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Conservative treatment of thoracic outlet syndrome

A review of the literature

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Thoracic outlet syndrome (TOS) is a debated topic. While there are many clinical studies concerning the efficacy of surgical treatment, there are few regarding conservative treatment. It has not yet been established whether or not conservative treatment is effective and what the best treatment is. The aims of this study were to evaluate the efficacy of conservative treatment in TOS with particular reference to physiotherapy, orthotics, and taping and to make general recommendations for conservative treatment. The literature was reviewed. Medical databases consulted: Medline, Embase, CINAHL, Current Awareness, Pedro, Cochrane Library, Medscape. We used the following key words: thoracic outlet syndrome, double crush syndrome, entrapment, conservative, treatment, rehabilitation, and management. Languages of the articles reviewed: English, French, German, Spanish, Italian, and Portuguese. This analysis focussed on 10 studies of conservative treatment and 3 studies comparing the outcomes of conservative and surgical treatment, published from 1983 to 2001. This review found no randomised controlled trials, systematic reviews, or meta-analyses. Conservative treatment seems to be effective at reducing symptoms, improving function, and facilitating return to work, also when compared to surgery. We could not establish whether or not conservative treatment was better than no treatment or placebo, or what type of conservative treatment was the best.

Key words: **Thoracic outlet syndrome - Nerve compression syndromes - Therapy - Rehabilitation - Exercises.**

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The problem of thoracic outlet syndrome

Thoracic outlet syndrome (TOS) has been one of the most debated clinical topics over the last 120 years.

The name "TOS" was proposed by Peet.[1] He used this term to group under one name entities that are anatomically and clinically different by representing a single common element, namely the compression of neurovascular structures during their passage through the thoracic outlet region.

TOS may present extremely variable clinical aspects due to the variety of tissues that can be involved (arteries, veins, nervous and muscular tissue) and the different sites in which compression or entrapment can occur.

With regards to conservative or surgical treatment there is no agreement among authors on how to classify, evaluate, and treat this syndrome, and whether or not treatment should be conservative or involve surgery. While there are many clinical studies examining the efficacy of surgical treatment, there are only a few regarding conservative treatment. The effectiveness of conservative treatment and the best type of treatment have yet to be established.

Methods

A literature review was conducted. The following computerised databases were consulted: Medline, Embase, CINHAL, Current Awareness, Pedro, Cochrane Lybrary and Medscape using the following key words: thoracic outlet syndrome, double crush syndrome, entrapment, conservative, treatment, rehabilitation, management. The review was limited to articles in English, French, German, Spanish, Italian and Portuguese.

Bibliographies of the articles thus located were scanned for further relevant publications. The search was independently conducted by 2 reviewers (C. V. and L. N.) from March 2004 to July 2004.

Pathoanatomy

There are several sites where compression of the neurovascular bundle within the thoracic outlet may occur. At least 6 different sites have been described:

1. The interscalene triangle.
2. The costoclavicular space.
3. The subpectoral tunnel.
4. The region anterior to the humeral head.
5. The compass of median nerve roots (the passage way for the median nerve roots).
6. The axilla.

The first 3 sites have been well described in the literature.[2-14] The remaining 3 are only cited by a few authors,[4, 6, 11] and refer to a wider concept of thoracic outlet.

Pathophysiology

Various factors may jeopardise the above mentioned anatomical sites and lead to the symptoms of TOS, e.g. by compression of the nervous bundle, the vascular (arterial or venous) bundle, or both.

The causes of compression can be anatomical/structural (congenital or acquired) and/or functional (Table I).

TABLE I.—*Causes of thoracic outlet syndrome (TOS).*

- Causes of TOS
  - — Anatomical
    - Congenital anomaly
      - Osseus
      - Soft tissues
    - Traumatic
      - Osseus
      - Soft tissues
    - Dynamic
  - — Functional
    - Postural alterations
      - Works activities
      - Sports
    - Psychological conditions
      - Work environment
      - Attitudes
    - Respiratory alterations

ANATOMICAL CAUSES.—The interscalene space may be constricted by various morphological alterations of the scalene muscles,[2, 7, 11, 15, 16] prominence of the C7 cervical transverse process,[2, 15] anatomical malformations of the first rib,[2, 15, 16] the presence of a cervical rib, and the presence of additional fibrous *fasciculus* such as the *scalenus minimus* muscle.[4, 11, 16]

The costoclavicular space may be constricted by morphological alterations of the subclavian muscle and excessive callus formation of the clavicle and ribs.[15, 17] Causes that may constrict the pectoral tunnel are the chondrocoracoidal fasciculus and anatomical variation or expansion of the clavipectoral aponeurosis.[4, 11]

The region anterior to the humeral head can be jeopardise by the so called pressure of the humerus, a condition in which compression may develop when the arm is extended or abducted at the shoulder more than 90°. In this case, the anteriorly displaced humeral head becomes a new fulcrum of bending for the neurovascular bundle. In addition, at over 110° of abduction, the median nerve, already at maximum tension, pushes the axillary artery against the humerus, depressing it in the bicipital groove.[4-6, 11]

The area the median nerve roots pass through can also be a site of compression when the arm is abducted more than 90°. When the axillary artery comes out of the pectoral tunnel, it passes under the medial chord, which may strangle the artery like a tourniquet.[11]

Langer's arch, an anatomical variation occurring in

10% of the general population,[18] can be present in the axillary region. This fibrous extension of the *latissimus dorsi* muscle, sometimes of the pectoralis major muscle, originates from the ventral and lateral fibres of these muscles and inserts in the bicipital groove of the humerus. When the arm is abducted or externally rotated, the neurovascular bundle is squashed under the arch [11, 18] (Figure 1).

Functional causes

These include generalised muscle imbalance of the cervical spine and shoulder girdle, which leads to thickening and fibrosis of some muscle groups with resultant constriction of the thoracic outlet.

