

The Treatment of Certain Cervical-Spine Disorders by Anterior Removal of the Intervertebral Disc and Interbody Fusion *

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INTRODUCTION

The purpose of this paper is threefold: to describe a surgical procedure for removal of cervical intervertebral discs and for fusion of the cervical spine by the anterior approach¹⁶, to outline some indications for this procedure, and to report the results in the first fourteen patients in whom this surgical procedure was employed.

Disc degeneration, with or without accompanying osteophyte formation, subluxation, instability of one cervical vertebra on another, or intervertebral-disc protrusion is the pathological change usually associated with neck, suprascapular, interscapular, occipital, arm, hand, and chest pain stemming from the cervical spine.

In the authors' experience intervertebral-disc degeneration with accompanying osteophyte formation (osteo-arthritis or spondylosis of the cervical spine) is the most common pathological change associated with neck, shoulder, arm, and hand pain^{5, 6, 7, 9, 13}. Of the fourteen patients reported here, ten had these changes associated with cervical-nerve-root irritation or compression. Three patients had disc degeneration alone⁸. This degeneration, not yet accompanied by visible osteophyte formation or significant disc narrowing, was demonstrated by discography. One patient had cervical subluxation and, in addition to pain in the neck, shoulder, and left arm, also had long-tract signs due to spinal-cord involvement secondary to the spine instability.

The position and size of osteophytes are important in the cervical spine. Those arising from the posterolateral vertebral-body joints (joints of Luschka) may impinge on cervical-nerve roots, on the vertebral artery, or on both^{7, 10, 12}. Those protruding posteriorly from the margin of a vertebral body may impinge on the spinal cord and the anterior spinal artery. However, even when osteophytes obvious by roentgenogram protrude into the intervertebral foramina, symptoms may not be present. Therefore, although the position and the size of these osteo-arthritic spurs are important, even more important in our opinion is the mobility of the neck at the level where the osteophytes occur.

Non-operative therapy is often effective in relieving head, neck, shoulder, and arm pain in the majority of patients^{9, 15}. This may require permanent reduction in daily activity and frequent use of traction, or of a stabilizing collar device. If conservative treatment fails to relieve the pain, or if the pain becomes excessively burdensome to the patient, then surgery is indicated.

The results of laminectomy are usually satisfying when used for relief of pressure due to posterior osteophytes impinging on the spinal cord^{2, 18, 23} or due to acute cervical-disc protrusion^{3, 4, 14, 20, 21, 22}.

Laminectomy is not so satisfying when posterior osteophytes compress nerve roots in an intervertebral foramen. Enlargement posteriorly of the intervertebral foramen, by removing the articular facet, as well as laminectomy may be necessary to relieve nerve-root pressure in the foramen. Unilateral excision of a posterior articulation may not cause spine instability, but when pain is bilateral adequate decompression of both intervertebral foramina at the same level may lead to instability.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 28, 1957.

If the source of trouble is a degenerated disc with or without osteophytes one would like to remove that disc, but in the neck the removal of a degenerated but non-prolapsed disc is not feasible or desirable by means of posterior laminectomy.

If enlargement posteriorly of the intervertebral foramen has been extensive and is followed by symptoms of cervical-spine instability or if pain has not been relieved by enlargement of the foramen and laminectomy, then fusion of the cervical spine is desirable. After an extensive laminectomy this is often difficult by the posterior approach since the usual anchor points for the bone grafts have been removed at the time of laminectomy.

If the symptoms are due to osteo-arthritic spurs impinging on nerve roots in the intervertebral foramina, particularly if the symptoms are bilateral or if due to disc degeneration or subluxation with or without missing posterior articulations, then in our opinion, disc removal and fusion of the cervical spine by the anterior approach is indicated. We therefore present our results with an operation that appears to achieve this goal. In our hands this operation (1) has less morbidity than laminectomy and foramen decompression or posterior fusion of the cervical spine; (2) allows one to remove a degenerated disc without disturbing the spinal canal; and (3) permits interbody fusion of the cervical spine at the specific intervertebral level from which symptoms arise.

Employing eight dogs, the authors found that the anterior surgical exposure of the cervical vertebral bodies and disc spaces is a reasonably safe procedure and that it is feasible. The intervertebral-disc material could be extensively removed from between the vertebral bodies through the anterior approach without damage to the spinal cord. Bone plugs from the ilium could be placed between the vertebral bodies in the interspace from which the disc material had been removed. This procedure was used by the authors on a patient for the first time in February 1954. A surgical exposure similar to that worked out on dogs by the authors was used by Lahey¹¹. However, he used it as a method of exposing esophageal diverticula and did not suggest this approach for exposing the bodies of the cervical vertebrae.

LOCALIZATION OF THE OPERATIVE LEVEL

The level at which the operation is to be carried out should be precisely localized preoperatively; the first step is the physical examination. There may be sensory deficits in a single nerve-root distribution. Specific muscle weakness in the arm and hand or reflex changes at the tendons of the biceps and triceps brachii or at the radial styloid process may point to the level of nerve-root compression. Occasionally involuntary twitching will be observed in some group of muscles referable to a particular nerve root.

Irritation or compression of the nerve roots emerging between the fourth and fifth and fifth and sixth cervical vertebrae commonly produces tenderness of the radial nerve and pain radiating to the thumb and index finger. A lesion between the sixth and seventh cervical vertebrae may refer pain to the middle finger, while lesions between the seventh cervical and first thoracic (and occasionally between the sixth and seventh cervical vertebrae) refer pain to the little finger. Prolonged hyperextension of the neck (one minute by the clock) may aggravate the pain in the neck, shoulder, and arm and even cause a clear radiation to one of the digits. With the patient sitting, downward compression applied to the head with the neck tilted to either side may cause a clear pain-radiation pattern which will facilitate localization of the lesion in the neck⁴.

The second step is trying to localize the involved cervical-spine level by simple roentgenography. Sometimes anteroposterior, lateral and right and left oblique roentgenograms of the cervical spine will enable one to localize definitely one isolated level (Fig. 1-B). For instance, between the fifth and sixth cervical vertebrae isolated disc degeneration and osteophyte formation may be obvious. Lateral roentgenograms made with the patient sitting or standing while he first flexes and then extends the neck may show a level of excess or limited motion between two vertebral bodies or an interruption at one level of the normally smooth curve of vertebral alignment.

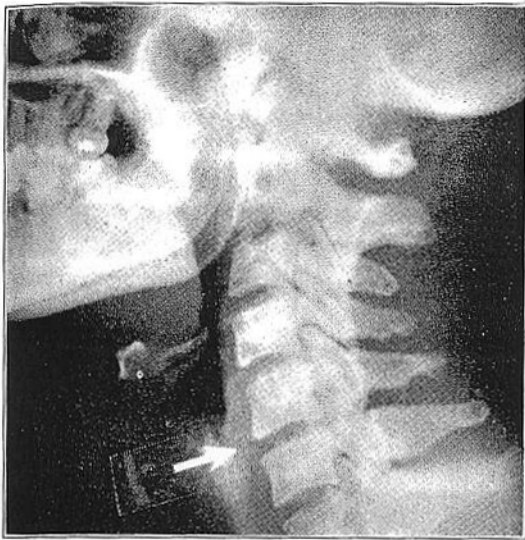


FIG. 1-A



FIG. 1-B

Figs. 1-A through 1-D: Roentgenograms showing the sequence of events during cervical-disc degeneration.
 Fig. 1-A: Lateral roentgenogram of the cervical spine made in 1950, three years after the onset of symptoms, shows what appears to be a practically normal intervertebral disc between the fifth and sixth cervical vertebrae. At that time, the patient complained of pain in the neck, some right occipital headache, and tenderness and spontaneous pain over the medial superior corner of the scapula with some general aching in the right shoulder.

