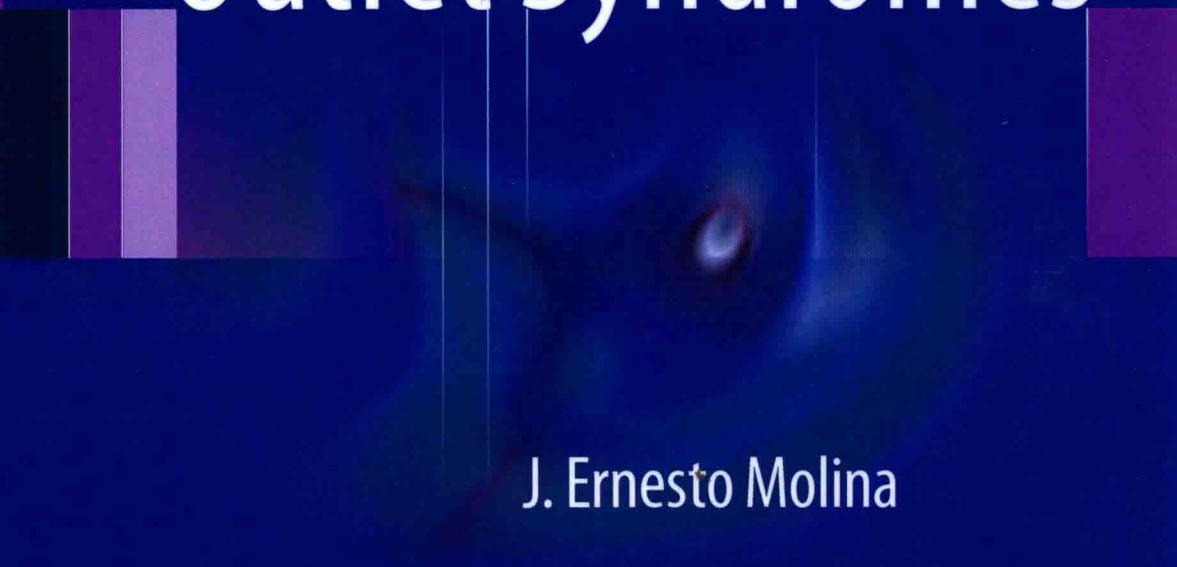
New Techniques for Thoracic Outlet Syndromes



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[Wir] dürfen uns nicht mit unseren Leistungen brüsten und sie als ein Ende ansehen. Eine neue Zeit wird kommen mit neuen Lehren und neuen Ideen. Sorgen wir dass wir aufnahmebereit sind und ihr Verständnis entgegenbringen.

[We may not boast with our accomplishments seeing them as a final end point. New times will come with new advances and new ideas. We should concern ourselves to be ready and to spread that knowledge.]

Ferdinand Sauerbruch
"Das war mein Leben"
Kindler Verlag Publ. München 1951

With gratitude and devotion to
God our Lord
Who granted me the time to be of service
to these patients suffering from Thoracic
Outlet Syndrome
who trusted the work of my hands.
To the inspiration and celestial light of the
Holy Virgin Mary.
To my devoted wife Carmen Aida
loyal companion throughout my entire life.
To the nurses who rendered their
unselfish service
to each and every patient entrusted
to their care.

Preface

Thoracic outlet syndromes being neurogenic-arterial, venous, or caused by the presence of a cervical rib or other anomalies affect mostly young people comprising from teenagers to middle-aged people, most of them in their productive years and fully active physically, either at work or in sports. Throughout the years, many approaches and treatments have been proposed to deal with this problem. However, most of the information regarding thoracic outlet is found only as journal articles or short chapters included in regular surgery textbooks. Currently a textbook dedicated to thoracic outlet syndromes to help physicians involved in caring for these patients does not exist. This book presents in a comprehensive format, the newest state of the art where the physicians encountering this entity can refer to in consultation to properly treat these patients using the resources that modern medicine offers. This is more relevantly shown in the chapter dedicated to the venous thoracic outlet syndrome in which the interventional radiologist and the surgeon together are the combination team that will provide 100 % cure for that problem. The book offers the newer surgical approaches that have been developed during the past 25 years. Some of the techniques described in the section dedicated to the neurogenic syndrome are modification of operations that were proposed previously but were not fully effective and left many patients suffering with permanent disability. A compendium of the proper management of these patients that cannot be found in isolated reports of literature is presented offering the most acceptable and effective methods to handle thoracic outlet syndromes.

