DISORDERS OF THE LUMBAR INTERVERTEBRAL FORAMEN (LIF): DIAGNOSIS AND TREATMENT

J.-M. VITAL*, F. RAZANABOLA*, V. DOUSSET**

* Unit of Spinal Disorders, Pellegrin University Hospital, Bordeaux, France
** Department of Neuroradiology, Pellegrin University Hospital, Bordeaux, France

The lumbar intervertebral foramen is defined as the part of the radicular canal that surrounds the lumbar nerve root situated between the pedicles of adjacent vertebrae. It should be distinguished from the vertebral foramen, which corresponds to the central spinal canal situated between the two pedicles of the same vertebra. MacNab [1] designated it "hidden zone", because of the difficulty in exploring this region by either imaging studies or surgery. The anatomy and physiology need to be reviewed, because they explain, to a great extent, the clinical manifestations, the work-up examinations called for, and the surgical procedures.

ANATOMY AND PHYSIOLOGY [2]

The radicular canal, which surrounds the lumbar nerve root before it leaves the vertebral foramen, consists of three portions: the retrodiscal space, the lateral recess medial to the pedicle of the vertebra that has the same number as the root, and the LIF between the same pedicle and the underlying pedicle (fig. 1). On axial imaging sections, one can draw two anteroposterior lines, one at the medial edge of the pedicle, the other at the lateral edge. Any lesion situated medial to the pedicle is designated "intraforaminal", straight under the pedicle between the two lines "foraminal" and lateral to the pedicle "extra-

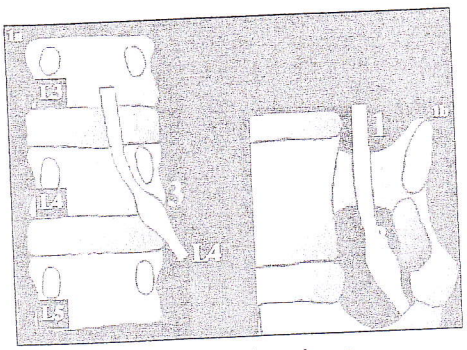

Fig. 1 : Radicular canal anatomy.
a) posterior view ; b) endocanalar view
1 = retrodiscal part
2 = lateral recess
3 = lumbar intervertebral foramen (LIF)

foraminal" (fig. 2). Of course, lesions exist that go beyond the limits of the pedicle, as we shall see in the chapter on foraminal herniated discs. On sagittal slices, the LIF is ear shaped with a bony upper portion, is inextensible and wider than the lower portion. The spinal nerve, or to be more precise, its ganglion lies in the upper part of the foramen.

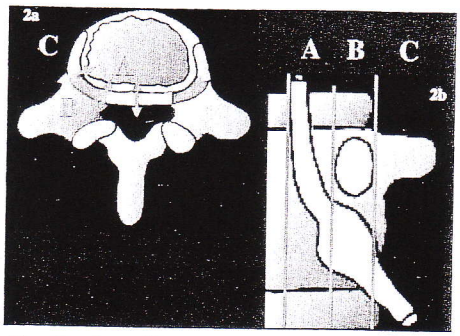

Fig. 2 : 3 portions.
a) axial view ; b) posterior view (rigth side)
A = intraforaminal
B = foraminal
C = extraforaminal

The lower part of the foramen is narrower, and mobile because it is bordered by the intervertebral segment, where it is more exposed to herniated disc and to degenerative osteoarthritis. The transvertebral veins pass through the lower part of the foramen. The LIF is ring shaped in the upper lumbar spine and shaped like a gutter oriented downward in the lower lumbar spine, because of the same orientation of the pedicles, which, in the lower lumbar spine, are not oriented horizontally as are the pedicles of L1 and L2. The roof of the LIF and its posterior limit are important because they conceal the foraminal region. These edges consist of the articular process of the underlying vertebra and the isthmus slightly above the facet joint. The lateral limit of the isthmus often appears as a crest. The closer one comes to the lumbosacral junction, the more lateral the crest. One might say that the more caudal the lumbar segment, the more the roof covers the foramen (fig. 3).

