Exploration of selected brachial plexus lesions by the posterior subscapular approach

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The application of an old surgical technique, previously employed for treatment of thoracic outlet syndromes, to lesions of the brachial plexus is discussed. Positioning of the patient, the surgical procedure, and selected indications for a posterior subscapular approach with resection of the first rib are discussed. The indications for the use of this approach are: proximal plexus lesions involving roots and/or trunks believed to be repairable, complicated thoracic outlet syndromes, prior anterior exploration for vascular or nervous structure disease, and progressive plexus palsy associated with damage to the soft tissue of the anterior chest wall and supraclavicular regions secondary to irradiation. The authors' experience to date with 12 such cases is presented in chart form, while five cases are presented in some detail.

Key Words • brachial plexus • posterior subscapular approach • plexus root and trunk • nerve action potential • irradiation change • nerve root • nerve trunk

Historically, the posterior approach to the brachial plexus is based on the evolution of the posterolateral approach for removal of the first thoracic rib for thoracic outlet syndrome. The technique of posterolateral first-rib resection had its origin during the pre-antibiotic era of treatment of tuberculosis and empyema. Simon in 1869 and Estlander in 1879 employed a trapezius-splitting incision for thoracoplasty in the treatment of chronic empyema. De Cerenville in 1885 and Quincke and Sprengler in 1888 formalized and named the procedure. In the United States, John Alexander popularized an apical thoracoplasty from the posterior, subscapular approach. In 1962, Clagett reported his experience with a similar posterior, subscapular approach for surgical amelioration of thoracic outlet syndrome. For a period of time this became the standard technique for first-rib resection. In recent years, the transaxillary or infracavicular approaches have become more popular than either the supravacular or the posterior approaches, but the latter is still in use by some surgeons. Thus, there has been a two-stage evolution of the posterior subscapular approach for first-rib resection.

The third stage in the evolution of the procedure came about via neurosurgical consultation from a thoracic surgeon. The patient in question had physical findings and a history suggestive of a thoracic outlet syndrome. However, primary brachial plexus involvement was suspected. It was decided that a joint effort, using the “old” subscapular ap-
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approach, would permit both first-rib resection and direct visualization of the plexus. The remarkable exposure as well as relaxation of the plexus gained at the root and trunk level, led to the use of this technique for exploration of selected plexus lesions. To our knowledge, this is the first reported series with the use of this technique for brachial plexus lesions.

Operative Technique

Positioning of the Patient

Proper positioning of the patient is essential for good exposure and easy access to the plexus. The position employed is a combination of the lateral decubitus and Fowler positions (Fig. 1). Initially, the patient is placed in the lateral decubitus position. He is then rolled approximately 80° toward the surface of the operating table. The upper extremity on the operative side is partially abducted and forward flexed at the shoulder. The arm is then flexed at the elbow and secured to a padded, adjustable arm board or Mayo stand at a level slightly below that of the operating table. The operating table is then tilted up 15° to 20°. This position places the plexus perpendicular to the surgeon's line of vision, thus greatly facilitating operative ease and orientation. During positioning, attention must be paid to protection of skin and nerves in proximity to the bony prominences of the ankles, knees, elbows, and wrists.

Procedure

A parascapular skin incision is made between the spinous processes and the medial border of the scapula (Fig. 2). The scapula is externally rotated with the patient in this position, so it is advisable to place the incision lateral to the spinous processes by 2 to 4 cm. This placement lends itself to protection of nervous and vascular structures coursing close to the vertebral border of the scapula. These structures include the spinal accessory nerve and the ascending branch of the transverse cervical artery. The dorsal scapular nerve and the descending branch of the transverse cervical artery, which course beneath the insertions of the rhomboid and levator scapulae muscles, are also protected by this incision. In most cases, the incision need not be extended to the superior margin of the trapezius muscle. If during the procedure the need for greater exposure becomes obvious, the incision can be extended slightly medial into the posterior region of the neck, and the trapezius fibers may be split in a medial and superior direction.

