, true negative, and false negative were extracted from eligible studies.

Data Synthesis and Analysis

A qualitative synthesis of the scientifically admissible studies was performed according to principles of best evidence synthesis.[29,30] Thus, only high-quality studies with a low or unclear risk of bias were eligible for analysis.[27,29] Meta-analyses were not performed because of the high heterogeneity of admissible studies and use of different comparators.

Results

A total of 3932 articles were retrieved. After removal of duplicates, 1767 articles were screened for titles and abstract, leaving 494 articles for full-text review. Ten articles met the eligibility criteria and were assessed for risk of bias (Fig 1).

Risk of Bias Assessment

Results from the QUADAS-2 methodological appraisal are shown in Figures 2 and 3. Of the 10 eligible articles, 1 study Demirbag et al[31] had a low risk of bias (ie, best overall quality),[31] 3 studies (Demondion et al,[32] Demondion et al,[33] and Panegyres et al[34]) had an unclear risk of bias,[32-34] and 6 studies had a high risk of bias.[35-40] The QUADAS-2 evaluates 2 dimensions: risk of bias and applicability concerns. The most common high risk of biases were in decreasing order: patient selection,[35,36,39,40] flow and timing,[37,38] and reference standard.[40] Risk of bias for patient selection, index test, and reference standard were unclear for half (5/10) of eligible studies. The applicability concerns regarding patient selection (ie, included patients do not match the review question) were unclear for most of the studies.[32-34,36,37,39,40]

We used the Quality Appraisal of Reliability Studies checklist[28] to assess the diagnostic reliability of the 4 articles that scored a low to unclear risk of bias (Table 1). Demirbag et al[31] was found to have a high-quality diagnostic reliability study, Demondion et al[32] and Panegyres et al[34] had an unclear quality (sampling of participants and blinded raters),[32,34] whereas Demondion et al[33] had a low-quality reliability score owing to nonblinded rater items.

Data Synthesis and Analysis

Characteristics of eligible studies are presented in Table 2. Of the 10 eligible articles, only 4 studies (Demirbag et al,[31] Demondion et al,[33] Demondion et al,[32] and Panegyres et al[34]) were deemed scientifically admissible for inclusion in