Acknowledgments

Editing

For the editing of this book, I am indebted to my good friend from our years of training in Minnesota, brilliant colleague, and outstanding academician Dr. Wallace P. Ritchie Jr., MD, PhD, who made possible the organization and orientation of, and gave proper direction to, all this material. His stellar career includes graduating from Johns Hopkins University Medical School and post graduate education at the University of Minnesota. He is a former Professor of Surgery at the University of Virginia, Professor of Surgery and Chairman of the Department of Surgery of Temple University School of Medicine, Executive Director/Secretary Treasurer of the American Board of Surgery, Chief of Gastrointestinal Surgery at Walter Reed Army Institute of Research, invited speaker and lecturer at many institutions and meetings, and author of over 300 publications and presentations.

His outstanding guidance and judgment made this book possible.

Interventional Radiology

The work on the venous thoracic outlet syndrome (Paget–Schroetter) would not have been possible without the total support from the Interventional Radiology Division under the leadership of David W. Hunter, MD and Charles W. Dietz, MD, who provided complete commitment and cooperation, which continues to the present day, in implementing the two-team approach, i.e., Radiology–Surgery, which achieved the present outstanding results treating this disease.

Secretarial Staff

The secretarial transcription work is appreciably acknowledged and consists of Mr. Richard A. Castillo, Executive Office and Administrative Specialist, and Mrs. Debra Gutzman, who dedicated long hours to this endeavor.

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- *Annals of Thoracic Surgery*
- *Journal of Vascular Surgery*
- *Seminars in Vascular Surgery*
- *International Journal of Angiology*
- *Journal of the American College of Surgeons*

Definition of the Entities

The historical aspects of the diagnosis and treatment of thoracic outlet syndromes are important for several reasons: first, they tell us how we arrived at our current level of expertise in this regard and identify the pioneers who preceded us in this effort; secondly, the information serves as a platform from which to lead us to find the proper sources and to develop new and better methods to treat these syndromes more effectively.

Three separate entities comprise the "family" called the thoracic outlet syndromes. The first is called the neurogenic-arterial thoracic outlet syndrome, which is a separate entity with different etiology and different treatment from the second condition, the venous thoracic outlet syndrome. The third, less frequently seen than the other two, is related to congenital anomalies resulting in neurogenic and arterial symptoms related to the presence of cervical ribs or to fusion of the first and second ribs. Although all three are called thoracic outlet syndromes, the term "outlet" applies only to the first and the third. The brachial plexus, which is the affected structure in the neurogenic thoracic outlet syndrome, originates in the cervical spine and from there it runs over the rib cage to reach the arm; it provides branches for not only the arm but also the chest wall muscles. However, the nerves do not come from the chest to the outside as the name outlet would signify. The only structure that exits the chest cavity and reaches the arm is the subclavian artery. In contrast, the venous thoracic outlet syndrome is actually a problem of the "inlet" to the chest where the subclavian vein enters the mediastinum running over the first rib. These entities are very different (these historical aspects will be described separately in the individual sections of this book). Failure to recognize this fact has resulted in many reports which intermix the results treating neurogenic compression with results obtained treating venous compression occurring at the upper aperture of the chest cavity. I have made an attempt to separate these entities in order to give the reader a more precise appreciation of what we call the neurogenic thoracic outlet syndrome and the clinical picture of venous compression (usually related to a Paget–Schroetter syndrome or effort thrombosis of the subclavian vein). The treatment of this last has expanded significantly to include other aspects of subclavian vein obstruction which are mostly iatrogenic entities resulting from implantation of central venous

