The thoracic outlet syndromes, though severely disabling, are readily correctable by appropriate surgery. Early and accurate diagnosis of the offending lesion, or lesions, are hence imperative. Until the recent past, the operative results have been marred by a large number of failures, caused by false or incomplete preoperative diagnosis. However, newer and more accurate means of preoperative diagnosis insure a significant improvement of the surgical results, and hence, corrective surgery is enthusiastically recommended for these patients.18

Until recently, the diagnosis has relied on time honored clinical criteria of damping of the pulse in certain positions, and upon absence or presence of cervical ribs, demonstrable on roentgenograms.1,7,8,10,18 These criteria, unfortunately, fail to differentiate the various subgroups of scalenus anticus syndrome and are unable to differentiate between the common scalenus anticus syndrome, the pectoralis minor syndrome, the hyperabduction syndrome, and/or the simultaneous presence of two or more lesions causing the condition. Many clinicians have attacked these lesions surgically, hoping to identify the site and cause of obstruction on the operating room table. Marked limitations of motion under surgical field conditions, and the decrease in tonus of the muscle groups under general anesthesia, make a positive identification of the obstructing lesion, or lesions, extremely difficult. Hence, the role of surgery had been relegated to a hit-or-miss

*Presented at the IX International Congress on Diseases of the Chest, Copenhagen, Denmark, August 20-25, 1966.

FIGURE 1: Normal appearance of the subclavian artery in modified hyperabduction maneuver.
proposition, when attempting to correct the obstructing lesion. The selective antegrade arteriography is the first method that allows assessment of these lesions in varying positions and under actual working conditions. The injection of contrast material, recorded on serial arteriographic films, allows a graphic demonstration of the offending lesion, or lesions, recorded in such positions and under such conditions that maximal symptoms are reproduced. Repeat examinations are feasible, and a patient can be assessed for the presence of multiple lesions by re-examination under varying conditions and in different positions. Moreover radioisotope flow studies allow a quantitative assessment of the hemodynamic significance of these lesions. The reduction of flow is calculated at a point distal to the apparent compression site, comparing flow rates obtained in a neutral position to flow rates in various other positions, causing maximal clinical symptoms.

**Technique**

A small Seldinger catheter, introduced into the femoral artery, is advanced under fluoroscopic control into either subclavian artery. Ten to 12 ml of 50 per cent iohexol injected in a neutral position. Eight to 10 ml of the same 50 per cent iodinated contrast medium suffice for injections in positions resulting in dampening of the arterial pulse. Serial arteriograms, four films covering a two second sequence, are usually carried out in neutral position, under Adson maneuver, Lang's maneuver, and in whatever other position that may produce maximal dampening of the pulse. A quantitative assessment of the hemodynamic significance of such a lesion, and the resulting reduction in blood flow in various positions, can be studied during the same examination. Radioactive iodinated blood albumin (RISA) is introduced through the catheter. A flow rate meter is placed over the radial artery at the level of the wrist. Varied positions may then be assumed, and the actual reduction in flow rate can be calculated.

Arteriograms and radioisotope flow studies complement each other, and furnish a composite picture of the severity of flow reduction and hemodynamic impairment. The arteriogram primarily furnishes evidence as to the site, or sites, of anatomic obstruction, and to the presence, or absence, of collateral pathways. The radioisotope flow studies assess the hemodynamic significance of the obstruction.

**Discussion**

The significance of various anatomic structures in the creation of the thoracic outlet syndromes has been recognized for a long time. As early as 1860, Willshire described the cervical rib syndrome. In 1905, Murphy described the effects upon the neurovascular mechanism resulting from pressure upon structures between a cervical rib and the scalenus anticus muscle. Naffziger and Grant, and Ochsner, Gage and DeBakey later pointed out that the tendons of the scalenus anticus alone may be responsible for pressure upon the neurovascular bundle, and cause this clinical syndrome.