For example, a bad posture with head and shoulders held in a forward position and the arm elevated beyond 90° may cause:

a) constriction of the costoclavicular space;

b) an increase in traction of the neurovascular bundle in the subpectoral tunnel;

c) shortening of the sternocleidomastoid muscle.

Over time this will lead to shortening of the scalene and small pectoral muscles, forming a vicious circle.[19-21] The muscles that counteract the forward head posture are: the *longus* and *longissimus cervicis*, the *levator scapulae*, the major and minor rhomboids and even the lower trapezius.[19, 22]

Furthermore, in order to promote the forward orientation of the glenoid fossa of the humerus, the *serratus anterior* tends to shorten by abduction of the scapula.

This causes lengthening of the lower and middle trapezius and forces the lower trapezius to stabilise the scapula in a mechanically disadvantageous position, which results in early fatigue.

Lastly, any weakness of the above mentioned muscles must be compensated by activity of other scapular muscles: upper trapezius, major and minor rhomboids and *levator scapulae* will be used as accessory muscles to elevate the shoulder and arm. Weakness and overuse hypertrophy of these muscles is then added to the problems found in the sternocleidomastoid, scalene and minor pectoral muscles.[19]

The most appropriate approach to facilitate the understanding of TOS seems to be to take both the anatomical and the functional causes into consideration. This avoids running the risk of what Roos [23] perceived as "to underrate" this pathology and Wilbourn [24] perceived as "to overdiagnose" it.

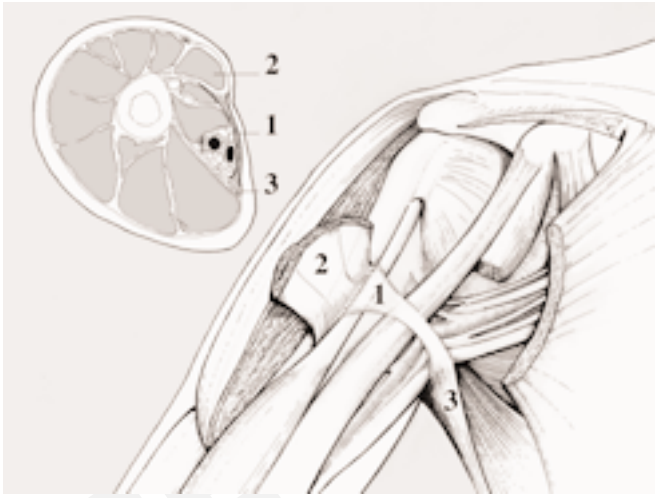

Figure 1.—Langer's axillary arch (1) extends between pectoralis major (2) and *latissimus dorsi* (3).

Clinical presentations

The clinical presentation of TOS in the literature is subdivided into 2 large groups: neurological TOS and vascular TOS.

Neurological TOS

This is found in 90% to 97% of cases.[25-28]

Wilbourn [24] subdivides this category into 2 different types: true neurologic TOS (true N-TOS), and disputed neurologic TOS (disputed N-TOS).

True N-TOS has a very low incidence and mainly affects females.[24] It is caused by compression or stretching of the primary nerve trunks and leads to pain and paresthesiae in the dermatomal distribution of the nerve trunks involved as well as a loss of dexterity, muscle weakness, spasms in neck and scapular muscles, and a feeling of heaviness. The symptoms are predominantly produced by activities with the arm elevated and/or abducted more than 90° and by carrying weights, and tend to worsen towards the end of the day and when sleeping at night. The sensory nerve fibres are affected first. Motor deficit occurs much later and manifests itself by a progressive reduction in strength and muscle atrophy, especially in the thenar eminence and, in very advanced cases, also in the forearm.[3, 15, 29, 30]

N-TOS is said to be true because the clinical picture is confirmed by objective diagnostic findings (anatomical and electrodiagnostic abnormalities).[31]

Disputed N-TOS is very diffuse and includes the majority of patients representing 85% of diagnosed TOS cases.[3, 24, 26, 32]

The symptoms can almost be the same as in true N-TOS.[3, 9, 13, 15, 16, 19, 24, 26, 32] Strange complaints can be associated with this symptomatology, such as pain in the face, disturbances of vision or hearing, headaches,[3, 15, 26] tachycardia,[33, 34] dyspnea, dysphagia, vertigo, tinnitus and sleeping disturbances.[34]

The term "disputed" implies controversy. In the case of disputed N-TOS, the controversy is based on the absence of bony and electrodiagnostic abnormalities, confirming the clinical diagnosis.

VASCULAR TOS

This includes approximately 5% to 10% of all TOS cases. It can be subdivided into 2 clinical forms: arterial TOS (from compression of the subclavian and/or axillary artery) and venous TOS (from compression of the subclavian and/or axillary vein).

Arterial TOS is very rare, but is also the most dangerous form. It is equally distributed between the sexes and affects 1% to 5% of vascular TOS patients.[25, 26, 32]

The most frequent symptoms are colds, pallor, weakness, early fatigue and pain in the upper extremity. Large movements of the arm cause pain and weakening of the radial pulse.[7, 9, 15, 16, 26, 27, 29, 32, 35, 36]

Venous TOS represents 2% to 3% of all forms of TOS.[25, 26, 32] Males are most frequently affected.[25] Most often the symptoms consist of swelling, stiffness in the fingers, cyanosis in the extremity of the upper limb, pain, and a feeling of heaviness and tension in the superficial veins in the arm and shoulder area. The pain increases along the course of the axillary vein.[7, 9, 15, 16, 27, 29, 32,35, 37]

Evaluation

The diagnosis of TOS is essentially based on history and clinical examination. Technical investigations can be helpful to confirm the suspected diagnosis, but a negative test does not rule out the syndrome.[15, 35, 38]

Useful diagnostic examinations for the assessment of TOS are:[39]

1) anatomical: X-rays, computerised tomography (CT), magnetic resonance imaging (MRI), angiography and venography;

2) physiological: thermographic studies, Doppler studies on blood flow, electrophysiological studies (EMG). Electrodiagnostic testing is useful for the diagnosis of true N-TOS, because it helps localise and quantify a lesion in the brachial plexus. It is also important to rule out other segmental or systemic neuropathies.[40, 41]

Given the low specificity and sensitivity of these diagnostic tests in revealing any form of N-TOS,[24, 30, 35] the most comprehensive diagnostic examination is based on history and physical examination, investigating all aspects of problems suffered by the patient (Table II).