The inferior trapezius should be divided along the entire length of the skin incision. Beneath the trapezius lie the levator scapulae

FIG. 1. Positioning of the patient for subscapular resection of the first rib and exploration of the brachial plexus. The patient is placed in a lateral decubitus position (upper) and then rolled into a semiprone position with the side to be operated on tilted 10° to 15° above the plane of the operating table (not shown) and his arm on an adjustable table and turned away from the operative side (lower).

FIG. 2. Site of parascapular incision (inset), section of the trapezius, and dissection of the rhomboid and levator scapulae muscles. Note the position of the chest or rib retractors.
superiorly, the rhomboid minor somewhat intermediate, and the rhomboid major in the inferior position. All three muscles insert on the vertebral border of the scapula. The rhomboid muscles are then divided. The levator scapulae muscle need not be divided initially, but rather later in the procedure if necessary for further exposure. The superior portion of the posterior serratus muscle may be divided as necessary. The major muscle bundles are marked by heavy suture to facilitate accurate approximation during closure. A large, self-retaining rib spreader is positioned beneath the scapula and paraspinal muscle mass. This maneuver externally rotates the scapula, thus exposing the rib cage. Further lateral rotation of the scapula can be gained by inferior adjustment of the armrest or Mayo table holding the arm. The ribs are then palpated. The second rib is the most obvious apical rib. Running the fingers superiorly over the second rib permits easy palpation of the first rib. Removal of a 2- to 3-cm segment of the second rib from the transverse process laterally greatly facilitates resection of the first rib. This resection may be done subperiosteally, decreasing the risks of pneumothorax. Removal of a segment of the second rib is not always necessary and may be left to the discretion of the individual surgeon. The first rib is then removed extraperiosteally from the articulation with the transverse process posteriorly, to the costoclavicular ligament anteriorly. The rib is stripped with an Alexander periosteal elevator and resected with rib shears or a heavy Leksell rongeur. Extraperiosteal resection of the first rib is of utmost importance because the periosteum may regenerate the rib, which could compromise the nervous and vascular structures in the thoracic outlet. In the process of removing the first and second ribs, both the scalenus posterior and scalenus medius muscles will be removed from their insertions. Upon reflecting these muscles superiorly, the brachial plexus comes into view at the level of the trunks (Fig. 3). The subclavian artery lies slightly anterior and inferior to the lower trunk, while the subclavian vein is anterior to both.

The remainder of the procedure is determined by the pathology encountered and the purpose of the surgery. To expose the divisions of the plexus, one follows the trunks medially with elevation and retraction of the paraspinal muscle mass and occasional muscle resection as indicated. The soft-tissue exposure may be extended to the superior edge of the trapezius and the levator scapulae muscle may be divided if necessary.

Closure of the wound should be meticulous. Attention should be paid to hemostasis to decrease pooling of blood, which can lead to an apical seroma and scar formation around the plexus. All bone edges should be carefully manicured and waxed to prevent injury to surrounding tissues. A small, extrapleural chest tube may be placed apically for 24 to 48 hours. The muscles should be sutured in as anatomic fashion as possible.

Case Reports

To date 12 patients have been operated on by this approach. These cases are outlined in Table 1, and five are presented in more detail.

Case 1

This 24-year-old female physical education teacher and trampolinist was referred to us by a thoracic surgeon. The patient presented with a painless onset of atrophy of the right hand, beginning with a tendency to claw the little finger which spread to other fingers, including the thumb.

Examination. There was a marked decrease in strength and atrophy in the ulnar-innervated intrinsic hand muscles, the extensor pollicis longus, abductor pollicis brevis, J. Neurosurg. / Volume 49 / December, 1978
### TABLE 1
Experience to date with posterior subcapular approach to brachial plexus