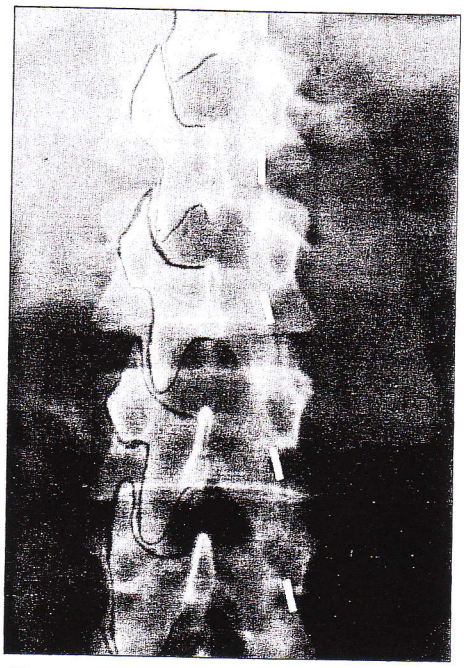

Fig. 3 : Lateral limits of LIF.
The more caudal the lumbar segment, the more the roof covers the foramen.

The dorsal root ganglion is the main element of the LIF. It is situated in the foramen in most cases, but it can also lie intraforaminally (notably at S1) or extraforaminally. the foraminal ratio is the ratio of the surface area of the ganglion to the surface area of the LIF: it ranges from 25% at L1 to 51% at L5. This ganglion is very rich in large-diameter cells (myelinated Aβ fibers, which transmit deep touch and pressure sensation) and in cells of smaller diameter (fibers C and Aδ conveying pain, light touch and temperature discrimination).

The dorsal root ganglion is very sensitive to vibrations, hypoxia and phospholipases. In the foramen it courses beside the radiculomedullary arteries (the most important being the Desproges-Gotteron radiculomedullary artery, which follows the L5 root and feeds the terminal cone) and the venous plexus.
During movements, there is a 20% reduction in the surface area of the LIF in extension [3] (fig. 4) and a marked reduction during ipsilateral lateral bending (fig. 5).

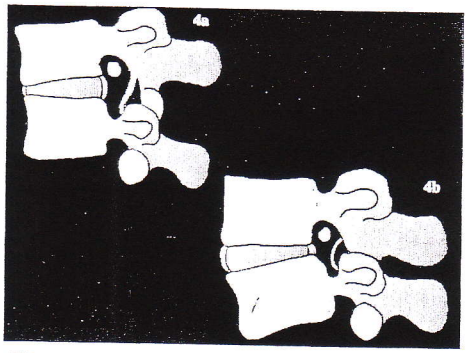

Fig. 4 : 20% reduction in the surface area of the LIF in extension (according to Revel). a) flexion ; b) extension

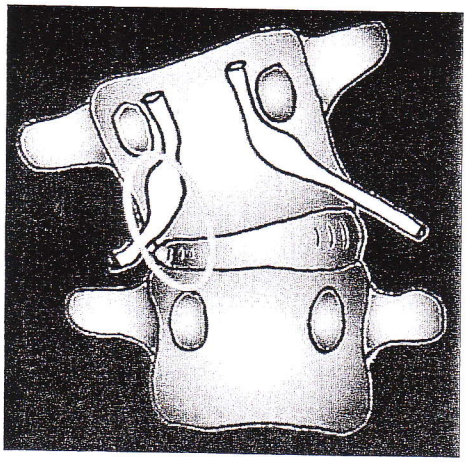

Fig. 5 : Reduction in the surface area of the LIF in the ipsilateral bending (according to Panjabi).

CLINICAL SIGNS

The clinical signs of foraminal nerve root pain generally lack specificity. They are typically very painful and associated with motor deficit. A pain-free position has been described: lateral decubitus contralateral to the compression and flexion of the ipsilateral hip and knee. The resulting pain radiates in the territory of the root which bears the number of the superior pedicle of the LIF. In cases of foraminal compression of L4-L5, we have often noted that the pain radiates to the lateral aspect of the buttock, thigh and calf, which does not correspond to the specific territory of either L5 or L4. This territory would appear to straddle these two distributions (fig. 6).