The history aims to gather information about the localisation, type, intensity, and severity of the symptoms, the onset and evolution over time, aggravating and alleviating factors, disability and participation problems.[14, 42]

Specific questionnaires can be used for the evaluation of pain such as the McGill Pain Questionnaire,[30] or for disability, The Northwick Park Neck Pain Questionnaire.[43]

The physical examination must be carried out with extreme caution so as not to exacerbate the symptoms.[13, 44] It consists of careful observation of the posture, particularly of the cervical spine and shoulder girdle, and accurate examination of the articular, muscular and peripheral nervous systems.

The articular examination involves palpation and active and passive physiological as well as accessory tests of the first rib, the joints of the shoulder girdle and the cervical and thoracic spine.

The muscular examination evaluates trophism, strength, coordination and length of the scalene, minor pectoral, major pectoral, levator scapulae, sternocleidomastoid, serratus anterior, major and minor rhomboid and trapezius muscles.

Finally, the nervous tissue, especially the brachial plexus, needs to be examined by Butler's tension tests and palpation examination (Tinel's sign).[8, 14, 15, 44, 45] Nerve conduction tests examine the reflexes, muscle strength and sensitivity. Examination of sensitivity, especially of vibration sense, is reliable in TOS patients and this type of sensation is the first to deteriorate when nerve conduction is impaired.[30, 44]

Provocation tests are well described in the literature [7-9, 13-16, 26, 29, 35, 38, 46, 47] and reproduce the pathophysiological mechanisms that may affect the neurovascular bundle in the thoracic outlet. As a result, it is possible to find out what mechanisms are involved in provoking the symptoms.

Some of the better known provocation tests are:

TABLE II.—*Classification of thoracic outlet syndrome according to the International Classification of Functioning, Disability and Health (ICF) model.*

Functions and disabilities		Contextual factors
Body functions	Activities and participation	Environmental factors
Alterations to the neuromusculoskeletal system and movement — Hypomobility of the joints in the scapular girdle, cervical and thoracic spine, and of the first rib — Shortening of the scalene and small pectoral muscle — Diminished endurance in the lower and middle trapezius muscles, lower rhomboid muscles, serratus anterior, flexors carpi, and thumb adductor — problems co-ordinating nimble movements with the hand	General tasks and demands — Difficulty carrying out simple and complex tasks using the upper limbs	Work environment — Compensation claims — Difficulty changing duties and workstation
Alterations to the sensory functions and pain — Disturbances to tactile and vibratory sensitivity (especially the fourth and fifth finger) — Pain (neck, upper body areas or behind the shoulders, upper limbs) — Paresthesia	Mobility — Inability to maintain a position with the limbs beyond 90° abduction-elevation — Inability to lift and/or move a weight using the upper limbs — Inability to carry out activities requiring nimble hands	Health environment — Knowledge of pathology lacking — Frequent diagnostic and therapeutic errors
Alterations to the vascular system — Alterations to venal functions (subclavian and axillary vein) — Alterations to arterial functions (subclavian and axillary artery) — Alterations to the lymphatic system	Self-care — Problems washing hair, combing hair, dress oneself above the waist	
Body structure	Domestic life — Difficulty moving weights — Difficulty doing domestic chores requiring the use of the upper limbs beyond 90° abduction-elevation (for example, dusting, cleaning windows, ironing)	
Involvement of structures in the nervous system — Peripheral nervous system (brachial plexus) — Sympathetic system (T2-T4, cervicothoracic ganglion)	Major life areas — Resignation from job if it involves moving weight, continual use or use beyond 90° of upper limb abduction-elevation (for example, cashier, plasterer, welder, information technology, musician, athlete)	
Involvement of structures used in movement — Cervical and thoracic structures — Shoulder girdle structures — Upper limb structures	Community, social, and civic life — Difficulty playing certain sports (swimming, volleyball, throwing the discus, canoeing, basketball) — Difficulty playing musical instruments (piano, violin, etc.)	

— Adson test, which may confirm constriction or otherwise of the interscalene triangle in the thoracic outlet;

— Wright test, which stretches the neurovascular bundle around the coracoidal process;

— Roos test, which constricts the costoclavicular space and above all demonstrates the functional ability of the upper extremities;

— Eden test, which increases the closure of the

costoclavicular space and places the minor pectoral muscle under tension, and thus may provoke pain in the neurovascular structures in 2 ways.

These tests may be of value in the evaluation and diagnosis of TOS, but, on average, their sensitivity is 72% and their specificity 53%.[8] The specificity increases when various tests are used in combination; nevertheless, these tests can never be the only findings on which diagnosis is based.

The history of conservative treatment

How to treat TOS is one of the most important points of discussion in the debate and study of this controversial pathology.[23, 24, 26, 32]

The main question is whether or not the treatment of choice should be conservative or involve surgical management.

At the beginning of the last century it was thought that only surgery was applicable as the main etiological factor was believed to be osseous anomaly.

Peet [1] was the first to suggest using only conservative treatment when he wrote, in 1956, about morphodynamic problems, which could affect the shoulder girdle and lead to TOS. He prepared a specific exercise programme with the aim of correcting these disturbances. Treatment included moist heat, massage, strengthening of *levator scapulae*, stretching of pectoralis and postural correction exercises. Peet's work was so far-sighted that even today, half a century later, many refer to his rehabilitation programme.