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Injury Interval</th>
<th>Injury or Lesion</th>
<th>Deficit</th>
<th>Electro-myography</th>
<th>Stimulation</th>
<th>NAP</th>
<th>Operation</th>
<th>Results</th>
<th>Follow-Up Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>24, F</td>
<td>yrs</td>
<td>stretch (gymnastics)</td>
<td>L.T.-severe loss</td>
<td>L.T.-I.D.</td>
<td>L.T.-P</td>
<td>P</td>
<td>neurolysis</td>
<td>improved</td>
<td>4 yrs</td>
</tr>
<tr>
<td>2</td>
<td>26, M</td>
<td>2 mos</td>
<td>gunshot wound; prior ant. vascular exploration</td>
<td>L.T.-severe</td>
<td>M.T.-C.D.</td>
<td>M.T.-P</td>
<td>P (small)</td>
<td>neurolysis</td>
<td>L.T. improved,</td>
<td>3½ yrs</td>
</tr>
<tr>
<td>3</td>
<td>18, M</td>
<td>6 wks</td>
<td>contusion &amp; stretch from football injury; supraclavicular hematoma</td>
<td>complete plexus palsy</td>
<td>L.T.-C.D.</td>
<td>M.T.-Ab</td>
<td>P</td>
<td>neurolysis</td>
<td>no change</td>
<td>3½ yrs</td>
</tr>
<tr>
<td>4</td>
<td>55, F</td>
<td>yrs</td>
<td>neurofibroma of plexus; 3 prior operations</td>
<td>L.T.-C</td>
<td>M.T.-C.D.</td>
<td>M.T.-Ab</td>
<td>Ab</td>
<td>resection</td>
<td>pain diminished,</td>
<td>3½ yrs</td>
</tr>
<tr>
<td>5</td>
<td>23, M</td>
<td>6 mos</td>
<td>gunshot wound; prior ant. vascular exploration</td>
<td>L.T.-C</td>
<td>M.T.-C.D.</td>
<td>M.T.-P</td>
<td>P</td>
<td>neurolysis</td>
<td>no change</td>
<td>2½ yrs</td>
</tr>
<tr>
<td>7</td>
<td>38, F</td>
<td>yrs</td>
<td>Hodgkin’s disease; post-irradiation scar</td>
<td>L.T.-I</td>
<td>M.T.-mild</td>
<td>M.T.-P</td>
<td>P</td>
<td>neurolysis</td>
<td>L.T.-worse, M.T. &amp; pain-improved</td>
<td>2 yrs</td>
</tr>
<tr>
<td>9</td>
<td>35, M</td>
<td>3 mos</td>
<td>postop transaxillary 1st rib resection with plexus injury</td>
<td>L.T.-C</td>
<td>M.T.-I</td>
<td>L.T.-Ab</td>
<td>Ab</td>
<td>sural nerve graft L8-T1 to L.T. M.T.-neurolysis</td>
<td>L.T.-no change, M.T.-improved</td>
<td>1½ yrs</td>
</tr>
<tr>
<td>10</td>
<td>34, F</td>
<td>2 yrs</td>
<td>postop transaxillary 1st rib resection</td>
<td>L.T.-I</td>
<td>L.T.-I.D.</td>
<td>L.T.-P</td>
<td>P</td>
<td>resection remainder 1st rib, neurolysis</td>
<td>improved</td>
<td>1½ yrs</td>
</tr>
<tr>
<td>11</td>
<td>40, F</td>
<td>4 yrs</td>
<td>malignant thymoma, post-irradiation scar</td>
<td>M.T.-I</td>
<td>M.T.-intact</td>
<td>L.T.-P</td>
<td>P</td>
<td>neurolysis, excision of scar</td>
<td>U.T.-worse, M.T.-no change, pain some improved</td>
<td>1½ yrs</td>
</tr>
</tbody>
</table>

*Abbreviations: L.T. = lower trunk; M.T. = middle trunk; U.T. = upper trunk; I = incomplete loss; C = complete loss; I.D. = incomplete denervation; C.D. = complete denervation; P = present; Ab = absent; NAP = nerve action potential (intraoperative).
and opponens pollicis. The median innervated lumbricales were also weak. The referring physician thought that some of the physical findings were suggestive of a thoracic outlet syndrome, but because he was concerned about the extensive functional loss he referred the patient to neurosurgery.

Cervical spine films and myelography were negative. Electromyogram (EMG) showed denervational changes in both ulnar- and median-innervated hand muscles. Distal median and ulnar conduction was slowed but there was no specific delay across the clavicle. Collaboration led to the decision to use the "old" posterior approach for first rib resection, because this would also permit direct inspection of the brachial plexus.

Operation. The exposure of the plexus was remarkable, especially from the root to trunk level. The plexus showed evidence of an old stretch injury with entrapment of the proximal plexus between scar, which involved root to trunk junctions at C7-T1, and the first rib. After resection of the first rib, a neurolysis of these roots and the lower and middle trunks was done.