catheters and transvenous devices to treat cardiac arrhythmias (e.g., pacemaker and defibrillator leads). Implants of dialysis catheters and other type of lines used for administration of antibiotics or chemotherapeutic agents for prolonged periods of time have also introduced cases of venous obstructions, which, sadly, are difficult to treat with fewer experienced physicians able to solve them. A major purpose of this book is to help guide new surgeons to the appropriate treatment of these new complex problems. In particular, I wish to make them aware of procedures which have been found ineffective in the past.

The principal point is this: basically, two general types of acquired thoracic outlet syndromes exist, each of which requires a different therapeutic approach. The widespread lack of appreciation of the distinction between these entities is derived from the fact that much of the published literature consists of series of cases in which both types have been admixed. The end-result: patients run the risk of undergoing an inappropriate operative procedure.

As a rough guide, expanded upon below, a patient presenting in a non-emergent setting complaining of weakness and parasthesias of the arm and fingers is different from the patient who shows up in the emergency room with a severely swollen arm in pain due to obstruction of the venous return circulation. In the first case the most likely diagnosis is a neurogenic thoracic outlet syndrome. Because of the considerations outlined in the anatomy section, these neurogenic symptoms are often combined with compromised arterial circulation to the arm. This presentation should be called a neurogenic-arterial thoracic outlet syndrome. A second type of presentation of a patient with an acutely swollen and painful arm due to obstruction of the venous return from the arm represents a venous thoracic outlet syndrome, which most of the time does not cause either neurogenic symptoms or evidence of compromised arterial circulation. This is therefore a venous thoracic outlet syndrome, commonly referred to as effort thrombosis of the subclavian vein, or as noted, Paget–Schroetter syndrome (named after the two physicians who described this clinical picture in the nineteenth century).

In summary, the conditions addressed in this book are presented in the following order:

1. Neurogenic-arterial thoracic outlet syndrome.
2. Paget–Schroetter syndrome or venous thoracic outlet syndrome.
   (a) Acute stage.
   (b) Chronic state.
3. Cervical rib.
4. Venous obstructions due to implanted devices.
5. Other congenital anomalies.

Anatomy and Classification

For most surgeons the term thoracic outlet refers anatomically to the upper aperture of the chest cavity. It should be noted, however, that some anatomy books, even recent ones, refer to the upper aperture as "inlet" and name as the "outlet" the base of the chest, the greater aperture of the rib cage in its lower portion i.e., the diaphragmatic circular space [1, 2]. Following the most common clinical interpretation, we will in this textbook identify as the thoracic outlet the upper aperture of the chest in order to avoid any confusion in terminology. This upper opening is basically delineated by the course of the first rib which originates at the first thoracic vertebral body, encircles the opening, and inserts anteriorly in the sternum below the sternoclavicular joint. The space is outlined medially by the structures located centrally, namely the trachea, esophagus, and the thoracic vertebral body. In this confined hemicircular space only one structure actually leaves the chest cavity, the subclavian artery, which then pursues its course over the first rib to reach the arm. The brachial plexus originates from the cervical spine and then follows a descending course over the first rib. Two important structures actually enter the chest in the anterior portion of this space, the subclavian vein and the thoracic duct (Fig. 1). The clavicle, which occupies a position above the level of the first rib, comes down in an acute angle to insert in the sternum and contributes only partially to form the thoracic outlet.