**Table 1—Results in a Series of Fifty Patients Subjected to Surgery without the Benefit of Preoperative Arteriographic Diagnosis**

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Surgical Procedure</th>
<th>Results</th>
<th>Improved</th>
<th>Not Improved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scalenus anticus syndrome</td>
<td>Scalenotomy, resection of the 1st anterior rib and 1st anterior rib, and splitting of the clavicle</td>
<td>26</td>
<td>7</td>
<td>19</td>
</tr>
<tr>
<td>Cervical rib</td>
<td>Resection of the 1st anterior rib and scalenotomy</td>
<td>13</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Total number</td>
<td></td>
<td>50</td>
<td>28</td>
<td>22</td>
</tr>
</tbody>
</table>
The clinical diagnosis of these conditions relied upon two examinations: the chest roentgenogram and assessment of the pulse qualities under Adson maneuver. The chest roentgenogram primarily ascertained the presence or absence of a cervical rib. The presence of a cervical rib was considered prima facie evidence for the diagnosis of a compression syndrome occasioned by the cervical rib.10,11,12,13 Resection of the cervical rib and scalenotomy was considered the procedure of choice, and the postoperative results appeared to be most gratifying (Table 1). It is felt that the excellent results are due to the fact that the lesion usually occurs as an isolated lesion, and that the basic anomaly is readily identified on the chest roentgenogram.

The diagnosis of all other forms of neurovascular compression syndromes relied on assessment of the pulse quality of the affected extremity under a maneuver described by Adson. This consists of extension of the neck, rotation of the head toward the affected side, abduction of the arm, and deep inspiration. The test, if positive, produces dampening of the pulse and gives rise to paresthesia and tingling in the fingers of the affected extremity. The maneuver results in narrowing of the interscalene space and compression of the subclavian artery in the scalene tunnel. Unfortunately, Adson's maneuver will produce a positive test in all types of scalenous anticus syndromes, in the pectoralis minor syndrome, and frequently also in the hyperabduction syndrome. Moreover, the test cannot differentiate between a solitary or multiple obstruction lesion.

### Table 2—Postoperative Results in a Series of 131 Patients Operated on the Basis of Preoperative Arteriographic Findings

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Total Number</th>
<th>Surgical Procedure</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total Number</td>
<td>Improved</td>
</tr>
<tr>
<td>Group 1—Scalenus anticus syndrome</td>
<td>51</td>
<td>51</td>
<td>45</td>
</tr>
<tr>
<td>A. Oblique compression defect</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>B. Torsion effect on subclavian artery</td>
<td>34</td>
<td>26</td>
<td>23</td>
</tr>
<tr>
<td>C. Ridge-like concentric compression</td>
<td>8</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>D. Sharp cut-off</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Group 2—Cervical rib syndrome</td>
<td>51</td>
<td>51</td>
<td>49</td>
</tr>
<tr>
<td>Group 3—Pectoralis minor syndrome</td>
<td>9</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>Group 4—Hyperabduction syndrome</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>A. Syndrome 1 and 2</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>B. Syndrome 1 and 3</td>
<td>9</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>C. Syndrome 1 and 4</td>
<td>5</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Total number</td>
<td>131</td>
<td>131</td>
<td>114</td>
</tr>
</tbody>
</table>
Division of the scalene anticus tendon, forming the posterior border of the scalenus anticus tunnel, was considered the surgical procedure of choice. The results of this procedure proved to be extremely variable, and soon dampened enthusiasm for surgical correction of these conditions. A series of patients operated on the basis of clinical examination alone showed failure in 19 of the 26 (Table 2). New experience, based on the study of arteriograms on patients suspected to suffer from scalenus anti-
cuss syndrome, readily explain the reason for the failure.

At least four subgroups of the scalenus anticus compression syndrome are recognized on the basis of their characteristic arteriographic appearance. The mildest form will show an oblique compression defect across the artery on serial arteriograms, recorded under Adson or Lang's maneuver. This compression defect is due to the tendon of the scalenus anticus crossing the artery.

Figure 4: The subclavian artery tapers to a complete cutoff at its point of entry in the scalenus anticus tunnel. Only a modified hyperabduction maneuver produces this type of obstruction.

Figure 5: A sharp linear cutoff of the subclavian artery at its point of entry into the scalenus anticus tunnel is produced with Adson's maneuver and modified hyperabduction maneuver. Severe anatomic tightness of the space delineated by the anterior first rib. The scalene anticus and medius tendon, and the midsegment of the clavicle is incriminated for this type of compression effect.
tery at this point. Scalenotomy alone will suffice to correct this condition.

The second subgroup shows a torsion and twist effect upon the subclavian artery, demonstrable on arteriograms performed under Adson or Lang's maneuver. Again, the torsion or twist is caused by the scalenus anticus and medius tendons rolling the artery between them. Scalenotomy alone suffices if the torsion effect is the only demonstrable result on arteriograms. If, however, certain positions (Lang's position in particular) will result in tapering and complete obliteration of the subclavian artery, at its point of exit from the scalenus anticus tunnel, resection of the first anterior rib is also deemed advisable.