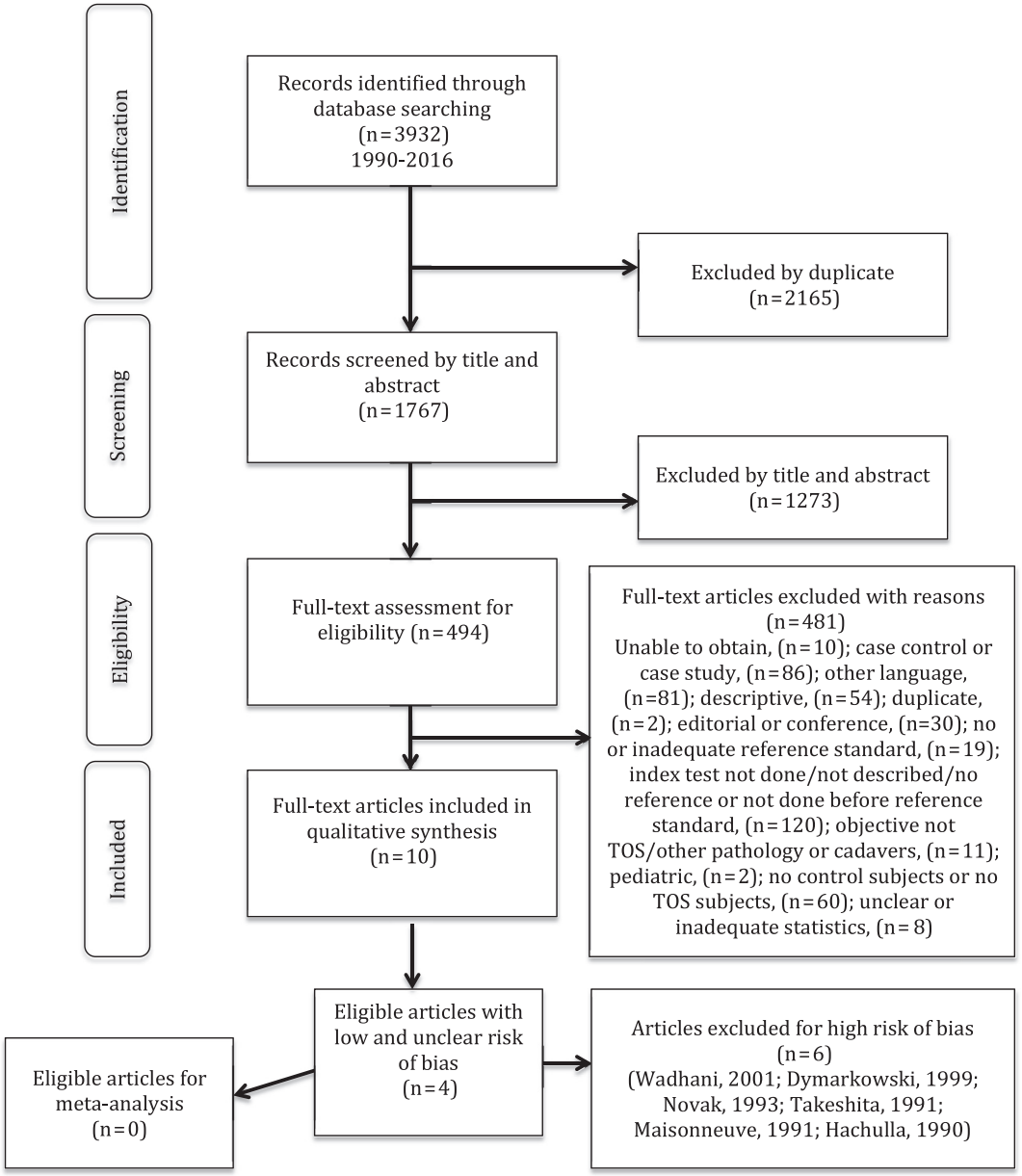

Fig 1. *PRISMA flow diagram. Literature search in Medline, CINAHL, MANTIS, Scopus, Web of Science, Cochrane, Embase, ProQuest, Index to Chiropractic Literature, and SCHOLAR (January 1, 1990, to December 11, 2013). Literature update in Medline, Embase, Web of Science, and MANTIS (December 12, 2013, to February 5, 2016).* PRISMA, *Preferred Reporting Items for Systematic Reviews and Meta-Analyses.*

the data synthesis. The remaining 6 articles[27,29,30] were excluded from final analysis owing to poor-quality evidence. Only 1 study by Demirbag et al[31] reported a positive Roos index test for all patients and a negative Roos for all controls at baseline. Among the 4 admissible studies, none of the articles compared the same index test with a positive result for all their patients. The criteria for patient inclusion in both the Demondion et al[33] and Demondion et al[32] studies was 2 positive tests out of 4 or 5 index. However, authors failed to specify which one of those tests were positive. Furthermore, these studies did not report positive or negative findings of index tests in the control group.

Descriptions of the 4 Admissible Studies

Demirbag et al. Demirbag et al[31] aimed to investigate changes in MRI findings in neutral and provocative positions and to examine the relationship between these differences and the results of physical examination tests in

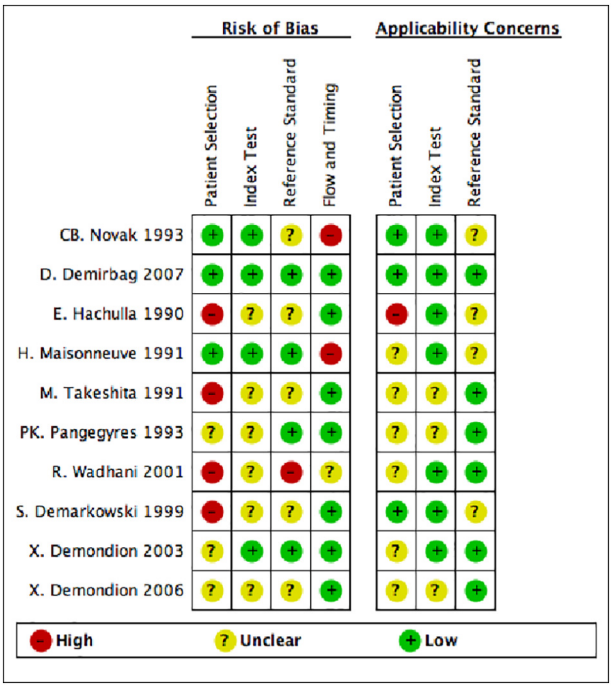

Fig 2. *Risk of bias and applicability concerns summary: review authors' judgments about each domain for each included study QUADAS-2.*