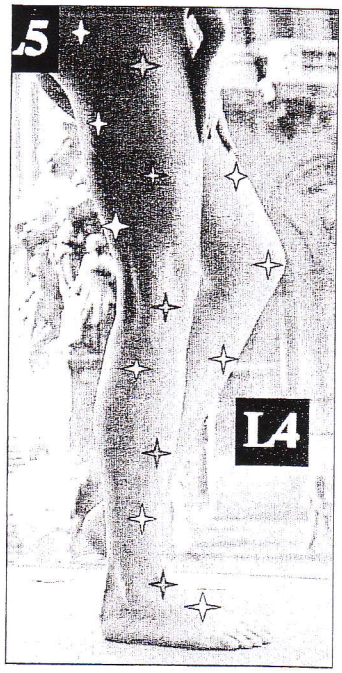

Fig. 6 : In cases foraminal compression of L4-L5, we have often noted that the pain radiates to the lateral aspect of the b uttock, thigh and calf, which does not correspond to the specific territory of either L5 or L4.

ELECTROPHYSIOLOGICAL SIGNS

Electrophysiological signs are essentially dominated by the study of sensory potentials in electromyography. Sensory potentials are preserved in cases of preganglionic involvement in which the central spinal canal is compromised, but they are altered when there is ganglion or post-ganglionic compression (fig. 7) [4].

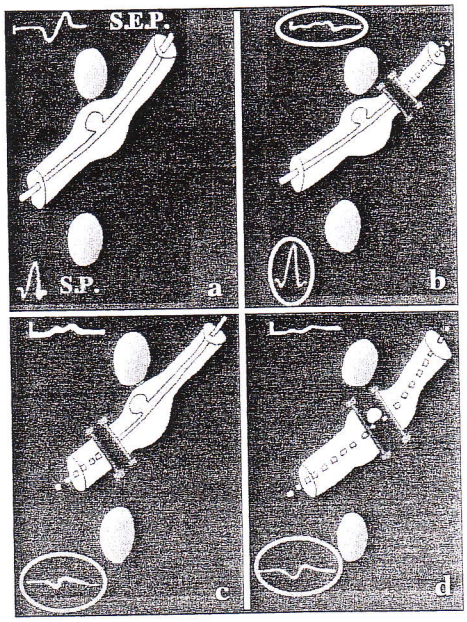

Fig. 7 : Sensory potentials (S.P.) are altered in ganglionic and post lesions.
a) normal
b) preganglionic lesion
c) postganglionic lesion
d) ganglionic lesion

RADIOLOGICAL EXAMINATIONS

Plain films show fixed displacements of spondylolisthesis or retrospondylolisthesis (which compresses the LIF more, as we shall see below) or lateral imbalance (asymmetric disc disease).

Computed tomography permits exploration of the bony upper portion of the LIF and of its lower portion next to the disc on classic axial slices (fig. 8). Sagittal reconstructions are useful in cases of spondylolisthesis by spondylolysis.

Myelography is of little usefulness because it only explores the root, not the dorsal root ganglion, the dural envelope ending at the proximal side of the ganglion.

Magnetic resonance imaging (MRI) is the most useful examination. With the various slices it provides, MRI best establish the anatomy of the contents of this hidden zone. The inextensible parts can be assessed, particularly the state of the cartilaginous endplates and subchondral bone, near the foraminal stenosis. Modic type-1 signal changes corresponding to hyposignal in T1-weighted sequences, hypersignal in T2-weighted sequences, a white signal in fat saturation sequences and increased signal intensity after injection of gadolinium, are caused by inflammatory edema and are often associated with an acute painful phase. Modic type-2 signal changes corresponding to hypersignal in T1- and T2-weighted sequences, decreased signal in fat saturation sequences and no increase in intensity by gadolinium enhancement are caused by less active, fatty changes and are found more frequently.

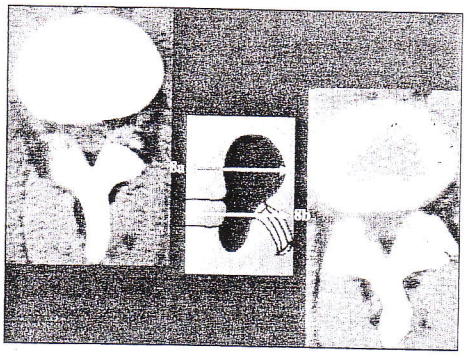

Fig. 8 : CT scan.
a) fixed LIF ; b) mobile LIF

TREATMENTS

Conservative treatment

The conservative treatment of classic foraminal nerve root pain consisting in rest, antiinflammatory drugs, and analgesics, can be attempted in most cases except in patients with neural deficits.

