Computed Tomography of the Postoperative Lumbar Spine

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Review

Computed Tomography of the Postoperative Lumbar Spine

J. George Teplick[1] and Marvin E. Haskin[1]

Up to 30% of patients who have had lumbar surgery for herniated disk or for spondylolisthesis or spinal stenosis have unsatisfactory results [1-4]. Postoperative symptoms are often quite similar to the preoperative pain and radiculopathy, sometimes less intense but often more distressing than before surgery. Once it has been determined that the persistent and recurrent postoperative symptoms are not due to some form of musculoskeletal imbalance or strain, causes to be considered must include changes or complications directly related to the surgery or to failure of the surgery to correct the preoperative condition. Indeed, Finneson [5] surveyed a group of surgical patients and concluded that 80% of these should not have been surgical candidates.

Among causes leading to unsatisfactory long-term results from surgery are extradural fibrosis or scarring, postoperative lateral or central spinal stenosis from bone overgrowth, recurrent or persistent disk herniation, and focal adhesive arachnoiditis [6-9]. Less frequent causes include the facet subluxations or disorders, pseudoarthroses from fusion, nerve injury, and wrong-level surgery [6]. Diagnostic failure leads to surgical failure. This applies particularly to lateral spinal stenosis, which may exist alone or concomitant with a herniated nucleus pulposus (HNP) [6]. In one series, 56% of patients clinically diagnosed with HNP had associated lateral stenosis or stenosis without HNP at surgery. The authors stated: "It is clear that a diskectomy patient cannot be considered adequately treated if stenosis is not looked for either before or during surgery and alleviated when found." In this context, preoperative CT studies become very important.

In the postoperative patient ordinary radiographs of the spine generally add very little information, revealing the usual postoperative bone changes and often postoperative narrowing of the intervertebral space. Myelography may sometimes be informative [10-12], showing evidence of focal arachnoiditis or a focal defect at the surgical site. However, the latter finding is difficult to interpret; is it a recurrent HNP? Is it an extradural scar? Myelography is also generally unrevealing in cases of lateral bony stenosis.

As experience with high-resolution CT scanning of the lumbar spine has been increasing, it is becoming apparent that this noninvasive and easily performed study can give considerably more information about the postoperative spine than any of the other current imaging methods.

Materials and Methods

About 750 patients with previous lumbar laminectomies had CT scanning within a 28 month period. Most of these were postoperative failed-back syndrome patients, with persistent or recurrent radiculopathy after surgery. A small group of 15 patients was scanned within 2 weeks after surgery to evaluate the early appearance of the postoperative spine. For the most part, these early postoperative patients were asymptomatic at the time.

Contrast enhancement studies to attempt distinction between recurrent disk herniation and extradural scar were performed on

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[1]Department of Diagnostic Radiology, Hahnemann University School of Medicine, Broad and Vine Sts., Philadelphia, PA 19102. Address reprint requests to J. G. Teplick.

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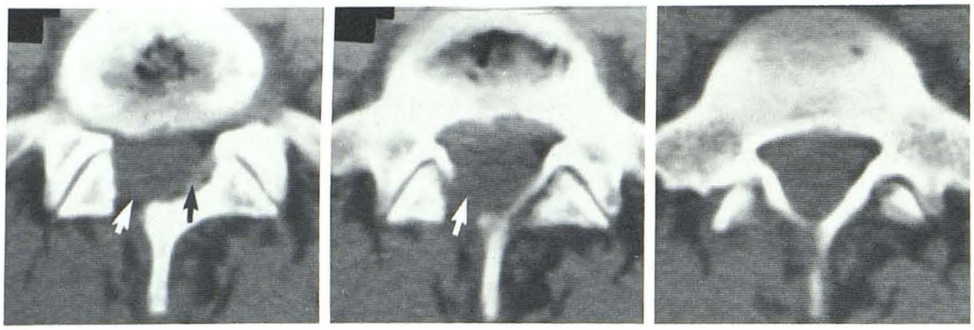

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Fig. 1.—Conventional laminectomy. Absence of right lamina and ligamentum flavum (*white arrows*) is unmistakable. An intact ligamentum flavum is on left (*black arrow*).

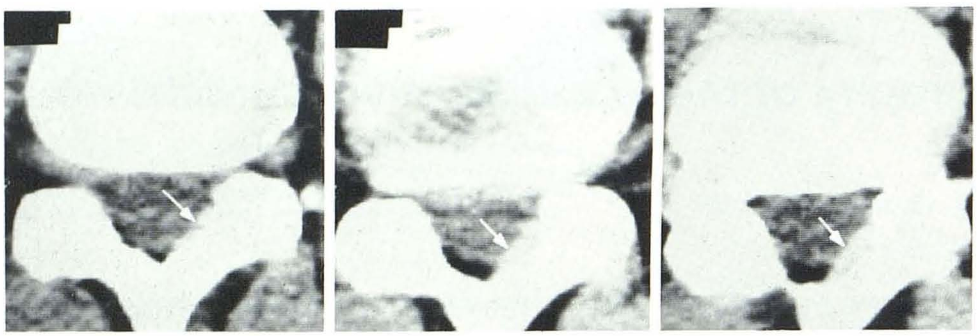

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Fig. 2.—Identifying site of minilaminectomy (laminotomy). On three successive slices, ligamentum flavum is on left (*arrows*), but not on right. Absence of one ligamentum flavum is virtually pathognomonic of laminectomy, even though clear-cut resection of lamina cannot be identified. When little or no bone is removed and surgical entry into canal is through ligamentum flavum only, procedure is more accurately termed *laminotomy*.

23 patients and will be discussed later. Unless otherwise indicated, examinations were performed without intravenous contrast enhancement.

Twelve of the patients who had previous surgery were reoperated after scanning. In three of these, a recurrent disk herniation was found, while in the rest no disk herniation, but scar was the principal finding.

All scans were obtained on a GE 8800 scanner using a digital lateral ScoutView with linear annotations indicating the location and angle of each cut. Each interspace from L3 to S1 was scanned with six cuts each 5 mm thick and 4 mm apart, angled as closely to the interspace angle as the gantry permitted. The technical factors were 120 kVp, 300–600 mA, and 9.5 sec. The patient was supine with the knees supported in mild flexion. Normal respiration was continued throughout the scanning. This is the same technique we use in the nonoperated patient with radiculopathy when searching for disk herniation, stenosis, etc.

Reformatting with coronal and sagittal reconstructions was used very rarely. We found that all the necessary information was available and interpretable on the axial sections; reformatting was reserved for the rare case with a complicated or confusing appearance on the axial sections.

It is true that reformatted coronal and sagittal images, with their spatial relations quite similar to conventional radiographs, are at first more appealing and more easily interpreted by the orthopedist and neurosurgeon. We are convinced, however, that the nonradiologists, after developing more familiarity and experience with the axial views, will accept, interpret, and trust the axial sections and will find need for the reformatted images only in the infrequent cases with confusing and complex bone changes.

Laminectomy and Laminotomy

To consider an extradural soft-tissue density as possible postsurgical scar or area of fibrosis, the lesion must be at the level and site of the laminectomy. Ordinarily, the exact site of surgery will be recognized by the absence of bone. However, in many cases when a laminotomy was done with the removal of little or no bone, the recognition of the exact site of surgery is difficult, yet important because sometimes the operative record of the exact interspace is unavailable or is confusing, especially when there has been a sacralized lumbar body or lumbarized sacral segment. A laminectomy bone defect is usually very easily recognized (fig. 1). However, after a laminotomy, particularly a minilaminotomy where no bone has been removed, the only definite clue to the site of the surgery is the absence of part or most of the ligamentum flavum (fig. 2). Since some of the ligamentum flavum must be resected if the canal is to be explored surgically, absence of part of the ligamentum flavum clearly indicates the site even when the newer microtechniques are used. However, we have encountered two cases where so little ligamentum flavum was removed during microsurgery that CT evidence of the laminotomy could not be found.

Normal Postoperative Lumbar Canal

In the absence of extradural scarring, fibrosis, or postoperative bony overgrowth, the postoperative spinal canal

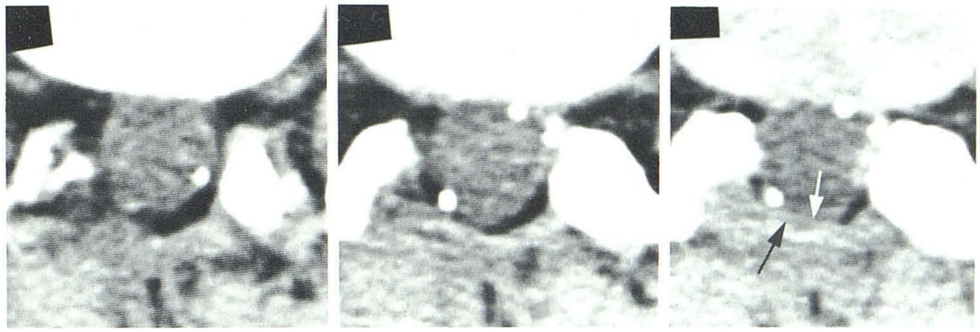

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Fig. 3.—Bilateral laminectomies without significant scarring. Three successive sections at L4–L5 disclose complete absence of bony laminae. Ligamenta flava have been removed. Droplets of old Pantopaque are seen within sac, which is still entirely surrounded by epidural fat; soft-tissue fibrosis has not replaced any of fat in canal, but a band of fibrosis (*black arrow*) has replaced lamina and fibrofatty tissue behind canal. Fibrosis appears to barely touch thecal sac at one point (*white arrow*).

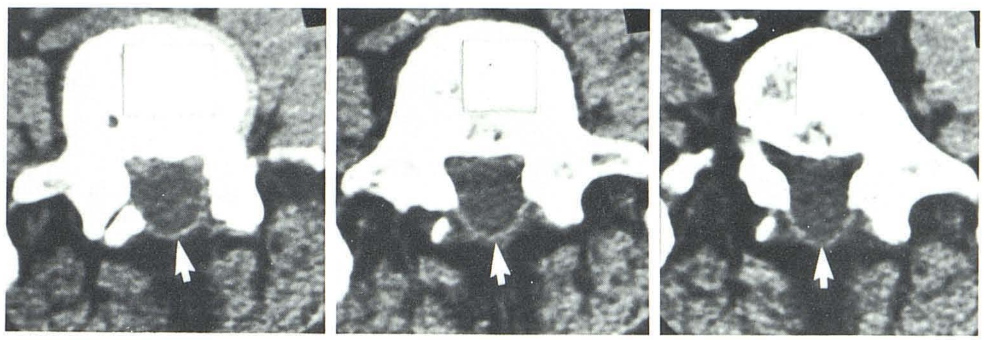

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Fig. 4.—Posterior bulge of thecal sac after laminectomies. Three successive sections at L4–L5 show posterior bulging of thecal sac (*arrows*). Extremely thin line of fibrosis at laminectomy site with preservation of fibrofatty tissue behind it. Posterior bulge of sac was confirmed by myelography.

appears quite similar to the normal preoperative canal. The thecal sac is centrally located and is surrounded by epidural fat, especially anterolaterally and posteriorly. If extensive laminectomies have been performed, fibrotic replacement of the posterior epidural fat may appear to "touch" the posterior thecal sac; the ligamentum flavum will of course be missing in part or in whole on the side of the laminectomy (fig. 3). Frequently, in the soft tissues immediately behind the laminectomy site, the fatty tissue will be replaced by fibrous tissue (fig. 3), a finding readily recognized on the CT. With extensive bilateral laminectomies, the thecal sac may be located slightly more posteriorly than usual (fig. 4), a desired result when spinal stenosis had been the underlying problem.

During an extensive laminectomy, parts of the posterior articular facet, which merges with the lamina, will be removed. In surgery on a stenotic canal or foramen, often medial aspects of both the anterior and posterior articular facets are resected. The spinous process is generally removed when extensive bilateral laminectomies are performed.

Extradural Scar

Scar and *fibrosis* will be used interchangeably in our forthcoming discussions.

Orthopedic surgeons and neurosurgeons have frequently encountered extradural scars in the lumbar canal during reoperation [10, 13–16]. In one series of postoperative myelograms, defects at the site of surgery were found in 38% [16] caused, in most cases, by extradural scars and less often by recurrent herniated disks.

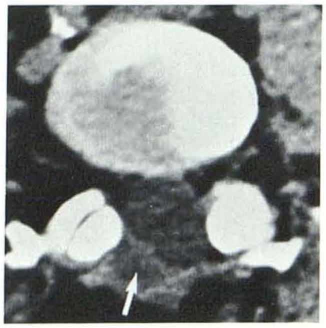
In about 700 of our patients who had previous laminectomy, usually with diskectomy, extradural scarring of some degree was noted in about 75% and sizable scars were found in about 40%.

The extradural scar appears as a soft-tissue density in the spinal canal, virtually always of greater CT density than the thecal sac. Most often its density is somewhat less than a herniated disk or the anulus itself.

The scar or fibrosis is always found on the side of the surgery and within the canal in one of the three surgical sites: (1) in the posterior part of the canal at the site of the laminectomy and ligamentum flavum excision; (2) in the anterior part of the canal at the site of a diskectomy, most often in a recess, although it can occur anteriorly and centrally, particularly if a large central disk has been removed; and (3) in the lateral wall of the canal at the site of a facetectomy. Frequently, the larger scar is a confluence of fibrosis from two or three of these primary surgical sites.

Posterior Laminectomy Scar

Laminectomy scarring may be limited to the laminectomy site (fig. 4) or may be incorporated into the postsurgical



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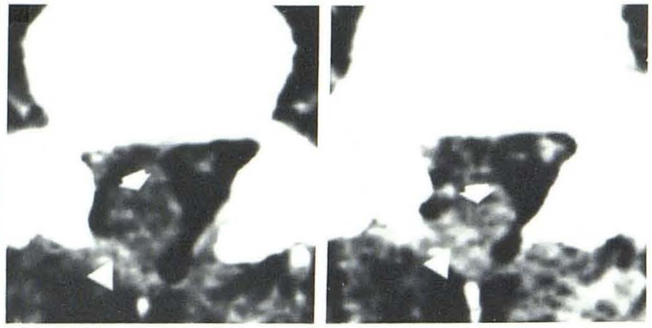

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Fig. 5.—Laminectomy scar; sac encroachment. Trapezoid laminectomy scar on right encroaches on right posterior aspect (*arrow*) of thecal sac.

