A Lateral Approach to the Cervical Spine: Technique and Indications*

H. VERBIEST, M.D.
Neurosurgical Department, State University of Utrecht, Utrecht, The Netherlands

THE lateral surgical approach to the cervical spine is a relatively recent development. Küttner[11] in 1917 described a technique for exposing the vertebral artery between the transverse processes. In his paper he mentioned that Helferich had suggested removal of the anterior rim of the foramen transversarium, but no further details of this technique were given until Henry's[8] precise description of the exposure of the second portion of the vertebral artery. This procedure was also used by Elkin and Harris[3] for traumatic vertebral arteriovenous fistulae.

We had occasion to perform this operation for a spontaneous vertebral arteriovenous fistula, following Henry's procedure. The vertebral artery was lifted from its bed by means of tapes applied above and below the lesion, and the abnormal communications could be occluded while the artery remained patent.[21] As we viewed the operative exposure, it occurred to us that this procedure provided excellent access to the lateral aspects of the cervical vertebral bodies, the intervertebral foramina, and the portion of the anterior rami of the brachial plexus lying in the neural grooves of the transverse processes.

Since then, we have used this approach (Figs. 1–3) on a small number of patients who had lateral bony spurs compressing the vertebral artery, arthritic spurs compressing cervical nerve roots, lateral rupture of a cervical disc, or damage to the upper portion of the brachial plexus near the transverse processes. All operations were performed under the control of an x-ray image intensifier and a television monitor to facilitate identification of the level of the lesion.

Lateral Spondylotic Spurs Compressing the Vertebral Artery

These deformities have been discussed recently by Bakay and Leslie,[1] who removed most of the lateral spurs using the Cloward technique.

Hardin, *et al.*,[7] were the first to describe relief of lateral spur compression of the vertebral artery by exploring the artery in its canal and removing the spur with a bone curette. No further details of the operative technique were given. Jackson operated on a similar patient reported by Gortvai.[5] Recently, Hardin[6] reported on 15 patients in whom osteophytic compression of the vertebral arteries was treated by removal of the anterior and posterior roots of the involved transverse processes. No mention was made of the removal of the spurs.

It is still an open question whether this type of decompression is sufficient, since rotation of the head with the chin to the opposite side, producing traction on the artery, may result in its displacement toward the lateral spurs. We have chosen to remove these spurs after exposure of the artery in its canal; excision of a disc or making holes in the vertebral bodies thus become unnecessary.

Operative Technique. Our operation has been a modification of Henry's technique. Henry placed the patient with the chin turned away from the vessel. In cases of spondylotic compression this position may lead to occlusion of the vertebral artery; therefore, we placed the head in a midposition. In this position, moreover, it is easier to approach the transverse processes between the sternomastoid muscle and the larger vessels on one side and the pharynx and larynx on the other, instead of retracting the sternomastoid muscle medially. The attachments of the longus colli, and if necessary of the longus capitis muscles, to the anterior tubercles of the transverse processes above and below the level of the lateral spur are sectioned (Fig. 3 A); these muscles are retracted medially, with care taken not to injure the cervical sympathetic chain.

Next, the anterior roots of these transverse processes as well as the costotransverse lamellae are removed, thus allowing lateral

Received for publication April 28, 1967.
* Presented at the Annual Meeting of the Harvey Cushing Society, San Francisco, California, April 20, 1967.

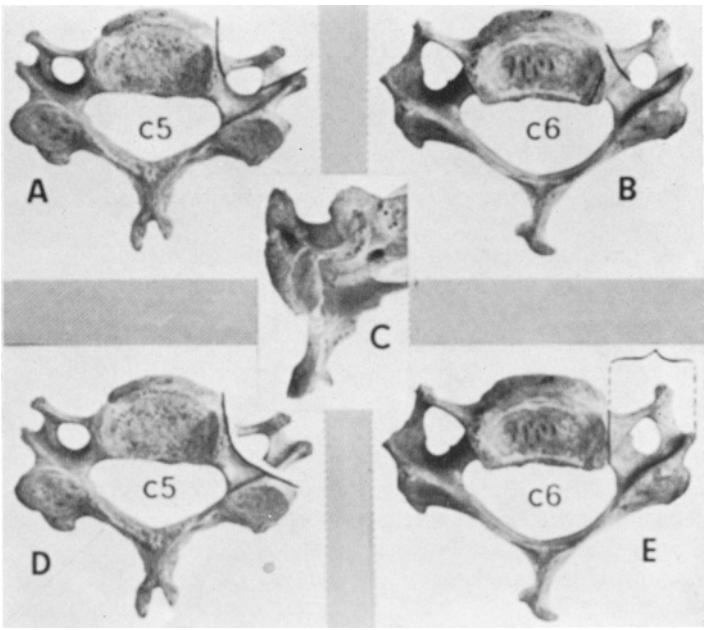

FIG. 1. Bony resections used in lateral approach to the cervical spine (dark lines). *A*. Resection of anterior root of the transverse process and costotransverse lamella allows lateral retraction of the vertebral artery and removal of lateral compressing spurs. *B*. Same resection as in *A* but in addition removal of the lateral portion of the uncinate process for access to posterior spurs or a lateral ruptured disc. *C*. Oblique view of transverse process. The anterior ramus lying in the neural groove is bounded anteriorly by the anterior tubercle, posteriorly by the posterior tubercle, and at the base by the costotransverse lamella. *D*. Resection of the transverse process in proximal lesions of the superior rami of the brachial plexus. *E*. Bracket indicates improved access to anterior rami for performing neurolysis or nerve suture.

displacement of the vertebral artery (Figs. 1 A and 3 B). This resection must be performed carefully to avoid damage to the anterior roots of the brachial plexus. After slight lateral retraction of the vertebral artery, the lateral spurs are removed piecemeal by a rongeur. Even in the presence of radicular branches, the vertebral artery can be safely retracted a few millimeters laterally.

Hypertrophic Changes of Luschka's Joints Producing Narrowing of the Intervertebral Foramen

The same operative technique allows a ready access to the intervertebral foramina, which are easily found by following the course of the exposed anterior rami of the brachial plexus medially (Fig. 3 B). The osteophytes can be removed by means of a guarded drill or small osteotomes (Fig. 1 B).[9] Disc excision is not necessary unless the disc space is opened. The advantage of this method compared to posterior foramenectomy is that the posterior articulations remain intact. Its advantage over an anterolateral approach is the visualization of the cervical nerve roots and the consequent reduction in the risk of damage to them.