Foraminal injections

Foraminal injections have a predominant role. They can be guided by fluoroscopy or even better by computed tomography. Berger [5] published with us a series of 160 foraminal injections, 139 of which were in the lumbar spine (fig. 9). Lumbar foraminal compression was due to disc disorders, osteoarthritis, or both. In a small number of patients there was no image of patent compression. Through a size 22 needle, the patient received 75 mg of hydrocortisone, 1 ml of lidocaine and 1 ml of contrast medium. Ideally, one should reproduce the same pain that prompted the patient to consult and to observe clear contouring of the dorsal root ganglion by the contrast medium. Using this protocol, Berger reported improvement qualified as acceptable by 64% of the patients. Sixteen percent of the patients were operated, among whom 90% had good or very good results if the pain reproduction test by injection was positive.

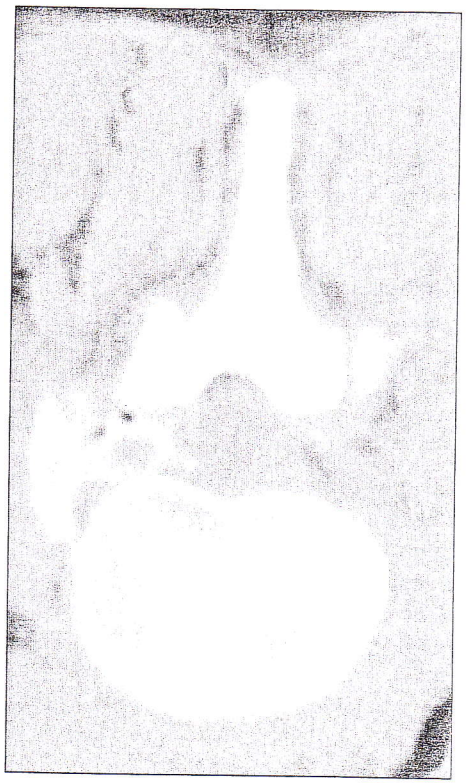

Fig. 9 : Foraminal infiltration guided by CT scan. Note the contrast medium contouring the ganglion.

Surgical treatment

The surgical treatment of foraminal stenosis was analyzed by Razanabola [2] in his medical thesis on 116 patients hospitalized for foraminal nerve root pain.

Eleven (9.5%) had conservative treatment (intravenous infusion or infiltration) and 105 (90.5%) were operated.

There were three prinicipal indications for surgery:
- foraminal herniated discs: 76 cases (72.1%),
- bony stenosis: 12 cases (11.4%),
- isthmic spondylolisthesis: 17 cases (10.2%).

Foraminal herniated discs

In the series cited above they were as follows:
- intraforaminal and foraminal in 25% of cases,
- foraminal in 20% of cases,
- foraminal and extraforaminal in 30% of cases,
- extraforaminal in 15% of cases (fig. 10).

Herniated discs that originate from the low and mobile portion of the LIF migrate upward lifting the root giving it a horizontal trajectory [6]. A bulging disc may be involved, or more rarely a true sequestrated disc.

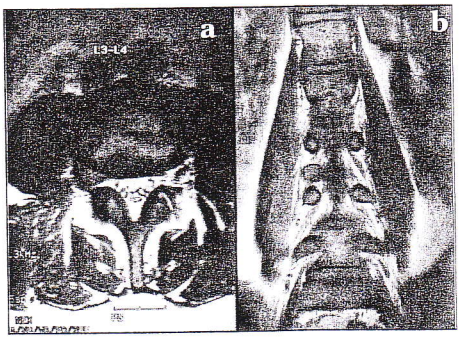

Fig. 10 : Right L4-L5 foraminal herniation on MRI.
a) axial view ; b) coronal view

Clinically, the average age is 50 years: Men are involved two times out of three. Lumbar stiffness and pain exacerbated by efforts or coughing are rare (25 %); a truly positive straight-leg raising sign is observed in only one out of three patients. However, a motor deficit is observed in 23% of cases. Surgery by the closest access possible is performed through the spinal canal in cases of intraforaminal and foraminal discs. In such cases, one should begin away from the disc fragment working in a caudal to cephalad direction, even if this means resection of the lamina (fig. 11). In cases of purely foraminal disc herniations, they can be approached through the spinal canal or without going through it. In some cases, relatively extensive resection of the facets is necessary to properly expose the foramen.