Fig. 6.—Small laminectomy scar; retraction of sac. Small right laminectomy scar (*arrowheads*) has become fixed to thecal sac (*arrows*) and has retracted sac to right. Retraction of thecal sac may conceivably put emerging roots on stretch and cause symptoms on side opposite scar.

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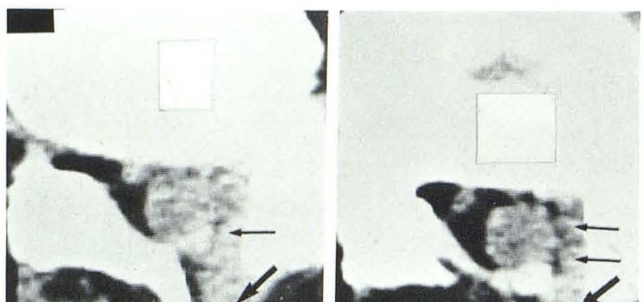

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Fig. 7.—Canal scar; thickened dura. Right side of canal is filled with soft-tissue scar (*black arrows*), which appears attached to thecal sac. Thickened wall of sac (*white arrow*) indicates dural thickening, which could be indicative of focal arachnoiditis.

Fig. 8.—Combined foraminectomy (facetectomy) and laminectomy scars. Left lateral canal scar (*small arrows*) is continuous with laminectomy scar (*large arrow*). **A**, Scar merges with left side of thecal sac. **B**, Distinct plane of separation between sac and scar.

A B C

Fig. 9.—Minimal diskectomy scar. **B**, Small density (*arrow*) medial to left nerve root is probably small scar. Left nerve root has somewhat fuzzy borders, probably from minimal surrounding scars. **C**, 4 mm below. Scar takes form of linear strand (*arrow*) extending from anterior sac to left nerve root.

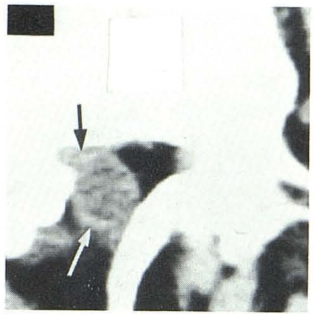
fibrotic changes that often replace the fibrofatty muscular tissue behind the lamina (fig. 3). The anterior part of the laminectomy fibrosis may not extend into the canal, and, in such case, the thecal sac will be seen completely separate from the scar (fig. 3). This type of fibrosis, which does not compromise the canal, is probably of no clinical significance. Sometimes, however, the laminectomy scar extends into the canal and seems to merge with the posterior part of the sac (fig. 5). Less often, the thecal sac is retracted by an adherent laminectomy scar (fig. 6).

Lateral Wall Scar

This is seen less often than laminectomy or diskectomy scars. Usually it appears at the site of a facetectomy, which is often done for relief of canal or neural foraminal stenosis. This lateral fibrosis may encroach on the wall of the dural sac (fig. 7) or may retract the sac, but more often is separate from the sac or barely touches it (fig. 8). The lateral wall scar often merges with a diskectomy and/or laminectomy scar, producing a larger scar mass.

Diskectomy Scar

After diskectomy, some degree of scarring or fibrosis in the anterior canal or recess is seen in most cases. The scar may vary from a small, thin, fiberlike strand (fig. 9) or small soft-tissue density in the recess replacing some of the epidural fat (figs. 9 and 10) to a larger mass resembling an HNP. The classical small diskectomy scar appears as a



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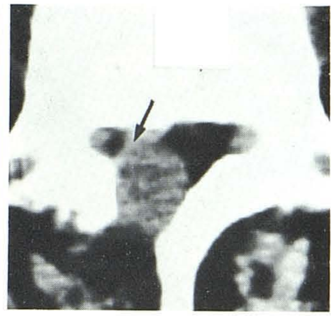

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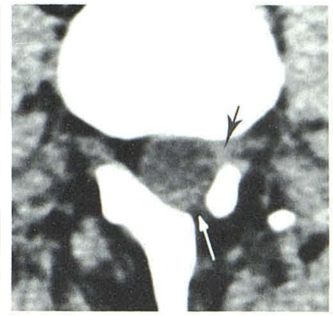

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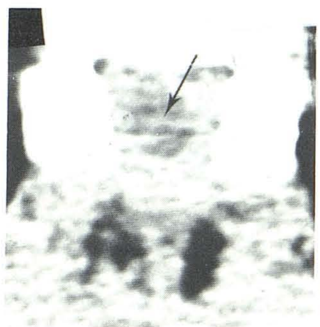
Fig. 10.—Diskectomy scar; retraction of sac. **A,** Sac is obviously pulled over to right side. A classical diskectomy scar (*black arrow*) fills right recess. **B,** Scar has become thick linear band extending from superior facet to posterior vertebral body. These changes are virtually pathognomonic of scar. Note thickened wall of thecal sac on right side (*white arrow*).

Fig. 11.—Classical diskectomy scar. Left recess epidural fat has been replaced by soft tissue (*black arrow*), which lies adjacent to thecal sac without pressure or compromise of sac. Note how it conforms to shape of sac. Also note absence of any laminectomy scar (*white arrow*). Such a classical diskectomy scar is quite characteristic and usually readily distinguished from recurrent herniated disk.



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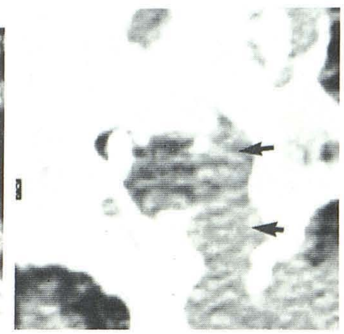

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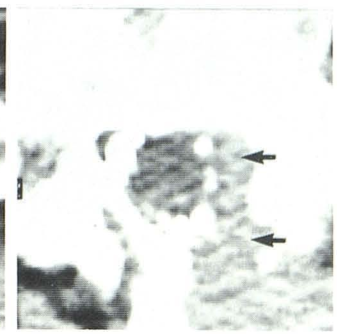

13B

Fig. 12.—Scar completely filling canal at L5–S1. Bilateral laminectomies and diskectomies were performed 5 months before. Thecal sac appears as rounded lucency (*arrow*) completely surrounded by dense scar tissue, which completely fills canal.

Fig. 13.—Combined scar; uniform CT density. Fibrosis (*arrows*) extends from left posterior soft tissue into laminectomy site and runs along thecal sac into left recess. Old droplets of Pantopaque are in sac. Uniform density of fibrosis both within and behind canal is significant evidence against associated recurrent herniated disk; the latter is generally of considerably higher density than scar.

replacement of the recess fat by a soft-tissue density that tends to conform to the curve of the sac without any apparent deformity of the sac (fig. 11).

A very important clinical consideration is the distinction of a diskectomy scar from a recurrent HNP. This will be considered in some detail below.

Combined Scars

Extensive scarring or fibrosis in the canal results usually from combined scars that apparently arise from two or more of the primary sites; for example, a combined diskectomy and lateral wall scar. These larger scars may surround one side of the thecal sac (fig. 8). When a laminectomy scar is also present and merges with the above, over half of the sac may appear surrounded by scar. Bilateral laminectomy can result in complete replacement of epidural fat by fibrosis, and the sac may at times appear as a rounded, relatively lucent area completely encircled by denser fibrotic tissue (fig. 12). The combined scars generally have a uniform density, and the recess part of the scar will not be confused with a recurrent HNP (fig. 13).

Clinical Significance of Extradural Scarring

The relation between extradural scars and recurrent symptoms is extremely difficult to evaluate. In well over half of the postoperative patients with early or late recurrence of low back pain or radiculopathy, sizable scars were present on the side of the previous surgery. However, in the other half of symptomatic patients there was no significant extradural scarring, and, in fact, in many of these there were no apparent postoperative complications such as recurrent HNP, bony stenosis, facet joint, or myelographic evidence of arachnoiditis. In these cases, the etiology of the recurrent radiculopathy remained obscure.

In many cases the scar envelops the ipsilateral nerve root and occasionally even a part of the dural sac. However, surgical scar excision and freeing of the nerve root is seldom undertaken since clinical relief is too often followed by a second recurrence caused by new and sometimes even greater scar formation. This was documented by CT in three of eight patients whose scars were surgically removed (fig. 14). Indeed, reoperation is generally undertaken with the hope and expectation that a recurrent herniated disk rather than a symptomatic extradural scar will be found. In one reported series of 34 reoperated cases [10], 20 had extradural scars only, 10 had recurrent herniated disk only, and four had scars above and below the interspace and a recurrent herniated disk at the interspace.

The clinical effects and significance of scars that are limited to the lateral canal wall or laminectomy site or both is uncertain, even when the scar encroaches on and deforms the lateral or posterior part of the thecal sac or

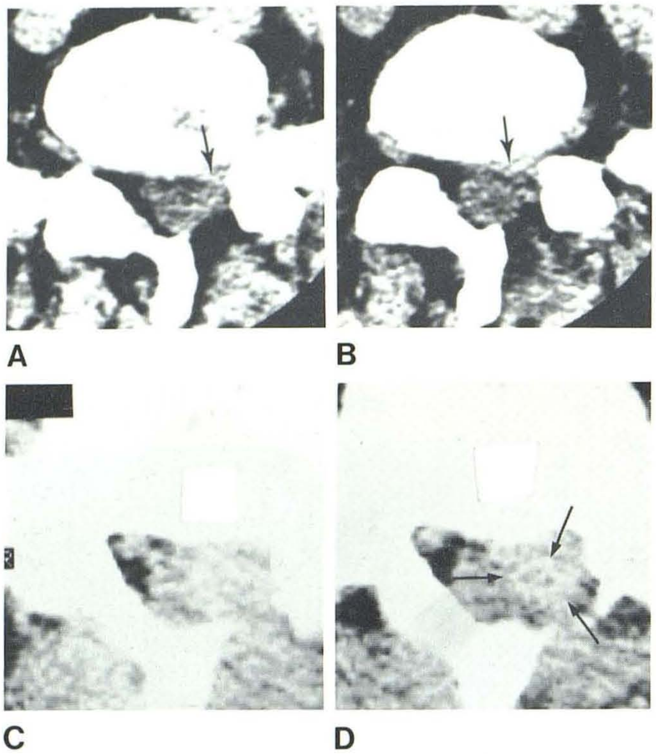

Fig. 14.—Recurrent scar after scar removal. **A** and **B**, Two sections of L5–S1. Soft-tissue density in left recess (*arrows*) was considered more likely to be scar than recurrent HNP. Because of severe radiating pain, surgery was performed. An extradural scar and no herniated disk were found; the scar was removed and nerve root freed. The symptoms returned 3 months after surgery, more severe than before. **C** and **D**, Sections at L5–S1 reveal large scar (*arrows*) filling almost entire left half of canal with obliteration of left side of sac and left recess.

retracts the thecal sac. This type of scar will often cause posterolateral deformations on the myelogram (fig. 15). Apparently some extradural scars extend to the dura and seem to be associated with dural thickening focally. This will be discussed later.

Recurrent HNP and the Diskectomy Scar

The clinician faced with the postdiskectomy patient who has a recurrence of pain and radiculopathy often quite similar to the preoperative symptoms usually entertains the possibility either of a recurrent HNP or more likely of a postoperative spinal stenosis. More recently, stronger consideration has been given to symptomatic diskectomy scars. In one report, the recurrent symptoms were more often due to recurrent HNP than to scar [6]. In our group of symptomatic postoperative patients, extradural scars were by far the most common and often the only finding, although, as previously mentioned, their clinical significance is far from certain. The distinction between a recurrent HNP and a large diskectomy scar becomes very important, since surgical excision may be indicated for a recurrent HNP, while an excision of an extradural scar is too often unrewarding (fig. 14) and may even result in a more disabled patient [14].

Myelography can sometimes suggest the distinction. Cronquist [10] believed that deformation on the postoperative myelogram, limited or most marked at the intervertebral level, indicates a recurrent herniated disk, but if the deformation extended significantly above or below the excised disk level, an extradural scar was present (fig. 15). Irstam and Rosencrantz [16], however, did not believe that this myelographic distinction was valid, especially since focal adhesive arachnoiditis can produce myelographic changes that may simulate recurrent disk herniation or extradural scar. However, the myelographic picture of arachnoiditis has no extradural component on CT and does not enter into the CT differential diagnosis between scar and HNP. Arachnoiditis and its relation to CT scars will be discussed later.

The diskectomy scar will frequently have CT features that can distinguish it from a recurrent herniated disk. The following CT characteristics are much more typical of scar than of recurrent HNP (see table 1):

1. Retraction of the thecal sac toward the soft-tissue lesion (fig. 10).
2. Diskectomy scar will often contour itself around the thecal sac (fig. 11). This type of scar will more often than not be associated with a negative myelogram.
3. Linear strandlike densities will occur frequently in scars and not in HNP (figs. 9 and 10).
4. The bulk of the scar is often above and/or below the disk interspace (figs. 15–18) in contrast to the recurrent HNP. This deformation above or below the interspace is also among the myelographic criteria for extradural scarring; however, only larger scars will be apparent on the myelogram.
5. Sometimes the anterior border of the diskectomy scar may not appear to be a direct extension from the intervertebral anulus in contrast to the usual disk herniation.
6. Diskectomy scar will enhance appreciably with intravenous contrast, unlike a herniated disk or disk fragment [17].
7. In many cases, the diskectomy scar will have a CT density number of 75 Hounsfield units (H) or less, while a recurrent disk herniation will have a much higher density (90–120 H) [18]. While this is generally true, sometimes a long-standing scar may have a density equivalent to recurrent HNP.