The components of the thoracic outlet named from front to back are (Fig. 2): First at the level of the insertion of the first rib into the sternum, a strong ligament arising from the clavicle called the costoclavicular ligament. Immediately next and in front of it is the subclavius tendon, which inserts on to the inferior aspect of the clavicle and forms a strong tendon positioned in front of the costoclavicular ligament. Together these two ligaments form a very firm and sharp ridge, which together with the first rib at the bottom form an acutely angled space through which the subclavian vein runs into the chest cavity. Immediately behind the subclavian vein, the anterior scalene muscle tendon also inserts on top of the first rib, thus completing the tunnel through which the vein travels to reach the mediastinum in the thoracic cavity. This tunnel has very definite borders therefore, all of which are very strong but which cause no problems in normal individuals (e.g., obstruction to flow in the subclavian vein). The study reported by Matsumura [3] shows the dynamics of the arm movements (observed

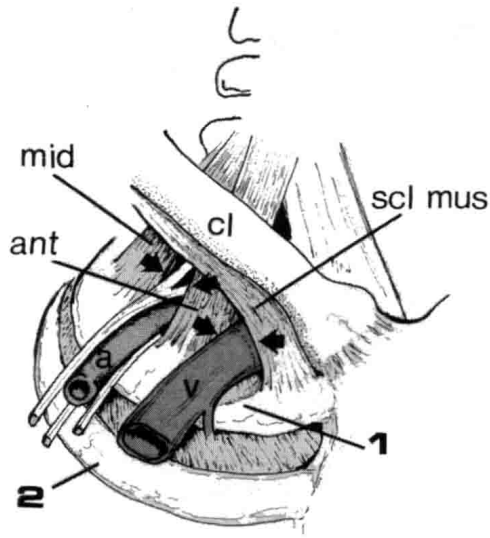

Fig. 1 Normal anatomy of the thoracic outlet on the right side. *Cl* clavicle, *Sclmus* subclavius muscle, *mid* middle scalene muscle, *ant* anterior scalene muscle. 1 = first rib, 2 = second rib, *a* = subclavian artery, *v* = subclavian vein

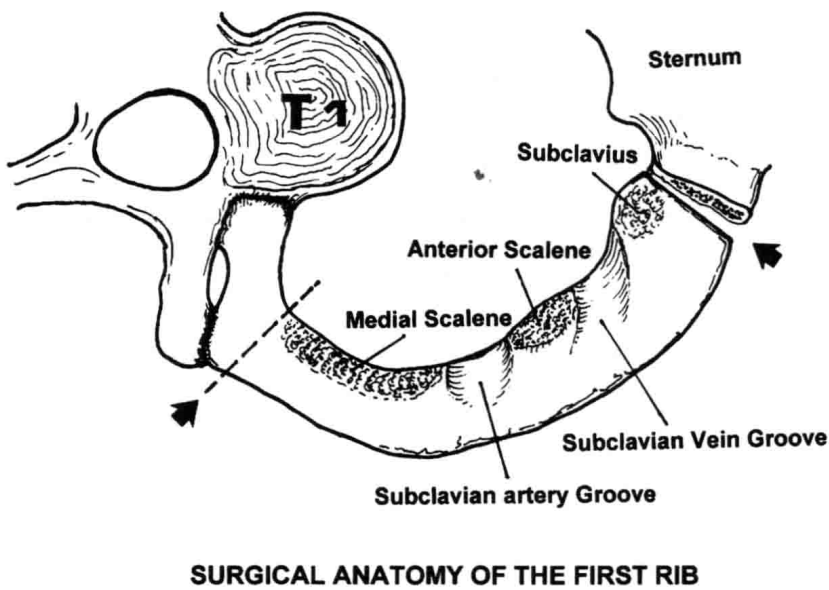

Fig. 2 Superior view of the first rib showing (*arrows*) the level at which the first rib should be divided for removal in cases with neurogenic thoracic outlet syndrome. Sites of muscle insertions are depicted