The lateral approach also allows removal of transverse ridges after excision of the uncinate process and the intervertebral disc; the transverse ridge is then removed proceeding from the intervertebral foramen inward. Better visualization of nerve roots is again an important advantage.[22]

When exposing the anterior rami we confirmed Kirgis' observation that many fibers of the anterior scalene muscle appear to originate from the sheaths of these nerves.[10] Kirgis stressed the possible significance of this relationship in the production of the scalenus anticus syndrome. We divided the muscular attachments to the exposed anterior rami. Venous bleeding was arrested by stripping the venous plexus from the artery in the exposed area, occluding its lateral branches, and applying surgicel on both ends of the exposed

portion of the artery. The stripping should be performed carefully to avoid damage to radicular arteries leaving the vertebral artery. These procedures were used in the following two cases.

Case 1. This 61-year-old man had complained of neck pain since 1949 and the development of right hemiparesis and paresthesia in the left leg since 1966.

Examination. Exaggerated tendon reflexes were present in the right arm and leg, a Babinski reflex on the right, diminished sensation for all modalities in the left leg, and extensor weakness of the right hand and fingers. There was no muscle wasting or signs of denervation in the electromyogram of the neck, the arms, and hands. The lumbar cerebrospinal fluid protein was 60 mg/100 ml, and there was no Queckenstedt response with extension of the head.

X-ray showed spondylotic wedged deformity of the vertebral bodies of C-4 and C-5, resulting in anterior angulation of the cervical spine. The AP view showed considerable lateral hypertrophic changes of the vertebral joints at C5–6 and C4–5. At these levels the intervertebral foramina were also very narrowed (Fig. 4 A). The tomoairmyelograms showed focal narrowing of the cervical spinal canal at the levels of the C4–5 and C5–6 discs, where a positive contrast myelogram revealed pronounced transverse ridges. The right vertebral angiogram demonstrated considerable lateral deflexion and narrowing of the artery caused by lateral spurs at C4–5 and C5–6 (Fig. 5 A). The left vertebral angiogram also showed narrowing of the vessel at the C4–5 level.

Operation (Bilateral). On August 30, 1966, after exposure of the transversarial foramina, the vertebral arteries were retracted slightly laterally with tapes, and the lateral hypertrophic bone removed. The uncinate processes of C-5 and C-6 were resected bilaterally, including the foraminal spurs. Through this lateral access, the C4–5 and C5–6 discs were excised. The posterior transverse ridges were removed proceeding from the intervertebral foramina inwards. Wedge-shaped tibial cortical grafts were inserted in the empty disc spaces for interbody fusion. Since there was no significant

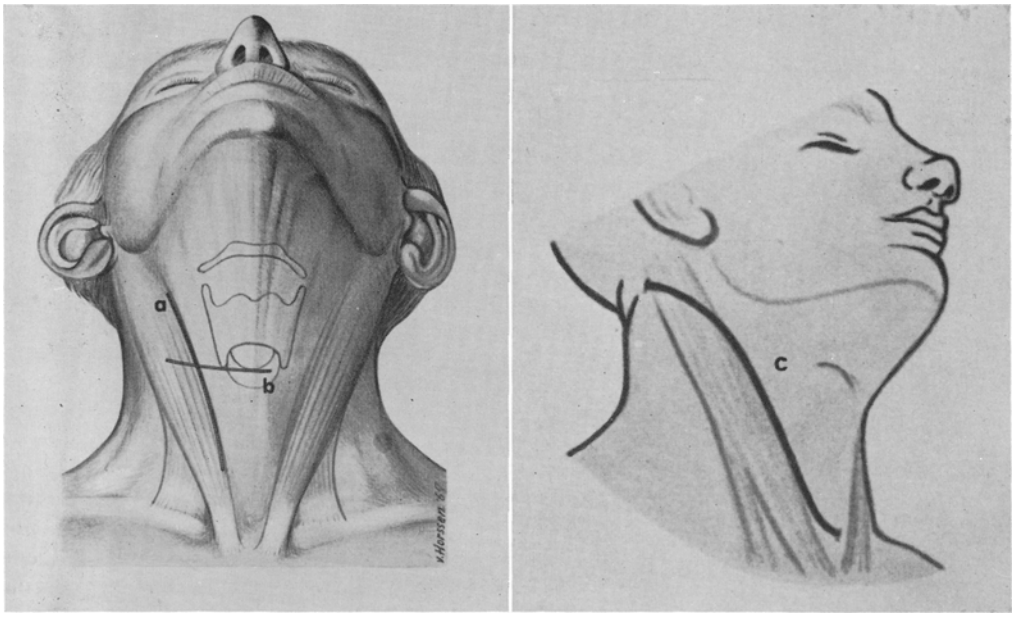

FIG. 2. Cutaneous incisions. Incision *a* is used for two-level operations on the middle or lower cervical spine, while *b* can be applied in one-level operations. For approaches to the upper portion of the cervical spine or for larger exposures, incision *c* is used. This allows section of the attachment of the sternocleidomastoid muscle to the mastoid process and eversion of this muscle. At the end of the operation the muscle is sutured to the mastoid process.