From the 1980s Revel,[48] followed by Bouchet,[49] Crielaard,[5] and Marinoni,[50] designed more complex rehabilitation programmes with the aim of restoring muscle balance. The muscles of the shoulder girdle were divided into 2 large groups: the first group composed of the muscles which open the thoracic outlet by raising the shoulder girdle and opening the costoclavicular space (for example, upper trapezius and sternocleidomastoid) and, secondly, the muscles that close the thoracic outlet (for example, lower trapezius and scalene muscles). Treatment consisted of strenghtening the muscles that open and stretching the muscles that close only if necessary. Respiratory re-education was included in order to learn correct diaphragmatic breathing.

At the beginning of the 1990s, the Anglo-American school proposed a new orientation based on the theories of muscle engram development.[21, 51] According to this theory, the maintenance of the muscle imbalance was caused more by muscle contraction than by a reduction of tone. Liebenson [52] therefore placed more emphasis on relaxing shortened muscles and less on shoulder girdle strengthening exercises. Mackinnon,[19] Novak,[53-55] Lindgren,[56] and Mayoux-Benhamou [10] proposed a treatment based on initial muscle relaxation, followed by selective strengthening. The treatment was completed with aerobic exercises to condition the patient, who was taught and encouraged to carry out a daily home exercise programme and to change bad habits.

Such a multifactorial approach also developed from the ideas of Smith [57] and Sällström.[58] Smith described a treatment protocol that included manual techniques to increase flexibility of the thoracic outlet, flexibility exercises, and behaviour and postural modification. Sällström proposed correction of postural disturbances by repositioning the joints of the shoulder girdle and pelvis, and by using muscle relaxation. He combined this with coordination exercises, physical activity, and ergonomic instructions in daily life activities.

Sucher,[51] Buonocore [59] and Peng [60] distanced themselves from this multifactorial approach.[61] Going back to the work of Travell and Simons,[12] Sucher proposed a treatment based exclusively on stretching and drug therapy, Peng on massage and acupuncture, Buoncore on connective tissue massage, traction, and isometric exercises for the cervical spine and shoulder girdle. Bilancini [62] also proposed a treatment based exclusively on postural physiotherapy including re-education of diaphragmatic breathing, active mobility exercises for shoulder and upper limbs, and postural control exercises for the spine.

More recently, Boissonot,[63] Farfan,[22] and Schomacher [64] have also proposed mobilisation of the cervicothoracic, sternoclavicular, acromionclavicular, and costotransverse joints.

At the same time as these therapeutic interventions, a new approach to TOS considers neurodynamic disturbance as an essential component of the syndrome. Butler [44] had already proposed an assessment and therapeutic model for the nervous system that could be applied to the TOS patient. Totten and Hunter [65] were the first to propose a treatment designed only for the peripheral nervous system.

Following this course Barbis,[66] Walsh,[13] Augros,[42] Edgelow,[45] Ault,[3] Berthe,[67] Crosby [68] and Wehbé [69] combined treatment of soft tissues and joints with neuromeningeal treatment. In this case, management included posture correction, treatment of affected

structures (neurological, muscular, articular) and a patient conditioning programme (intensive physical activity and control of emotional components). The latest generation multifactorial model, dealing with the TOS patient as a whole, is thus outlined.

Clinical trials and observational studies of conservative treatment efficacy

There are over 200 scientific publications on the efficacy of surgery for TOS,[70] but only a few studies concerning the efficacy of conservative treatment.[71] The studies aim to: a) verify the efficacy of conservative treatment and b) compare the outcome in operated and nonoperated patients. No study has compared different types of conservative treatment or treatment *versus* nontreatment or *versus* placebo. Unfortunately, there is a lack of high quality studies such as randomised and controlled trials [24, 72] or systematic reviews and meta-analyses. In Table III and Table IV the most recent 10 studies [13, 48, 53, 58, 59, 62, 71, 73-75] on conservative treatment are brought together (Tables III, IV). Tables V and VI present the 3 studies that compare the outcomes of surgery with those of conservative treatment (Tables V and VI). Studies on medical therapy, block of the scalene muscles, block of the brachial plexus and stellate ganglion and selective chemodenervation involving botulin were not considered in this review.

The studies reviewed for this paper are prospective or retrospective. Randomised and/or controlled clinical trials are lacking. Five studies were carried out with small patient samples (under 30). Therefore, it is impossible to carry out a meta-analysis or draw definite conclusions from the available evidence. Furthermore, the studies present important differences.

The inclusion criteria vary or are not clearly defined. Firstly, in all the studies, except for that of Landry,[72] the type of TOS suffered by the patients is not clear (vascular TOS, true N-TOS, or disputed N-TOS). Secondly, the criteria for the clinical evaluation of TOS are different, in particular with regards to clinical tests, provocative tests, and use of diagnostic imaging. Lastly, the studies that compared conservative treatment with surgical treatment used very specific patient populations such as patients who had suffered a road accident,[76] or disabled patients.[72, 77]

The exclusion criteria are not outlined in 3 studies and they vary in the remaining studies.

None of the studies clearly show how long the patients had been suffering from TOS and the severity of the vascular or neurological disturbances is not always stated. Some studies are very detailed regarding the type of conservative treatment, number of sessions, duration of the sessions, and total duration of the treatment. In contrast, other studies are very generic or include different types of treatment or different treatment providers such as physiotherapists and chiropractors.[72] Furthermore, the protocol was sometimes the same for all the patients;[59, 62, 71, 74] in other cases the treatment was adapted to the symptoms and clinical signs of each subject.[53, 75, 77]

Only a few studies stated whether or not the person who evaluated the results was involved in selecting or treating the patients or whether he or she was blind.

In some studies, follow-up was carried out at the end of the treatment,[59, 62, 71] in others there was medium to long-term follow-up, from a minimum of 1 year to a maximum of 4 years,[53, 58, 72, 74-77] after the end of the treatment. Outcome was evaluated using different parameters. First of all, nonhomogeneous evaluation categories were used such as excellent, good, moderate, acceptable, bad, or poor. Secondly, sometimes impairment outcome measures were used (pain and other subjective symptoms, range of motion, neurological signs), at other times disability outcomes (performance of activities of daily living, in particular, those with the arms hanging down or elevated) or social participation outcomes (return to work) were used.