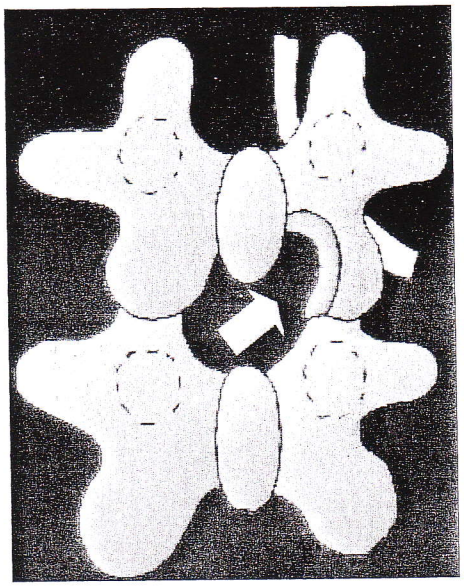

Fig. 11 : In case of intra and foraminal herniation we can perform endocanalar approach with working on opposite side and cephalad direction.

In patients with extraforaminal disc herniation, one may consider removing it through a lateral exposure, either using Wiltse's approach [7], which passes through the fatty space between the multifidus and the longissimus muscles (fig. 12); this approach is easier in the upper part of lumbar spine where the isthmus crest is more medial (fig. 13) [8]. The latter approach begins at the midline, but courses between the two transverse processes after removal of the intertransverse muscles and ligaments. The ganglion and the spinal nerve that extends from it have to be located under the superior pedicle; the herniated fragment is in the angle between the nerve and the dura. Endoscopic approaches provide better exposure in the axis of the LIF and ideal lighting.

Bony stenosis

Bony stenosis can be qualified as "aligned" or "nonaligned". In aligned stenoses in which the disc height is reduced because of ageing and the LIF has narrowed, one may be surprised by the good tolerance of this compression, which may develop very gradually. Nonaligned stenoses are typically more poorly tolerated. Retrospondylolistheses exhibit a marked tendency to narrowing. In degenerative spondylolithesis, compression is situated mainly in the vertebral foramen and lateral recess, analogical to the action of a cigar cutter. In contrast, the LIF tends to be oriented horizontally and becomes more oval without actually narrowing. Foraminal compression is more patent in asymetric disc disease. In a specific series of 38 cases, we diagnosed: 2 cases of primary degenerative disc disease (DDD) (fig. 14), 10 postdiscectomy DDD, 8 rapidly destructive postdiscitis DDD, 10 cases of degenerative scoliosis, and 8 isthmic spondylolistheses.

In degenerative scoliosis, compression occurs in the lumbosacral concavity or more rarely in the main concavity. In isthmic spondylolisthesis, asymmetry is

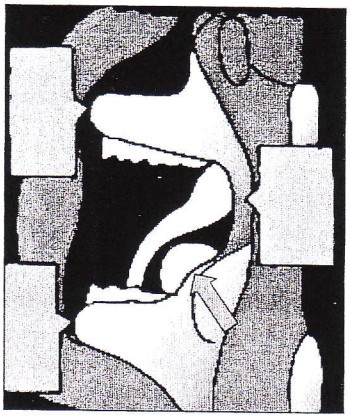

Fig. 12 : In case of this left extra foraminal herniation, lateral approach between multifidus and longissimus is prefered.