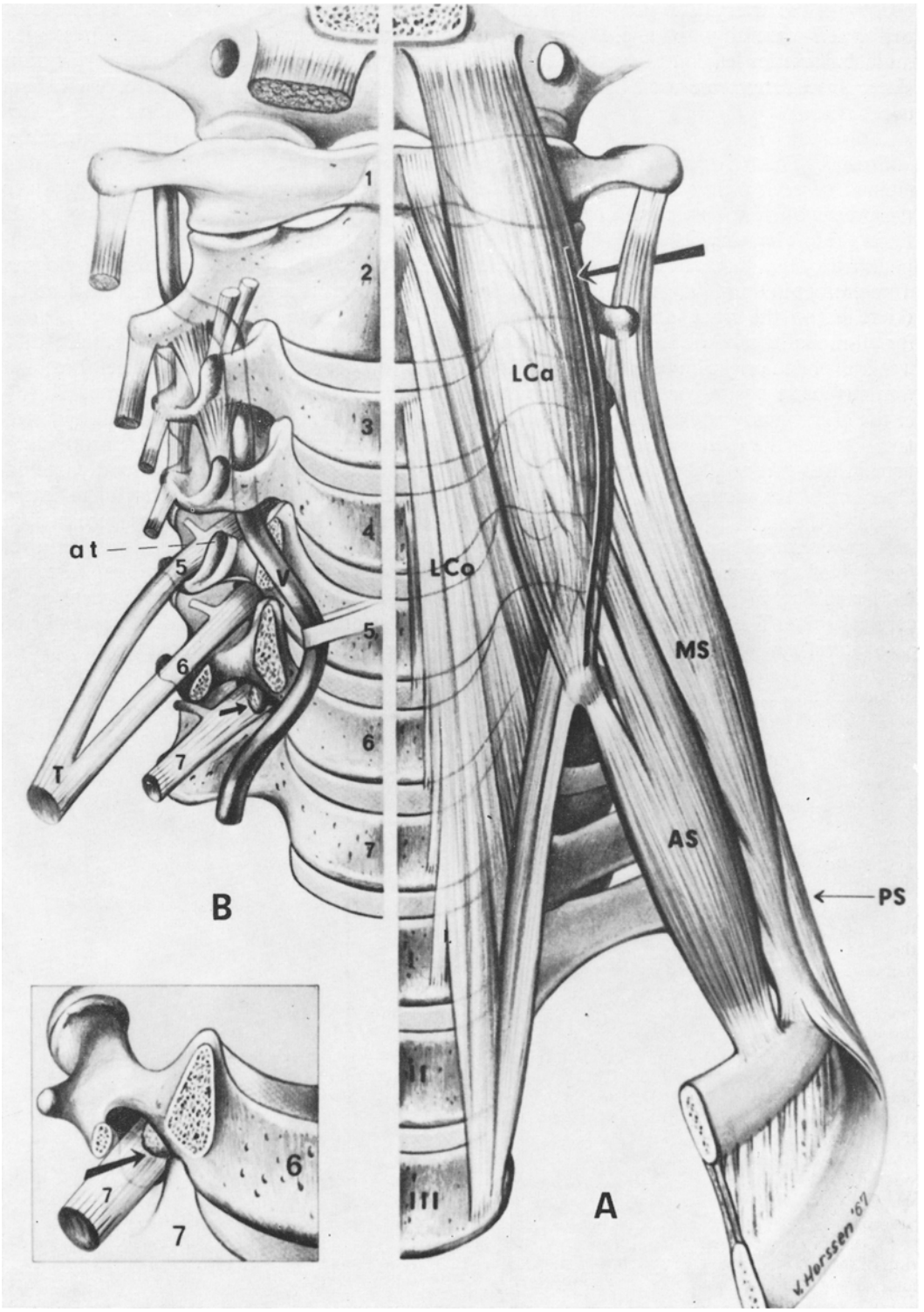

FIG. 3. Lateral exposure of the cervical spine. (*See facing page for legend.*)

transverse ridge at the C3–4 level, the C3–4 disc was removed by excision of the anterior annulus fibrosus. The posterior annulus fibrosus was left intact, and a wedge-shaped tibial cortical graft was inserted for correction of the anterior angulation.

Postoperative course. Vertebral angiography (Fig. 5 B) showed that the narrowing and deflections of the vertebral arteries produced by the lateral spurs no longer existed and that the lateral spurs had been removed on both sides. The intervertebral foramina at C4–5 and C5–6 in the oblique x-ray views showed the decompression in their anterior portions (Fig. 4 B). X-ray control films of the cervical spine 6 months later showed satisfactory fusion and correction of anterior angulation at the C3–4 level. The disturbance of sensation in the left leg disappeared, and the tendon reflexes became normal. The power in the legs was markedly increased. The patient could now walk for 30 minutes, whereas before the operation he was tired after 5 minutes.

Case 2. This 53-year-old man had complained for $1\frac{1}{2}$ years of paresthesia of the left middle and ring fingers and weakness of the left arm and hand, including complete paralysis of finger extension.

Examination. Atrophy and electromyogram denervation potentials were found in the left adductor pollicis, interosseus IV, abductor digiti V, extensor digitorum communis, flexor carpi ulnaris, and triceps brachii muscles. There were diminished left biceps and triceps tendon reflexes, and hypesthesia in the left C-7, C-8 and T-1 dermatomes. There were normal manometric tests on lumbar puncture

FIG. 3. *A. Muscles attached to the lateral portion of the cervical spine.* These muscles are approached between the sternocleidomastoid muscle and the great vessels on the lateral side, and the airways and esophagus on the medial side. The following muscles are identified: *LCa*=longus capitis; *LCo*=longus colli; *AS*, *MS*, and *PS*=anterior, medial, and posterior scalenus muscles respectively. *Arrow* points to line of incision in this muscle mass. The longus colli and longus capitis muscles are retracted medially. The attachments of the anterior scalenus muscle are cut if the anterior tubercle must be removed.

B. Important skeletal landmarks for exposure of the vertebral artery, the intervertebral foramen, and the rami of the brachial plexus. *V*=vertebral artery; *5*, *6*, and *7*=the anterior rami of the brachial plexus; *T*=superior trunk of the brachial plexus. Exposure of the vertebal artery in its canal. The insertions of the longus capitis and longus colli muscles to the anterior tubercles of the transverse processes are sectioned in the area involved, and these muscles are retracted medially. The anterior intertransverse muscles extending between the anterior roots of the transverse processes are also removed, and the anterior rim of the foramen transversarium is resected. In the drawing, this has been performed with the transverse process of C-5. The vertebral artery is retracted laterally with tape (not shown) if it is compressed medially by bony spurs. Lateral retraction is facilitated by resection of the anterior tubercle and the costotransverse lamella, which form the lateral border of the foramen transversarium. The *inset* shows this resection performed at the C-6 level. Bony spurs can then be easily removed.

Exposure of the intervertebral foramen. The anterior rims of the foramina transversaria above and below the intervertebral foramen are resected, and the vertebral artery is retracted anteriorly. The extent of retraction depends on the presence and length of radicular arteries, which should not be torn. The radicular arteries leave the vertebrals 0.1 to 1 cm inferior to the roots.[20]

Identification of the intervertebral foramen is greatly facilitated by first exposing the corresponding anterior ramus of the brachial plexus where it lies behind the anterior tubercle (*at*) of the transverse process. This necessitates resection of this tubercle, care being taken not to damage the anterior ramus which lies just below (*inset*). Removal of the anterior tubercle entails also the removal of the corresponding insertion of the scalenus anterior muscle. Some of the latter fibers connect with the anterior ramus of the brachial plexus and these should also be interrupted. Following the anterior ramus from this point medially, removing the surrounding connective tissue as much as possible, leads without difficulty to the intervertebral foramen. Without following these landmarks, however, it is very difficult to identify the intervertebral foramen. Intraforaminal spurs are removed by means of small drills or osteotomes.

In Cases 3 and 4, soft lateral disc protrusions bulged outside the intervertebral foramen as indicated here in *B* and the *inset* by the arrow at the level of the C6–7 intervertebral foramen. In Case 5, the protrusion was completely inside the intervertebral foramen and the adjoining portion of the cervical spinal canal. The lateral disc protrusion is removed piecemeal by means of a pituitary forceps, whereas residual fragments in the anterior portion of the intervertebral foramen are removed using a small but strong curette. The curetting is performed towards the posterolateral aspect of the vertebral bodies to avoid damage to the dural sac or nerve roots. The protrusion may be adherent to the anterior ramus or spinal ganglion and then careful dissection is needed. In case of an associated anterior scalene syndrome, a superior scalenotomy is performed, with division of all attachments of the muscle to the anterior tubercles and anterior rami.