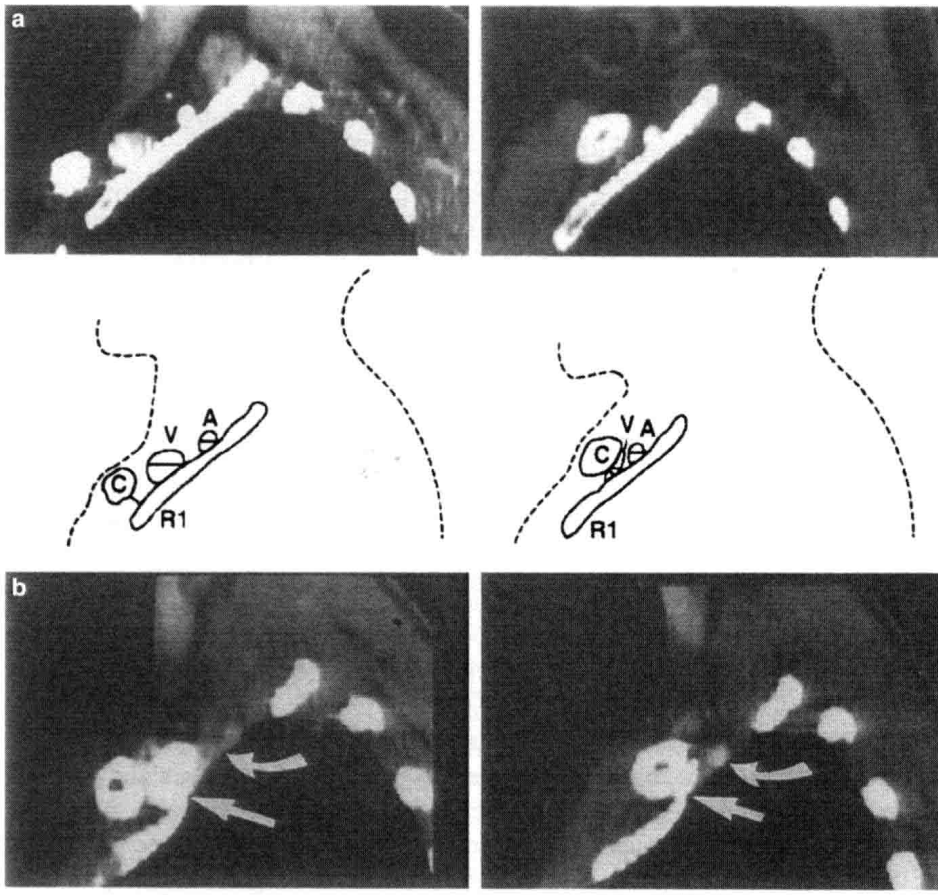

Fig. 3 Matsumura Report 1997. *Above*: Composite of sagittal CT image at costoclavicular region demonstrates neutral (*left*) and abducted positions (*right*). Posterior movement of clavicle causes scissoring impingement of the vein. Artery is posterior to swinging clavicle. *Below*: Schematic depiction of sagittal plane shows first rib (*R1*), clavicle (C), measurement of costoclavicular distance (*oblique line*), venous diameter (v), and arterial diameter (a)

using helical computer tomography) demonstrating that abduction of the arm causes posterior movement of the clavicle which results in an obvious scissoring impingement of the vein, occasionally to the point of interrupting the blood flow temporarily (Fig. 3). However in some individuals, the surrounding muscles become very prominent due either to their occupations, or to vigorous sports activities like weight lifting. Repeated movements of the arm over the head, lifting, and pushing heavy objects can lead to the thickening of both the subclavius tendon and the anterior scalene muscle tendon that contributes to a narrowing of the tunnel which over long periods of time or even acutely on occasion, especially with a sudden effort of the arms the muscles become tense and working as a vise clamp down on the vein causing injury of the endothelium leading to thrombosis (see next section on Paget–Schroetter syndrome).