A number of interesting aspects arise from the review.

The analysis of groups by age and sex confirms findings in the literature that women are mainly affected by TOS epidemiology. In particular, disputed N-TOS does not occur in the elderly. Therefore, the natural history of this syndrome seems to be one of gradual improvement.[72]

Whatever method used, all the studies demonstrate some degree of efficacy for conservative treatment of TOS patients, with good or very good results in 76% to 100% at short-term follow-up (within a month) and 59% to 88% at medium-to-long-term follow-up (after at least 1 year).

The studies comparing conservative with surgical treatment provide contradictory long-term follow-up results. The study of Mailis,[76] carried out on road accident victims, demonstrated that surgery was bet-

TABLE III.—*Studies about conservative treatment - characteristics of the studies.*

Reference	Type of research	Aim	Inclusion (I) and exclusion (E) criteria	Sample size and features	Follow-up
Revel and Amor 1983 [48]	Open non controlled study	To evaluate the outcome of a conservative treatment program	I: Compression signs of subclavial artery, subclavial vein and lower brachial plexus E: Not specified	26 patients: 23 women, 3 men aged 18 - 73 years (mean 41 years)	Not specified
Sallström and Celegin 1983 [58]	Open non controlled study	To evaluate the usefulness of the correction of postural disturbances correlated to the severity of symptoms of TOS	I: Mild, moderate or severe symptoms of TOS; 17 patients with previous history of trauma E: Not specified	99 patients: 67 women, 32 men aged 21-61 years (mean 39.8 years)	Mean 12.4 months (range 3 - 30 months after first evaluation)
Walsh 1984 [13]	Open non controlled study	To evaluate the outcome of Smith's treatment program	I: Insidious onset of symptoms, 2 or more provocative maneuvers positive E: History of trauma	16 patients (19 extremities)	Not specified
Prost 1990 [73]	Open non controlled study	To evaluate the outcome of a conservative treatment program	I: Clinical diagnosis of TOS E: Not specified	42 patients: 30 women, 12 men aged 16-61 years	Not specified
Bilancini *et al.* 1992 [62]	Open non controlled study	To evaluate the outcome of a conservative treatment program	I: Clinical diagnosis of bilateral TOS, Roos's test and Wright's test positive E: Vascular complications, neurological deficits, severe cervical patology	20 patients: 15 women aged 20-42 years (mean 33,5 years), 5 men aged 34-50 years (mean 38.7 years)	At the end of the treatment
Kenny *et al.* 1993 [71]	Open non controlled study	To evaluate a supervised physiotherapy program of graduated resisted shoulder elevation exercises	I: Positive Adson's test E: Previous history of trauma; entrapment neuropathies	8 patients: 6 women, 2 men aged 34-59 years (mean 45 years)	At the end of 3 weeks
Nakatsuchi *et al.* 1995 [74]	Open non controlled study	To evaluate long-term patient outcome after application of a strapping device for elevation of the shoulder	I clinical diagnosis of TOS; symptoms induced or aggravated pulling downward the arm and improved or eliminated pulling upward the arm. Symptoms were classified as proximal (pain in the shoulder girdle) and distal (neurological deficits related to the brachial plexus) E: diseases of the cervical spine and peripheral neuropathy	86 patients: 74 women, 12 men aged 13-52 years (mean 27.1 years)	1st follow-up: mean 2.3 years (range 6 months-5.9 years) 2nd follow-up: mean 4.1 years (range 8.5 months-8.9 years)
Novak *et al.* 1995 [53]	Retrospective non controlled study	To evaluate long-term subjective patient outcome following conservative management	I: Clinical diagnosis of TOS (patient complaints and positive provocative maneuvers), participation in physical therapy program at least 6 months prior the study E: cervical disc diseases, nerve root impingement, shoulder pathologies, tendonitis	42 patients: 37 women, 5 men aged 20-67 years (mean 38 years)	Mean 1 year
Lindgren 1997 [75]	Prospective clinical trial	To evaluate long-term outcome after conservative therapy program that aims to restore normal function to the thoracic upper aperture in patients with TOS	I: At least 3 of following criteria: -history of paresthesia in the segments C8-T1 -tenderness over the brachial plexus superclavicularly -history of aggravation of symptoms with the arms in the elevated position -positive Roos test E: Other causes for the symptoms	119 patients: 91 women aged 19-58 years (mean 42.4 years), 28 men aged 26-63 years (mean 39.4)	Mean 24.6 months (range 0-60 months)
Buonocore *et al.* 1998 [59]	Open non controlled study	To evaluate the outcome of a conservative treatment program	I: Positive provocative tests; E: Entrapment neuropathies; C7-C8-T1 nerve root compression; anamnesis of other vascular or nervous system pathology	13 patients : 9 women, 4 men aged 44±12.75 years	At the end of the treatment

TABLE IV.—*Studies about conservative treatment - type of treatments and results.*

