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Percutaneous Nucleotomy

An Alternative to Spinal Surgery

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Summary. As an alternative to the well-established surgical procedures for the treatment of disk herniation, percutaneous nucleotomy has proved to be very satisfactory. In several cases this approach has brought complete relief to the patient without sacrifice of bone and without causing soft tissue damage as would have been inevitable with the usual surgical methods. Percutaneous nucleotomy is also a true alternative to chemical nucleolysis when leakage of contrast agent into the spinal canal has already been observed during diskography. Furthermore, this method avoids disagreeable complications encountered in chemical nucleotomy, for example, anaphylactic shock or the escape of the nucleolytic agent into the spinal canal. The method basically consists of removing the nucleus pulposus (or a major part of it) by means of a forceps that is introduced to the site through a cannula. In this manner a reduction of volume of the disk is achieved. The procedure can easily be carried out under local anesthesia. This method should be avoided in the case of prolapse within the spinal canal and especially when displacement beyond the level of the disk has occurred. In the period between 1979 and 1985 we carried out percutaneous nucleotomies in 51 patients with herniation mostly combined with a narrow spinal canal or spondylolisthesis. The clinical results from 32 of 51 patients can be assessed as very good, good, or satisfactory. We consider the proportion of patients showing good clinical results to be high, bearing in mind that the indication was not just disk herniation alone but, in most cases, combined with other lumbar pathologies as well.

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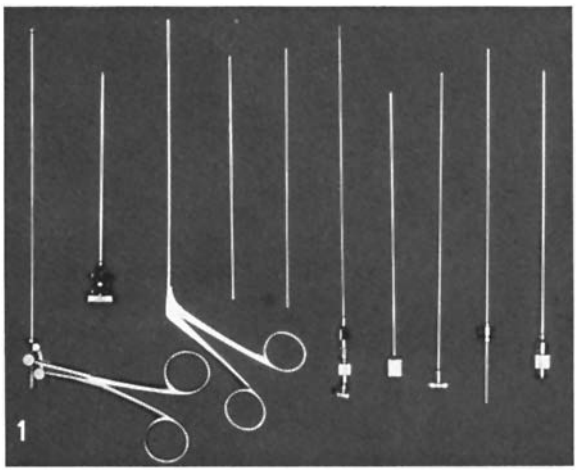
Hemilaminotomy, both with and without a microscope, was performed on approximately 600 patients at the Department of Orthopaedic Surgery, University of Zurich/Balgrist, from 1974 to 1984. This standard operation was successful in about 72% of the patients. Postoperative follow-up revealed that unsatisfactory results were frequently seen in patients with combined causes of lumbago, i.e., relatively narrow spinal canal, spondylolisthesis, or lumbosacral assimilation [24].

Hemilaminotomy leads to a loss of equilibrium of the affected area and to a reduction of the stability of the adjacent vertebral segments. Hematoma, scar formation, adhesions, alteration of soft tissue and bone properties, and postoperative narrowing of the disk can produce an increase in the symptoms characteristic of a narrow spinal canal or segmental instability. On the other hand, extensive decompression, with or without spinal fusion as a primary procedure, is not clearly indicated if no definite symptoms such as those of a narrow spinal canal or segmental instability appear. Percutaneous nucleotomy has proved to be very effective in relieving the symptoms of a herniated disk even in patients with complex disorders producing lumbago [25]. Because the procedure is atraumatic, the worsening of symptoms due to accompanying causes of lumbago can be avoided. The following is a report on our initial clinical results, surgical technique, indications, and the therapeutic spectrum of this method.

Surgical Technique

The original surgical instrumentarium of Hijikata consists of a 20-cm long needle that fits within a fine-caliber tube, three shorter tubes of larger caliber, and forceps which pass only into



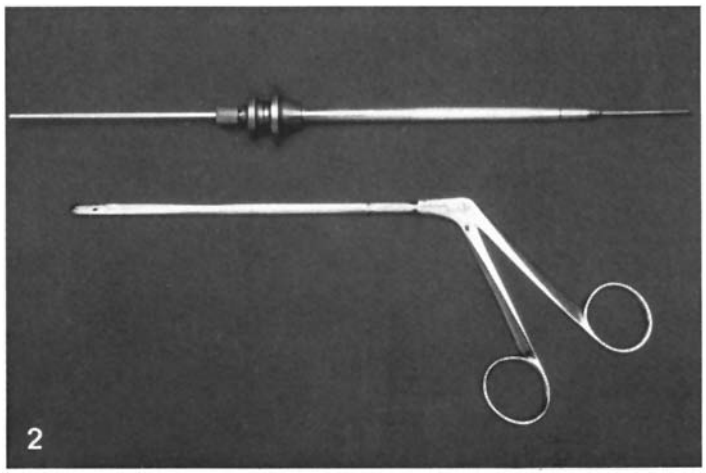


Fig. 1. Hijikata's original instrumentarium for percutaneous nucleotomy [6]. A 2-mm diameter cannula is the largest that can be safely inserted into the intercorporal space through an outer guide with a target needle, avoiding irritation of nerve root and important organs