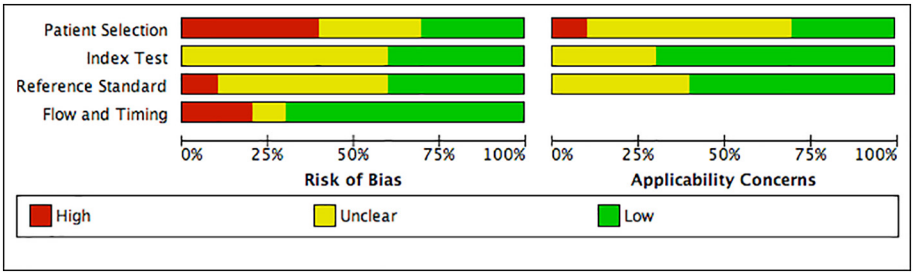

Fig 3. *Risk of bias and applicability concerns graph: review authors' judgments about each domain presented as percentages across included studies QUADAS-2.*

patients with TOS. The patient group (29 TOS: 23 women, 6 men; mean age 41.3 ± 8.3 years) was compared with healthy volunteers (n = 12 controls: 10 women, 2 men; mean age 46.2 ± 7.7 years). To be eligible, the Roos stress test performed on all patients had to reproduce symptoms on both arms, whereas controls had to have a negative Roos test bilaterally. Findings (presence/absence of radial pulse) were recorded for all participants. A medical specialist performed in a blinded fashion 3 provocative tests (Adson, military costoclavicular, hyperabduction) on all participants. Magnetic resonance imaging was performed in a supine position with both arms in adduction (neutral), and then a second sequence was done in provocative positions with both arms above the head (130° arm abduction and 130° flexion of elbow).

Significant differences in MRI findings were found between the neutral and provocative position in the patient group only ($P > .05$), and in the positional change values between the patient and the control groups ($P > .05$). When only considering absence of pulse during provocative maneuvers, only the military costoclavicular test had a significant between-groups difference, with half of the patient group testing positive on the military test compared to less than 10% in the control group ($P = .01$). Interestingly, a statistically significant difference was found in the minimum costoclavicular distance between patients with a positive military test and a negative military test ($P > .05$) on MRI. Overall, for the provocative position, the patient group showed 22.9% arterial, 52.3% venous, and 12.1% nervous compression. In contrast, the control

Table 1. *Results From QAREL Checklist*

	QAREL Item											
Study	1	2	3	4	5	6	7	8	9	10	11	Quality
D. Demirbag[31]	Yes	Yes	Yes	N/A	Yes	Yes	Yes	UNC	UNC	Yes	No	Good
X. Demondion[33]	UNC	Yes	No	N/A	No	UNC	No	No	UNC	Yes	No	Low
X. Demondion[32]	UNC	UNC	UNC	N/A	Yes	UNC	UNC	UNC	Yes	UNC	No	UNC
P. K. Panegyres[34]	UNC	Yes	UNC	N/A	Yes	UNC	UNC	UNC	UNC	UNC	No	UNC

N/A, not applicable; *QAREL*, Quality Appraisal for Reliability Studies; *UNC*, unclear.
QAREL items:

1. Was the test evaluated in a sample of participants who were representative of those to whom the authors intended the results to be applied?
2. Was the test performed by raters who were representative of those to whom the authors intended the results to be applied?
3. Were raters blinded to the findings of the other raters during the study?
4. Were raters blinded to the clinical information that was not intended to be provided as part of the testing procedure or study design?
5. Were raters blinded to the results of the accepted reference standard or disease status for the target disorder (or variable) being evaluated?
6. Were raters blinded to clinical information that was not intended to be provided as part of the testing procedure or study design?
7. Were raters blinded to additional cues that were not part of the test?
8. Was the order of examination varied?
9. Was the stability (or theoretical stability) of the variable being measured taken into account when determining the suitability of the time-interval between repeated measures?
10. Was the test applied correctly and interpreted appropriately?
11. Were appropriate statistical measures of agreement used?

group showed 1.4% arterial and 41.7% venous compression. The highest sensitivity (Sn) and specificity (Sp) for neurovascular compressions were found in the costoclavicular region during provocative position on MRI (arterial Sn = 50% and Sp = 95.8%, venous Sn = 62.1% and Sp = 58.3%, nervous Sn = 31% and Sp = 100%).