Behind the anterior scalene muscle, the subclavian artery exits from the chest cavity and rides over the first rib toward the arm. Behind this artery the middle scalene

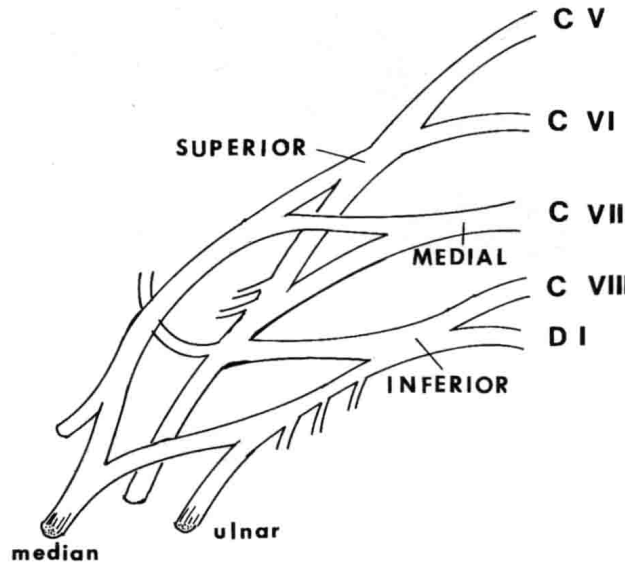

Fig. 4 Anatomical structure of the brachial plexus

muscle inserts in a long linear fashion on the upper surface of the rib extending back to the point where the first rib joins the transverse process of the T1 vertebral body (Fig. 2). The middle scalene muscle upper insertions run from C third, fourth, fifth, and sixth posterior tubercles of the transverse process. The anterior scalene inserts in the fourth, fifth, and sixth anterior tubercles of the same transverse processes. Between the fibers of the middle and the anterior scalene muscle, the nerve trunks of the brachial plexus originating at the cervical spine travel together with the subclavian artery to reach the arm. This is an area where the brachial plexus branches are intermingled with the muscle fibers and where compression of these structures can occur causing symptoms.

The structure of the brachial plexus is as follows. There are three major trunks superior, anterior, and posterior. Most of the innervation to the muscles of the forearm and hand are provided by the median and the radial nerve which run anteriorly and superiorly. The nerves innervating the ulnar area of the forearm and the third, fourth, and fifth, fingers run in the posterior trunk, which originates in the lowest portion of the cervical spine and at the level of T1 of the thoracic spine (Fig. 4).

The previous description makes clear that there are two different zones in the thoracic outlet; (Fig. 5) the anterior portion (the space through which the subclavian vein circulates) and the posterior space behind the anterior scalene muscle (through which the subclavian artery and the trunks of the brachial plexus emerge). The presence of a cervical rib or its equivalent always forces the subclavian artery into an abnormal course, riding over the cervical rib itself or its extended ligaments. This places the artery in a higher position and at a sharper angle while traveling to the arm (Fig. 6). Note: The artery never runs between the cervical rib and the first rib; it always travels over the cervical rib or its tendinous extension. In fact the space created between the cervical rib and the first rib is invariably filled with fibers belonging to the middle or the anterior scalene muscles.