Fig. 1-B: Roentgenogram made in 1955 shows narrowing of the fifth and sixth cervical intervertebral-disc space with anterior and posterior bone-spur formations.



FIG. 1-C



FIG. 1-D

Fig. 1-C: A myelogram, made at the time of the roentgenogram seen in Fig. 1-B, shows the encroachment of the posterior spurs and overlying soft tissues on the dural sac which has been outlined with pantopaque.

Fig. 1-D: The bridge of bone is shown which has formed between the fifth and sixth cervical vertebral bodies following anterior removal of the intervertebral disc and interbody fusion. No motion could be seen in the cervical spine in lateral roentgenograms made while the patient flexed or extended his neck and a bone bridge between the two vertebral bodies was obvious. This is considered a solid bone fusion.

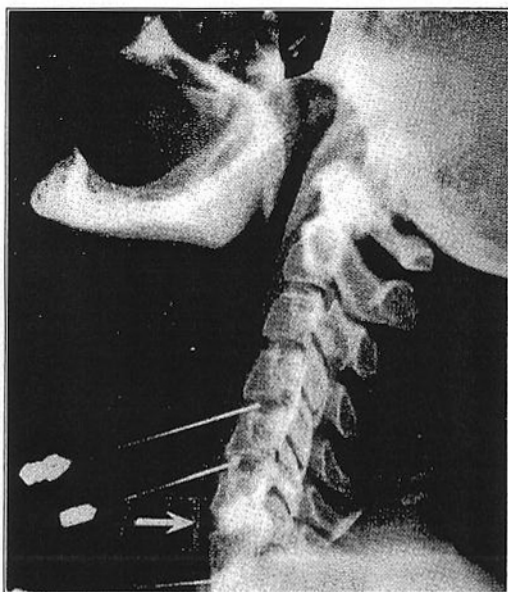


FIG. 2-A

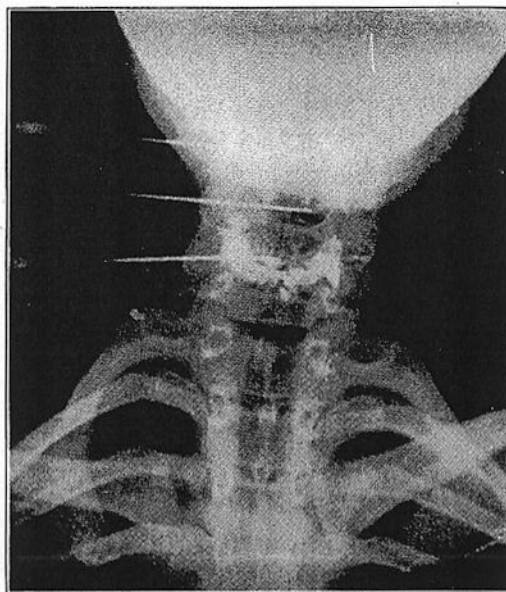


FIG. 2-B

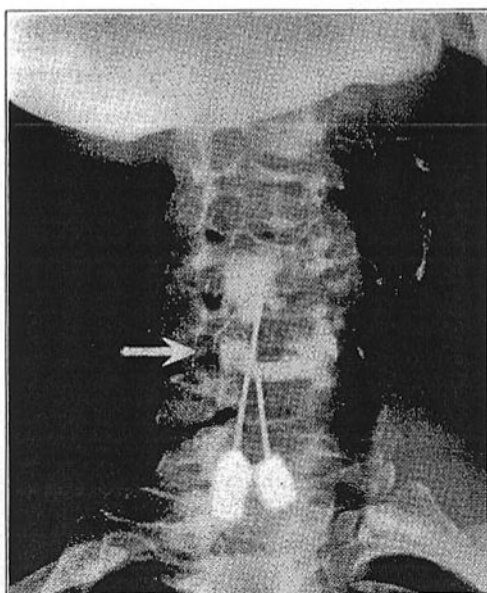


FIG. 2-C

Fig. 2-A: Case 3. Lateral view showing the extravasation of the contrast medium posteriorly under the posterior longitudinal ligament at the sixth and seventh cervical vertebral interspace.

Fig. 2-B: Case 3. Anteroposterior view of the same cervical spine showing irregular spread of the contrast medium throughout the disc space bilaterally, and through the joints of Luschka into the region of the intervertebral foramina.

Fig. 2-C: Case 14. A slightly oblique view made to show the spread of the contrast medium through the joint of Luschka into the intervertebral-foramen area. One may note that on the side of the neck, opposite to that of the arrow, a previous foraminotomy had caused removal of an articular-facet joint at the fifth and sixth cervical vertebral interspace. Symptoms had recurred subsequently on the side opposite the foraminotomy site. Foraminotomy on the side of recent symptoms would have probably necessitated partial or complete removal of the one remaining articular-facet joint at this level. Therefore, disc removal and fusion was performed to avoid instability at this level.

If such an isolated level by roentgenographic and physical findings corresponds (within anatomical limits of variability), one can be fairly certain that the level for surgery has been located.

However, plain roentgenograms and physical examination may show no well developed disc degeneration (Fig. 1-A) or the physical findings may suggest that, although one level appears abnormal by roentgenogram, physical signs and symptoms are arising from another level. Therefore, as a third step to localize precisely the involved level, special diagnostic methods may be necessary. Discograms (Figs. 2-A, 2-B, and 2-C) were made preoperatively in all of our group of fourteen patients. Myelography was done on only two patients and then only because of questionable long-tract signs (Fig. 1-C). Contrast material was injected by means of a needle inserted anterolaterally approximating the route of the anterior surgical approach to the cervical intervertebral discs. In most cases

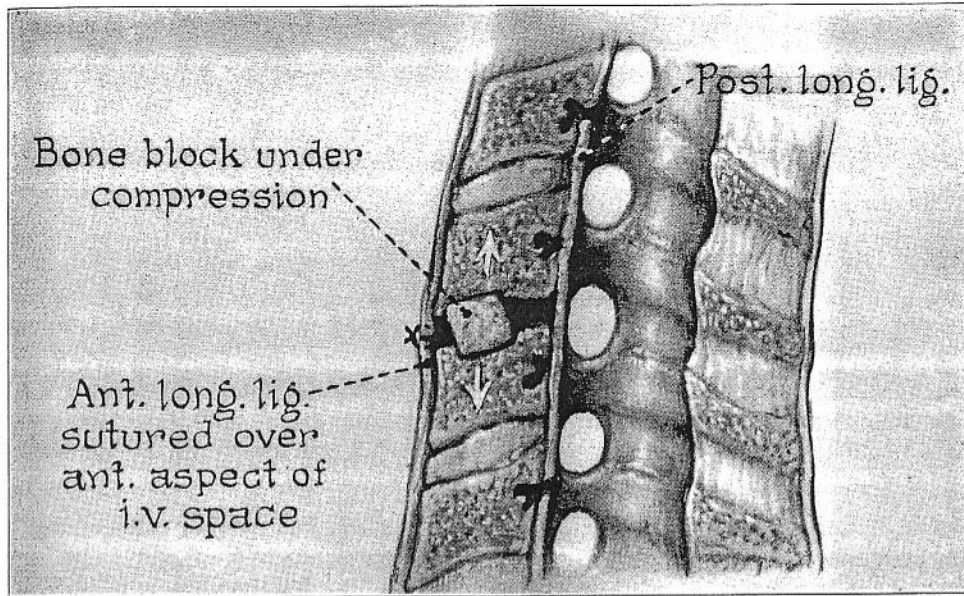


FIG. 3

Diagram showing the block of bone in place between two cervical vertebral bodies. One will note that the bone block is countersunk below the anterior longitudinal ligament so that the ligament may be resutured over it,