At 4-year follow-up examination, this patient has a marked degree of improvement in hand function.

Case 2

This 26-year-old man sustained a .38 caliber gunshot wound to the supraclavicular region in early July, 1974. The supraclavicular vessels had been explored on the day of injury by the General Surgery service and a subclavian vein injury was repaired without use of a graft. In addition, a severely comminuted fracture of the clavicle was resected. From the onset he had a severe loss of nerve activity in the lower trunk, and almost complete middle and partial upper trunk loss. He also had a causalgic-like pain involving the forearm and hand. This was a burning and dysesthetic pain but was not true causalgia, for with distraction one could manipulate his hand and forearm without great difficulty. An EMG showed complete lower trunk and partial middle and upper trunk loss of function.

Operation. On September 12, 1974, his brachial plexus was explored through the posterior subscapular approach. The first rib was resected, and scar was found enveloping the entire plexus, particularly the middle and lower trunks and roots leading to these trunks. It appeared as if the missile fragment had grazed the lower trunk. After performing a neurolysis of all of the roots and trunks of the plexus, excellent nerve action potentials could be recorded from the upper trunk as well as from the middle trunk, although the amplitude of the latter was small. By stimulating the C-8 root a small nerve action potential could be recorded distal to the lower trunk lesion, whereas stimulation of the T-1 root gave no nerve action potential. Since a small response could be recorded from a portion of the lower trunk and since this was such a proximal injury involving neural elements that normally innervate very distal structures, it was elected not to resect this lesion (Figs. 4 and 5).

Postoperative Course. The patient’s postoperative course was uncomplicated, and his wound healed without difficulty. His pain improved within a few weeks of operation and
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FIG. 5. Nerve action potential (NAP) traces recorded after operative exposure of the elements shown in Fig. 4. There was no NAP on stimulation of the T-1 root with recording from distal lower trunk (L.T.) while stimulation of the C-8 root gave a small NAP, so a neurolysis of L.T. was done. A small NAP was also recorded with stimulation of the C-7 root and recording from the middle trunk (M.T.). An excellent NAP was recorded from the upper trunk (U.T.) with input from C-5 and C-6 nerve roots. Amplification and time for each division is shown below each trace. Distance from stimulation to recording = 5 cm.

neither sympathetic blocks nor sympathectomy were necessary. Three years postoperatively, function in the upper and middle trunk is now complete. He has had improvement in sensation in the ulnar distribution and has excellent forearm muscle function, including flexor profundus, to all fingers as well as finger and thumb extensors. Intrinsic muscles of the hand, particularly the interossei and the abductor pollicis, remain weak.

Case 4

In 1971, this 55-year-old woman developed pain and weakness in the ulnar distribution of her left arm. She had undergone a transaxillary first-rib resection in that same year for a suspected thoracic outlet syndrome. She had enjoyed initial relief, but her symptoms recurred approximately 3 months postoperatively. In February, 1973, the patient had a transaxillary re-exploration with further resection of the first rib. Because of progression of her neurological deficit to involve median- and ulnar-innervated hand muscles, a supraclavicular exploration of her plexus was performed in 1974. A large neurofibroma of the proximal plexus was encountered. Resection was attempted under the microscope by a neurosurgeon and approximately 25% of the mass was removed. At this time the patient was referred to the L.S.U. Medical Center.

Examination. She had complete lower and middle trunk dysfunction and partial upper trunk loss of function. In addition, she had severe arm and hand pain which was difficult to control by medication. An EMG demonstrated complete denervation in the lower and middle trunks and partial denervation in the upper trunk. Myelography showed extradural defects at the left C-7, C-8, and T-1 levels.

Operations. A cervical laminectomy was performed with excision of neurofibromas involving nerve roots C-7, C-8, and T-1. The roots were then sectioned as far lateral in the intervertebral foramina as possible. The patient was returned to the operating room 3 weeks later for exploration of the brachial plexus by the posterior subscapular approach. At operation, a large mass was found involving the lower and middle elements of the plexus (Fig. 6). Nerve action potentials were absent in both middle and lower trunks but could be recorded from the upper trunk when either the C-5 or C-6 roots were stimulated. Excision of the remainder of the tumor was accomplished by section of the lower elements of the plexus at the level of the divisions.