On the other hand, recurrent HNP usually has a CT appearance quite similar to the usual primary disk herniation (figs. 19 and 20). It may press on the thecal sac and does not conform to the shape of the sac. The posterior border of a recurrent HNP is generally sharp and discrete, and it may displace a nerve root posteriorly. The bulk of the soft tissue of an HNP is at the interspace level and appears to be a continuation of the anulus, although a large HNP may also extend above and below the interspace. The herniated disk and the anulus itself generally do not enhance after intravenous contrast.

Table 1 presents the distinguishing features of diskectomy scar and recurrent HNP. Most diskectomy scars can be identified fairly accurately on CT scans. Features such as retraction of the thecal sac, linear stranding, contours that follow the curve of the sac, and the continuity and merging

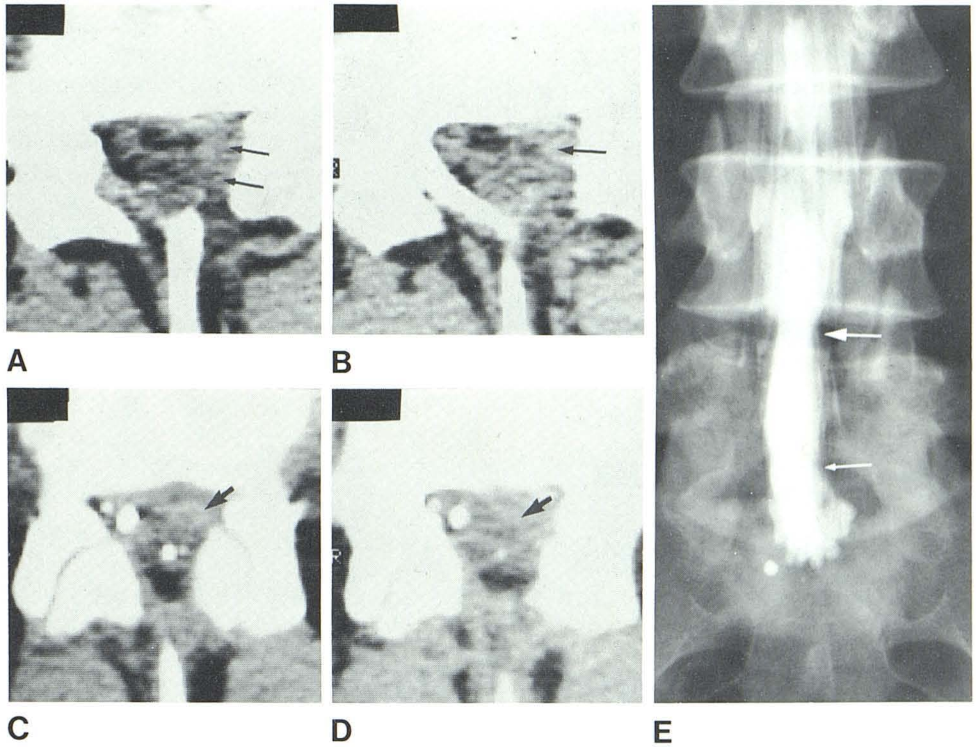

Fig. 15.—Scar and recurrent herniated disk. A 36-year-old man had left laminectomies at L4–L5 and L5–S1 for herniated disks with recurrent left radiculopathy. **A** and **B,** At L5–S1. Left canal scar (*arrows*) extends into left recess. Note uniform density of scar in canal and recess and absence of pressure deformity on sac. At surgery, this proved to be a scar. **C** and **D,** At L4–L5, left recess is filled with soft-tissue mass (*arrows*), which has a higher attenuation value than tissue in **A** and appears to be pressing on thecal sac. At surgery, this was recurrent herniated disk. **E,** Myelogram confirms left-sided defect (*large arrow*) at L4–L5 and minimal deformity (*small arrow*) above L5–S1 interspace on right. Myelographic findings suggested recurrent herniated disk at L4–L5 and epidural fibrosis at L5–S1.

TABLE 1: **Differential Features of Diskectomy Scar and Recurrent Herniated Disk**

CT Characteristics	Diskectomy Scar	Recurrent Disk Hernation
Shape	From strands to mass, often irregular, but can be regular; often contours around the thecal sac	Masslike density; does not follow sac contours
Location	Frequently extends well above or below the interspace; largest part may not be at interspace	Usually limited to interspace (rarely, fragment may migrate above or below)
Relation to thecal sac	Often retracts sac; often conforms to contour of sac; rarely compresses sac	Never causes sac retraction; may compress or deform sac
Associated scars	May be solitary or continuous with canal wall scar	Very infrequently associated with sizable scarring; if associated usually appears somewhat denser than adjacent scar
Free border into canal	Either sharp or indistinct	Free border usually sharp and distinct
Anterior (vertebral body) border	May not appear to be direct extension of anulus	Usually appears to be direct extension of anulus
Intravenous contrast enhancement	Shows marked enhancement	Little or no enhancement
CT density (Hounsfield units)	Usually less dense than disk herniation (50 to 75 H)	Generally denser than scar (90 to 120 H)

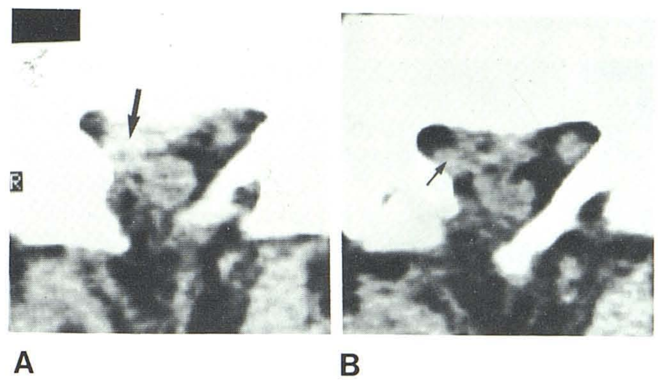

Fig. 16.—Recurrent HNP or extradural scar? A 28-year-old man had recurrent severe right S1 radiculopathy 2½ years after diskectomy. CT scans showed right laminectomy at L5–S1 and anterior canal soft-tissue mass of high density (*large arrow*) extending down canal and displacing S1 root posteriorly (*small arrow*). Recurrent or residual herniated disk was suspected from these findings, especially with evidence of root displacement. At surgery, however, S1 root was found entrapped by scar and swollen; no disk herniation was found.

with the canal scars and their major location above and below the interspace generally allow confident assessment of the lesion as a scar. This type will usually not be mistaken for a recurrent herniated disk on CT. If a myelogram is obtained, usually the deformation of the contrast column at the interspace is minimal or absent.

However, when CT reveals a sharply demarcated density resembling an HNP (figs. 16 and 17), it is virtually impossible to make a CT distinction between an HNP and a sharply marginated scar. In such cases, enhancement techniques after rapid intravenous contrast [17] might allow distinction,

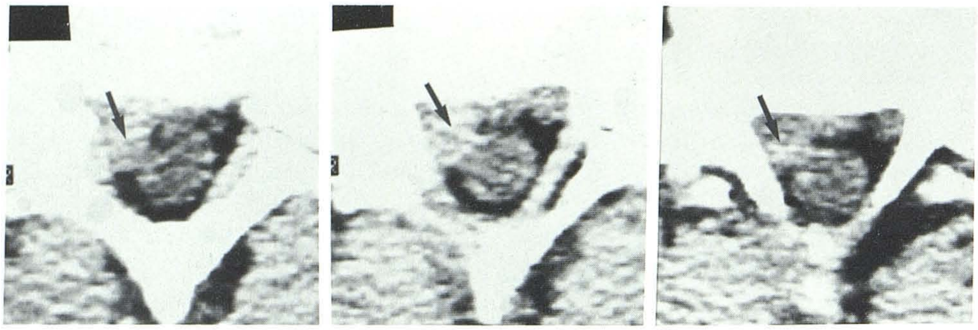
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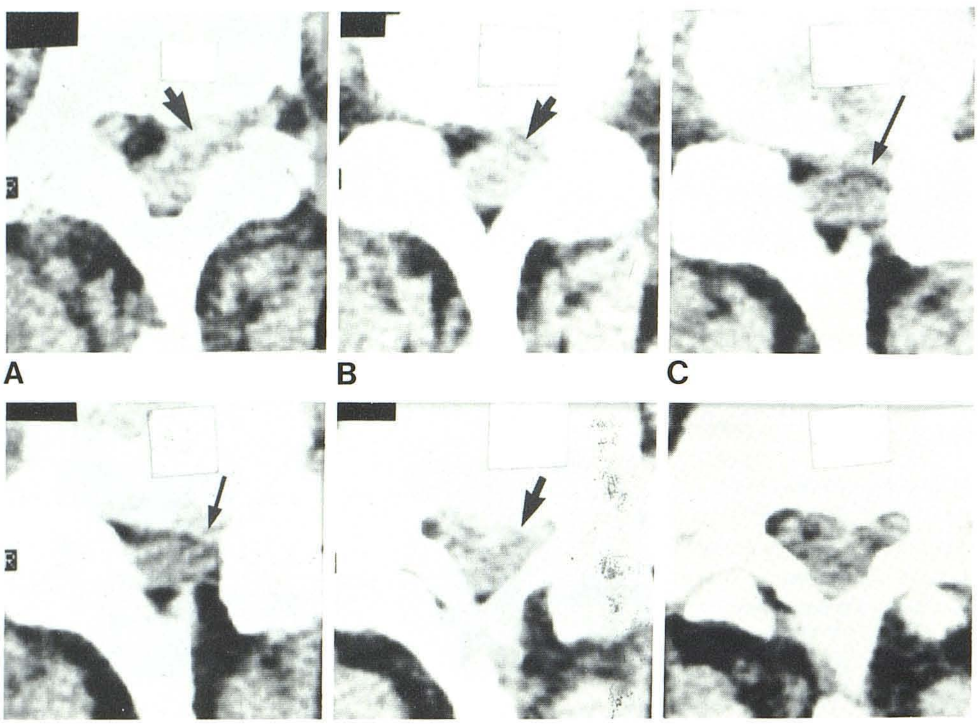
Fig. 17.—Scar or recurrent HNP? Right radiculopathy of S1 root 2 years after diskectomy. Scans at L5–S1 show right laminectomy and fairly dense recess mass (*arrows*) with relatively sharp margin. Density extended from anulus level down canal. Although the mass was not compromising the sac, the clinical picture suggested recurrent herniated disk. Myelography showed a defect consistent with herniated disk. At surgery, the root was completely entrapped by scar and no herniated disk was found.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D E F

Fig. 18.—Recurrent HNP versus scar; value of CT. Left diskectomy at L4–L5 1 year before with recurrent left radiculopathy. Sections at L4–L5 show soft-tissue density (*arrows*) in left recess, not only at interspace level (**C** and **D**) but also well above interspace (**A** and **B**) and a bit below it (**E**). Although posterior border of density appears sharp on **C** and **D**, note how it appears to maintain contour of sac. The density appears more bulky and more irregular on most cranial section (**A**) than at anulus level (**C** and **D**). From these features, the density was considered to be much more likely a scar than recurrent disk. At surgery only a large scar and no disk herniation was found.

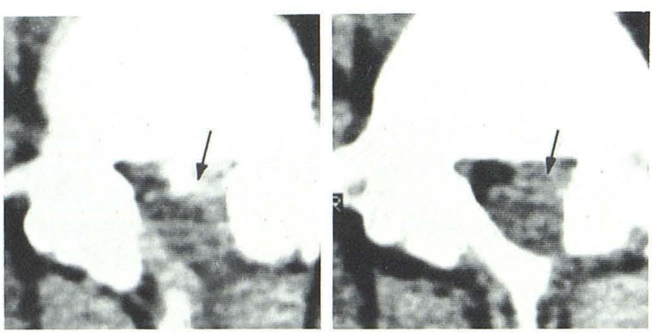
A B

Fig. 19.—Recurrent HNP. L5–S1 scans of patient who had left diskectomy 2 years before with recurrence of left radiculopathy reveal partly calcified density (*arrows*) in anterior canal. Calcified herniated disk was confirmed at surgery.

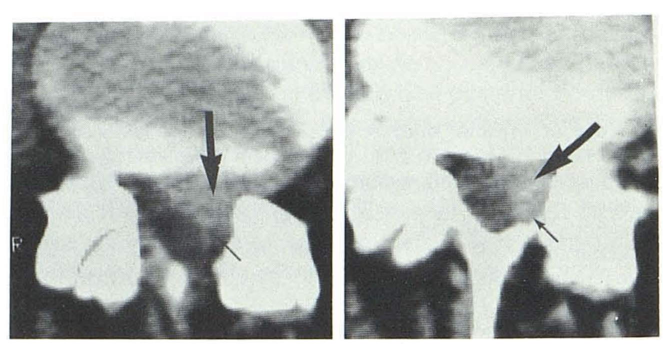
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Fig. 20.—Recurrent HNP at L4–L5. Sciatica developed 8 years after left diskectomy. Scans at L4–L5 show large soft-tissue mass (*large arrows*) projecting from left side of anulus and extending considerably posteriorly (*small arrows*). Large recurrent disk herniation was proven at surgery.