Demondion et al. A second study by Demondion et al[32] aimed to compare the dynamic modifications of the thoracic outlet to assess the presence and location of vasculonervous compressions using the MRI. The patient group (n = 54 TOS: 8 men, 46 women; mean age 39 years) presented neurological, arterial, or venous symptoms. The control group (n = 35 healthy volunteers: 10 men, 25 women; mean age 36 years) had no symptoms in any arm position. All patients were evaluated using provocative clinical tests (Adson, Roos, Wright, costoclavicular, Tinel). Patients were included if they had 2 of 5 positive clinical tests reproducing their symptoms. There is no mention of any absence of radial pulse, and it is unclear if volunteers also underwent these clinical tests. Magnetic resonance imaging was done in supine position arm alongside the body and at 130° abduction, unilaterally for patients and bilaterally for volunteers.

Vascular or nervous compression was found on MRI for 81.5% (44/54) of patients. However, true negative and false-negative values were not provided for volunteers. Patients with TOS had a smaller costoclavicular distance in provocative position ($P < .001$), a thicker subclavius muscle in both arm position ($P < .001$) and a wider retropectoralis minor space in provocative position ($P < .001$) than did the controls. Venous compression was frequently demonstrated in the 3 compartments of the thoracic outlet in both groups. Arterial and nervous compressions were seen in 72% and 7% of patients; none were seen in the controls. Neurovascular compressions mostly were observed in the costoclavicular space, then in the interscalene triangle, and last, in the retropectoralis minor space.

Demondion et al. A third study by Demondion et al[33] aimed to evaluate the usefulness of power Doppler ultrasonography in association with B-mode imaging in the assessment of subclavian and axillary arterial cross-sectional areas during upper limb elevation in patients with clinical suggestion of arterial TOS. The patient group (28 arterial TOS: 9 men, 19 women; mean age 32.9 ± 8.3 years) was compared with healthy controls (n = 44 volunteers: 10 men, 34 women; mean age 28.6 ± 9.4 years). One clinician examined all participants. No detail was provided regarding the study time frame and patient selection at the hospital. To be included, patients had to have 2 of 4 positive clinical tests (Adson, hyperabduction, Roos, and costoclavicular) defined as having arterial symptoms and disappearance of radial pulse simultaneously. Unfortunately, results provided did not allow the authors to determine which of the tests was positive. Furthermore, only the absence of positive dynamic tests was reported for the control group. In a nonblinded fashion, a second operator examined all participants with the Doppler to assess the subclavian artery in 3 different compartments (interscalene triangle, costoclavicular space,

Table 2. *Characteristics of Eligible Studies*

#	Author	Study Design	TOS Patients	Controls	Index Test	Reference Standard	Risk of Bias
1	D. Demirbag[31]	Prospective nonrandomized control trial study	29 disputed TOS	12 unilateral	Roos/Wright/Adson/ costoclavicular	MRI neutral/130°	Low
2	X. Demondion[33]	Prospective nonrandomized controlled trial study	28 arterial TOS	44 bilateral	Roos/Wright/Adson/ costoclavicular	Ultrasound neutral/ 90°/130°/170° and MRI neutral/130°	Unclear
3	X. Demondion[32]	Prospective nonrandomized controlled trial study	54 all types of TOS	35 bilateral	Roos/Wright/Adson/ costoclavicular /Tinel	MRI neutral/130°	Unclear
4	R. Wadhwani[40]	Retrospective cross-sectional study	5 TOS not specified but seems arterial	5 unilateral	Wright/Adson	Ultrasound neutral/ 90°/120°/180° and angiography	High
5	S. Dymarkowski[35]	Retrospective cross-sectional study	5 vascular TOS	2	Wright/Adson/ military	3D MRI angiography	High
6	P. K. Panegyres[34]	Prospective nonrandomized controlled trial study	20 neurological TOS	10 healthy for MRI comparison/10 cervical trauma for XR comparison	Wright/Adson/Tinel	MRI neutral, radiography, electrodiagnostic	Unclear
7	C. B. Novak[38]	Retrospective cross-sectional study	50 all types of TOS (58 TOS sides)	42 healthy sides of patients	Wright/Tinel	CT scan, radiography, and electrodiagnostic	High
8	H. Maisonneuve[37]	Retrospective cross-sectional study	104 all types of TOS (165 SX sides)	43 healthy sides of patients and 412 control subjects presenting signs of Raynaud	Roos/Allen	Ultrasound, electromyography, and electrodiagnostic	High
9	M. Takeshita[39]	Retrospective cross-sectional study	180 neurological TOS	30 with cervical symptoms	Wright/Adson/ costoclavicular	Neurography	High
10	E. Hachulla[36]	Retrospective cross-sectional study	22 subjects supposedly healthy with a presentation of all types of TOS	73 healthy subjects	Roos/Wright/Adson/ Halstead/Allen	Ultrasound and radiography	High