Special Warning. Because of the normal cervical lordosis, the anterior ramus of C-6 lies more anteriorly than that of C-7. During selective exposure of the C-7 anterior ramus, care should be taken not to damage the C-6 anterior ramus with a retractor.

and a CSF protein content of 54 mg/100 ml.

X-rays demonstrated spondyloarthritic changes of the lower cervical spine. The left intervertebral foramina at C5–6 and C6–7 were considerably narrowed by hypertrophic arthritic disease (Fig. 6 A). The AP view showed large lateral spurs at C5–6 and C6–7. The myelogram showed slight transverse ridges between C-4 and C-7 and a left lateral filling defect at the site of the C-8 root sleeve. Left vertebral angiography in the neck by retrograde pressure injection in the left brachial artery showed local narrowings and lateral deflections of the vertebral artery caused by pressure from the lateral spurs at the C5–6 and C6–7 levels and to a lesser degree at C4–5 (Fig. 7 A). Arteriography with the head turned to the right produced an occlusion at the C5–6 level, although rotation took place only in the upper cervical vertebrae (Fig. 7 B). No occlusion occurred when turning the head to the left.

Operation. On January 19, 1967, the anterior roots and costotransverse lamellae of the three corresponding transversarial foramina were removed and the vertebral artery exposed. The lateral spur at the C5–6 level was resected, but the vertebral artery did not re-expand, probably because of constricting fibrous tissue. After the latter had been dissected free, the artery assumed its normal width. The lateral spur at C6–7 and a lateral hypertrophic connective tissue mass at C4–5 were also removed, whereupon the diameter of the vertebral artery became normal at all exposed levels. The vertebral artery was then slightly retracted laterally with tapes; the cervical nerves C-6 and C-7 were exposed and followed to the intervertebral foramina. Anterior decompression of the foramina C5–6 and C6–7 was achieved by removal of the spurs and part of the uncovertebral joints. Since this resulted in exposure of the intervertebral discs, the latter were removed by means of a curette. The empty disc spaces were so flat that interbody fusion was not performed. The exposure of the C7–T1 intervertebral foramen was more difficult, but good

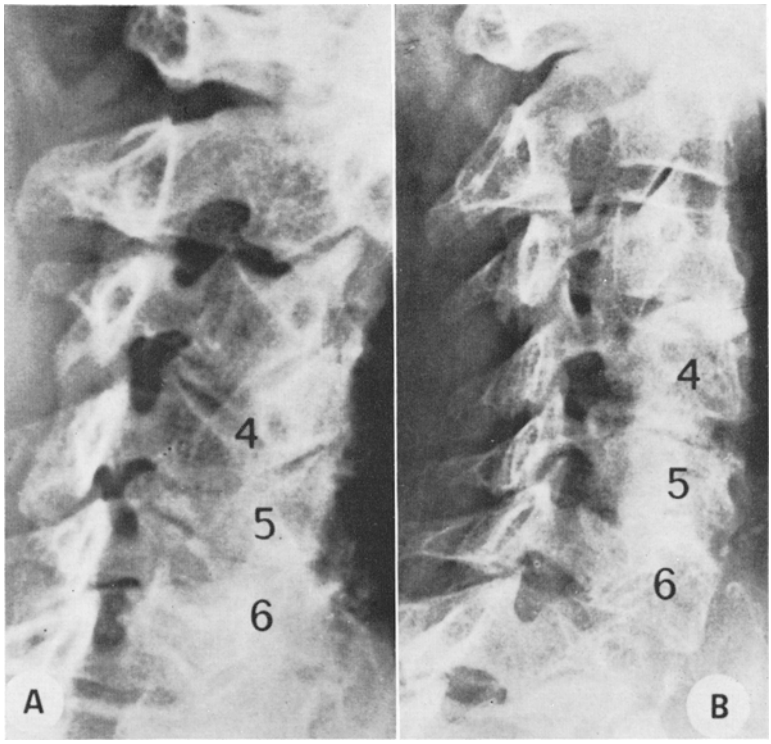

FIG. 4. *Case 1. A.* X-ray showing preoperative narrowing of intervertebral foramina C4–5 and C5–6. *B.* Postoperative x-ray showing anterior decompression of the foramina following removal of spurs. Note three-level interbody fusion.

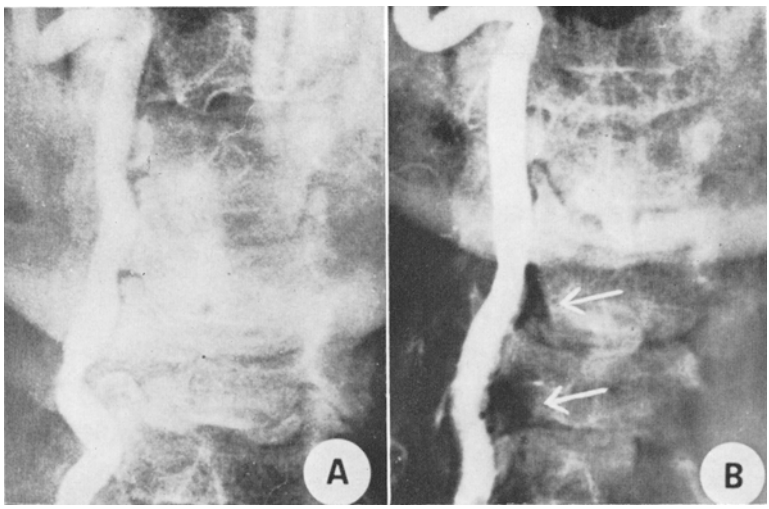

FIG. 5. *Case 1. A.* Preoperative angiogram showing lateral deflexion and narrowing of the right vertebral artery caused by lateral spurs at C4–5 and C5–6. *B.* Postoperative angiogram showing decompression of artery and removal of lateral spurs and uncinate processes (*arrows*).

access was obtained by removing the anterior root of the transverse process of C-7. A small curette was introduced into the foramen and a soft protruding disc mass removed.

Postoperative course. The postoperative left vertebral angiogram showed that the narrowing and distortion of the artery had disappeared (Fig. 7 C). No occlusion occurred when turning the head to the right. The oblique x-ray view of the cervical spine showed the anterior decompression of the left C5–6 and C6–7 intervertebral foramina (Fig. 6 B). Two months after the operation an increase of power in the left arm and hand was noted; the patient now could extend his fingers, although with diminished strength.