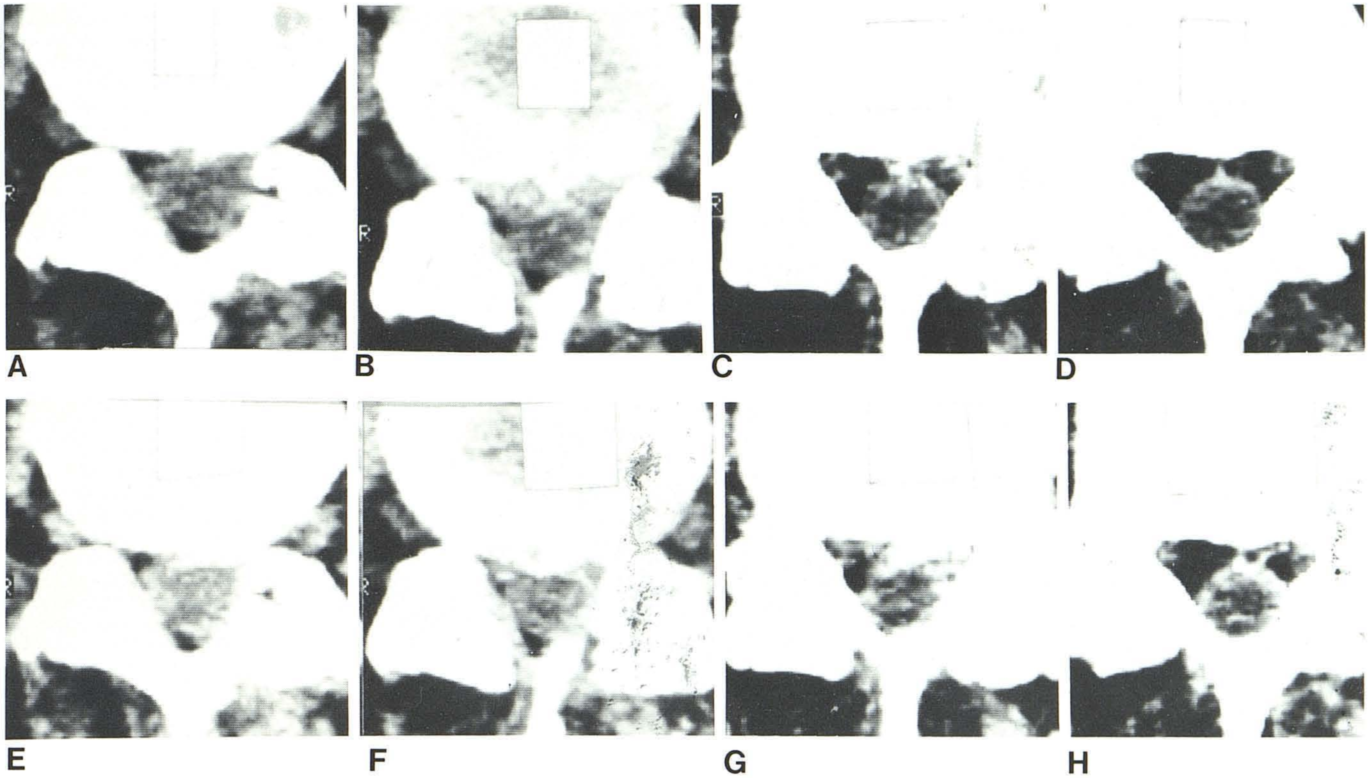

Fig. 21.—Recurrent HNP vs. scar; enhancement study. Recurrent left radiculopathy about 1½ years after successful diskectomy. **A–D,** Successive sections before enhancement. **E–H,** Identical sections after enhancement. All extradural soft-tissue shadows clearly enhanced, including fibrous strands **(H)** and anterior half of thecal sac **(H)** indicating fibrosis but not recurrent HNP. No reoperation was performed in light of these findings.

since the scars will always enhance but the herniated disk will not. In many but not all cases, the CT density is 90 H or greater for an HNP and less than 75 H for the scar [18]. In many cases of recurrent HNP proven by surgery (figs. 19 and 20), myelograms were positive showing deformation at the interspace level. It is our current impression that a recurrent HNP cannot be distinguished unequivocally from a masslike scar by CT appearance alone, but an enhancement study may prove more conclusive (figs. 21 and 22), especially if the CT density number is equivocal. In our experience, the extradural scar that is readily identified as such on CT is seen far more often than either a recurrent herniated disk or a scar that resembles a herniated disk.

To date, intravenous contrast enhancement studies have been done on 23 patients whose postoperative scans showed an extradural soft-tissue mass that could have been either a scar or a recurrent disk herniation. The following technique for the study has been used:

1. The interspace in question is scanned before intravenous contrast infusion is begun. The patient is advised not to move until after the infusion is completed.
2. A rapid infusion of 70% Conray (or its equivalent) via a 19 gauge needle is started.
3. After at least 100 ml of the infusion has been used, with the infusion continuing unabated, the interspace in question is scanned again using the identical slice positions.
4. Using the multiimage software, the corresponding pre- and postinfusion sections are imaged and photographed together, allowing accurate evaluation of any tissue enhancement.

Although enhancement is readily perceived on these corresponding sections, Hounsfield numbers can also be used. Scar tissue will generally be about 35–60 H before enhancement and 80–100 H after enhancement. Because enhancement disappears within minutes after infusion stops, it is very important to continue the infusion during the scanning.

To our surprise, enhancement of extradural fibrous tissue occurs even when surgery had been performed as long as 7 years before.

Not only does the extradural fibrosis enhance, but often the wall of the thecal sac on the side of the prior surgery will enhance, suggesting thickening of the meninges and focal arachnoiditis (figs. 21 and 22). The anulus does not enhance.

The 23 patients in whom CT could not confidently distinguish a scar from recurrent disk herniation were postoperative, ranging from 6 months to 7 years. In one, diagnosis of scar was confirmed surgically. In another, the enhancement study suggested both scar and disk fragments (fig. 22); this was confirmed surgically. In the third, a triangular enhanced scar extending from the sac to a bulging anulus was found. At surgery, however, a disk fragment was found anterior to the scar, apparently held up against the anulus by the scar. In the other 20 patients who were not reoperated, scar enhancement was clearly evident as the nature of the soft-tissue mass. However, in two, there were also

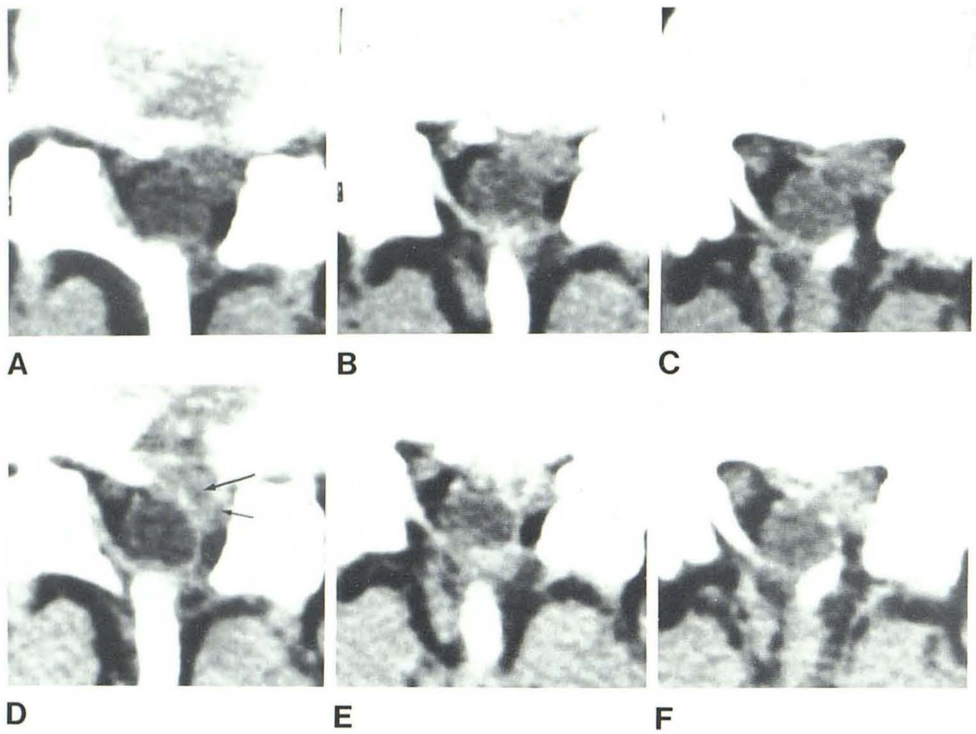

Fig. 22.—Enhancement study; combined scar and recurrent disk herniation? Recurrent pain and left radiculopathy began about 2 years after left diskectomy at L5–S1. **A–C,** Before enhancement. Soft-tissue mass in left recess extends above and below disk level. **D–F,** Postcontrast scans show marked enhancement, but anulus level (**D**) has nonenhanced areas (*black arrows*). This study suggests that the bulk of soft tissue is scar or fibrosis, but disk fragments (nonenhancing) are possibly also present. Disk fragments within fibrous tissue were confirmed surgically.

of the soft-tissue mass. However, in two, there were also nonenhancing areas within or adjacent to the scar suggestive of disk fragments.

When CT findings are inconclusive, the clinical history can be of some help. If recurrent symptoms have appeared within a few months or up to 2 years after diskectomy and have worsened, the possibility of a scar etiology is very high. However, when back pain and radiculopathy recur several years or more after surgery, the soft-tissue mass seen on the CT is more likely to be a recurrent herniated disk.

The distinction between an extradural diskectomy scar and recurrent HNP is important for treatment planning. When a scar only is found at surgery, the ultimate clinical result is often poor since new and sometimes extensive extradural scarring with symptoms may develop later. The surgeon, therefore, is reluctant to operate if an extradural diskectomy scar will be the most likely finding. On the other hand, removal of recurrent HNP is much more likely to provide a long-term satisfactory clinical result.

Postoperative Extradural Hematoma

In 15 patients who had diskectomy, CT of the postoperative spine was performed 4–14 days after surgery. In three, the scans were obtained because of early and persistent postoperative radicular pain; in the others, the early postoperative scans were investigational to determine the appearance of the canal soon after successful surgery.

In 13 of the 15, extradural soft-tissue densities were seen at the operative site. Although none of these cases were reoperated, and, therefore, positive identification of these extradural densities was not obtained, it seems quite reasonable to assume that these represented postoperative hematomas (figs. 23–25). In only two patients were there virtually no detectable postoperative hematomas, and, in one of these, microsurgical technique was used. However, in another case of microsurgery, the hematoma was quite sizable.

Although this series is small and limited, it suggests that most patients develop hematoma within the canal, most often at the diskectomy site. To date, five of these patients have been reexamined by CT 2 months or later after the early postoperative scan to determine the fate of these hematomas. In each case the extradural soft-tissue shadow had persisted with relatively minimal changes (fig. 26). This persistence suggests that the hematoma had become an extradural scar or fibrosis. Corroboration of the hematoma converting to an extradural scar would require, of course, a much larger series, which we hope to obtain eventually. This conversion of hematoma to scar is not unexpected. For some time others have believed that extradural scars were mainly the result of organization of a postoperative extradural hematoma [10, 19, 20].

Since the extradural fibrosis and scarring is a significant cause of postoperative recurrence of low-back symptoms and radiculopathy, it would be reasonable to assume that by minimizing the postoperative hematoma the incidence and extent of extradural scarring would be diminished. Certainly this could be verified by a larger series of both early and late postoperative CT scans. It is hoped that with the rapid proliferation of high-resolution scanners such a

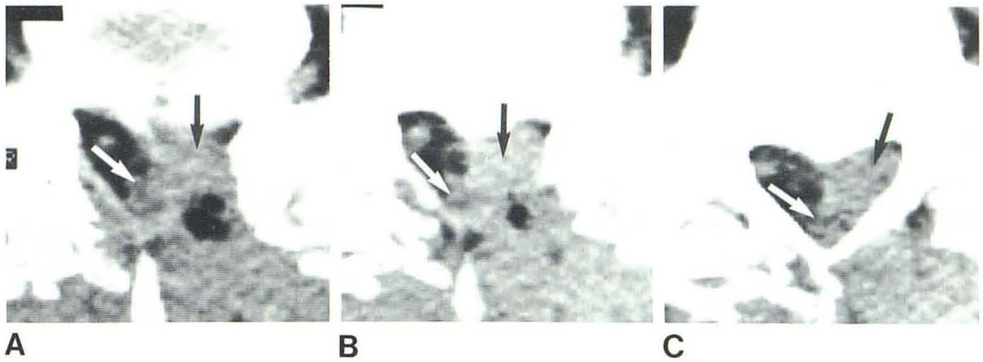

Fig. 23.—Postdiskectomy extradural hematoma. Scans at L5-S1 8 days after surgery. Large soft-tissue density (*black arrows*) fills left canal, extending from posterior vertebral area to small thecal sac (*white arrows*). Epidural fat in left recess is not entirely obliterated.

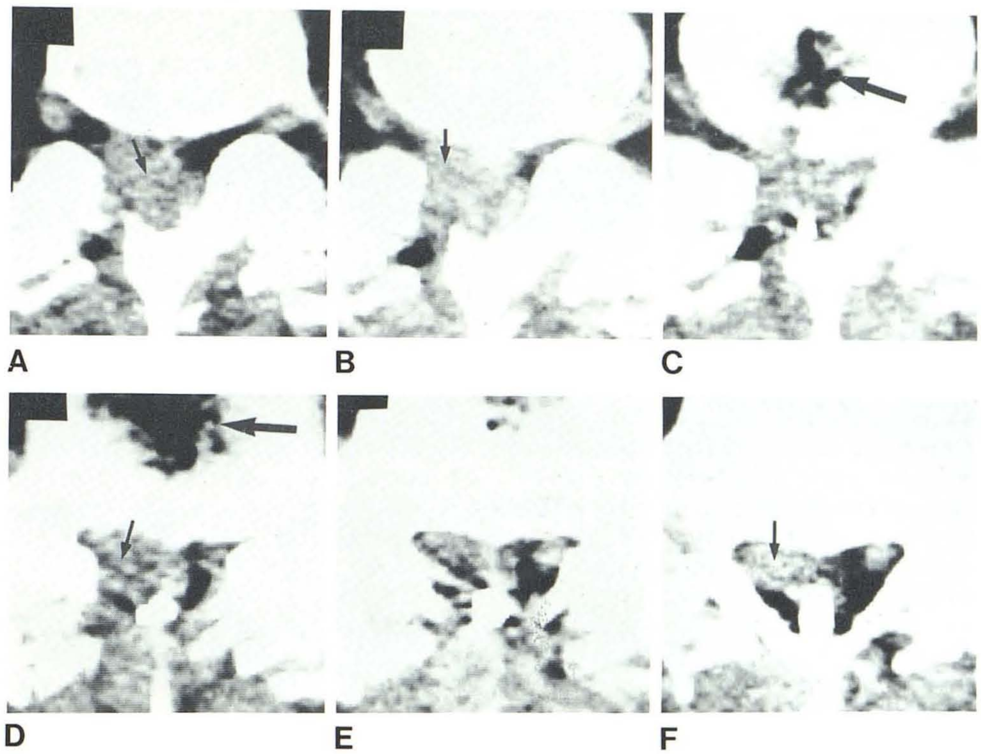

Fig. 24.—Postoperative hematoma and vacuum disk. Scans of L5-S1 8 days after right diskectomy. Fairly large hematoma (*small arrows*) extends well above actual interspace. Extradural scars deriving from hematomas are frequently most marked above or below interspace, in contradistinction to recurrent HNP. A vacuum disk (*large arrow*) has developed.