Fig. 2. Our supplementary instruments – a cannula of larger bore (up to 5 mm) and a viewing system (diskoscope) – make more efficient removal of larger quantities of nucleus pulposus possible in a shorter time

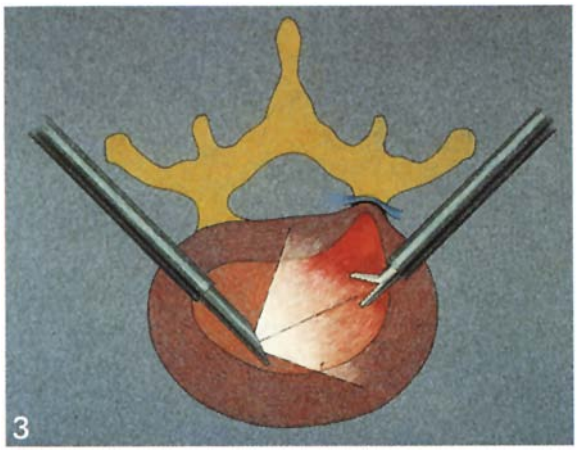


Fig. 3. Percutaneous nucleotomy using a diskoscope enables visibility inside the disk at all times, allowing the nucleus pulposus to be extracted from either the ipsi- or the contralateral side

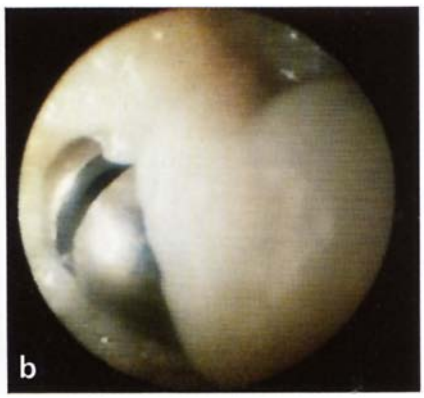


Fig. 4a, b. Intraoperative exposure of the nucleus pulposus. Introduction of the diskoscope dorsolaterally through the anulus fibrosus allows positioning of the instrument for excising the nucleus pulposus without the use of an X-ray image intensifier

the tubes more than 2 mm in diameter (Fig. 1). We added three wider tubes (3–5 mm in diameter), and forceps with various forms of jaws to this original instrumentarium, thereby simplifying and shortening the entire operative course (Fig. 2). Under local anesthesia and with the aid of an X-ray image intensifier, the first, finest needle is introduced dorsolaterally into the affected intercorporal space. The position of the needle can be verified by injecting a contrast medium (Jopamiro 300, a water-soluble contrast medium containing iodine). At the same time, indigo carmine may be injected into the nucleus pulposus to facilitate differentiation of this structure from the anulus fibrosus.

The procedure is performed with the patient prone or in the lateral position. Occasionally, access to L-5/S-1 may be obstructed by the iliac crest. In these cases, lateral positioning with marked extension of the lumbosacral disk – using a large pillow under the flank – is helpful.

The purposes of this procedure are the decrease of the entire disk volume by partial removal of the nucleus pulposus and perhaps the creation of a permanent opening between the nucleus pulposus, the anulus fibrosus, and the outside of the vertebra (see also Discussion). One should attempt to remove as large a portion of the indigo-carmine–stained material as possible. According to studies by Hijikata [6, 7], the total weight of

removed disk material should be at least 0.5 g if symptoms are to be relieved, and in our experience at least 2 g should be removed.

Since early in 1982 we have been performing this procedure with the aid of diskoscopy, which enables us to inspect the inner layer of the nucleus pulposus under direct vision (Fig. 3). We can thus identify the site of damage and designedly remove the nucleus pulposus (Fig. 4). At the same time, the period of X-ray exposure can be substantially reduced.

Indications

At present, we define the indications for percutaneous nucleotomy as follows:

1. Persistent sciatica due to disk herniation which is resistant to all conservative methods of treatment
2. (Occasionally) uncertain results with regard to traditional hemilaminotomy, as in the case of medial disk herniation, herniated disk at multiple levels, recurrent herniation of an operated disk or lumbago and sciatica associated with spondylolisthesis or spondylolysis, diskopathy of a so-called balloon disk, a relatively narrow spinal canal, or lumbosacral assimilation at the same or other levels
3. Small and moderate disk herniation, but not herniation which produces subtotal blockage of the contrast medium

One restriction applies: herniated disks which dislocate into the vertebral canal, particularly those that prolapse beyond their corresponding disk level.