Lateral Protrusion of a Cervical Disc

In our cases, the anterior roots and costotransverse lamellae of the transverse processes above and below the lesion were resected and the vertebral artery was slightly and gently retracted laterally with tapes. A small curette was introduced into the intervertebral foramen and the protruded disc mass removed. In one of the patients (Case 3) there was an associated scalenus anticus syndrome. Semmes and Murphey,[15] who in 1943 made their basic contribution to our knowledge of lateral cervical disc rupture, noted that this rupture will cause spasm of the scalenus anticus muscle. Kirgis's anatomical finding,[10] described above, suggests that this muscle spasm causing traction on the anterior rami of the brachial plexus may contribute to the pain associated with a compressed nerve root. In Case 3, the scalenus anticus syndrome had preceded that of disc rupture for many years, so that there was reason to treat the conditions as separate entities. The advantage of the lateral approach was that removal of the protruded disc and scalenotomy could be performed in one operation.

Case 3. This 39-year-old man, for 24 years, had experienced paresthesia in all fingers of the left hand when elevating that arm. For 4 years he had suffered from recurrent left shoulder pain. In February, 1966, he felt a sudden severe cervical pain which spread to the radial side of the left arm and was accompanied by a stiff neck.

Examination. There was diminished sensation on the lateral side of the left forearm and a depressed left biceps reflex. The Adson test was positive on the left. Compression of the neck to the left by Spurling and Scoville's test produced radiating pains in the left shoulder and down the lateral side of the left arm. The electromyogram was normal. X-rays of the cervical spine showed a flattened C4–5 disc space with calcified deposits in its posterior part. There was no cervical rib. The lumbar CSF protein content was 77 mg/100 ml. The cervical myelogram showed a left lateral C5–C6 filling defect (Fig. 8 A). A diagnosis of

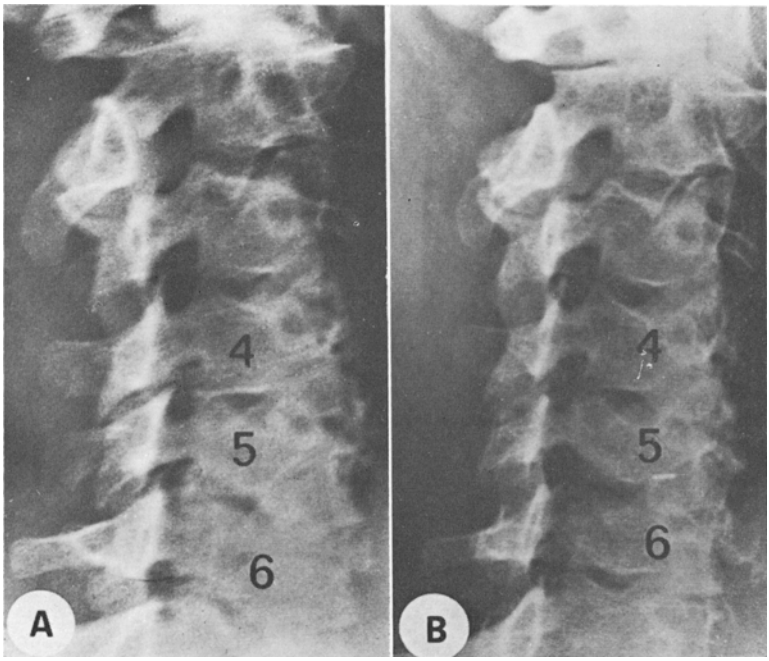

FIG. 6. *Case 2.* *A.* Preoperative oblique x-ray shows narrowing of intervertebral foramina at C5–6 and C6–7. *B.* Postoperative x-ray shows anterior decompression of these foramina.

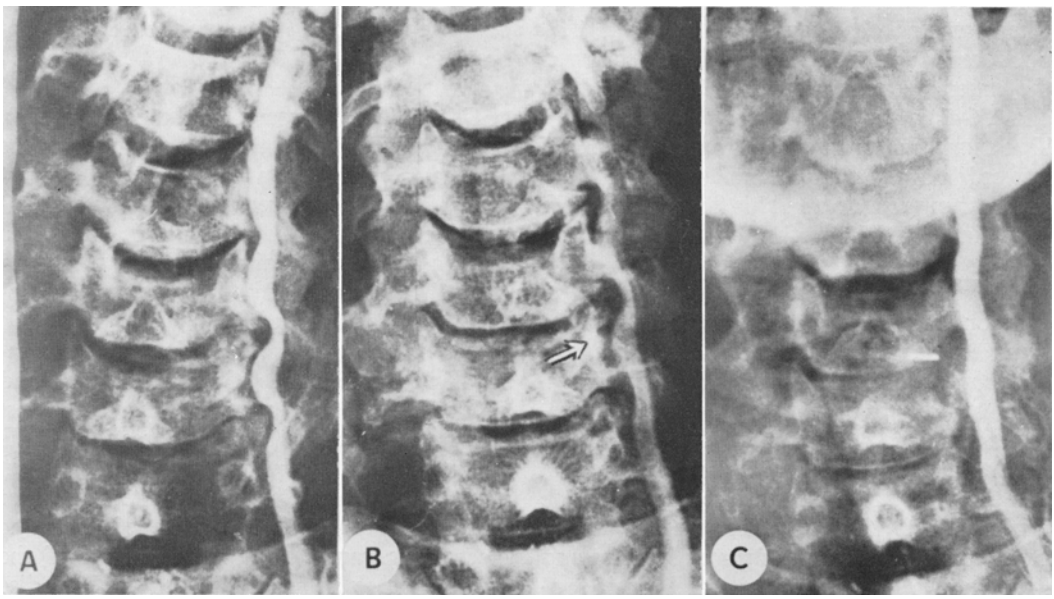

FIG. 7. *Case 2.* *A.* Preoperative left vertebral angiogram shows local narrowing and lateral deflection of the artery at C6–7, C5–6, and C4–5. *B.* Preoperative rotation of head to the right produced occlusion of vertebral artery at C5–6 level, although the rotation took place only in the upper cervical vertebrae. *C.* Postoperative vertebral angiogram shows decompression of artery by removal of uncinate processes and lateral spurs.

a combined left scalenus anticus syndrome and a left lateral protrusion of the C5–C6 disc was made.

Operation. On March 9, 1967, the well-developed scalenus anticus muscle was exposed through a supraclavicular T incision. It was cut and the subclavian artery dissected free from enveloping membranes. The C5–6 transverse processes were then exposed, their anterior roots resected, and the vertebral artery slightly retracted laterally with tapes. Profuse bleeding from the venous plexus and vertebral veins was controlled by gentle tape traction. A soft disc protrusion was removed from the intervertebral foramen at C5–6 by means of a curette.

Postoperative course. The patient made an uneventful recovery, and the complaints disappeared. Repeat cervical myelography 14 days after the operation showed that the left lateral filling defect was no longer present; the root sleeve of C-6 did not yet fill well (Fig. 8 C).