CT, computed tomography; *MRI*, magnetic resonance imaging; *SX*, symptomatic; *TOS*, thoracic outlet syndrome; *XR*, x-ray.

and retropectoralis minor space) with arm alongside the body at 90°, 130°, and 170° of abduction. Patients were evaluated on the symptomatic side only while controls were evaluated bilaterally.

Most of the compression occurred during abduction in the costoclavicular space when comparing patients and volunteers ($P < .01$). Authors conclude that 130° abduction arm test best discriminated between the 2 groups. All patients had substantial arterial stenosis (>50%) at 130° and at 170° abduction. Seven of 19 patients (9 excluded owing to refusal, contraindication, or poor quality imaging) undergoing MRI examination of the thoracic outlet did not have any arterial stenosis using this technique. Sensitivity and specificity in the costoclavicular space at 130° abduction were 78% ± 24 and 80% ± 16, respectively.

Panegyres et al. A fourth study by Panegyres et al[34] aimed to determine whether MRI could demonstrate compression or distortion of the brachial plexus or of the adjacent blood vessels and whether MRI could demonstrate cervical ribs or other structures responsible for deviating the brachial plexus in neurological forms of TOS. The patient group (20 neurological TOS: 10 men, 10 women; age range: 26-62 years; mean age 42.5 ± 6 years) was compared to 2 control groups (n = 10 healthy volunteers undergoing MRI studies bilaterally and n = 10 participants with post-traumatic cervical spine radiography to assess the integrity

of C7 transverse processes). No additional information was provided for the control groups. Four patients were bilaterally affected, and the asymptomatic side was evaluated for some index tests.

Patients were referred and included based on various clinical suspicions: ulnar nerve sensory disturbance and thenar muscle weakness or wasting, or patients with various combinations of other features like pain, weakness, or discoloration of hand. Clinical tests included Tinel, Adson, and hyperabduction tests. Tinel was performed during patient selection. It is unclear, however, when Adson and hyperabduction tests were performed. Positive findings for Adson and hyperabduction were obliteration of pulse, whereas for Tinel test, a positive finding was a reproduction of pain and paraesthesia in the supraclavicular fossa. Magnetic resonance imaging position was not described. For the index tests, Adson was positive in 4 affected sides and 2 asymptomatic sides among the 20 patients. Hyperabduction was positive for 6 affected sides and 1 asymptomatic side. Tinel was positive for all 20 patients and 1 of 30 controls (10 bilateral healthy volunteers and 10 cervical post-trauma volunteers), whereas the asymptomatic side of patients was negative. It is unclear if the Adson and hyperabduction index tests were performed within the control group.

The combined results of all patients showed brachial plexus deviation on MRI in 19 of 24 symptomatic sides. For the control group, there was an absence of distortion in 14 of 16 asymptomatic sides on MRI. Authors report an Sn of 79%, an Sp of 87.5%, and false-positive rates of 9.5%.

Discussion

Of the 3932 articles retrieved from 10 databases, only 10 studies were eligible for quality assessment. One low risk of bias[31] and 3 unclear risk of bias studies[32-34] were deemed scientifically admissible. Roos, military costoclavicular, Tinel, and hyperabduction tests were the main index tests used in the included studies. Magnetic resonance imaging was the main reference standard in 3 studies.[31,32,34]

Neurovascular compression was more common in the costoclavicular space during provocative MRI in 2 of 4 studies[31,32]; however, venous compression was frequently observed in all 3 thoracic outlet regions in the healthy group. Results from 1 study using a Doppler suggested that most arterial compressions occur in the costoclavicular space at 130° abduction.[33] However, of the 19 patients with a diagnosis of subclavian artery stenosis on Doppler, 7 had a normal subclavian artery on MRI. Thus, MRI seems to be the reference standard of choice to confirm a diagnostic of TOS because it can evaluate the neurovascular bundle of the thoracic outlet in different arm positions.