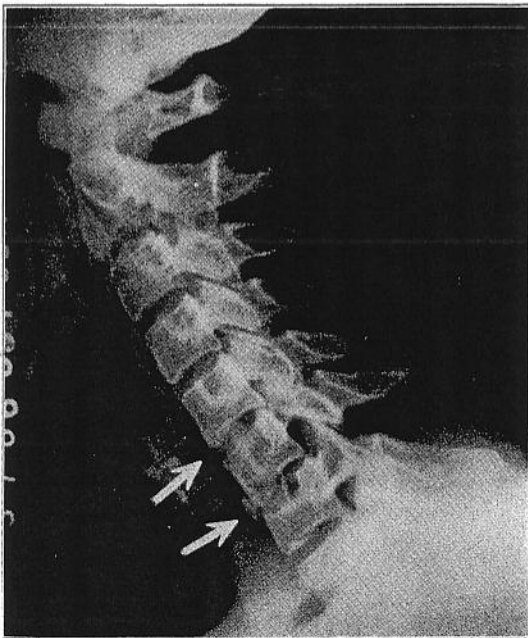


FIG. 4-A



FIG. 4-B

Roentgenograms made in flexion (Fig. 4-A) and in slight extension (Fig. 4-B) six months postoperatively of patient in Case 13. There is a bone bridge between the fifth and sixth and between the sixth and seventh cervical vertebral interspaces. There was no demonstrable motion. However, at the sixth and seventh cervical interspace the bone graft was not as well countersunk as that at the fifth and sixth. Although there was complete relief of symptoms at that time, there was no increase in the height of the intervertebral space secondary to operation at the sixth and seventh interspace and the interspace between the fifth and sixth cervical vertebrae showed only the preoperative height.



FIG. 5-A



FIG. 5-B

Lateral roentgenograms of the cervical spine made in flexion and extension in the patient in Case 7 fourteen months after surgery when all the symptoms had been relieved. It will be noted that there is a bone bridge between the fifth and sixth and sixth and seventh vertebral bodies, most apparent between the fifth and sixth vertebrae. Comparison of these two roentgenograms showed no evidence of motion at these two levels and the fusion was considered solid.

the injection of contrast medium at the involved level reduplicated or exaggerated the typical pain pattern. Discography was therefore useful in those patients in whom there were multiple disc narrowings and in whom it was not clear which of the multiple levels was the source of the major complaint. In some cases the discogram showed only a slightly abnormal pattern at a level where nerve-root signs suggested the probable location of trouble, whereas a discogram made at another possible pain-producing level demonstrated the site of election for surgery by an extremely abnormal roentgenographic pattern in addition to clear reduplication of the pain. This procedure was also useful in those patients with disc degeneration in whom both narrowing of the disc and spur formation were not remarkable by roentgenogram (Figs. 2-A, 2-B, and 2-C).

OPERATION

The patient is under general anaesthesia and should be intubated. Intubation *via* the mouth often requires a degree of neck extension which may be dangerous in the presence of extensive hypertrophic changes on the posterior edges of the vertebral bodies because of possible spinal-cord injury. Therefore, intranasal intubation is recommended in such situations. The patient is placed on the operating table in a supine position. A small pad is placed between the scapulae just caudad to the neck allowing slight head and neck extension. The chin is turned about 10 degrees to the right. Traction of twenty pounds may be applied to the head by means of a halter.* The skin over the left anterior portion of the neck and the right iliac crest is prepared for surgery and the areas draped. A transverse incision is made along a skin crease at about the level of the fifth cervical vertebral body, to the left of the mid-line and about three finger-breadths above the clavicle. If the incision is made high on the neck one must be careful to avoid perforating the pharynx above the glottis. If the spine is not too heavily encased in soft tissue the carotid tubercle on the sixth cervical vertebra can be palpated before the incision is made. If the operation is to be at the fourth, fifth, sixth, and seventh cervical vertebral levels, the incision should be just at or a little above this deep osseous identifying structure.

* This has become routine practice at the Johns Hopkins Hospital.