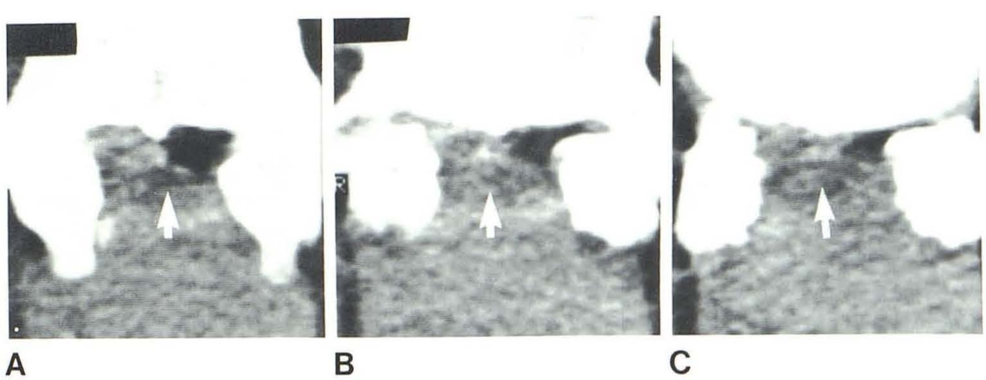

Fig. 25.—Extensive hematoma after bilateral laminectomy for right-sided HNP. Extradural soft tissue, undoubtedly hematoma, surrounds more lucent thecal sac (*arrows*) 6 days after bilateral laminectomy and diskectomy. Only left recess is clear. The patient was experiencing unexpected postoperative low back pain and right radiculopathy. Most likely, this hematoma will be transformed into scar and probably will fill entire canal (as in fig. 26).

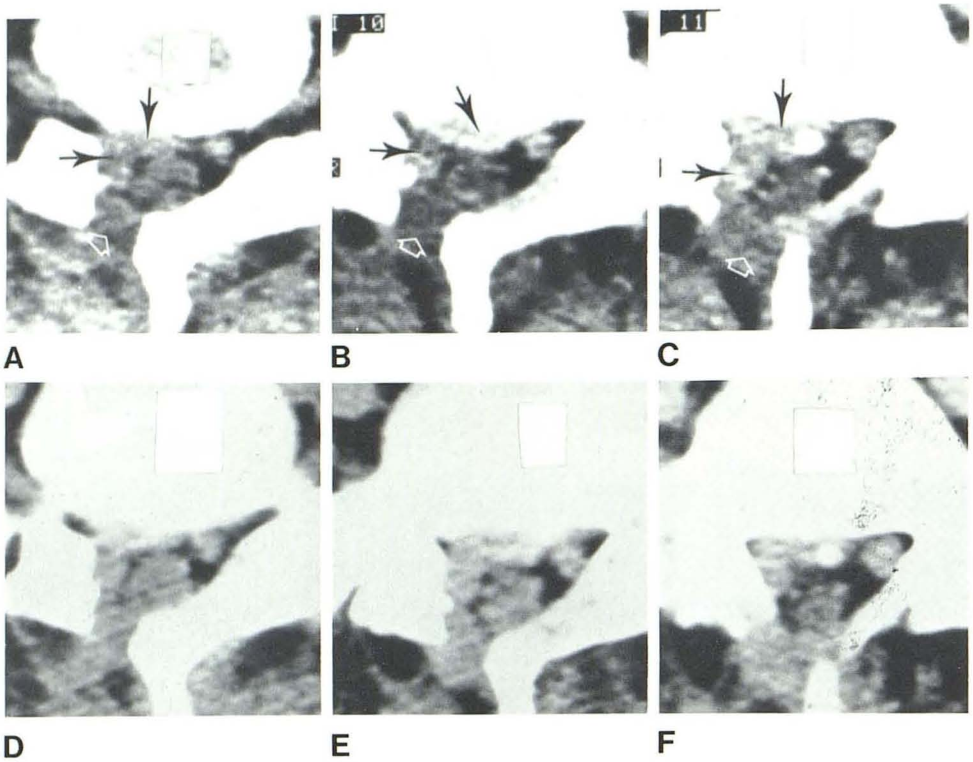

Fig. 26.—Hematoma changing into scar. **A–C,** 2 weeks after diskectomy. Extensive extradural soft-tissue densities (*closed arrows*) undoubtedly represent hematomas at diskectomy and facetectomy sites. **D–F,** 2 months later. Hematomas have contracted slightly and have become slightly more dense, indicative, we believe, of contracting scars. The patient was symptom-free at this time. Note that soft tissue at laminectomy site (*open arrows*) has changed from low density (edema?) at 2 weeks to higher density (fibrosis) after 2 months.

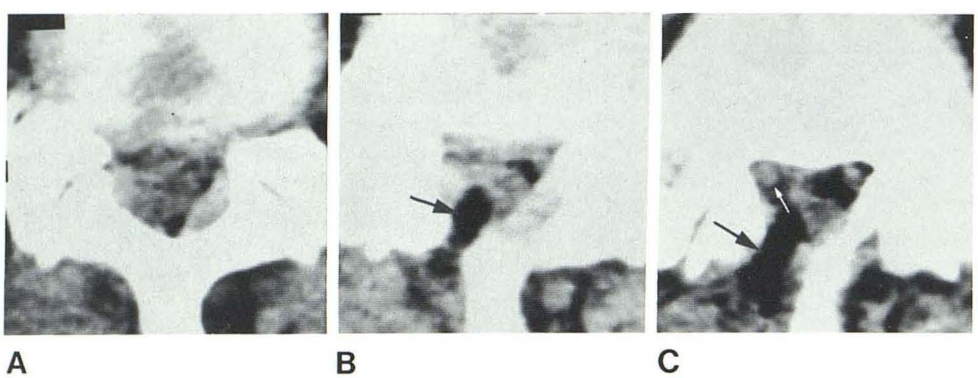

Fig. 27.—Fat graft. CT 8 months after right laminectomy and diskectomy. Fairly large fat graft (*black arrows*) extends from laminectomy site anteriorly to right S1 root (*white arrow*). Very little scarring is seen.

series would be forthcoming from various centers within the next few years.

Minimization of the extradural hematoma and subsequent scarring has been attempted by the placement of absorbable Gelfoam or grafts of fat to protect the neural structures from fibrosis. Experimental animal studies and some correlative human data suggest that the efficacy of Gelfoam is minimal or questionable, but that fat grafts remain viable and offer considerable protection to the nerve root or sac from fibrotic encirclement [4, 21]. The fat grafts within the canal are usually recognized on the CT scans of the postoperative spine (fig. 27).

Hematoma, edema, and later fibrosis are also frequently seen outside the spinal canal in the soft tissues of the operative field behind the laminectomy. In several cases, however, postoperative fibrosis outside the canal was eventually replaced by a normal-appearing pattern of symmetric fat and fibrous tissue virtually identical to the preoperative appearance.

Perhaps this decrease of fibrous tissue and restoration of fat can also occur in the postoperative spinal canal. The cases showing conversion of the extradural hematoma to permanent scar are too few to be certain that this always occurs. Final opinion on the matter must be reserved until a large series of serial postoperative scans have been obtained and analyzed.

Postlaminectomy Pseudomeningocele

This complication apparently results from an inadvertent tear of the dura during surgery. The cerebrospinal fluid extravasates posteriorly and forms a rounded collection of

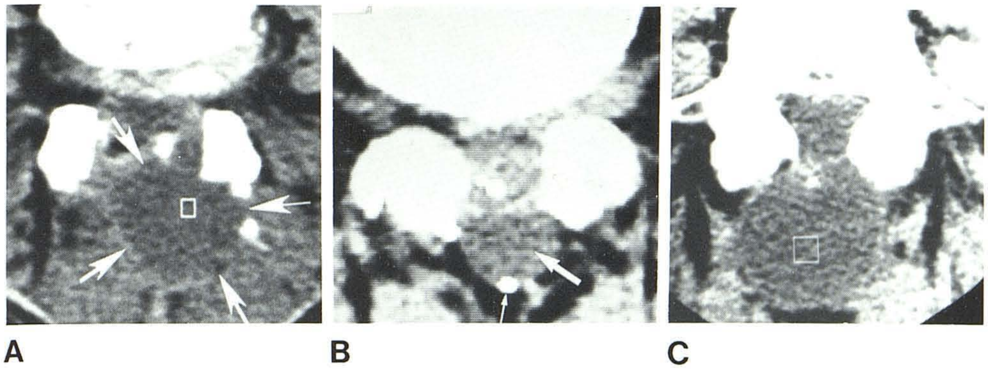

Fig. 28.—Postlaminectomy pseudomeningocele in three patients. **A,** 1 month after bilateral facetectomies. A 2 cm low-density rounded mass (*arrows*) is behind laminectomies, a characteristic appearance of pseudomeningocele. **B,** 1½ years after bilateral laminectomies at L4–L5. A 1.5 cm rounded low-density mass (*large arrow*) is directly behind laminectomy. Droplet of Pantopaque (*small arrow*) in posterior tip of lesion indicates its connection (at one time, at least) with subarachnoid space. **C,** 6 years after bilateral laminectomy at L4–L5. A 3 × 5 cm low-density rounded mass is directly behind laminectomy.

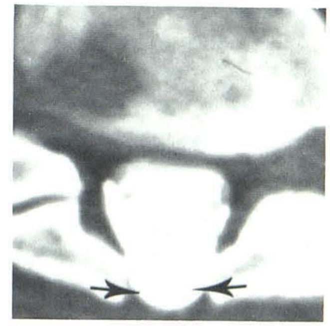

Fig. 29.—Posterior "herniation" of thecal sac after bilateral laminectomies. Posterior herniation of thecal sac containing metrizamide (*arrows*) is readily apparent. This posterior "herniation" or bulge, when seen on myelogram, has unfortunately been incorrectly termed *pseudomeningocele*.

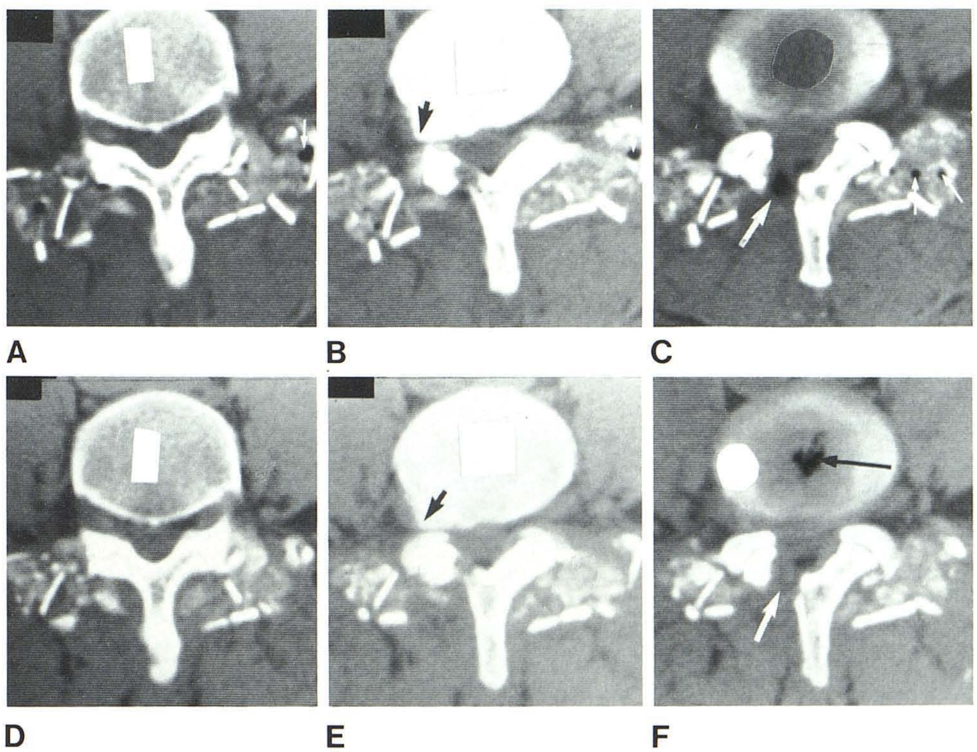

Fig. 30.—Failure to correct foraminal stenosis. Scans 8 days (**A–C**) and 6 months (**D–F**) after L4–L5 diskectomy for continuing right radiculopathy. Severe right foraminal stenosis caused by posterior vertebral spur was not corrected (**B** and **E**, *arrows*). Bone chips behind and lateral to facets remain discrete, suggesting fusion is not occurring. "Vacuum" disc (**F,** *black arrow*) has developed in operated interspace. Gas bubbles (**A–C,** *small white arrows*) are not seen on later scans. Gas within canal and at site of fusion 2 weeks after surgery is normal. Piece of Gelfoam (**C,** *large white arrow*) inserted at laminectomy site is completely replaced by fibrosis in 6 months (**F,** *white arrow*).

low CT density (fig. 28) behind the laminectomy at or very near the midline. The appearance is quite characteristic on the CT [22, 23].

Most of these collections are extravasations or leaks of cerebrospinal fluid that may eventually develop a fibrous capsule. In some cases, apparently a superficial dural tear will allow herniation of the intact arachnoid, which gradually enlarges. This becomes an arachnoid-lined true meningocele, but apparently this type is much less common.

Since the pseudomeningocele often loses its communication with the dural sac after the healing of the tear, it is not surprising that often myelography will fail to demonstrate it. This was true in several cases. Obviously CT is the most accurate method for uncovering a pseudomeningocele and perhaps the only method available when there is no communication. In our 12 cases of pseudomeningocele shown by CT, the finding has been totally unexpected in 10. The earliest encountered was 1 month postoperatively; the oldest was seen 6 years postoperatively (fig. 28).