Case 4. This 45-year-old man had had neck pain for 1 year. Two months before admission he experienced severe acute pain in the neck that radiated through the left arm to the index and middle fingers. Since then, the neck had been held rigidly to the right; the patient also complained of paresthesia in the left index, middle, and ring fingers.

Examination. Examination showed a left C-7 root compression with a positive compression test, weakness of the triceps muscle, reduced triceps tendon reflex, and hypesthesia in the index, middle, and ring fingers and the dorsum of the hand. No other abnormalities were found except a positive Rossolimo sign on the left. The cerebrospinal fluid was normal. X-rays showed right lateral inclination of the neck, a small left lateral spur at C5–6, but no foraminal or posterior spurs. Cervical myelography demonstrated a left lateral filling defect at C6–7.

Operation. On March 14, 1967, the left C6–7 intervertebral foramen was exposed according to the technique already described. The lateral spur demonstrated by x-ray had created a small depression in the vertebral artery and was removed. The anterior ramus of C-7 was hyperemic and surrounded by fibrous adhesions. A soft tissue mass protruded from the intervertebral foramen of C6–7 and was adherent to the anterior aspect of the C-7 nerve root. It was dissected free and removed. The intraforaminal portion of the ruptured disc was removed with the bone curette.

Postoperative course. Neck movements were free and the pains had disappeared by the next day. The patient still had numbness of the left index, middle, and ring fingers. A control myelogram revealed that there was no longer a filling defect at the C6–7 level.

Case 5. This 50-year-old man had a sudden development of pain in the left arm radiating

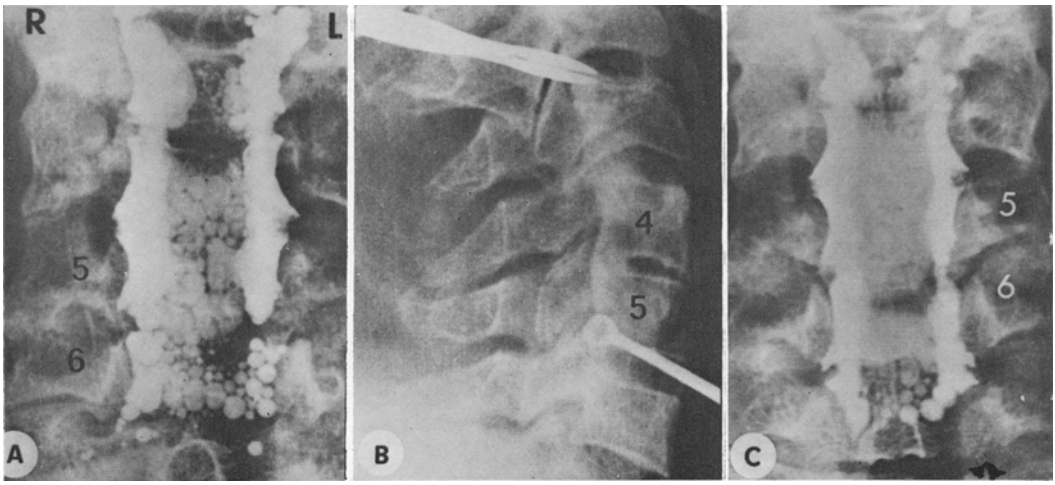

FIG. 8. *Case 3. A.* Preoperative myelogram shows interruption in the column of contrast medium at the left C5–6 level. *B.* X-ray taken during operation shows curette introduced laterally into the superior portion of the left intervertebral foramen C5–6. *C.* Postoperative myelogram no longer shows interruption of the contrast medium at C5–6. Left root sleeve of C-6 is still not filled.

into the index and middle fingers 2 months before admission. This was followed by neck pains a few days later. Flexion and extension of the head and compression tests produced shooting pains in the left arm. The left triceps reflex was reduced, and there was marked hypesthesia in the index finger and to a lesser degree in the middle finger and dorsum of the hand. An electromyogram showed denervation potentials in the left extensor muscles of the neck and in the left triceps brachii muscle. The lumbar CSF protein content was 108 mg/100 ml. The cervical myelogram showed a filling defect on the left at the C6–7 level (Fig. 9 A).

Operation. On September 9, 1967, the left intervertebral foramen C6–7 was exposed. There was no protrusion of disc mass outside the foramen. The anterior border of the intervertebral foramen was enlarged by drill and osteotome. Following this, protruding disc material lying in front of the spinal ganglion and the origin of the C-7 anterior ramus could be removed.

Postoperative course. The patient was mobilized the day after operation. His pains had disappeared, and the myelogram repeated 7 days later was normal (Fig. 9 B).

Postganglionic Upper Brachial Plexus Paralysis Due to Traction Injuries

Erb,[4] whose name is associated with this type of lesion, found its most frequent site at or near the junctions of the C-5 and C-6 anterior rami, where they form the superior trunk (Erb's point). Traction injuries leading to upper brachial plexus paralysis have been thought to be due to forceful shoulder-head separation while the patient's arm is at his side. It has been shown experimentally that this mechanism produces greatest stress on the upper nerve roots,[19] which results either in root avulsion from the cord or rupture of the extraspinal portion at or near Erb's point. It is important to distinguish between these two lesions because only the rupture is apt to be treated surgically. There are two major problems in surgical repair:

1. After resection of the damaged area, the gap may be of such length that end-to-end suture of the nerve stumps is impossible. In such cases the gap can be repaired by using autogenous nerve grafts.[14]
2. The damage may be extended to or into the area where the anterior rami lie in the neural grooves of the transverse processes.[18]

Taylor[18] stressed that with proximal extension of the lesion adequate nerve suture cannot be performed; he applied a modified procedure instead. He split the cicatrized root up into the intervertebral foramen, and, if good nerve bundles were exposed above, he sutured the distal end of the nerve into the cleft "with the hope that good union will occur." In 1922 Stookey[16] still advised the Taylor procedure,

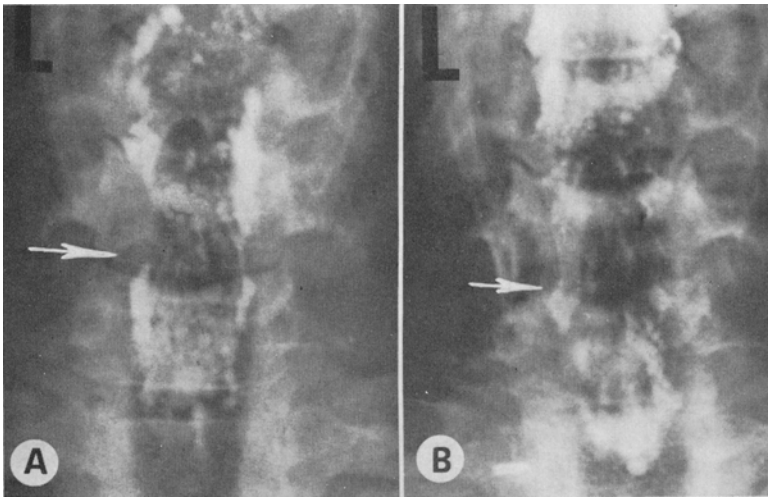

FIG. 9. *Case 5. A.* Myelogram before operation showing left lateral filling defect at the C6–7 level (*arrow*). *B.* Myelogram 1 week after operation no longer shows interruption of the contrast medium at the left C6–7 level (*arrow*) and even the C-7 root pouch is filled with contrast medium.

but Pollock and Davis[13] considered these lesions surgically unapproachable, an opinion shared by d'Aubigné[12] 20 years later. Tarlov and Day[17] advised the use of a plasma clot suture.