The arteriographic demonstration of these lesions in these first two subgroups is largely dependent upon the tonus of the involved muscle groups. Hence, frequently lesions may not be reproducible in the early morning hours, but are usually best seen in the late afternoon, at a time when the muscle tonus is at a maximum.

The third subgroup presents with a concentric ridge-like compression of the subclavian artery as the vessel passes through the scalenus anticus tunnel. A compression is usually demonstrated on arteriograms recorded under Adson's maneuver. Lang's maneuver will frequently result in tapering and complete obliteration of the subclavian artery at its point of exit from the scalenus anticus tunnel. Scalenotomy and resection of the first anterior rib are considered necessary to correct this condition.

The last subgroup is rather rare, and presents with a sharp linear cutoff of the subclavian artery at its point of entry into the scalenus anticus tunnel, demonstrable both under Adson's and Lang's maneuvers. Resection of the first anterior rib, scalenotomy, and usually splitting of the clavicle are recommended to correct this lesion.

The divergence of surgical procedures necessary to correct these various types of scalenus anticus syndromes explains the high rate of failure in the pre-arteriographic era. The scalenotomy usually performed

![Image](http://journal.publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/21442/)
on these patients did not suffice to correct the condition. Clinical examination alone failed to differentiate the various subgroups, and failed to help select appropriate surgical correction. It is of interest to note that a small group of patients subjected to scalenotomy and resection of the anterior rib in the pre-arteriographic era showed a similarly satisfactory result (Table 1). This suggests that the subgroups correctable by scalenotomy alone are quite rare (Table 2).

The hemodynamic significance of the various anatomic variations of scalenus anticus syndrome can be assessed by radioisotope flow studies. The subgroup A will usually result in a flow reduction of some 60 per cent. The subgroups B and C show a similar flow reduction under Adson’s maneuver; however, under Lang’s maneuver, a more marked reduction of flow rate becomes manifest. Moreover, a marked delay in the ascending limb of the curve and decrease in the steepness of ascent is readily appreciated. The subgroup D, showing a sharp linear cutoff of the artery at its point of entry into the scalenus anticus tunnel, showed the most severe flow reduction. The flow rate was reduced to 8 per cent of the flow rate in neutral position.

The pectoralis minor syndrome is clinically indistinguishable from the scalenus anticus syndrome. Only the arteriogram readily differentiates the two entities. A marked depression and deflection of the junction segment of the subclavian and axillary artery, caused by the pectoralis minor tendon crossing at this point, are the arteriographic characteristics of this lesion. The frequent simultaneous occurrence of pectoralis minor syndrome and scalenus anticus syndrome has contributed to the poor surgical results in an attempt to correct these lesions. In almost all documented instances, the surgical correction was limited to the scalenus anticus compression site, and the presence of a pectoralis minor syndrome was not recognized. Resection of the pectoralis minor tendon, freeing of the junction segment of the subclavian artery and axillary artery, will promptly correct the pectoralis minor syndrome.

The hyperabduction and costoclavicular syndrome are the result of tightness in the costoclavicular space and apical axillary triangle. This, by necessity, also narrows the interscalene triangle. A number of anatomic structures interact in this area and may give rise to substantial spacial congestion; the head of the humerus, the coracoid process, the subclavian muscle, the pectoralis minor muscle, the coracoid ligament, the clavicle, the scalenus anticus and medius muscles, and the first rib. Fractures of the clavicle or first rib with hypertrophic callus formation will frequently accentuate the already existing tightness of the costoclavicular space. The arteriogram will usually demonstrate point or points of compression of the artery, and appropriate surgical correction can be carried out. Arteriographic recordings are carried out in the routine positions, but also in an exaggerated military position, utilizing weighed shoulder straps to draw the shoulders backwards. This maneuver, in particular, will reduce the apical axillary triangle and costoclavicular space, and bring forth compression effects in these areas. In contrast to the scalenus anticus syndrome, the hyperabduction and costoclavicular syndromes result in compression over a much longer segment of the neurovascular bundle. For this reason, thrombosis of the subclavian and axillary veins may frequently be encountered. Venography is opportunistically added to obtain further pertinent data, particularly in the apical axillary triangle.

The true compression syndromes have to be differentiated from the various entities of intrinsic arterial disease. The arteriogram readily differentiates arteriosclerosis of the subclavian artery, fibromuscular hyperplasia, subendothelial hyperplasia, fibrous replacement of the brachiocephalic vessels (Takayasu’s syndrome) from extrinsic compression effects upon the subclavian or axillary artery.