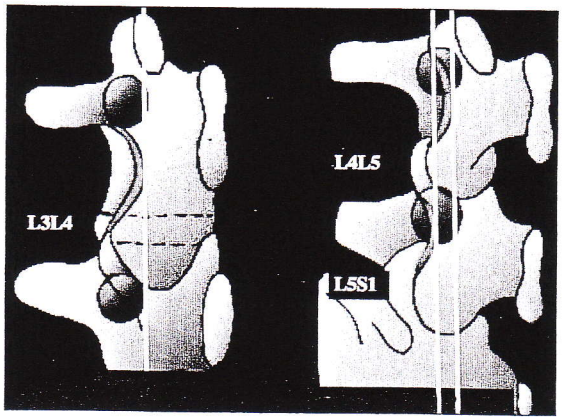

Fig. 13 : The lateral limit of the isthmus often appears as a crest. We can note the more medial position of this crest at L3-L4 level.

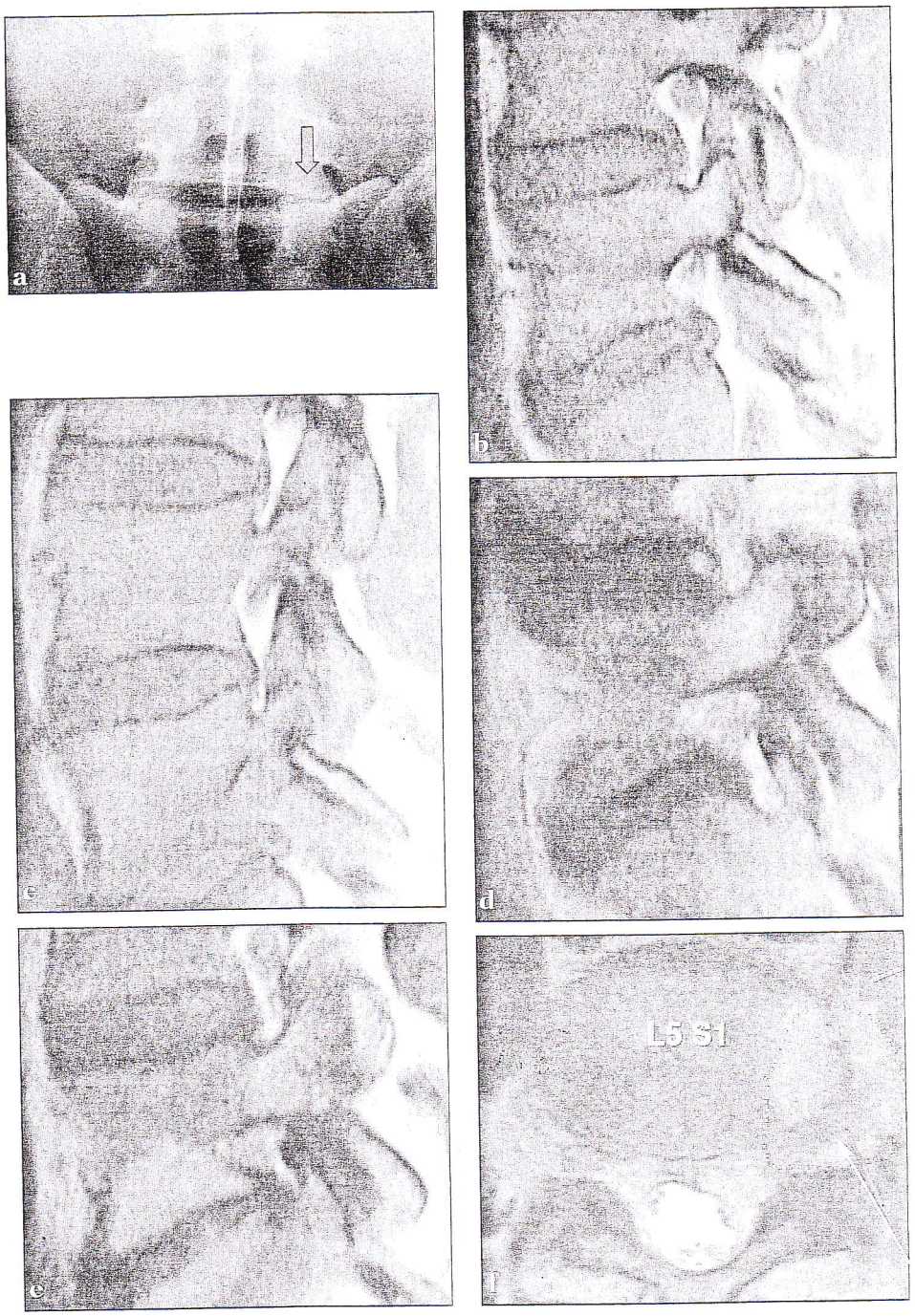

Fig. 14 : Primary asymmetric disc disease.
a) ascending AP view with asymmetry on the left ; b) right normal LIF on T1 sequence ; c) left pathologic LIF on T1 sequence ; d) right normal LIF on T2 sequence ; e) left pathologic LIF on T2 sequence ; f) axial view on T2 sequence ; note the inflammation on the end plate and in the foramen.