Our experience showed that resection of the transverse processes (Fig. 1 D) and retraction of the vertebral artery upward and medially allowed good access to the anterior rami as far as the real intervertebral foramina. The gain in exposure was about 2 cm at C-6 and 1.5 cm at C-5 (Fig. 1 E). Most authors agree that, of all types of brachial plexus lesions, the surgical repair of a postganglionic upper plexus lesion has the best chance of ultimate functional recovery. Surgical exploration, however, is only justified when it has been proven that the lesion is postganglionic. In the following two cases, the diagnosis was based on the results of sweating and intradermal skin tests, a normal cervical myelogram, and the absence of electromyographic changes in the neck muscles innervated by the fifth and sixth cervical nerves. Although a preoperative diagnosis of proximal extension of the lesion in the anterior rami can be made with considerable confidence, the extent of the damage can only be ascertained during operation.

Operative Technique. The procedure was the same in both cases (Fig. 10). We used a T-shaped supraclavicular incision, its horizontal leg parallel to the clavicle and its vertical leg extending to the junction between the upper and middle thirds of the sternomastoid muscle. This muscle, the carotid arteries, and internal jugular vein we dissected free, allowing them to be retracted medially as well as laterally during the operation. The attachments of the anterior scalenus muscle to the anterior tubercles of the transverse processes of C-4, C-5, and C-6 were sectioned. In both cases, these parts of the muscles were fibrotic, confirming Barnes' statement[2] that, before pathological stretching of the nerve roots can occur, the violence must be severe enough to rupture the scalene muscles or to avulse the tubercles of the transverse processes. The fibrotic portion of the anterior scalenus muscle was removed.

The attachments of the longus colli and capitis muscles to the anterior tubercles of the transverse processes of C-4, C-5, and C-6 were sectioned and the muscles retracted medially. We took great care not to sever the phrenic nerve or the cervical sympathetic chain. The anterior roots of the C4–6 transverse processes including their anterior tubercles, the costotransverse lamellae, and posterior tubercles were removed, a delicate procedure because of the proximity of the anterior rami. The vertebral artery was lifted from its bed with tapes. No radicular branches of the vertebral artery were encountered. The anterior rami were freed from surrounding connective tissue as far as the real intervertebral foramina (Fig. 10). The only remaining bony structures in these areas were the posterior articular processes, which lie posterolaterally to the intervertebral foramina and posteriorly to the anterior rami (Fig. 1 D).

Since the anterior rami of C-5 and C-6 make downward angles across the transverse processes, these angles increase to 180° after the bony resections. This implies some reduction of the gap between nerve ends after resection of the scar, but the greatest advantage is that nerve sutures can be made in an area which heretofore has been inaccessible. This procedure is demonstrated in a cadaver dissection (Fig. 10).

Case 5. This 31-year-old man was admitted in October, 1966, 4 months after a right brachial plexus lesion caused by a motorcycle accident.

Examination. There was a complete deficit in the areas supplied by the anterior rami of C-5 and C-6. The function of the diaphragm was normal.

Operation. The superior trunk of the brachial plexus was normal on palpation except in its proximal portion. The distal portions of the anterior rami of C-5 and C-6 were adherent to each other and surrounded by scar tissue. The scar tissue extended into the area of the transverse processes. Following resection of the latter, the anterior rami of C-5 and C-6 could be freed from dense extraneural scar and separated from each other. The rami showed no swelling, had a normal diameter, but were unusually hard as far as the intervertebral foramina. The phrenic nerve was also adherent to the scar and was dissected free. The length of abnormal nerves was too great to allow end-to-end sutures after resection, and the operation was terminated after neurolysis.

Postoperative course. When last seen in February, 1967, the patient showed considerable improvement of motor power. Active

contractions of the right deltoid and biceps muscles against gravity were noted.

Case 6. This 58-year-old man had an upper brachial plexus paralysis caused by a motorcycle accident on August 14, 1966. The clinical picture indicated a proximal lesion of the anterior rami of C-5 and C-6.

First operation. On January 16, 1967, a left hemilaminectomy of C-5 and C-6 was performed; the intradural nerve roots and the root pouches were intact.

Second operation. On February 6, the supraclavicular brachial plexus was exposed. The anterior rami of the fifth and sixth cervical nerves were short and involved in an endoneuroma extending from the transverse processes down to the superior trunk. After resection of the transverse processes of C-5 and C-6 and of the anterior root of the transverse process of C-4, the vertebral artery was retracted with tapes and the neuromas were resected. In the C-5 ramus, all nerve bundles appeared to be interrupted by scar tissue, and in the C-6 ramus, only one small nerve bundle traversed the scar. The cut nerve ends had a healthy appearance; the gaps between the ends were about 3 cm. After elevation of the shoulder it was possible to place a suture between the anterior rami and the superior trunk. At the end of the operation the elevated shoulder was immobilized in plaster.

Thus, resection of the transverse processes made possible exact cuts between the scarred and healthy zones of the anterior rami, and facilitated the application of end-to-end nerve sutures, which otherwise would not have been possible.