Transient small pseudomeningoceles may be more common than anticipated. In two postoperative patients, CT scans obtained within 3 weeks of surgery showed a rounded area of lower density behind the laminectomy, quite suggestive of a pseudomeningocele. Scans obtained a few months later showed disappearance of these lesions. Perhaps they are the result of inadvertent small dural tears, which rapidly seal off. In 1974, Kim et al. [24] found transient pseudomeningoceles on air myelograms after cervical spinal surgery.

Clinically, a pseudomeningocele may be totally asymptomatic or may cause a localized backache. Symptoms are more likely to occur if it is still connected to the dural sac; coughing or sneezing may then cause ballooning and local pain. If a root is trapped or herniates partly into the pseudomeningocele tract, severe radiculopathy may occur. Some neurosurgeons believe that a pseudomeningocele should be suspected if symptoms occur shortly after surgery, particularly if the surgeon has manipulated the thecal sac. A pseudomeningocele caused by a dural tear and extravasation posteriorly should not be confused with posterior displacement of the thecal sac that may occur after extensive bilateral laminectomy (fig. 29). When this type of displacement of the sac is seen on the myelogram it has also been termed *pseudomeningocele* in the literature, an unfortunate confusion of terms.

Postoperative Stenosis

Bony stenosis, especially of the recesses or foramina (lateral spinal stenosis), is considered the leading cause of failure of back surgery by some authors [6, 8]. From two rather extensive series, Burton et al. [6] reported that lateral spinal stenosis, either overlooked at disk surgery (fig. 30) or caused by bony overgrowth from the surgery, was considered the cause of recurrent symptoms in almost 60% of patients with failed back surgery. Central stenosis accounted for 7%–14% [6, 8]. In one of their series of 225 patients who were preoperatively diagnosed as having herniated disks, 56% had concomitant lateral spinal stenosis or lateral spinal stenosis alone at the time of surgery [6, 8].

In many cases, late postoperative radiculopathy may result from narrowing of the intervertebral disk after surgery, which is a postoperative result. The narrowed intervertebral space permits upward movement of the superior facets with possible compromising pressure on the nerve root in the foramen. With narrowing of an intervertebral space the diminished width and length of the neural foramina is usually apparent.

Bony overgrowth or spur formation of a facet or vertebral body can be secondary to surgical resection. Apparently during the procedure of removal of the HNP and exploring the anulus for fragments, the bony margin adjacent to the interspace may be scarified or even resected (fig. 31), and this may result in reparative bony overgrowth with subsequent lateral stenosis. If the spur of bone overgrowth compromises the canal, the neural foramen, or the recess, clinical symptoms may occur (figs. 32–34). A less common cause of postoperative spinal stenosis is overgrowth of a bone fusion with some of the bone extending into or constricting the canal [6] (figs. 35 and 36).

In our series, we found that extradural scars are a much more common finding than significant postoperative stenosis, unless we include patients who develop postoperative narrowing of the intervertebral space with subsequent decrease in the total size of both neural foramina. Unexpectedly, we have found that postoperative bony stenosis on CT is much more often caused by a vertebral body spur at the diskectomy site than by facet overgrowth.

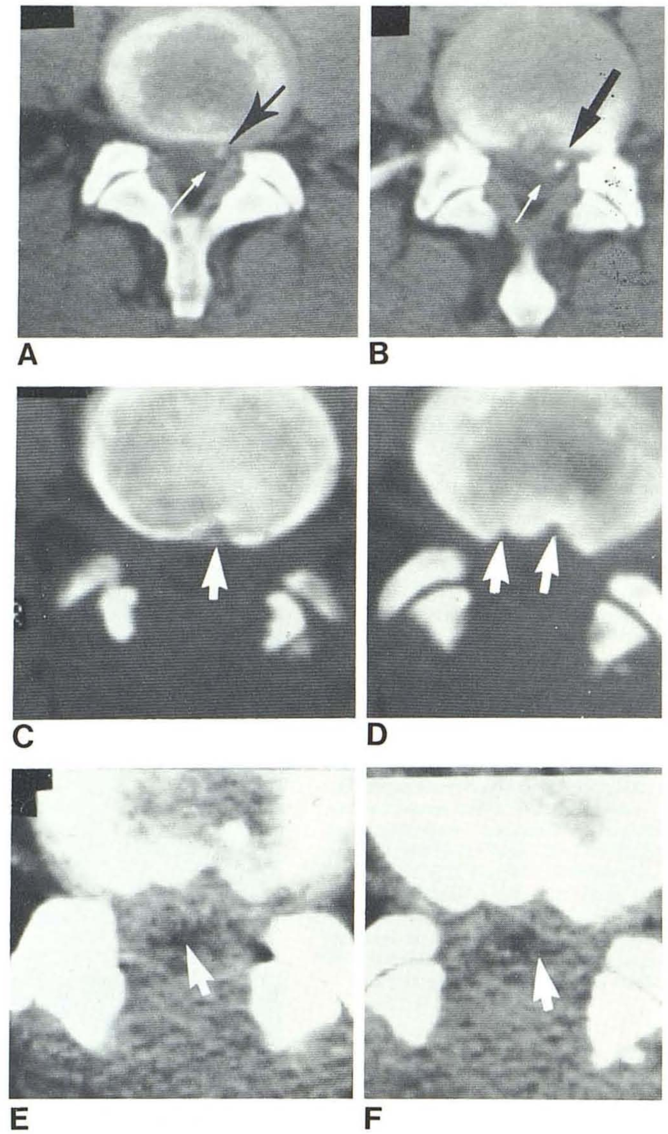

Fig. 31.—Extensive scarring from vigorous surgery. **A** and **B**, Preoperative scans (bone windows) of L4–L5 disclose a central and left-sided HNP (*white arrows*); some calcium is in herniation (*black arrows*). **C** and **D**, 2½ months after surgery. Large bilateral laminectomies. Irregular defect, bordered by sclerosis (*arrows*) in posterior vertebral body of L4 just above interspace. **E** and **F**, Scar tissue completely fills canal and soft tissues posterior to canal. Lower-density thecal sac (*arrows*) is completely surrounded and engulfed by fibrosis. Large amount of scar tissue, probably responsible for early recurrence of symptoms, is most likely end result of excessive bleeding and hematomas from excessive laminectomies and inadvertent removal of bone from vertebral body.

Postoperative Arachnoiditis

Chronic adhesive arachnoiditis of the lower spine is a myelographic diagnosis. Most cases are found in patients

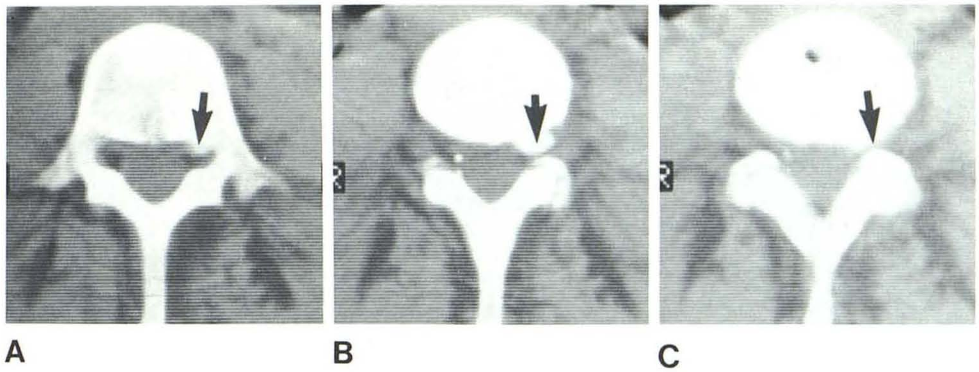

Fig. 32.—Postdiskectomy spur and foraminal stenosis. Left radiculopathy developed about 6 years after left laminectomy and diskectomy at L4–L5. CT revealed a large bony spur (*arrows*) at diskectomy site; left neural foramen is seriously compromised by spur.

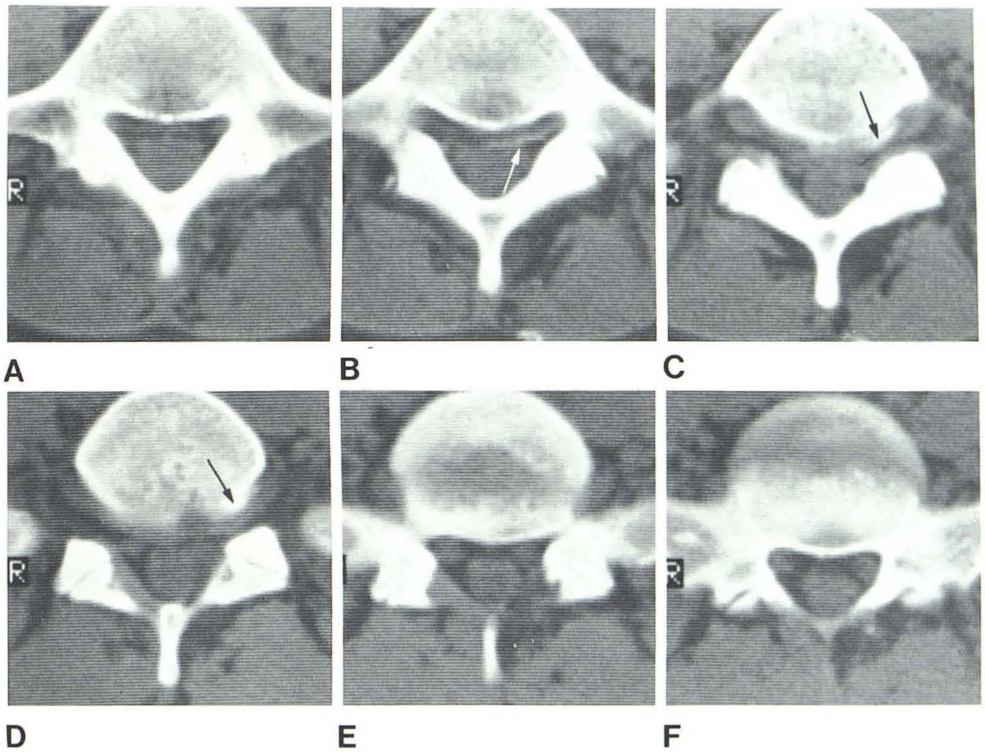

Fig. 33.—Postoperative recess and foraminal compromise. Low back pain and left radiculopathy 8 years after left L5–S1 diskectomy. CT scans (bone windows) show linear bony spur traversing left recess (*white arrows*) and becoming more dense exostosis from vertebral body (*black arrows*). This is compromising the left neural foramen. Postoperative bony overgrowth causing lateral stenosis is more likely to arise from vertebral body than from superior facet.

who have had previous spine surgery [10, 11, 13–16]. "Arachnoiditis" is a misnomer, since histologically all layers of the meninges are involved and invariably the dura is thickened. The etiology of postoperative arachnoiditis is unknown. It has been postulated that microvascular traumatization of the arachnoid during surgery might be an important factor [15]. Irstam and Rosencrantz [16] found that in reoperated cases, there was no real correlation between the presence or absence of extradural scarring and the existence or severity of adhesive arachnoiditis. However, in the relatively few cases of arachnoiditis that were reoperated [13, 14, 16], there was always some epidural scarring around the sac associated with thickened dura. These findings were always at the previously operated site, and the proliferative dural changes were also more marked on the side of the diskectomy, although they might extend above and below the operated interspace.

Although arachnoiditis can be one of the causes of postoperative symptoms [6, 13], no distinct clinical symptom complex is associated with the myelographic diagnosis of arachnoiditis [14]. Nevertheless, Burton et al. [6] believe that adhesive arachnoiditis is responsible for recurrent symptoms in 6%–16% of cases.

On CT, focal thickening of the dural sac, especially near the operative site, is often seen in the postoperative patient (figs. 7, 9–12). This thickening on CT was also seen in two cases of arachnoiditis corroborated by myelography. In our enhancement studies performed to distinguish scar from recurrent herniated disk, we noted distinct enhancement of a thickened wall of the sac in many of these (figs. 2, 22, and 36). It seems likely that this finding represents thickened dura and probably also arachnoid, which are somehow related to the surgery and are most prominent on the side of the surgery. Perhaps this dural thickening of the sac may

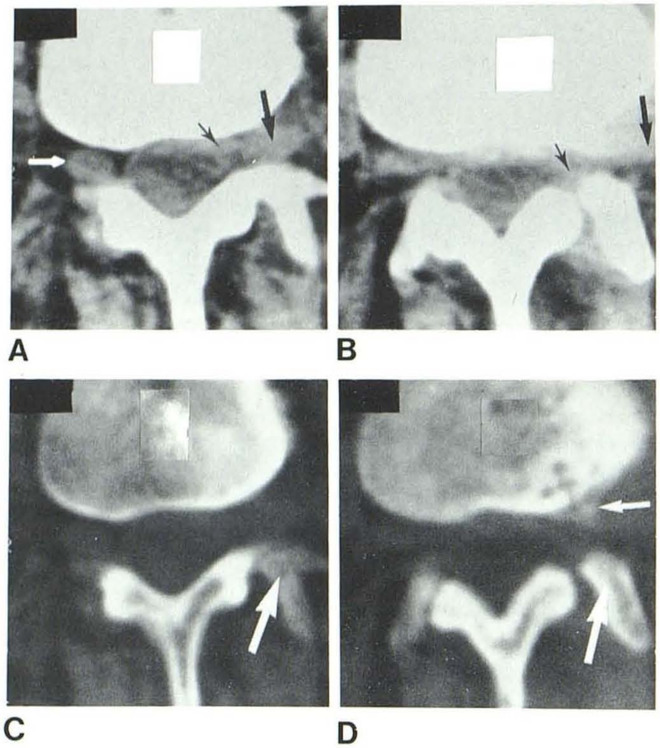

Fig. 34.—Late postdiskectomy radiculopathy with facet subluxation. Recurrent left radiculopathy 5 years after successful left diskectomy at L4–L5. Soft-tissue (**A** and **B**) and bone (**C** and **D**) windows. Small diskectomy scar adjacent to sac (*small black arrows*). Enlarged and slightly irregular nerve root on left (*large black arrows*). Right root and ganglion (**A**, *white arrow*) are normal. **C** and **D**, Subluxed superior facet (*large white arrows*) and bony spur (*small white arrow*) extend from body into the neural foramen. At surgery, swollen left root was found entrapped between scar, subluxed facet, and bony spur. No recurrent HNP was found. Symptoms were relieved.

be the CT manifestation of postoperative arachnoiditis [25] (fig. 37). When metrizamide is present in the sac, thickening and bunching of the nerve roots within the sac may be seen and appreciable thickening of the meninges is more easily demonstrated (figs. 38 and 39).