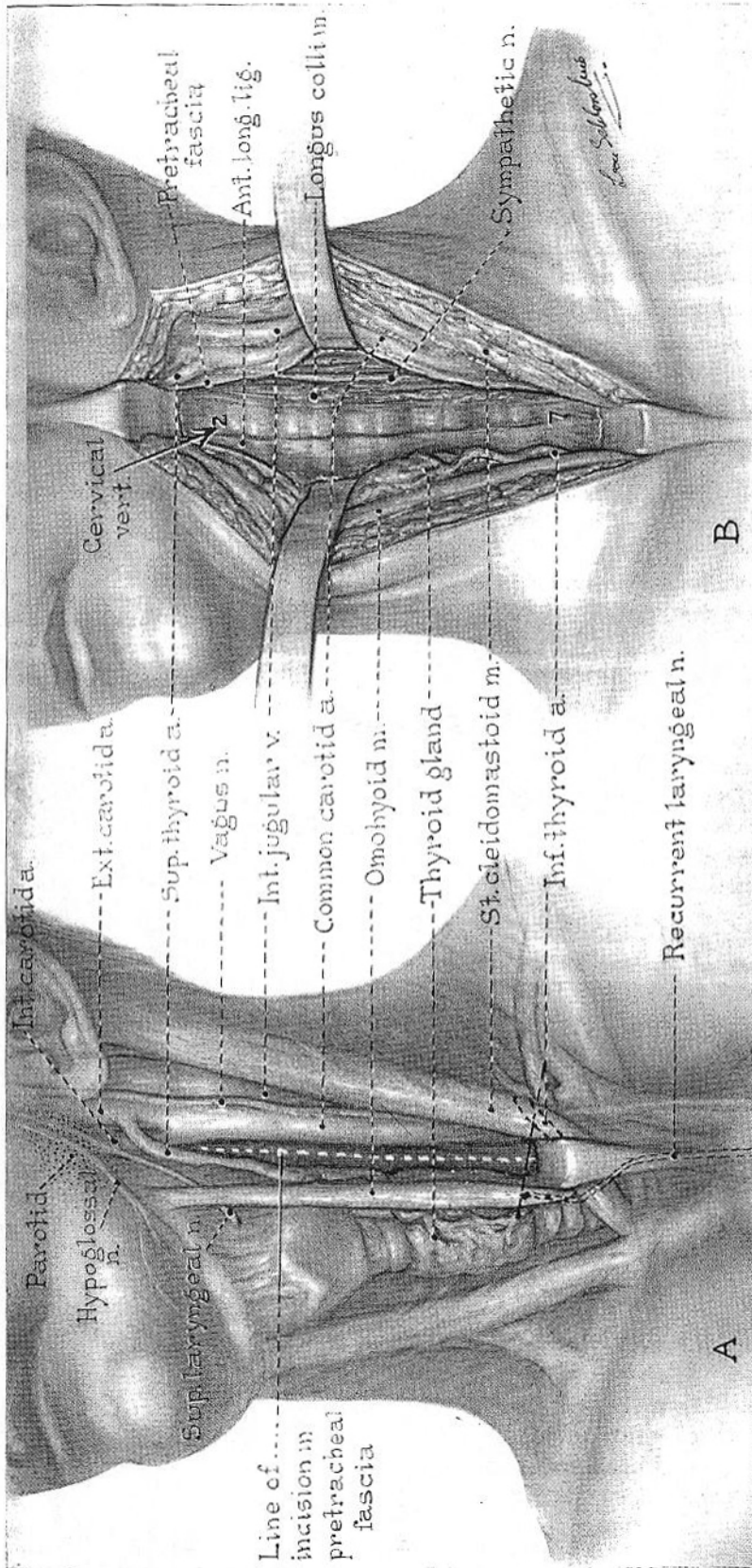


FIG. 6

Drawing showing the operative approach to the cervical spine. The flexibility of the cervical spine depends on several factors. First, if several vertebral bodies are to be exposed between the second cervical and first thoracic levels, a slightly oblique vertical incision following the anterior border of the sternocleidomastoid muscle may be used. If only one or two vertebral bodies are to be exposed, a short transverse incision at the appropriate level may be used. (Detailed descriptions of the transverse and vertical incisions may be found on page 635 of the June 1957 issue of *The Journal*.) Second, the omohyoid and sternocleidomastoid muscles may be retracted freely, thus exposing the pretracheal fascia that covers the entrance to the interval between the structures in the carotid sheath and those in the mid-line compartment of the neck. [Third, by incising the pretracheal fascia parallel to the carotid artery, one passes through the areolar tissue directly to the thin prevertebral fascia. Fourth, one can pass freely between the mid-line structures of the neck and the carotid sheath since there is a long interval between the origin of the superior thyroid artery and the origin of the inferior thyroid artery where no important nerves or arteries pass. Finally, the prevertebral fascia on the floor of the interval between the mid-line and lateral structures of the neck forms a thin transparent cover over the anterior longitudinal ligament, the anterolateral portion of the vertebral bodies, the longus colli muscles, and the sympathetic nervous system. The fascia can be incised vertically over the vertebral bodies and retracted to either side so that the operative site is directly exposed for intervertebral-disc removal and interbody fusion.]

The incision is made on the left since the possibility of traction on the recurrent laryngeal nerve appears less than if the right side is used. The incision should be about eight to ten centimeters in length. It is carried through the skin, subcutaneous tissue, and platysma muscle. A vertical incision along the medial border of the sternocleidomastoid permits one to retract that muscle laterally and to retract the sternohyoid, sternothyroid, and omohyoid muscles medially and inferiorly. The carotid sheath is then seen in the center of the wound and the carotid-artery pulse should be palpated. If neck extension makes this difficult the anaesthetist may flex the patient's head and neck slightly until a good pulse is definitely palpated. A second vertical incision is then made through the pretracheal fascia just medial to and parallel with the carotid artery. The areolar soft tissue beneath this incised fascia is then spread with the fingers between the structures in the center of the neck (the thyroid gland, trachea, and esophagus) and the carotid sheath laterally. With impunity a superior or inferior thyroid artery and vein may be ligated and divided to give better exposure although in our experience this was rarely necessary unless the first thoracic or second cervical vertebra was exposed. The danger of perforating the esophagus is avoided by confining the exposure to the area between the medial and lateral structures of the neck. The carotid sheath and the sternocleidomastoid muscle are retracted laterally with a thyroid retractor. The sternohyoid, sternothyroid, and omohyoid muscles, the esophagus, trachea, and thyroid gland are retracted medially with a medium-sized Richardson retractor. Thus are exposed the prevertebral muscles and the anterior longitudinal ligament behind the esophagus. The two retractors are relaxed at ten-minute intervals to avoid prolonged tracheal or carotid-sheath pressure (Fig. 6).

The surgeon should palpate the underlying bone structures at this point from one side to the other of the neck to locate the mid-line. Thus the possibility of mistaking the irregular transverse processes for osteo-arthritic vertebral bodies is avoided and perforation of the vertebral artery is thereby obviated. The transparent prevertebral fascia is then vertically incised over the vertebral bodies. The cervical sympathetic trunk lies under this fascia over the longus colli muscles just lateral to the vertebral bodies. The longus colli muscles lie over the transverse processes of the cervical vertebrae.

The anterior longitudinal ligament glistens over the mid-line of the vertebral bodies even through the prevertebral fascia. It clearly marks the mid-line when the prevertebral fascia is drawn aside. By cleaving to the mid-line and making sure that the tip of the lateral retractor does not press on the region of the ascending sympathetic-nerve fibrils, the surgeon avoids a postoperative Horner's syndrome.

When osteo-arthritic spurs are present at only one or two intervertebral levels they can be palpated through the anterior longitudinal ligament. At this point a metal object such as a spinal needle is placed in the suspected disc space and a lateral roentgenogram is made in the operating room to confirm the position of the involved intervertebral level. (If one desires, a discogram may be made at this time.)* A fairly reliable identifying structure is the carotid tubercle which may be palpated through the wound and is usually part of the sixth cervical vertebra. Occasionally, it is found on the seventh cervical vertebra but if there is doubt about this anatomical variant its presence may be noted in the lateral roentgenogram as a shadow overlying the cervical body, usually the sixth.

A flap of the anterior longitudinal ligament is then turned back over the indicated disc space. The middle of the flap directly over the disc is intimately attached to the pellicle and the annulus. Thus the middle of the flap must be raised by sharp dissection. This flap is then laid back from the front of the disc space but remains attached to the right side of the anterior longitudinal ligament. Through this aperture the intervertebral-disc material, including the nucleus pulposus and the cartilage plates which separate the intervertebral-disc material from the bone of the vertebral bodies above and below the

* Discograms made during surgery rather than before have become the more common practice. This avoids the pain associated with the procedure, but gives only objective evidence of disc degeneration.

disc, is removed with pituitary rongeurs and curettes. If the anterior osteophytes are large and overhang the disc space they may have to be pared back a little to expose the disc space and to permit insertion of a curette and pituitary rongeur, but an effort is made to preserve the anterior cortical edges of the vertebral bodies adjacent to this disc space. In this way there remains, after the removal of the soft tissues in the disc space, a superior and inferior cortical-bone edge posterior to which the bone graft may be countersunk. Thus these cortical edges of the adjacent vertebrae are preserved to hold the bone block in place when the neck is brought to a normal neutral position, between flexion and extension, after surgery. The bone should be exposed by removal of the cartilage plate and subchondral bone at the top and at the bottom of the intervertebral-disc space if osseous union is to be subsequently expected between the adjacent vertebral bodies. The space is then measured. The space usually accepts a block of bone ten to fifteen millimeters high, ten to fifteen millimeters wide, and ten to fifteen millimeters deep.

A short incision is then made over the crest of the ilium and a suitable piece of iliac bone is obtained with a sharp osteotome to fill the space between the two cervical vertebral bodies. The size of the bone plug removed from the ilium should be greater than the final size of the trimmed block. Two vertical cuts, two centimeters deep, are made about two centimeters apart along the top of the iliac crest. The rough bone plug then measures about two by two by two centimeters, a full thickness of the crest. The iliac wound is closed and the bone graft is shaped. As cut from the ilium it is horseshoe-shaped and consists of cancellous bone surrounded on three sides by cortical bone. The top, bottom, and one end of the bone graft, as it is to be used in the intervertebral space, are cancellous. The cancellous end is inserted into the disc space. The cancellous top and bottom surfaces of the graft lie against the previously exposed cancellous surfaces of the superior and inferior vertebral bodies while the cortical exterior of the graft assumes a vertical position in the intervertebral space.

The prepared intervertebral space is then widened as much as possible by extending the patient's neck. The vertebral-body edges may be further spread apart with bone hooks or wedging devices. The head-neck traction helps to widen the intervertebral space when the disc material has been removed. The bone graft, when inserted into the intervertebral aperture, is tapped into position with a tamper and is countersunk in relation to the anterior cortical edges of the intervertebral aperture (Figs. 4-A and 4-B). When it has been seated it should be very stable. After hemostasis is complete, the flap of anterior longitudinal ligament is repositioned over the intervertebral aperture by two or more sutures.

The soft tissues are allowed to fall together. Sutures are placed in the fascial sheath of the platysma, the subcutaneous tissue, and the skin. A dry sterile dressing may be placed over the wound. No immobilization of the neck is used at this time.