Reference	Procedures	Therapeutic tools	Frequency of sessions and length of treatment	Results	Self-treatment at home
Revel and Amor 1983 [48]	Passive and active manual therapy Breathing exercises Adhesive elastic bandage in severe conditions	Cervical and scapular massage Passive mobilization Muscular relaxation Muscular strengthening Breathing exercises Heat Adhesive elastic bandage to elevate scapular girdle	From 12 to 30 sessions, 2-3 times a week	76% of patients had good or excellent results 24% of patients had fair or poor results Better results for artery compression than vein and nerve compression Better results for cervical and thoracic pain than scapular pain Better results in patients who did regular home exercises Positive results for elastic taping	Daily home exercises program, 2-3 times a day (Peet's exercises)
Sallström and Celegin 1983 [58]	Correction of postural disturbances Treatment of the muscular pain Education	Reposition of the sacro-iliac joint and treatment of the iliopsoas pain Ultrasound/heat and soft tissue mobilization Ergonomic instruction and posture training	Some weeks	The results was correlated to the severity of the symptoms (slight symptoms: relief in 78%; mild symptoms: relief in 72%; severe symptoms: no benefit in 81%) The poor results are correlated to previous trauma or long duration of the symptoms	Coordination exercises 2 times a day for 30 min Physical activities: walking, skiing, skating, riding
Walsh 1984 [13]	Mobilization of the soft tissues Flexibility program Education	Soft-tissue mobilization techniques for the thoracic outlet Flexibility exercise program Behaviour and posture modification activities	From 2 to 14 sessions (mean 10.5 sessions)	68.5% of patients were asymptomatic 10.5% of patients obtained moderate relief 5.2% of patients obtained temporary relief 15.8% of patients obtained no relief	Not specified
Prost 1990 [73]	Massage Relaxation Postural correction Passive mobilization Strengthening exercises Adhesive elastic bandage Education Exercises based on the history and on the findings of the physical examination	Peet's exercises Strengthening of the posterior muscle of the spine Elevation of the shoulder girdle Isometric exercises for serratus anterior and minor pectoral, Active exercises to lower the first rib Adhesive elastic bandage to elevate scapular girdle	From 8 to 30 sessions (mean 14 sessions) Duration of the treatment: mean 1 year (range 1-18 months)	70% of patients: good results (negative clinical signs, negative Doppler exam) 10% of patients: moderate results (symptoms improved or disappeared, but recurrences during work activities) 20% of patients: poor results	Daily home exercises program: breathing exercises active exercises of the shoulder girdle active exercises of the shoulder with weight in each hand up to 1 kg
Bilancini *et al.* 1992 [62]	Postural correction Exclusion of any strengthening exercises Graduated resisted shoulder elevation exercises	Postural correction of the spine and shoulder girdle, in supine, sitting and standing position Breathing exercises 10 exercises progressively carried out during each session	10 session, 1 session every 2 days	100% of patients had a negative Roos's test 100% of patients improved the angle of positive Wright's test (from mean 40° to mean 130°)	Not specified

(to be continued)

TABLE IV.—*Studies about conservative treatment - type of treatments and results (continued).*

Reference	Procedures	Therapeutic tools	Frequency of sessions and length of treatment	Results	Self-treatment at home
Kenny *et al.* 1993 [71]	Graduated resisted shoulder elevation exercises Exclusion of any additional exercises	Written instructions and supervised exercises Shoulders elevation, holding for count of 5, then relaxation of the shoulders Improved weights in each hand from 0 to 5 lb	9 sessions (3 times a week for 3 consecutive weeks)	All patients reported pain relief Full neck and shoulder range of motion was restored in all patients Neurological examination was normal Blood pressure measurements were not significantly different	Daily home exercises program: week 1: from 15 to 20 exercises x 5 times daily week 2: from 10 to 20 exercises x 5 times daily week 3: from 10 to 30 exercises x 5 times daily
Nakatsuchi *et al.*1995 [74]	Application of a strapping device for elevation of the shoulder Shoulder girdle exercises (Britt's method)	Instruction to the patients to wear the device at all times except when bathing or sleeping until symptoms improved Shoulder girdle exercises (Britt's method)	In 66.2% of the patients mean period of application of the device was 119 days 33.8% of the patiens was still wearing the device at the final follow-up	Distal symptoms group: pain disappeared or improved in 67% of patients, numbness in 85%, sensory disturbance in 84% and motor disturbance in 80% Proximal symptoms group: symptoms were relieved in only 65% of patients Ability to perform ADL: excellent in 33% of patients, good in 44%, fair in 12% and poor in 9%	Shoulder girdle exercises (Britt's method)
Novak *et al.* 1995 [53]	Posture modification Specific physical therapy program One physical therapist	Education regarding positions and postures and their integration in daily living activities Graduated stretching program for shoulder girdle elevators and chin retraction exercises Strengthening program for lower scapular stabilizers Aerobic conditioning program	Initially 1 session a week; then 1 session a month Mean duration of the treatment 3 months (SD, 2 months) Mean number of sessions 4 (SD, 2 sessions)	25 patients (59%) reported symptomatic improvement 10 patients (23%) reported same symptoms 7 patients (16%) reported worse symptoms Poor overall outcome was related to obesity, worker's compensation and associated carpal or cubital tunnel syndrome	Home exercises program and behaviour modification
Lindgren 1997 [75]	Multidisciplinary approach Active exercises based on the findings of the physical examination Recommendation about the future of the patient If needed, psychiatric or psychological consultation or intervention by occupational therapist	Shoulder girdle exercises Active mobilisation of the upper parts of the cervical spine Active exercises for the anterior, middle and posterior scalene muscles Stretching of the shoulder girdle elevators and the small pectoral muscle Strengthening exercises for the stabilizators of the scapula Recommendations about the return to work	Mean of 11.4 days (range 4-24 days)	88.1% of patients were satisfied with the outcome 73% of patients had returned to work The return to work was a more often successful if the work was sedentary rather than heavy In most of the symptoms-free patients the function of the first rib and the cervical range of motion was normalized	Repetition of the exercises from 5 to 10 times a day, depending on the type of the exercise
Buonocore *et al.* 1998 [59]	Massage and kinesitherapy Postural correction and education One physical therapist	Connective tissue massage Shoulder girdle massage and shoulder resisted adduction and extension Cervical isometric exercises and stabilisation Cervical manual traxion	10 sessions; from 30 to 50 min a session	Rest symptoms completely disappeared in all patients Paresthesia disappeared in 92% of patients Pain disappeared from 78 to 100% of patients Provocative tests were negative from 57% to 100% of patients	Exercises and behaviour modification

TABLE V.—*Studies comparing conservative and surgical treatment - characteristics of the studies.*