Calcification of the spinal meninges due to chronic arachnoiditis is very rare [26]. The calcification was clearly seen on CT in a case report of diffuse thoracic and lumbar arachnoiditis, with obvious linear calcification of the wall of the thecal sac on plain radiographs [26].

We have encountered one case of focal postoperative arachnoiditis proven by myelography in whom CT clearly showed ring calcification of the thecal sac (fig. 40) limited to the area of focal myelographic arachnoiditis at L5–S1. Apparently, calcification of the spinal meninges on CT can be considered a finding virtually diagnostic of chronic arachnoiditis.

Presumably information on arachnoiditis as a cause of postoperative symptoms could be obtained if postoperative myelograms and intravenously enhanced CT scans could be obtained on a series of both symptomatic and asymptomatic postoperative patients. Nevertheless, it appears that a thickened dural sac wall can be seen with or without contrast enhancement, and it may often occur in the post-diskectomy patient. This thickening may uniformly encircle the sac or may be segmental and nonuniform. When segmental, the thickening occurs most often on the side of the laminectomy. We can postulate that if the dural thickening compromises the arachnoid space even focally, some degree of arachnoiditis might be seen on the myelogram. However, dural sac thickening alone on the postoperative CT scan cannot accurately indicate the presence or severity of arachnoiditis. This condition still remains an exclusively

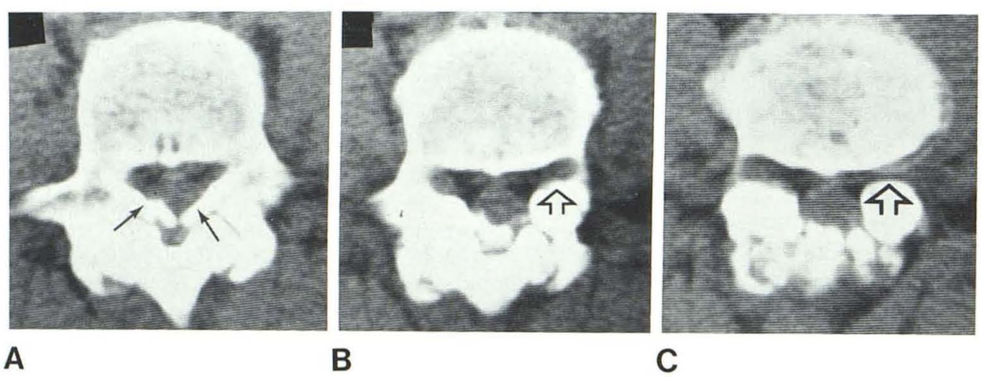

Fig. 35.—Postfusion encroachment on canal. Left L5 radiculopathy. Posterior fusion fragments encroach on posterior canal (*closed arrows*). Hypertrophied left facet (*open arrows*) encroaches on left recess and foramen.

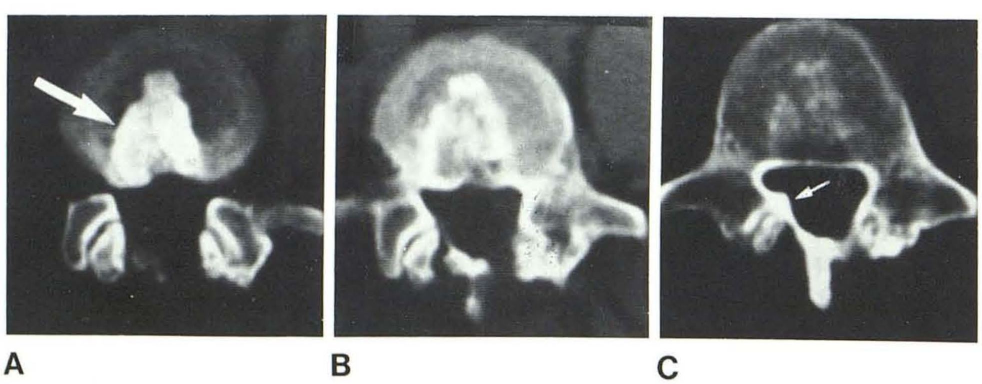

Fig. 36.—Postoperative minimal stenosis. Right-sided radiculopathy. After extensive laminectomies and facetectomies, there has been overgrowth of right facet (*small arrow*) causing some compromise of right recess. One anterior fusion bone fragment (*large arrow*) extends somewhat into inferior part of right neural foramen.

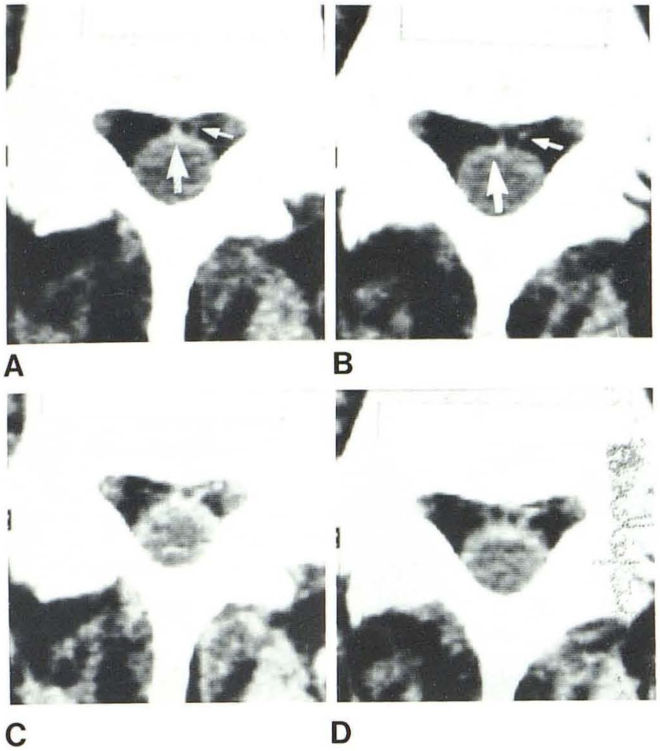

Fig. 37.—Enhancement of sac wall and fibrous strands. Central HNP had been removed at L4–L5 about 1 year before. **A** and **B**, Before intravenous contrast. Somewhat thickened anterior sac wall (*large arrows*) and barely visible thin fibrous strands (*small arrows*). **C** and **D**, After contrast. Full extent of thickening of anterior sac wall and fibrous strands is shown.

myelographic diagnosis. Nevertheless, it is possible that focal dural thickening might be related to recurrent radiculopathy in some patients with otherwise negative postoperative CT studies.

Miscellaneous Postoperative Findings

Arthrodesis and Spinal Fusion

The early (figs. 23 and 30) and late (figs. 41 and 42) appearances of posterolateral fusion and arthrodesis and its degree of success can be depicted by CT. Poor results may show failure of fragments to coalesce (fig. 30), pseudoarthrosis, fusion overgrowth with some compromise of the canal (figs. 35 and 41), or failure to obliterate the apophyseal joints. Total obliteration of the joints and solid fusion (figs. 35, 36, and 42) are the desired results.

In anterior fusion (interbody fusion), bone fragments are placed within the intervertebral disk and end-plates (figs. 36 and 43). If one fragment inadvertently bulges into the canal (fig. 36), it may cause symptoms. The anterior fusion is now rarely employed.

Postoperative "Vacuum Disk" Phenomenon

In many patients who had both preoperative and postoperative CT, it became apparent that a vacuum disk had developed within days after diskectomy (figs. 30 and 44). This apparently results from surgical extraction of degenerated disk material through the defect of the anulus fibrosis. This evacuated area in the anulus apparently fills quickly with gas, producing the vacuum disk. It has been shown that the gas is mainly nitrogen.

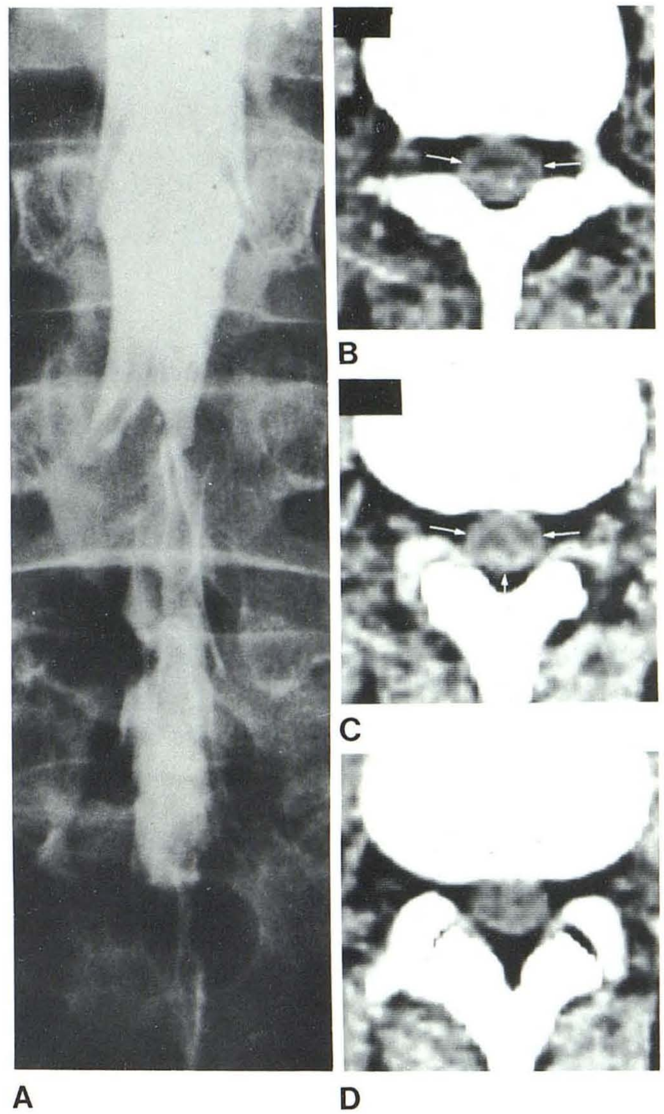

Fig. 38.—Postoperative arachnoiditis. **A**, Metrizamide myelogram about 1 year after diskectomies at L4–L5 and L5–S1 shows severe arachnoiditis from L3 to S1. **B** and **C**, CT at L3–L4 shows thickened sac wall (*arrows*). However, at L4–L5 (**D**), where myelogram also indicated definite arachnoiditis, wall of thecal sac did not appear thickened on CT.

Air in the Thecal Sac

A unique complication occurred when the dura was accidently torn and repaired during diskectomy. The patient developed unexpected low back pain very soon after surgery (fig. 45). A CT scan 4 days after surgery showed an air-distended thecal sac. The patient was allowed to stand and move, and his symptoms became less severe within a

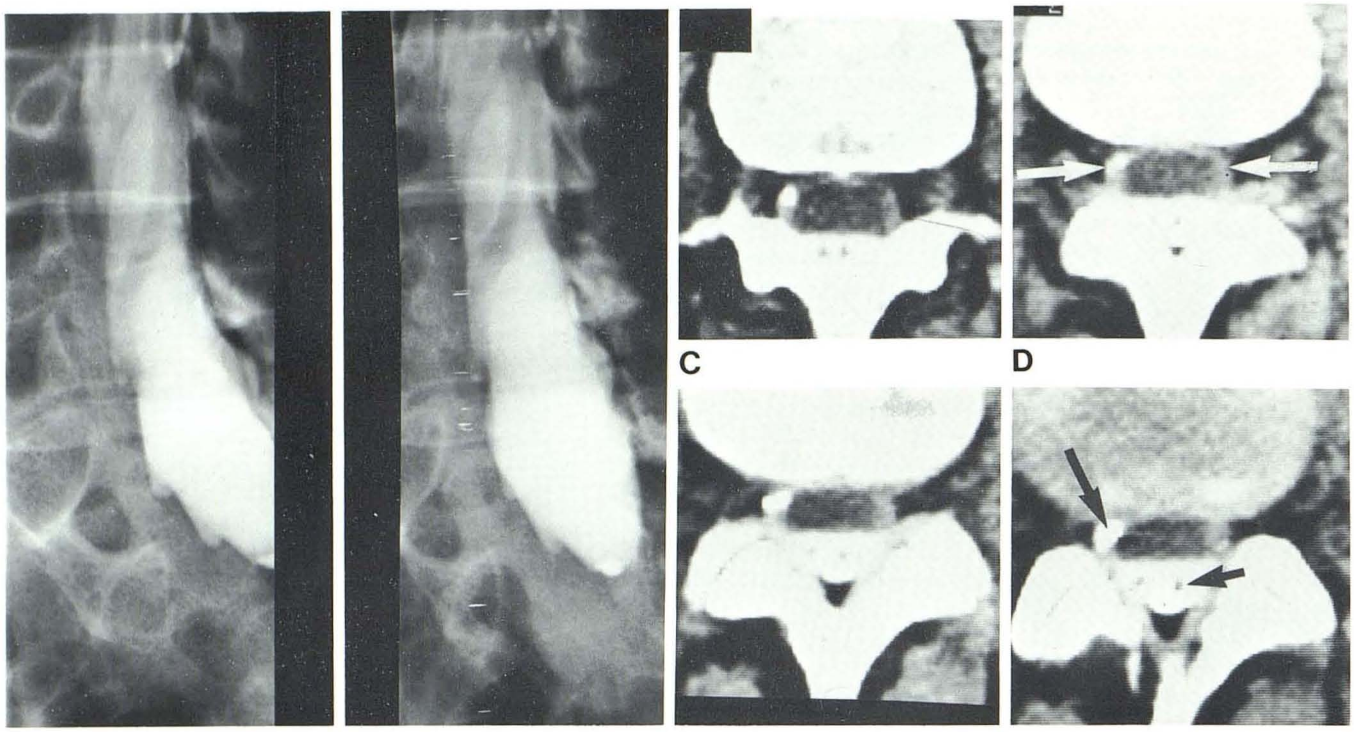
A B E F

Fig. 39.—Postoperative arachnoiditis; CT findings. **A** and **B**, Metrizamide myelogram. Right laminectomy at L5–S1 shows typical changes of arachnoiditis: blunted nerve root sleeves and thickening of intradural nerve roots in L3–L5 area. **C–F**, Scans at L4–L5 shortly after myelography. Layered metrizamide (*black arrows*) in sac and in proximal nerve sleeve. Wall of sac is markedly thickened in all sections (*white arrows*), probably representing thickening of dura and arachnoid.