POSTOPERATIVE COURSE

The arm pain may not disappear at once although the preoperative neck and suboccipital pain are usually absent immediately following surgery. One or two days postoperatively the patient is permitted to be up and walk. At four days the skin sutures are removed. The patient is allowed to go home about five to seven days after operation. When one space has been fused it has not been customary to immobilize the neck externally, but if some pain returns postoperatively a removable head-neck-shoulder splint made of plaster of Paris or a well fitted neck brace is used for one to three months. When multiple levels have been fused it has become routine to immobilize the neck for three to six months. The more spaces fused, the longer and more complete the postoperative immobilization.

A continuous bone bridge from one vertebral body to another is seldom apparent by roentgenogram for six to nine months after surgery.

TABLE I
RESULTS OF ANTERIOR REMOVAL OF INTERVERTEBRAL DISCS AND FUSION IN THE CERVICAL SPINE

Case	Age (Years)	Sex	Bilateral Signs	Bilateral Symptoms	Discs Removed	Relief of Preoperative Complaints	Months After Surgery at Follow-Up
1. B. R.	39	M	×	×	1	Excellent	36
2. F. L.	43	M	×	×	1	Excellent	31
3. E. M.	35	F	×	×	2	Poor	28
4. M. H.	46	F	×		2	Excellent	27
5. L. P.	35	F		×	1	Fair	27
6. V. E.	38	F			2	Excellent	27
7. C. S.	50	M			2	Excellent	26
8. T. F.	35	F		×	3	Fair	25
9. W. L.	25	M		×	1	Excellent	24
10. C. N.	38	F ¹			1	Excellent	20
11. M. G.	36	F ¹			1	Excellent	20
12. J. R.	33	M	×	×	2	Good	16
13. C. S.	34	F			2	Good	16
14. B.W.	43	F	×	×	1	Excellent	15

RESULTS

The results are summarized in Tables I and II. The oldest patient in the series was fifty and the youngest was twenty-five years of age, the average age being thirty-eight years. All of the patients were white. Five of the patients were men and nine were women. Eight had bilateral symptoms and six had definite bilateral physical signs. The remainder had unilateral symptoms and signs.

Twenty-two intervertebral spaces were cleaned out anteriorly and filled with a bone graft by the anterior approach. Each disc removed was grossly degenerated. The levels operated on are shown for each patient in Table II; the fifth and sixth and sixth and seventh cervical intervertebral levels were most frequently involved.

The criteria for solid fusion were a solid bridge of bone visible roentgenographically between two vertebral bodies and lack of measurable motion in the two vertebral bodies on lateral roentgenograms made during flexion and extension of the cervical spine. Although motion might have been observable at the operative site, no fusion was considered solid until a continuous bone bridge could be seen on a lateral roentgenogram (Fig. 1-D). Thus of the twenty-two intervertebral discs operated upon, eighteen eventually showed a bone bridge, and twenty-one showed no motion on roentgenograms made at follow-up examinations. In other words, in three of twenty-one disc spaces a fibrous instead of an osseous union had occurred as seen on follow-up roentgenograms. The average period of follow-up was twenty-four months.

Two patients had a fair final result. One patient (Case 3, E. M.) had no apparent relief from the disc removal and interbody fusion; subsequently due to persistent bilateral symptoms and signs, foraminotomy at two levels was performed. These procedures were extensive; most of four facet joints at the levels of the fifth and sixth and sixth and seventh cervical vertebrae were removed. The results in this patient are fair since the final procedure, but the result of the anterior fusion alone was poor. However, extensive foraminotomy could not have been done as safely, in our opinion, unless there had been stability of the spine by the anterior fusion performed several months prior to laminectomy and excision of the posterior articulations. The other patient had a fair result after anterior fusion was repeated (Figs. 7-A and 7-B).

One patient had a good and not an excellent result although all of the arm and hand pain disappeared. A little discomfort in the neck was occasionally noted and the medial

TABLE II
CERVICAL INTERVERTEBRAL DISCS REMOVED IN FOURTEEN PATIENTS

Case	Third and Fourth	Fourth and Fifth	Fifth and Sixth	Sixth and Seventh	Seventh Cervical and First Thoracic	Total
1					×	1
2				×		1
3				×	×	2
4			×	×		2
5			×			1
6			×	×		2
7			×	×		2
8	×		×	×		3
9			×			1
10			×			1
11			×			1
12		×	×			2
13			×	×		2
14			×			1
Total	1	1	11	7	2	22

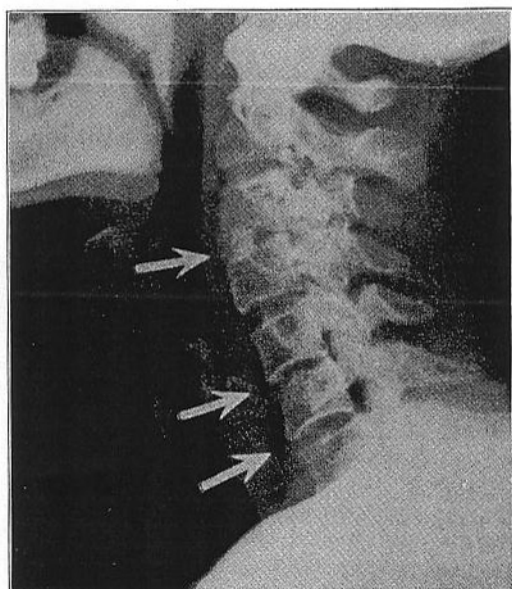


FIG. 7-A



FIG. 7-B

Fig. 7-A: Case 8. Lateral roentgenogram of the cervical spine made nine days after removal of intervertebral-disc material between the third and fourth, the fifth and sixth, and sixth and seventh cervical vertebrae. One can see that the interspace between the third and fourth vertebral bodies is blocked apart by a bone graft.

Fig. 7-B: Lateral roentgenogram of the cervical spine of the same patient made nine months after operation. A good bone bridge had formed between the third and fourth cervical vertebrae. However, the disc space had returned to its preoperative height and showed no widening as a result of surgery. There was a good bone bridge between the sixth and seventh cervical vertebrae with calcification under the anterior longitudinal ligament extending up in front of the sixth cervical vertebra. The interspace between the fifth and sixth cervical vertebrae failed to show any evidence of fusion. Re-operation was done at this level resulting in symptomatic improvement.

superior scapular tip was tender. Another patient has a good result, but in view of his preoperative problem, a few residual symptoms are not of great importance.

Nine of the fourteen patients were completely relieved of their preoperative pain by this operation alone and are considered to have excellent results. Thirteen of the fourteen were improved. One was not improved by this operation alone.

An interesting observation was that the neck and occipital pain was usually relieved immediately and that the arm pain disappeared within a few days following surgery and did not return. However, one patient continued to complain for nine months until the fusion at two levels became solid as seen by roentgenogram after which he was pain-free for two years. No external immobilization was used postoperatively for this patient.

COMPLICATIONS

Two patients had Horner's syndrome, one lasting about one week and the other about six months; two had paralysis of a vocal cord, one clearing in about three weeks and the other between the sixth and ninth postoperative month; one patient had postoperative tracheitis requiring steam inhalations for five days; and in one patient the vertebral artery was perforated without sequelae.

After this series was finished the pharynx of one patient was perforated just above the glottis. In that instance the pharynx was repaired and operation on the cervical spine was delayed six weeks. The esophagus healed properly without sequelae.

No wound infections occurred. In the description of the operation the technical modification which we have found best for avoiding each of these technical complications has been noted.