Reference	Type of research	Aim	Inclusion (I) and exclusion (E) criteria	Sample size and features	Follow-up
Mailis *et al.* 1995 [76]	Descriptive prospective study	To record symptoms and signs, operative findings, and long-term outcome in operated and nonoperated patients with the diagnostic of TOS after a motor vehicle accident.	I: Clinical diagnosis of TOS (specific symptoms and positive provocative maneuvers) after injuries sustained in a car accident E: Peripheral nerve entrapment, cervical radiculopathy, complex regional pain syndromes, myofascial pain syndromes, brachial plexopathy, articular and periarticular pain syndromes	32 patients: 23 women, 9 men aged 23-55 years (mean 37.5 years)	Mean 3 years (range 7 months - 4.9 years) for non surgical group Mean 33 months after first intervention (range 12-66 months) Mean 25 months after second intervention (range 12-37 months)
Franklin *et al.* 2000 [77]	Descriptive retrospective study	To determine the predictors of outcome in TOS surgery in a population-based cohort of injured workers To compare a sample of operated patients with a sample of nonoperated patients for work disability and medical cost outcomes	Sample I: All injured workers in the Washington State Worker's Compensation system who received TOS surgery during 1986 to 1991 E: Repeated surgery, severe traumatic injuries Comparison group I: Workers with a TOS diagnosis who did not receive surgery during 1987 to 1989	Operated workers: 74 Nonoperated workers: 95	1st follow-up (for work disability status): 1 year after surgery 2nd follow-up (for functional status and disability outcome): mean 4.8 years after surgery
Landry *et al.* 2001 [72]	Descriptive retrospective study	To evaluate the long-term functional outcome of a cohort of patients with disputed NTOS, treated by surgery or conservative management	I: Patients with disputed NTOS whose symptoms caused at least temporary inability to work E: Electrodiagnostic evidence of true NTOS, not lost work time because of TOS symptoms	Operated patients: 15 Nonoperated patients: 64	Mean 4.2 years (range 2-7.5 years)

ter at reducing pain by 20%. It is worthwhile mentioning that in trauma, histological changes take place in the scalene muscles. In particular, there may be "a significant increase in connective tissue, which represents muscle scarring".[37, 78] On the other hand, the studies of Franklin [77] and Landry [72] concluded that conservatively treated patients had less work disability and less time off work than those who underwent surgery.

Almost all the authors underline the correlation between favourable outcome and patient compliance with a home exercise programme, and modification of behaviour patterns both at home and at work.

Nearly all the authors recommend improving the patients' posture by strengthening exercises and stretching/lengthening of the shoulder girdle muscles, even if there is no agreement on which muscles need strengthening and which ones need lengthening. In fact, the studies that followed Peet's exercise model [48, 71, 73, 74] propose strengthening the muscles that elevate the shoulder girdle and lengthening the minor pectoral, whereas other studies [53, 75] include stretching exercises for the *levator scapulae*, scalene, and minor pectoral muscles, as well as strengthening of the inferior stabilising muscles of the scapula. Some authors also recommend passive cervical exercises [75] and mobilisations [13, 48] in order to improve the range of motion.

Only a few studies [13, 73] recommend manipulative treatment to widen the thoracic outlet or mobilise the first rib. In fact, authors of other studies indicate that direct mobilisation of the first rib could provoke the symptoms and the benefits of deep massage to "mobilise the first rib" might well be disputable. In order to restore normal function of the costotransverse joint, they advise an indirect 'hold-relax' technique of the scalene muscle.[75]

In patients with moderate to severe symptoms, the

TABLE VI.—*Studies comparing conservative and surgical treatment - type of treatments and results.*

Reference	Procedures	Therapeutic tools	Frequency of sessions and length of treatment	Results	Self-treatment at home
Mailis *et al.* 1995 [76]	Transaxillary or supraclavicular exploration of the thoracic outlet versus conservative management (to improve strength, range of movement and postural abnormalities)	Conservative management : Physical modalities Stretching exercises Active exercises When available, specific retraction harness for a 2-3 month trial period If needed, trigger points injection, facet joint blocks, stellate ganglion blocks, cervical collar, cervical manipulation, biofeedback/relaxation, hypnosis, vocational counselling	Length of the conservative treatment: several months	Operated patients: very good to excellent pain relief in 47%, modest pain relief in 13%, poor or no pain relief in 40%. Conservatively treated patients: very good to excellent pain relief in 20%, modest pain relief in 20%, poor or no pain relief in 60%. Most of the improved patients with conservative treatment weared retraction hearness for several hours during the day Poor outcome in nonoperated patients was related to variable degrees of psychoemotional disturbances	Not specified
Franklin *et al.* 2000 [77]	Surgical treatment versus no surgery	Not specified	Not specified	Operated patients: after 1 year 60% of workers were still work disabled; after 2 years 40% Operated patients: after 4.8 years 44% of workers didn't work; 72.8% were limited a lot in vigorous activities. Compared with nonoperated patients, the operated had 50% greater medical costs and were 3 to 4 times more likely to be work disabled in the 2 to 3 years after TOS diagnosis	Not specified
Landry *et al.* 2001 [72]	Surgical treatment (14 first rib resection, 1 combined cervical and first rib resection) versus conservative management	Conservative management by physical therapists or chiropractors	Conservative management before surgery: 3.7±1 years Conservative management in nonoperated patients: not specified	Operated patients: more lost work time (mean 27.6 months); 60% returned to work Conservatively treated patients: less lost work time (mean 14.9 months); 78% returned to work No significantly differences in current severity and frequency of symptoms, symptomatic status since onset and long-term medication requirements	Not specified

use of taping, adhesive elastic bandages,[48, 73] or braces to elevate [38] or retract [76] the shoulder girdle seem to be effective.

Some treatment programmes [48, 58] also included the use of physical methods to reduce pain and promote muscle relaxation (especially moist heat and transcutaneous electrical nerve stimulation), although none of the authors felt this procedure was essential to the treatment.