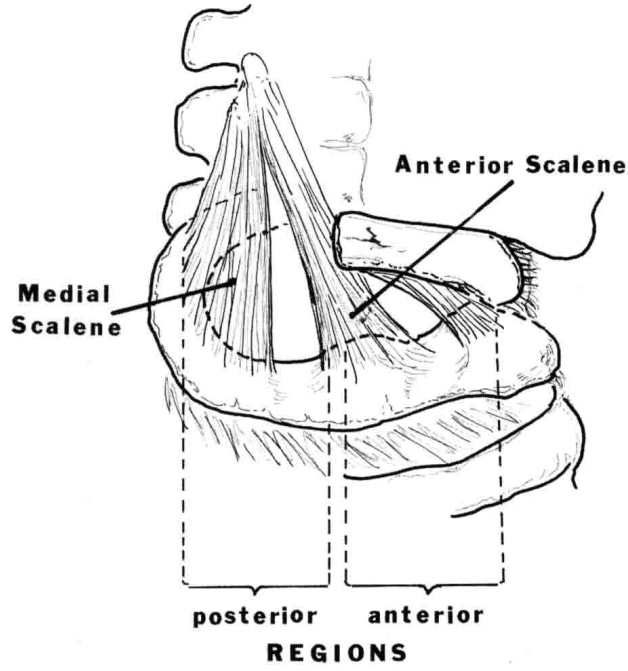

Fig. 5 This illustration shows the two regions of the thoracic outlet separated by the anterior scalene muscle. The anterior space which constitutes the inlet is outlined by the subclavius muscle the anterior scalene muscle and the first rib. The posterior space behind the anterior scalene muscle shows the separation between the anterior scalene muscle and the medial which constitutes the "trigonum costal-interscalenicum" of Puusepp through which the brachial plexus and the subclavian artery run. The medial scalene muscle forms a fan-shaped insertion on the superior aspect of the first rib

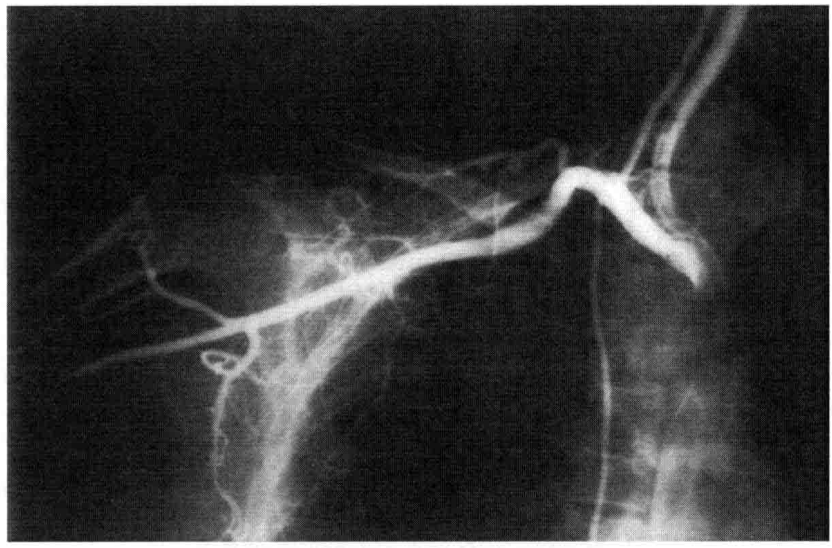

Fig. 6 Arteriogram of the right subclavian artery showing the forced superior course of the subclavian artery passing over the cervical rib before reaching the arm

According to Sanders and Roos [4, 5], the triangular space formed by the anterior and middle scalene muscles and the first rib has several differing configurations in humans. The nerve trunks that cross this space arise at different levels. In cadavers of both genders the nerves emerged higher in the triangle in those who had had symptoms of the neurogenic thoracic outlet syndrome than in those who were asymptomatic. (The differences were greater in women than in men). It is probable that, when the muscles contract, they exert a pinching mechanism on the nerve trunks that may on occasion involve the subclavian artery. The age-related sagging of the shoulder position in adults may also stretch the scalene muscles to a more acute angle at the level where the nerve trunks emerge. This may explain why in childhood or even in puberty, the patients may not have symptoms but until later in adulthood particularly in women who experience a greater shoulder descent to a more sloping position, as suggested by Naffziger and Grant [6] in their excellent monograph. Loss of muscular tone and drooping of the shoulders with aging may have the same effect regardless of gender.

Compression of the brachial plexus trunks constitutes what we call a neurogenic thoracic outlet syndrome. In 51 % of the cases it involves compression of the subclavian artery as well [7–9]. Both structures are affected because of their common position in the posterior triangular space of the thoracic outlet.

Another important anatomic consideration is the position of the phrenic nerve. In the neck the nerve crosses diagonally in front of the anterior scalene muscle as it reaches the first rib. At the level of the clavicle the nerve usually separates from the anterior scalene muscle to enter the mediastinum behind the first rib. Therefore in the infraclavicular portion of the scalene muscle the phrenic nerve is already away from the muscle tendon and becomes medial following the course of the superior vena cava. This has surgical implications on the approach to be implemented when operative interventions are aimed to relieve compression of the thoracic outlet.

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