CASE HISTORIES

CASE 3. E. M., a white housewife and secretary, thirty-five years old, reported no trauma in connection with the neck. Previous spine surgery had consisted in an exploration at the lumbosacral joint with disc removal and fusion in 1949. Cervical symptoms began two years prior to hospital admission during which time the patient had had non-surgical treatment for the cervical pain. Prior to operation she had numbness of the right ring finger and weakness of the grip in the right hand. She had noticed intermittent muscle twitching in the upper and lower portions of both arms, and complained of interscapular pain with the recurrent episodes of pain in the neck and arms. Prior to the intervertebral-disc removal and fusion there was hypaesthesia over the distribution of the eighth cervical-nerve root and diminished reflex of the biceps and triceps brachii on the right as compared with that on the left. There was interspinous tenderness between the sixth and seventh cervical vertebrae posteriorly and on prolonged extension of the neck, pain in both arms and hands was reproduced.

Lateral roentgenograms showed that the interspace between the fifth and sixth cervical vertebrae was very slightly narrowed. The fifth, sixth, and seventh cervical vertebrae and the first thoracic vertebra tended to remain in a neutral fixed position during flexion or attempted flexion of the neck. At the same time, above the fifth cervical vertebra flexion occurred. No remarkable spurs were seen in the oblique roentgenograms of the cervical spine. Discogram showed an abnormal pattern of a filling defect and degeneration at the fifth and sixth, and sixth and seventh cervical vertebral interspaces and at that between the seventh cervical and first thoracic vertebrae. However, the patient's pain was reproduced only at the lower two interspaces. Therefore, on October 8, 1954, intervertebral-disc removal and interbody fusion was performed from the right side at the sixth and seventh cervical vertebral interspace and at that between the seventh cervical and first thoracic vertebrae, in view of the fact that her clinical symptoms and signs were best correlated with nerve-root compression or irritation at these two levels. Postoperatively the patient was improved and muscle fibrillations that she had noted disappeared, but she still had pain into both shoulder areas and into the right hand upon extension of the neck. She continued to complain that she had pain in the neck and arms running to the ring and little fingers of both hands. The consensus of several examiners was that there was no improvement after the disc removal and fusion and the result was classified as *poor*, twenty-eight months after surgery.

Stabilization of the neck at the sixth and seventh cervical and the seventh cervical and first thoracic interspaces resulted, however, from the anterior-fusion procedure. On July 16, 1955, after this stability had been gained, a multiple foraminotomy including partial bilateral excision of the posterior articulations at the sixth and seventh cervical and seventh cervical and first thoracic levels was performed, ten months after the first operation. Following the second operation there were no complications. Neck extension was not

accompanied by severe pain into the shoulders and arms as before the second procedure. The patient returned to work for the first time in several years and when re-examined twenty-eight months after the original procedure and eighteen months after the secondary laminectomy and foraminotomy, her symptoms and signs involving the right arm were relieved, and she complained only of "aching muscle tiredness" in the left shoulder and arm. The over-all result from both procedures was classified *fair*. She not only returned to doing her own housework but was working as a part-time secretary (Figs. 2-A and 2-B).

CASE 4. M. H., a white housewife, forty-six years old, reported no trauma specifically related to the neck. One year prior to disc removal and interbody fusion the patient had had a foraminotomy on the left side at the fifth and sixth cervical vertebral interspace which involved complete excision of the posterior articulations. The patient had severe recurrence of her symptoms four months prior to the second procedure which had not been relieved by non-surgical treatment.

The patient had had a gradual onset of pain, first in the left shoulder and arm, about 1952. Four months prior to surgery she had had a severe recurrence of pain which had not responded to extensive non-surgical therapy. Preoperatively her symptoms consisted of pain in the neck and right shoulder, pain in the right arm and hand, and numbness in the right arm and in the thumb, index, and middle fingers. The neck pain included interscapular pain. There was a positive extension test of the neck reproducing pain into the right arm and hand. When in extension the neck was rotated, acute pain in the right arm was produced. The periosteal radial reflex was diminished on the right. There was weakness of the extensor tendons of the right hand and elbow.

Roentgenograms showed that at a previous operation on the cervical spine excision of the posterior articulations on the left had been performed at the fifth and sixth cervical vertebral interspace. There was disc narrowing and spur formation at the interspaces between the fifth and sixth and sixth and seventh cervical vertebrae bilaterally. The spurs were both posterior and posterolateral. Discogram showed abnormal outline and injection of the contrast medium produced pain at both the fifth and sixth and sixth and seventh cervical vertebral interspaces. On November 4, 1954, intervertebral-disc removal and interbody fusion was performed from the right side at the fifth and sixth and sixth and seventh cervical vertebral interspaces. Postoperatively, the abnormal physical findings rapidly disappeared and there were no residual complaints four months postoperatively. The patient was working without complaints twenty-seven months postoperatively. The result is considered *excellent*.

CASE 7. C. S., a white contractor and builder, fifty years old, stated that he had been severely mauled in a labor dispute in 1939. For twelve years the neck, shoulder, and arm pain was intermittent but the attacks became more frequent and more prolonged until they were almost constant by 1952. Various forms of non-operative treatment had been employed by various physicians for one and one-half years prior to surgery without any relief of symptoms.

On physical examination prior to surgery there was obvious spontaneous muscle twitching in the right forearm in the region of the extensor muscles of the hand and fingers which could be increased by prolonged extension of the neck. Extension of the neck also produced pain at a point behind the medial superior tip of the right scapula which proceeded down the posterior edge of the deltoideus muscle, then along the radial groove to the elbow, and along the extensor surface of the elbow to the thumb and index finger. There was tenderness of the radial nerve. There was pain and tenderness on the anterior aspect of the elbow and over the extensor muscles on the right arm down to the wrist. There was paraesthesia over the thumb and index finger. There was partial paralysis of the sixth cervical-nerve root noted by absence of the periosteal radial reflex and the reflex of the left biceps brachii with partial loss of pain and touch sensation over the thumb and index finger and the lower radial side of the forearm.

Roentgenograms showed moderate narrowing of the fifth and sixth cervical intervertebral space and slight narrowing at the sixth and seventh cervical vertebral interspace with spur formation posterolaterally into the intervertebral foramen on the right side at the fifth and sixth cervical vertebral interspace. Injection of contrast medium at both the fifth and sixth and sixth and seventh cervical vertebral interspaces produced pain and the discogram showed an abnormal pattern.

On December 3, 1954, intervertebral-disc removal and interbody fusion at the fifth and sixth and sixth and seventh cervical vertebral interspaces was performed from the right side. Postoperatively there was a Horner's syndrome and temporary paralysis of the right vocal cord. These complications completely disappeared in nine months. When reviewed twenty-six months postoperatively, the patient showed only a slight residual weakness of the triceps brachii muscle but all other symptoms and signs had gradually regressed in the one year following surgery. The result was considered *excellent* (Figs. 5-A and 5-B).

CASE 8. T. F., a white female nurse, thirty-five years old, reported that a fall on a hard floor in a sitting position in 1947 caused neck symptoms. The patient stated that symptoms in the neck, shoulders, and arm continued despite two operations on the neck on the left side which had consisted of seven foraminotomies. Prior to surgery in January 1955 she complained of pain in the left shoulder, index finger of the left hand,

and weakness in the grip of the left hand. There was pain in the neck, particularly on the left side. All of these symptoms had failed to respond to non-operative therapy and surgery over the previous five years.

On physical examination the patient showed hypaesthesia over the left thumb, the index and middle finger. The extension test of the neck was positive and reproduced pain into the left shoulder and down the left arm into the left index finger. Flexion of the neck reproduced the pain in the left shoulder.