At follow-up examination, 2 1/2 years postoperatively, the patient was free of pain and had no evidence of recurrence. Triceps, most forearm, and all hand function remained absent.

Case 7

This 38-year-old woman with Hodgkin's disease was referred to our service. She had received 50 cobalt radiation treatments to the neck and supraclavicular area 5 years previously. She complained of generalized tingling and weakness of the right hand, worse in the ulnar distribution. In addition, she had shoulder, arm, and hand pain.
Examination. There was a partial lower trunk and mild middle trunk dysfunction with intact upper trunk function. An EMG showed incomplete denervation of muscles innervated by the lower trunk. In addition to these neurological findings, the patient had extensive radiation changes of the anterior chest wall, with dense scar formation palpable over the entire supraclavicular fossa.

Operation. A posterior subscapular approach was employed because of suspected involvement of the plexus at the root and trunk level and the irradiation changes anteriorly. At surgery, dense scar enveloping all the trunks and some roots and divisions were encountered. Scar excision and neurolysis were performed. The neural elements were yellowed and somewhat atrophic. Nerve action potentials were present in all three trunks, but were quite small in the lower trunk.

Follow-up examination at 1½ years post-operatively found the patient with decreased hand intrinsic muscle function but considerably improved middle trunk function and relief of most of her pain.

Case 9

This 35-year-old man was referred for evaluation of left arm weakness following an unsuccessful transaxillary first-rib resection for thoracic outlet syndrome.

Examination. There was complete lower trunk and partial middle trunk dysfunction. An EMG and nerve conduction studies confirmed partial denervation in muscles innervated by the middle and lower trunks with those of the lower trunk being more severely involved.

Operation. Because of the proximal involvement of the plexus and prior transaxillary approach, a posterior subscapular approach was employed. At surgery, the T-1 nerve root was found to have been avulsed, with extensive scar formation about the lower and middle trunks. Nerve action potentials from C-8 to the lower trunk were absent. Nerve action potentials from C-7 root to the middle trunk were present. Scar excision and neurolysis of the middle and lower trunks were performed. Sural nerve cable grafts from the C-8 and T-1 roots to the lower trunk were performed. At follow-up examination 1 year later, there has been no improvement in lower trunk function; however, middle trunk function has improved.

Discussion

Indications for surgical exposure of the brachial plexus via the subscapular approach are varied. Proximal brachial plexus lesions involving extraspinal roots and/or trunks can be advantageously exposed by this technique provided there is some potential for surgical correction. Each of the cases reported in this series had proximal lesions but not all were correctable. Suspected thoracic outlet syndromes complicated by extensive neurological findings can be handled with the
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In addition to resection of the first rib from a posterior approach, a neurolysis of most of the proximal brachial plexus was carried out in this series of patients. The ability of a neurolysis to improve function distal to an injured neural element is debatable, for regeneration may occur without neurolysis. However, the procedure of neurolysis, since it frees the nerve from surrounding scar and adjacent anatomic structures, does permit accurate identification of the injured element, and more importantly, electrophysiological assessment by nerve action potential recording. If nerve action potentials are recorded at the proper interval following injury, it may provide at least physiological grounds for a decision for or against resection and suture. In addition to possible improvement in distal function, neurolysis may sometimes help pain of a non-causealgic nature, especially if the procedure decompresses constrictive scar particularly in an area anatomically predisposed to entrapment, such as the thoracic outlet or the olecranon notch or carpal tunnel regions. Manipulation of the nerve necessary to accomplish such a decompression may also be responsible for relief of pain in some of these cases. Thus, in our cases where pain was a problem, particularly in those with severe postirradiation damage, any relief gained might be attributed either to first-rib resection and removal of scar (and thus decompression of the thoracic outlet) or to manipulation of the nerve. Since irradiation affected not only soft tissue surrounding the brachial plexus but also the neural elements themselves, which appeared yellowed and atrophic, manipulation of these damaged elements, even if done carefully, could lead to further functional loss as may have happened in Case 11.

References

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