possible with nerve root pain and narrowing of the LIF on MRI on one side and, in some cases, unilateral Modic type-1 signal changes with an inflammatory pattern in the entire foramen.

Regarding surgery for bony stenosis, decompression can be performed through a spinal canal approach (as for herniated discs) or through a lateral approach, notably using the procedure described by Farcy, which consists in cutting and resecting the tip of superior articular process of the lower vertebra. Use of pedicle screw fixation in moderate distraction is the conventional treatment and the use of interbody cages through a posterior approach (PLIF) ensures better opening of the foramens and better stability. The TLIF technique with insertion of a cage through a posterolateral approach after complete facetectomy is probably the technique best adapted to this foraminal disorder.

In degenerative scoliosis, one may consider using limited surgery (applied to the compression of the lumbosacral concavity in elderly subjects) or extensive surgery taking into account the entire scoliosis (when compression is in the concavity of the scoliosis and the patient is young).

Overall, the results of surgery for foraminal compression are good and very good in 70% of cases. The results differ according to the disorder treated: 78% of good and very good results in SPL, 70% in herniated discs (poorer than in posterolateral herniated discs [9]), and 62% in cases of bony stenosis.

IN CONCLUSION

The diagnosis of LIF compression has been improved by modern imaging studies, but electrophysiological examinations (sensory potentials) and steroid injection tests can also help establish the diagnosis.

In decompressive surgery, one should avoid destabilizing this hidden zone, notably by not hesitating to use the extraforaminal approach. If there is the least doubt regarding postoperative instability, one should employ pedicle screw fixation in some cases with interbody cages.

Mediocre clinical results can be explained by the duration of the disorders before diagnosis and by lesion of the dorsal root ganglion, a fragile and sensitive structure.

REFERENCES

[1] MC NAB I.
Negative disc exploration; an analysis of the causes of nerve root involvement in sixty eight patients.
J Bone Joint Surg 1971; 53 A: 891-903.

[2] VITAL J.M.
Foramen intervertébral lombaire: anatomie, exploration et pathologie. Cahier d'Enseignement de la SOFCOT.
Conférences d'Enseignement 2000, Elsevier, Paris, 139-63.

[3] REVEL M., MAYOUX-BENHAMOU M.A., AARON C., AMOR B.
Variations morphologiques des trous de conjugaison lombaires lors de la flexion-extension et de l'affaissement discal.
Rev Rhum 1988; 53: 361-6.

[4] HERAUT L.H.
Electrophysiologie et syndrome du canal lombaire étroit.
Rev Chir Orthop 1996; 76 suppl 1: 49-51.

[5] BERGER O., DOUSSET V., DELMER O., POINTILLART V., VITAL J.M., CAILLE J.M.
Evaluation de l'efficacité des infiltrations foraminales de corticoïdes guidées sous tomodensitométrie dans le traitement des radiculalgies par conflit foraminal.
J Radiol 1999; 80: 917-23.

[6] ROSENBLUM B.
The perpendicular nerve root sign.
Spine 1989; 14: 188-9.

[7] WILTSE L., SPENCER C.
New uses and refinements of the paraspinal approach to the lumbar spine.
Spine 1988; 13: 696-706.

[8] POINTILLART V., BROC G., SENEGAS J.
A novel paraspinal approach for lumbar lateral extra foraminal root intrapment.
Eur Spine J 1997; 6: 102-5.

[9] LEJEUNE J.P., HLADKY J.P., COTTEN A., VINCHON M., CHRISTIAENS J.L.
Foraminal lubar disc herniation: experience with 83 patients.
Spine 1994; 19: 1905-8.