Discograms were made at each interspace between the third and the seventh cervical vertebrae. It was difficult in this patient to interpret the pain distribution with the injection of contrast medium but the pain seemed to be duplicated when injection was done at the third and fourth, the fifth and sixth, and the sixth and seventh cervical vertebral interspaces. The spine was straighter than normal in the lateral view. There was roentgenographic evidence on the plain films of foraminotomy at each interspace between the third and the seventh cervical vertebrae. At three of these levels the foraminotomy was bilateral and at one level, unilateral. No large spur formation was seen. There seemed to be some narrowing at the interspaces between the fifth and sixth and the sixth and seventh cervical vertebrae.

On January 11, 1955, intervertebral-disc removal and interbody fusion at the third and fourth, the fifth and sixth, and the sixth and seventh cervical vertebral interspaces was performed from the left side. Postoperatively, this patient had severe tracheitis for five days which was believed due to sensitivity to the intertracheal tubing used for intubation anaesthesia. It should be noted that a similar complication followed a thyroidectomy on this patient several years previously. The second complication was the development of a keloid. Postoperatively the patient complained of pain in the lumbar spine as well as in the neck. She had had multiple operations previously in the area of the cervical spine and one exploration in the area of the lumbar spine. Physical findings were unchanged from the preoperative state and therefore after ten months the result was classified as *poor*.

Approximately eleven months after the procedure of January 11, 1955, the patient was re-operated upon in her home area and the fifth and sixth intervertebral level of the cervical spine was found to be movable and was re-fused *via* the anterior approach. Roentgenograms and operative exploration showed bone fusion at the third and fourth and sixth and seventh cervical intervertebral levels. The total result of these procedures was not reviewed by the authors but the patient was reported improved by her attending surgeon. The total result from disc removal and interbody fusion is listed as *fair* twenty-five months after the secondary vertebral-body fusion (Figs. 7-A and 7-B).

CASE 13. C. S., a white female beautician, thirty-four years old, stated that she had had neck injury in an automobile accident about eight months before surgery. For the past seven months there had been persistent pain in the neck and left arm and weakness, particularly partial weakness in the grip of the left hand despite non-surgical therapy with a collar and traction. Preoperatively the patient complained of pain in the neck, the left shoulder, the left hand, and numbness in the left shoulder, arm, and hand with suboccipital headaches. There was tenderness posteriorly over the neck between the fifth and sixth vertebrae in the mid-line. The extension test of the neck was positive and rotation of the chin to the right gave severe pain into the left arm and down to the index finger and the thumb. There was tenderness of the radial nerve and diminution of the radial styloid reflex. A myelogram made prior to surgery was negative and roentgenograms were not remarkable except for perhaps a slight straightening of the neck in the lateral view. Injection of contrast medium at the fifth and sixth and sixth and seventh cervical vertebral interspaces caused reproduction of the pain in the arm and the discogram showed a pattern typical of disc degeneration.

Operation was performed on October 27, 1955, when intervertebral-disc removal and interbody fusion at the fifth and sixth and sixth and seventh cervical vertebral interspaces was performed from the left side. There were no postoperative complications. The preoperative findings disappeared except for some tenderness and mild discomfort over the superior medial tip of the left scapula and very occasional aching in the neck. Sixteen months after the disc removal and fusion the patient considered that she was at least 75 per cent improved. An independent examiner judged that the patient had perhaps 15 per cent of residual disability in the neck. The final result is considered *good* (Figs. 4-A and 4-B).

CASE 14. B. W., a white housewife, forty-three years old, gave no definite history of trauma in relation to the neck. Removal of intervertebral-disc material at the fifth lumbar and first sacral interspace and spine fusion at that level had been performed in 1953. Results of that operation were excellent.

At the onset the pain was gradual and intermittent, involving the neck, both shoulders, arms, hands, the fingers, and the interscapular area for eight years. The intermittent attacks had become more frequent and more prolonged so that in the year prior to surgery the discomfort had been practically continuous and accompanied by numbness in the right thumb with pain in the right anterior portion of the chest. Extensive conservative therapy, such as collars and traction, had failed. On examination there was a decreased biceps brachii reflex on the right and an absent periosteal radial reflex and biceps reflex on the left. The extension and rotation test of the neck reproduced the neck pain and that radiating into the right arm. There was on such tests some discomfort into the left shoulder and arm. On testing there was some weakness of the grip in the right hand. Roentgenogram showed definite narrowing of the fifth and sixth cervical vertebral inter-

space and discogram at this level showed a positive pattern and injection of contrast medium reproduced the patient's pain distribution. On November 15, 1955, intervertebral-disc removal was performed followed by interbody fusion at the fifth and sixth cervical vertebral interspace. In this case bone-bank bone (frozen bone from the rib) was used. Postoperatively the patient had no complications. The preoperative findings disappeared. She resumed full activity without complaint and when evaluated fifteen months postoperatively the result was considered *excellent* (Fig. 2-C).

DISCUSSION

Four of the patients in this particular series had had previous thyroid surgery. This series, as well as other patients with discogenic disease who have had previous thyroid surgery, strongly suggested to us the possible importance of a metabolic factor in intervertebral-disc disease.

A degenerated intervertebral disc can apparently create abnormal mechanics in the cervical spine even before roentgenograms show significant intervertebral-space narrowing or remarkable spur formation. From such a level shoulder, neck, occipital, and even arm pain may arise. The localizing signs may not be clear in these patients on physical examination. However, a discogram at the involved level should give a roentgenographic pattern typical of disc degeneration (Figs. 2-A, 2-B, and 2-C) and the pain which forms the chief complaint may be reproduced during the discographic procedure. Pain arising during discography may occasionally be so diffuse that the patient will have difficulty associating it with the pain which he originally had. Critical analysis of this pain reduplication during discography depends in large measure on the patient's emotional stability and the surgeon's experience with the procedure. However, the contrast medium flows with little resistance into a degenerated disc whereas into a normal disc only a small amount can be inserted and that only under great pressure. The discogram shows an abnormal pattern: instead of a neat lense-shaped outline of a normal cervical nucleus pulposus, an irregular extension of the contrast medium beyond the central nucleus occurs across the disc space to the region of the joints of Luschka and into the area of the intervertebral foramina. In the lateral view the contrast medium usually proceeds out of the disc space up and down under the posterior longitudinal ligament (Figs. 2-A, 2-B, and 2-C) when the disc is degenerated.

When true disc protrusion or large posterior osteophytes cause compression of the cord and evoke long-tract signs, posterior decompression of the spinal cord and possibly section of the dentate ligaments appears indicated^{18, 23}. In those patients with long-tract signs a myelogram is indicated prior to such surgery. It is possible that in such situations spine fusion by the anterior approach may, by stabilizing the osteo-arthritis portion of the spine, decrease soft-tissue swelling over large posteriorly protruding osteophytes, or stop any irritation of the cord or of the anterior spinal artery, or of both, which may occur secondarily to osteophyte motion. However, the authors have used anterior spine fusion only once for such a situation. In that patient (Case 12, J. R.) spinal-cord irritation existed only intermittently and in mild degree. However, the patient's symptoms were relieved clinically by the anterior cervical-spine fusion at two levels.

Spurs on the superior element of the posterior cervical articulations and on the joints of Luschka are reported to cause intermittent or continuous pressure on the vertebral artery with spasm of the artery in some instances^{7, 10}. Possibly they may also irritate or compress the posterior sympathetic plexus which accompanies the vertebral artery^{1, 17}. This condition may eventually have to be differentiated from Ménière's syndrome and may possibly give rise to syncopal attacks although such a clinical syndrome is not as yet clearly defined¹⁷. So far the operation described has not been used primarily for this condition but it would appear to be indicated in such a situation if the exact level of vertebral-artery irritation can be precisely localized.