Some positive and negative prognostic factors for conservative treatment were identified. In general, positive prognostic factors are compliance of the patient regarding the home exercise programme [48, 53] and the modification of behaviour patterns at home and work.[53] Particularly, having a sedentary rather than physically demanding job is a positive prognostic factor for returning to work.[75] Negative prognostic factors are obesity, double crush syndrome,[53] prior

trauma,[53, 58] severity of symptoms,[58] and psychosocial factors such as compensation claims [53] and psycho-emotional disturbances.[75, 76] Long symptom duration is almost always considered to be a negative prognostic factor.[53, 58]

Some of these negative prognostic factors are identical to those found in studies on the outcome of surgical treatment. Axelrod [79] indicated the importance of psychological and social factors (depression, being unmarried, low level of education). Sanders [80] revealed poor treatment outcome in patients with onset of symptoms following work related trauma or repeated stress at work. Lindgren81 and Franklin [77] outlined how the length of work absence due to illness before surgery might be strongly correlated with the length of work absence due to illness after the operation. Franklin [77] identified a correlation between significant postoperative work disability and a long time lapse between trauma and diagnosis of TOS or advanced age at onset of the trauma. The results of radiographic and neurophysiological examinations [56, 77] or provocation tests [77] do not predict the final outcome of surgery, neither does the type of surgery, gender of the patient, nor experience of the surgeon [77] predict postoperative work disability.

TABLE VII.—*Levels of evidence and grades of recommendations.*

Grade of recommendation	Level of evidence	Basis of evidence
A	1a	Systematic review (with homogeneity) of RCTs
A	1b	Individual RCT
B	2a	Systematic review (with homogeneity) of cohort studies
B	2b	Individual cohort studies
B	2c	Outcomes research
B	3a	Systematic review (with homogeneity) of case-control studies
B	3b	Individual case-control studies
C	4	Case series (and poor quality cohort and case-control studies)
D	5	Expert opinion

RCT: randomized clinical/controlled trial.

TABLE VIII.—*Recommendations.*

Recommendations	References	Grade of recommendations
a. Accurate history to identify onset (when and following what), characteristics and evolution of symptoms, disability, and social participation problems over time	13, 53, 58, 73-75	D
b. Accurate physical examination to identify all anatomical and functional sources of compression/entrapment, and to exclude or identify other pathologies	13, 53, 73, 74, 76	D
c. Identification of psycho-emotional factors, and factors related to workers compensation claims, which can affect disability	74-76	B
d. Early activation of conservative treatment in order to address the above factors as soon as possible and facilitate early return to work	58, 76	B
e. An active treatment strategy composed of information, education, correction of posture and positions at home, at work and at night, daily home exercises, simulation of daily living activities, breathing exercises, and general aerobic conditioning	13, 48, 53, 58, 59, 62,73-76	B
f. Adaptation of treatment to individual syndrome characteristics, with a "patient oriented approach", considering the specific sites of compression, muscular, articular and neurodynamic dysfunctions, and daily self-management at work, at home and during recreational activities	13, 53, 58, 59,75, 76	D
g. The treatment sessions are preferably not scheduled daily but 1 to 3 times weekly at the beginning of treatment, and 1 to 2 sessions monthly at the end of treatment. This helps to contain costs and facilitates the learning process	48, 53, 75	D
h. In more severe cases orthoses, taping, and adhesive elastic bandages or physical modalities (moist heat, TENS, ultrasound) can be used, but these procedures must not substitute the active exercises and the correction of posture and muscle imbalance	48, 58, 73, 74, 76	B
i. Consider the positive and negative prognostic factors, emphasise the positive factors such as patient compliance and intervene when possible in the negative factors (obesity, psycho-emotional factors, and problems at work)	53, 75	B
j. Schedule vocational consultation, work hardening, and work place modification interventions	53, 75, 76	B
k. It is helpful if the patient is managed by a coordinated team composed of a surgeon, neurologist, and physiotherapist, with possible advice from a psychologist or psychiatrist in cases of severe or chronic pain, and from an occupational therapist or vocational consultant in order to facilitate return to work	75	D

Recommendations for treatment

Some general guidelines can be identified and several recommendations for the treatment of TOS patients can be made.

In general, the initial approach should be conservative treatment,[13, 48, 53, 58, 59, 62,71-77] except in cases of thromboembolic phenomena with acute vascular insufficiency, symptoms of chronic vascular occlusion, stenosis, arterial dilation,[75, 82] or progressive neurological deficit.[31, 83, 84]

More specifically, based on data shown in Table VII, Table VIII shows recommendations for conservative treatment (Tables VII and VIII).

Conclusions

Firm conclusions cannot be drawn from the review of the literature on conservative treatment. Conservative treatment seems to be effective at reducing symptoms, improving function, and facilitating return to work, also when compared to surgery. Whether or not the conservative treatment is better than no treatment or placebo treatment, or what kind of conservative treatment is best cannot be established.

Further studies are necessary, particularly prospective randomised controlled trials in order to compare conservative with surgical treatment outcomes,[24, 72] and to compare the outcomes of different conservative treatments, or treatment *versus* no treatment or placebo treatment. These studies pose many problems. Landry *et al*.[72] calculated that "to demonstrate a difference between surgical and non-surgical groups with power equal to 80% a sample of 19 900 would be necessary with regards to the current level of symptoms, and 1 900 subjects regarding the progression of symptoms since onset" .

Furthermore, as TOS is very difficult to diagnose due to the lack of a gold standard test, it would be useful to carry out further studies looking more specifically at diagnosis, assessment, as well as management, and prognosis of the TOS patient in relation to the principal variables (mode of onset, topography and duration of symptoms, compression sites, impairments, and disabilities).

Finally, TOS should be considered a syndrome that arises due to multifactorial causes. This involves a certain number of constitutional factors, aggravated by dysfunctions or traumas. Consequently, it is probably presumptuous to attempt to correct all these factors by surgery and exercises.[70] The authors of this paper agree with the wisdom of Novak [54] when she says, "the management of patients with TOS should be directed toward altering (-not eliminating-) factors that aggravate symptomatology".

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