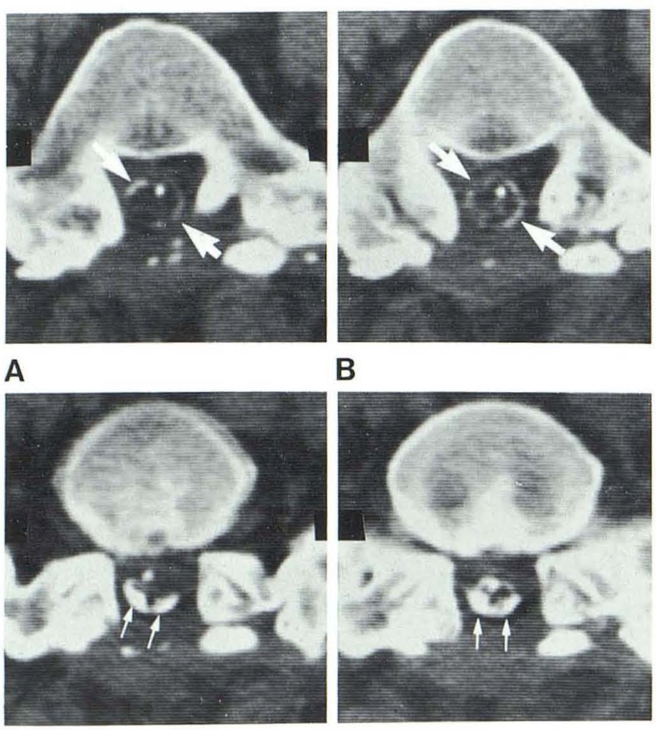
C D

Fig. 40.—Calcified postoperative arachnoiditis. Severe recurrent radiculopathy 6 months after diskectomy. Myelogram 3 years later showed severe arachnoiditis with narrowed sac at L4–S1. Pain and disability continued. **A–D**, CT scans 6 years after diskectomy show virtually complete ring calcification of sac (*large arrows*) at L5–S1. Calcification becomes thick and irregular, especially posteriorly in more caudad cuts (*small arrows*). Sac was not calcified at L4–L5 or L3–L4.

few days. A CT scan 6 days later (10 days postoperatively) showed considerably less air and distension of the sac. It is interesting that as the sac distension subsided, the soft-tissue hematomas became more apparent.

Fat Graft

By its appearance and position the fat graft can usually be readily recognized on early and late CT scans postoperatively and can be distinguished from the normal epidural fat found in the canal. There seems to be little doubt that a viable graft prevents fibrosis at least in the area occupied by the graft (fig. 27).

Postoperative Facet Disturbances

Postoperative subluxations of the facet have been encountered in a few patients. The subluxation is usually on the same side as the laminectomy and sometimes is associated with a facetectomy done to correct foraminal stenosis. However, the mechanism of the focal apophyseal joint subluxation is not clear in many of the cases. One interesting example was associated with severe recurrent radiculopathy after an apparently successful diskectomy (fig. 34).

Incomplete or Incorrect Surgery

CT of the postoperative spine will probably prove to be a mixed blessing to surgeons. A positive feature indeed is an imaging method that will help reveal the possible causes of

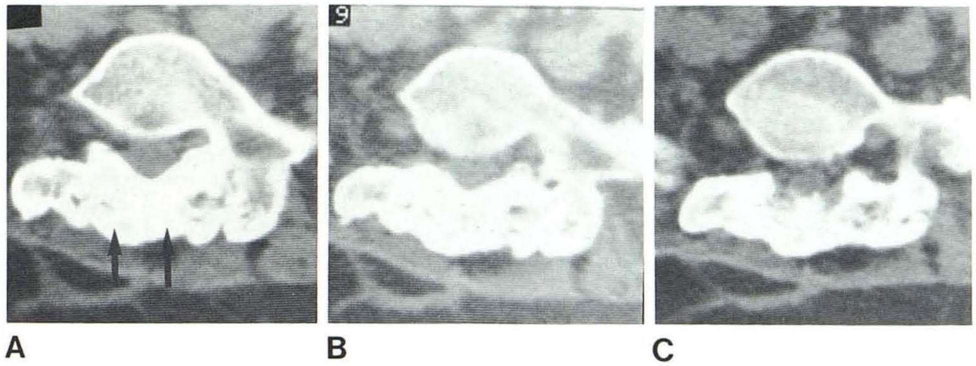

Fig. 41.—Solid fusion; bony overgrowth. Although there is solid fusion across midline and laterally (*arrows*) and total obliteration of apophyseal joints, canal has become narrowed, particularly its anteroposterior diameter, because of bony overgrowth of fusion.

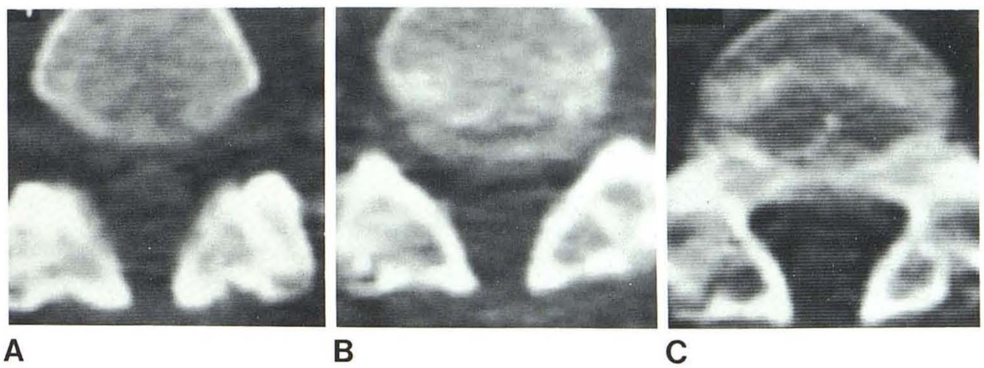

Fig. 42.—Lateral fusions and laminectomies. Bone chips placed lateral to facets are completely incorporated into facets on both sides with total obliteration of apophyseal joints. No chips were placed at laminectomy site to avoid overgrowth into canal.

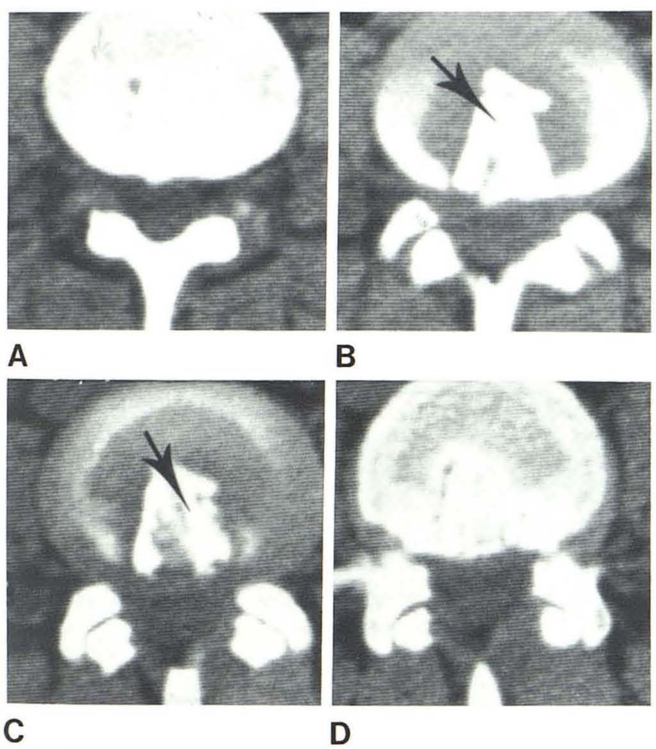

Fig. 43.—Anterior fusion. Bone fragments (*arrows*) have been placed within central and posterior parts of disk.

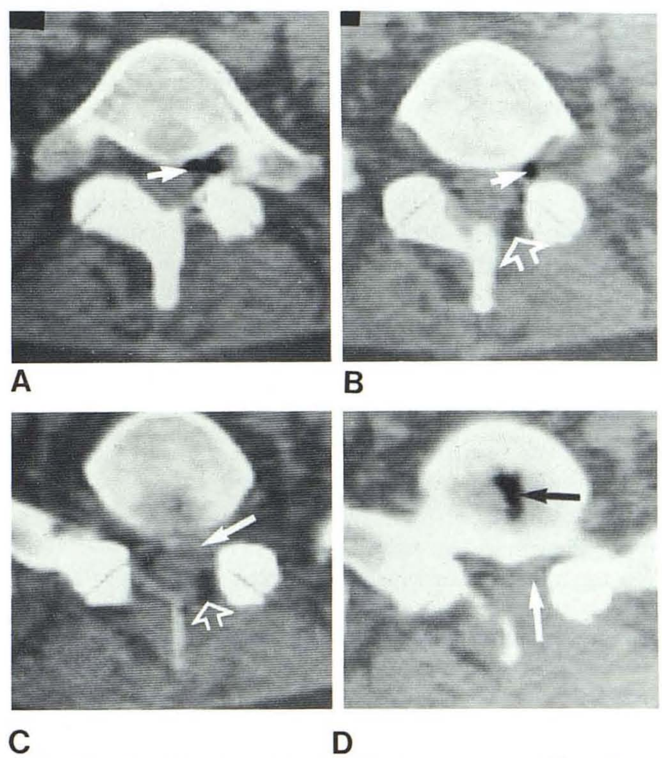

Fig. 44.—Postoperative "vacuum" disk, gas in canal, and hematoma. L5–S1 scans 1 week after left diskectomy disclose abnormalities, although patient had excellent pain relief. Hematoma (*large white arrows*) at diskectomy site. Low-density area (*open arrows*) represents Gelfoam. "Vacuum" disk (*black arrow*) in L5–S1 interspace *not* present preoperatively. Gas bubbles in left recess and foramen (*small white arrows*). While these gas bubbles could have been introduced during surgery, gas may arise from vacuum disk. We have encountered many cases with vacuum disk and associated gas bubbles in anterior canal in both nonoperated and postoperative patients.

recurrent or new low back pain and radiculopathy. CT might identify recurrent disk herniation, extradural fibrosis or scar, spinal stenosis, facet subluxations, pseudoarthrosis after fusion, pseudomeningoceles, etc.

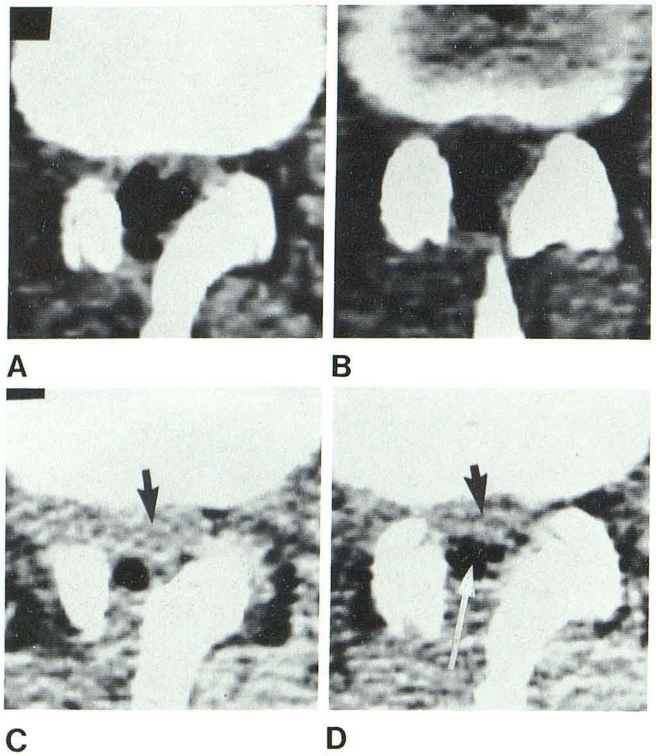

Fig. 45.—Postoperative complications; air in thecal sac. **A** and **B,** L4–L5 scans 4 days after right diskectomy. Thecal sac was inadvertently opened, but tear was noted and repaired. Thecal sac is distended with gas. **C** and **D,** 6 days later. Considerably less gas and less distension of thecal sac (*white arrows*). Soft-tissue hematomas (*black arrows*) are now much more apparent. Clinically the patient, who had been allowed to stand and walk, was considerably improved.

Conversely, the postoperative scan can pry into the errors or inadequacies and incompleteness of a spinal surgical procedure, hitherto an inaccessible area for scrutiny other than the surgeon's notes. Incorrect interspace approach, wrong-side operation, failure to note or correct lateral stenosis, over-zealous explorations, excessive hematoma and subsequent scar formation, etc. will become apparent when comparing preoperative with postoperative scans (figs. 30 and 31).

Conclusions

High-resolution CT of the postoperative spine offers more information than has hitherto been available by any other imaging method. The location and size of extradural scars, the recurrent herniated disk, the postoperative bony stenosis, the postoperative facet abnormalities, and iatrogenic pseudomeningoceles are all revealed considerably more accurately on CT than on myelography. Assessment of the degree of extradural hematoma can be made on early postoperative scans. Postoperative arachnoiditis, however, still remains mainly a myelographic diagnosis. Despite the current value of CT, more data are needed on the postoperative CT features in "asymptomatic" patients in order that the clinical significance of the postoperative CT changes may be assessed more accurately.

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