As different index tests were used across studies and none of the included studies combined index tests when comparing with a gold standard, we cannot conclude which of the index tests has the highest diagnostic accuracy. Nonetheless, Demirbag et al[31] found that both Roos and military costoclavicular tests had acceptable Sn and Sp.

Although abduction of the arm was used as a provocative position during MRI and Doppler in 3 studies,[31-33] the Sn and Sp values for the hyperabduction clinical test were low in 2 studies.[31,34] In addition, the diagnosis of venous TOS appears to have low validity as venous compression was frequently observed in healthy volunteers during provocative position on MRI. Finally, arterial compression was more frequent in the provocative position[31,32] when considering the percentage of nervous and arterial compression on MRI for any types of TOS presentation.

Recommendations for Practice

Results suggest that practitioners evaluating patients with TOS presentation and not responding to care should consider prescribing MRIs during provocative positioning to confirm a diagnosis of a TOS. Clinicians should keep in mind the high false-positive rate of venous compression in asymptomatic populations. Justifying the medical necessity of MRIs to third-party payers can be challenging considering the associated high costs and the controversy around this syndrome. But from an academic point of view, using MRI in a provocative position as a reference standard for TOS diagnosis may enlighten our knowledge on its real etiology (neurogenic TOS, arterial TOS, venal TOS, or nonspecific TOS). These findings may help to understand the real distribution among the TOS population. However, owing to lack of homogeneity across studies regarding the use of index tests, it is hazardous to recommend using one index test over another at this time.

Recommendations for Research

Few articles met our eligibility criteria, and the overall methodological quality of included studies was low. Researchers are encouraged to use validated checklists for assessing risk of bias such as the QUADAS-2[27] or the Scottish Intercollegiate Guideline Network.[16] Following the Cochrane Handbook for Systematic Reviews of Diagnostic Test Accuracy[41] may ensure all important steps are considered when designing diagnostic accuracy studies. Well-designed studies using similar index tests and reference standards to compare TOS patients with asymptomatic participants are needed to allow pooling of data in meta-analyses. This will improve our understanding of the validity of index tests and possibly establish a gold standard for the diagnostic of TOS. In light of the complexity of the task at hand, experts in anatomy, pathophysiology, and

clinical biomechanics should be consulted when planning such studies. Lastly, reporting guidelines such as the STAndards for the Reporting of Diagnostic accuracy studies checklist[42] or Consolidated Standards of Reporting Trials[43] should be used.

Study Limitations

To our knowledge, this is the first diagnostic accuracy review of clinical tests on TOS. A comprehensive literature search was conducted and 2 validated tools were used to assess methodological quality and the appraisal reliability of included studies.[27,28] In addition, we conducted a qualitative synthesis of the scientifically admissible studies according to principles of best evidence synthesis,[27,29,30] providing more robust results. Nonetheless, our study has some limitations. First, only the lead author independently extracted the data, and a second reviewer verified findings. Second, by including only articles in English or French, we may have missed potentially relevant articles. Finally, predictive values, likelihood ratios, and receiver operating characteristic curves could not be estimated owing to poor reporting of included studies.

Conclusion

This systematic review evaluates the diagnostic accuracy of clinical tests commonly used to diagnose a TOS. The overall methodological quality of included studies was low. We cannot conclude at this time which of the index tests has the highest diagnostic accuracy. Future studies should aim to use established criteria to help determine the validity of clinical tests for diagnosing patients with TOS.

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Appendix A. Supplementary data

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Contributorship Information

Concept development (provided idea for the research): I.D.-D., A.B.
Design (planned the methods to generate the results): I.D.-D., A.B.
Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): G.B., A.B.
Data collection/processing (responsible for experiments, patient management, organization, or reporting data): I.D.-D., A.B.
Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): I.D.-D., A.B.
Literature search (performed the literature search): I.D.-D.
Writing (responsible for writing a substantive part of the manuscript): I.D.-D., G.B., A.B.
Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): G.B., A.B.

Practical Applications

- Of 3932 articles retrieved from 10 databases, 10 articles met our eligibility criteria and 4 were scientifically admissible.
- Roos, military costoclavicular, Tinel, and hyperabduction tests were the main index tests used.
- Practitioners evaluating patients with TOS presentation should consider prescribing MRIs during provocative positioning to confirm a diagnosis of a TOS, while keeping in mind the high false-positive rate of venous compression in asymptomatic populations.
- Little evidence currently supports the validity of clinical tests for the diagnosis of TOS.

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