A comparison of the group of patients operated in the pre-arteriographic era and
the patients operated on the basis of arteriographic findings illustrates a significant improvement of the postoperative results. In the pre-arteriographic series, a failure rate of 44 per cent was encountered; this in spite of the relatively heavy loading of this series with cervical rib syndromes, a group which tends to show the best surgical results. In the post-arteriographic series, the failure rate has dropped to 15 per cent. This attests to the significance of an accurate preoperative diagnosis, guiding the selection of the corrective surgical procedure.

**SUMMARY**

The results of corrective operative procedures in the group of some 131 patients operated on the basis of arteriographic diagnosis of thoracic outlet syndromes are compared to those in the group of some 50 patients operated on the basis of clinical diagnosis and surgical exploration alone. The rate of failure declined from 44 to 15 per cent. This improvement emphasizes the importance of arteriography in the accurate localization of the obstructing lesion, or lesions, and selection of the appropriate surgical correction. The safety of arteriography is emphasized. Moreover, arteriography is recognized as the only technique able to diagnose the presence of multiple obstructing lesions and to assess the condition in varied positions and with normal tonus of the involved muscle groups. The hemodynamic significance of these lesions can be readily assessed by radioisotope flow studies.

**RESUMEN**

El estudio comparativo de los resultados del tratamiento quirúrgico en 131 pacientes con síndromes obstructivos de la abertura toracocervical, en los que se practicó la arteriografía preoperatoria, con los obtenidos en 50 pacientes operados a base del diagnóstico clínico y la exploración quirúrgica solamente, ha permitido comprobar un descenso en el porcentaje de fracasos de un 50 a un 15 por ciento. Esto prueba la importancia de la arteriografía en la localización precisa de la lesión o lesiones obstructivas y en la selección de la técnica quirúrgica correctiva más apropiada. El autor destaca la inocuidad de la arteriografía, reconocida hoy como la única técnica efectiva para el diagnóstico de las lesiones obstructivas múltiples y para la evaluación del efecto de las distintas posiciones y del tono normal de los grupos musculares, participantes. La significación hemodinámica de estas lesiones puede ser determinada sin dificultad mediante el uso de los isótopos.

**ZUSAMMENFASSUNG**


Die Wichtigkeit der Arteriographie wird hervorgehoben Darüber hinaus muß man die Arteriographie anerkennen als die einzige Technik zur Diagnostik des Verlegens multipler obliterierender Läsionen und um die näheren Umstände bei verschiedenen Stellungen zu ermitteln und mit normalem Tonus der betroffenen Muskelgruppen. Die hämodynamische Bedeutung dieser Läsionen läßt sich mittels Durchströmungsstudien mit Radioisotopen genau erheben.

**REFERENCES**


DISTRIBUTION OF PULMONARY BLOOD FLOW

The uneven topographic distribution of blood flow in the lung is an inevitable consequence of the intimate apposition of blood and air which results in a large pressure difference across the pulmonary vessels at different levels in the lungs. The resulting imbalance of blood flow and ventilation causes large regional differences in gas exchange, but interference with overall gas transfer is negligible unless the normal pulmonary arterial pressure is reduced, or alveolar pressure is increased, when an alveolar dead space may develop. In general, the pattern of distribution of blood flow observed in health and disease can apparently be explained by the interference between the pulmonary arterial, venous and alveolar pressures. However, patients with an increased pulmonary venous pressure as in mitral stenosis or left ventricular failure may exhibit a reduction of blood flow in the lower zones and a similar pattern has been found in the isolated lung where it is caused by interstitial edema. The mechanism is postulated to be an interference with the normal expanding action of the inflated lung parenchyma on the extra-alveolar blood vessels.


RESPIRATORY FUNCTION IN MITRAL STENOSIS

Hemodynamic and respiratory function studies were carried out on 14 patients with mitral stenosis. The respiratory function is directly affected according to the degree of mitral stenosis. According to the authors, the worst effect of mitral stenosis is pulmonary hypertension which in turn affects the lung parenchyma and its function. The changes in the interstitial lung tissue are partly responsible for the abnormal distribution of blood flow and gas exchange. The most important change after commissurotomy is the reduction in ventilation, both on resting and exertion.


CONGENITAL TRACHEOESOPHAGEAL FISTULA

Congenital tracheoesophageal fistula without esophageal atresia occurs more frequently than has been previously recognized. It is usually present in the cervical region, at the junction between the upper and middle thirds of the trachea. In most instances, the fistula can be reached and surgically corrected through a supraclavicular incision. In any patient with the characteristic clinical picture, even when diagnostic studies are inconclusive, an exploration of the neck should be undertaken to prove or disprove the presence of a fistula.