Originally we hoped that after cleaning out the intervertebral-disc material through the anterior approach it would be possible to wedge the vertebral bodies apart and that

this would also increase the diameter of the intervertebral foramina (Fig. 3). Actually, however, opening up the interbody space may tend to extend the cervical spine, a position which causes pain in many patients having constriction of the intervertebral foramina by osteophytes. Extension alone does not effectively enlarge the intervertebral foramen. Furthermore, the bone graft is largely resorbed and remodeled. Even though it originally acts as a conductor of osteoblasts between the two vertebral bodies it eventually ceases to exist as an effective mechanical strut for separating the two vertebral bodies. Therefore, in late postoperative roentgenograms the two vertebral bodies that were propped apart at the operating table by the bone plug have either returned to their preoperative position in relation to each other or the space between them has become narrower than it was preoperatively.

CONCLUSIONS

1. Disc degeneration in the cervical spine usually associated with osteo-arthritic changes is a cause of nerve-root irritation and compression giving rise to occipital and hemicranial headaches, pain in the neck, shoulder, between the scapulae, in the anterior portion of the chest, and in the arm and hand. Instability of a cervical vertebra can also cause similar pain.

2. The cervical-spine level from which such pains arise when exactly localized can be fused after excising the disc by placing a bone graft anteriorly between the vertebral bodies. Such a fusion appears to stop the pain.

3. This method of treatment without serious complication has completely relieved the discomfort of nine of fourteen patients and caused improvement in four others. Conservative therapy and other surgical attempts had failed to relieve the discomfort of these patients prior to the disc removal and interbody fusion.

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DISCUSSION

DR. J. E. M. THOMSON, LINCOLN, NEBRASKA: This presentation is timely and commendable in that it brings us closer to understanding one of the most confusing and illusive pain syndromes. The authors thoroughly covered the numerous etiologic potentialities which cause local symptoms in the neck as well as those referred to the chest, back, and upper extremities. They correctly emphasized the importance of definite adequate diagnosis of the particular pathological conditions involved and its relative importance in connection with the effective conservative or surgical treatment.

The exposure of the anterior portion of the bodies of the cervical vertebrae has been ably demonstrated by Dr. Southwick and Dr. Robinson^a. The method is intriguing but it seems to demand a very skilled and experienced hand. The transitory complications of two Horner's syndromes, two instances of paralysis of the vocal cords, one instance of tracheitis, one vertebral artery perforated, and then a ruptured esophagus in a later case forms a formidable group.

It is gratifying that the authors tried their technique on eight dogs before turning to human beings. We have not got beyond canine investigation, either from an operative or a discographic standpoint.

In the patient, E. M. (Case 3), the result of the disc removal and interbody fusion was poor and extensive bilateral foraminotomies at two intervertebral levels were later performed with fair results. In this case, one can agree with the authors' opinion that the subsequent extensive foraminotomies could not have been done as safely as they were without the stability afforded by the preceding fusion. Hence, although the result of anterior fusion itself was poor, it nevertheless made possible a subsequent procedure which improved the result.

The authors' comments concerning the attempts to force the vertebrae apart in order to enlarge the intervertebral foramina were interesting. The osteoclastic activity, invariably present, apparently has a flattening effect on the graft to the extent that ultimately the intervertebral space could be less than that before surgery. Therefore the assuring feature of this method after all is the fusion.

Dr. Smith and Dr. Robinson should be commended for their courageous approach to this problem. Their results indicate the importance of this method of treatment in a selected group of patients with cervical-disc nerve-root syndromes. If our specialty is to progress, we cannot afford to look askance at original approaches to difficult surgical problems and not add to our armamentarium those surgical techniques which, although unusual, have proved by experience to give a measure of good results.

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DR. JAMES GORDON PETRIE, MONTREAL, QUEBEC, CANADA: At the Montreal Neurological Institute and the Royal Victoria Hospital, Montreal, Dr. W. V. Cone and I have been much interested in this subject for many years in the treatment of trauma as well as in the treatment of neck pain with or without radiating pain.

We all know that skull traction in a young person will give some separation of the cervical vertebrae, but we have found that considerable traction, up to seventy-five pounds, as used occasionally with fracture-dislocation of the cervical spine, gives only minimal or no separation of the vertebrae at the level of an old degenerated disc, and in the adult, widening of the intervertebral disc at normal levels and under heavy traction is not marked. This raises the question as to how traction benefits some of these patients. Is it due to change of posture and relief of muscle spasm?

One point that should be stressed in the treatment of intervertebral lesions is that the operation is usually for pain, and therefore is one of election, and the simplest, safest procedure should be used. If muscle weakness is present then it should be considered an emergency. If fusion alone will relieve the pain we believe an articular-facet fusion along with parallel grafts is the shortest procedure. It is simple to fuse up to four

vertebrae together. As Abbott and others have shown, cancellous bone possesses a high osteogenetic power, whereas cortical bone possesses strength but little osteogenetic power. We expect the articular facets to be well fused in two months, and the parallel cortical grafts to take a longer period of time to fuse.

We have had very little experience with discograms. We would not want to do them on normal discs, as Dr. Reuben Rabinovitch has shown with young animals (rabbits, dogs, and monkeys), using an eighteen-gauge needle, that disc material may be extruded from a normal disc following puncture. We do believe myelography is important, not so much in the diagnosis of a ruptured intervertebral disc, but rather to give us a clue as to the level of the involved disc or discs.

We believe the best indication for the anterior fusion is when a wide laminectomy, as far as the articular facets, has been carried out previously and there is increasing pain and deformity of the neck.

MAKING THE MILWAUKEE BRACE

(Continued from page 528)

A traction frame (Fig. 4) is fastened to the pelvic girdle to correct pelvic obliquity. Pins through the tibiae are incorporated in casts. Traction is made on the high side which has the short cast. A spring balance is interposed to measure the force. The leg on the low side with the toe-to-groin cast is pulled upward with heavy rubber bands in the back and front.

APPLYING THE BRACE

The brace is reassembled and put on the patient by the orthotist. It should be checked carefully by the orthopaedic surgeon. It should fit loosely with only slight corrective force. If the spine was considerably elongated during the application of the model, it will be necessary to shorten the brace one-half inch (1.27 centimeters) or more before applying it. No additional correction of the curve should be attempted until the skin is accustomed to the pressure of the brace. The patient should be able to raise his chin and occiput simultaneously from the head support, or rest the head on its support and shift the chest away from the lateral pressure pad. This situation must prevail at all times during and following the correction. The appearance of pressure areas is evidence that too much force is being used.

The brace should not be uncomfortable even when first worn. With the patient in the prone position, the pelvic girdle should be loosened and the skin of the entire torso given nursing care at least once a day for the first six weeks that the brace is worn. When the belt (Fig. 2, B) is to be fastened again, it is wise to pull on the patient's legs so that the girdle will fit snugly above the waist and not cause pressure on the lateral surfaces of the ilia. The gap between the posterior edges of the pelvic girdle must remain constant. As the belt stretches, it must be tightened further to maintain this position.

The chin must be capable of protrusion at any time. Pain at the temporomandibular joint or pain in the teeth means that the brace must be shortened. Vigorous distraction will obviously make pressure on the teeth. Rarely, in young children, protrusion of both upper and lower incisors has occurred. This protrusion has always receded rapidly upon removal of the brace at the completion of treatment. Permanent deformity has not occurred.

A marked overbite is a frequent finding in idiopathic scoliosis as noted by Chandler. Care should be taken to examine the jaws prior to the onset of treatment. If an abnormality exists, an orthodontist should be called in consultation and he should prepare a plaster mold of the teeth as a record. Mandibular deformities should not erroneously be ascribed to the brace. No change of bite has been observed with the use of the brace.

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