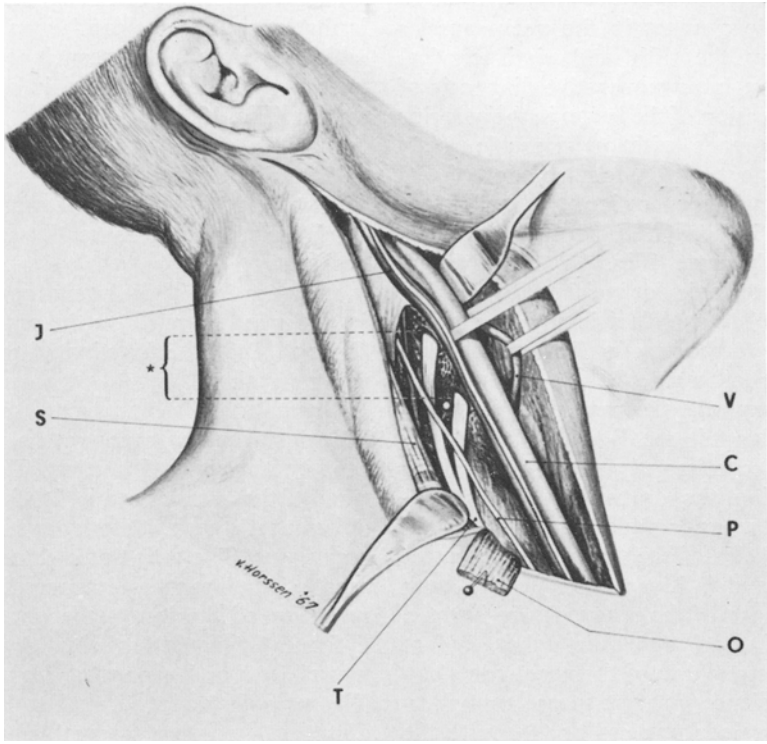

FIG. 10. *Exposure of superior brachial plexus lesions as far as the area of the neural grooves of the transverse processes.* (artist's drawing of a cadaver). Because of the rigidity of the embalmed tissues, another incision was used than that described in the text. *V* = vertebral artery; *C* = carotid artery retracted with tape; *J* = jugular vein; *S* = sternocleidomastoid muscle; *P* = phrenic nerve. The anterior scalenus muscle has been resected. *T* = superior trunk of the brachial plexus. Asterisk and bracket, which enclose the same area as in Fig. 1 E, indicate gain in length of exposure of the anterior ramus of C-5 following resection of the entire transverse process of C-5. The same procedure has been followed at the C-6 level. In resecting the scalenus anterior muscle, care has been taken not to injure the phrenic nerve (*P*). Interruption of the omohyoid muscle (*O*) may facilitate the exposure of the superior trunk of the brachial plexus and forward retraction of the great vessels.

Postoperative course. When the patient was last seen in October, 1967, active contractions of the biceps were possible.

Summary

We have described techniques for the lateral approach to the cervical spine which provide satisfactory access to the vertebral artery, lateral aspects of the cervical vertebral bodies, intervertebral discs, intervertebral foramina, and anterior rami of the brachial and cervical plexuses. We have reported application of these methods to removal of lateral spurs compressing the vertebral arteries, hypertrophic compression of cervical nerve roots in the intervertebral foramina, soft lateral disc protrusions, and neurolysis and nerve suture in certain lesions of the brachial plexus.

References

1. BAKAY, L., and LESLIE, E. V. Surgical treatment of vertebral artery insufficiency caused by cervical spondylosis. *J. Neurosurg.*, 1965, *23:*596–602.
2. BARNES, R. Traction injuries of brachial plexus in adults. *J. Bone Jt. Surg.*, 1949, *31B:*10–16.
3. ELKIN, D. C., and HARRIS, M. H. Arteriovenous aneurysm of vertebral vessels: report of 10 cases. *Ann. Surg.*, 1946, *124:*934–951.
4. ERB, W. Ueber eine eigenthümliche Localisation von Lähmungen im Plexus Brachialis. *Verh. der Naturhist. Mediz. Vereins zu Heidelberg, neue Folge*, 1874–1877, *1:*130–137.
5. GORTVAI, P. Insufficiency of vertebral artery treated by decompression of its cervical part. *Br. med. J.*, 1964, *2:*233–234.
6. HARDIN, C. A. Vertebral artery insufficiency produced by cervical osteoarthritic spurs. *Archs Surg., Chicago*, 1965, *90:*629–633.
7. HARDIN, C. A., WILLIAMSON, W. P., and STEEGMANN, A. T. Vertebral artery insufficiency produced by cervical osteoarthritic spurs. *Neurology, Minneap.*, 1960, *10:*855–858.
8. HENRY, A. K. *Extensile exposure.* Edinburgh and London: E. and S. Livingstone Ltd., 1966, 320 pp. (See pp. 58-72.)
9. JUNG, A. Résection de l'articulation unco-vertébrale et ouverture du trou de conjugaison par voie antérieure dans le traitement de la nevralgie cervicobrachiale Technique opératoire. *Mem. Acad. Chir.*, 1963, *89:*361–368.
10. KIRGIS, H. D., and REED, A. F. Anatomical relations of possible significance in the production of the scalenus anticus syndrome. *Anat. Rec.*, 1947, *97:*348
11. KÜTTNER, H. Die Verletzungen und traumatischen Aneurysmen der Vertebralgefässe am Halse und ihre operative Behandlung. *Beitr. klin. Chir.*, 1917, *108:*1–60.
12. MERLE D'AUBIGNÉ, R., BENASSY, J., and RAMADIER, J. O. *Chirurgie orthopédique des paralysies.* Paris: Masson et Cie., 1966, 431 pp. (See pp. 122–139.)
13. POLLOCK, L. J., and DAVIS, L. *Peripheral nerve injuries.* New York: Paul B. Hoeber, 1933, 678pp. (See pp. 448–449.)
14. SEDDON, H. J. The use of autogenous grafts for the repair of large gaps in peripheral nerves. *Br. J. Surg.*, 1948, *35:*151–173.
15. SEMMES, R. E., and MURPHEY, F. The syndrome of unilateral rupture of the sixth cervical intervertebral disk. *J. Am. med. Ass.*, 1943, *121:*1209–1214.
16. STOOKEY, B. *Surgical and mechanical treatment of peripheral nerves.* Philadelphia and London: W. B. Saunders, 1922, 475 pp. (See pp. 249–251.)
17. TARLOV, I. M., and DAY, R. Myelography to help localize traction lesions of the brachial plexus. *Am. J. Surg.*, 1954, *88:*266–271.
18. TAYLOR, A., and CASAMAJOR, L. Traumatic Erb's paralysis in the adult. *Ann. Surg.*, 1913, *58:*577–600.
19. TAYLOR, P. E. Traumatic intradural avulsion of the nerve roots of the brachial plexus. *Brain*, 1962, *85:*579–602.
20. TURNBULL, I. M., BRIEG, A., and HASSLER, O. Blood supply of cervical spinal cord in man. A microangiographic cadaver study. *J. Neurosurg.*, 1966, *24:*951–965.
21. VERBIEST, H. Extracranial and cervical arteriovenous aneurysms of the carotid and vertebral arteries. *Johns Hopkins Med. J.*, 1968. (In press).
22. VERBIEST, H., and PAZ Y GEUSE, H. D. Anterolateral surgery for cervical spondylosis in cases of myelopathy or nerve-root compression. *J. Neurosurg.*, 1966, *25:*611–622.