Clinical Course and Postoperative Treatment

Up to now, we have kept patients hospitalized for 1–3 weeks postoperatively in order to perform a sequence of stabilizing back exercises under pain-free conditions. Rehabilitation in the previous occupation is similar to that following conventional disk surgery. Office work – provided the patient does not work uninterruptedly in the sitting position – is permissible 4–6 weeks postoperatively.

Patients

At the Department of Orthopaedic Surgery of the University of Zurich, lumbar percutaneous nucleotomy was performed in 49 patients, 31 men and 18 women, between October 1979 and January 1985. The patients' ages ranged from 19 to 71 years, the average being 39.8. Postoperative follow-up intervals range from 6 months to 5.5 years, the average being 3.75 months.

In two patients (one male and one female) the approach was not possible because of a high iliac crest at the level of L-5/S-1. They are not included in the above figures.

Localization of the Herniated Disk

In all patients, disk herniation with nerve root filling defect was demonstrated myelographically. The herniation was at the level of L-5/S-1 in 11 patients, at L4–5 in 34 patients, at L3–4 in 14 patients, at L2–3 in two patients, and at multiple levels in 12 patients.

Table 1. Causes of pain. Numbers in ( ) are the cases with more causes than just the one mentioned

Causes		No. of patients	
Disk herniation	(one level)	21	
	(two or more levels)	4	(+8)
Recurrence of previously operated DH		5	(+2)
DH combined with:	Narrow spinal canal	10	
	Spondylolisthesis	5	(+1)
	Osteochondrosis	1	(+1)
	Sacral cyst	1	

Combined Causes of Lumbago and Sciatica

Six patients had an associated spondylolisthesis and/or spondylolysis, ten had a relatively narrow spinal canal at the same or another level than the herniation, and seven had recurrent disk herniation at the same level (Table 1). In six patients the disk herniation was medial; in the rest it was mediolateral. The five patients with recurrent herniation had previously had hemilaminotomies on the same side and at the same level. In five patients, we observed displacement of the disk beyond the corresponding disk level; in all of these five this finding was later confirmed when standard hemilaminotomy became necessary.

Results

Clinical Symptoms

With all patients the preoperative complaint was lumbago and sciatica, which were markedly dependent on motion and weight bearing. All had stiffness of movements in the lower back with or without compensatory scoliosis (forced antalgic position) and positive Lasèque's sign; 40 had sensory disturbances, 28 had motor deficiencies, ten had ATR weakness, and three had questionable neurogenic intermittent claudication.

In evaluating the clinical results, we used a point system based on the factors listed below (0 points = poor, 1 = moderate, 2 = good). Total scores of 12–10 points were interpreted as being very good, 9–7 as good, 6–4 as satisfactory, and less than 4 as unchanged.

The following factors were considered in the evaluation: pain (drug requirements), mobility, weight-bearing tolerance (how long the same posture – sitting, standing, walking, etc. – can be maintained), radicular signs (motor, sensory, and reflex), local symptoms (musculature, irritation of vertebra or vertebral joints), and ability to work. The 0–1–2 point system was applied to these six factors, the clinical results being represented by the total score. The results were found to be very good in 14 patients, good in 12, satisfactory in nine, and unchanged in 14.

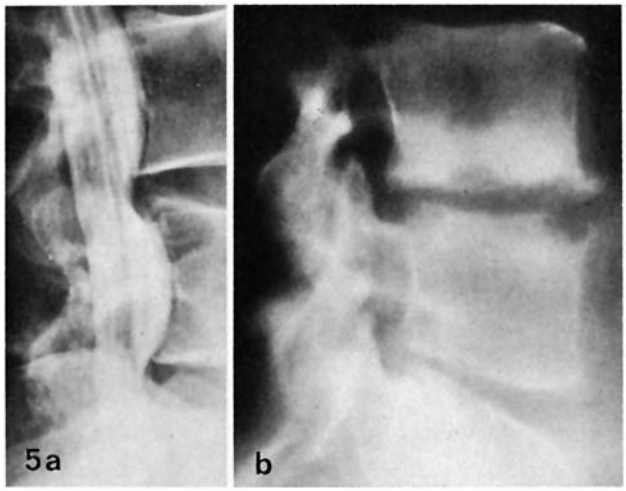


Fig. 5a, b. S.W., 52-year-old woman. Because of constant radiating pain in left leg for several months, percutaneous nucleotomy (PN) was performed at L3–4 and at L4–5 in October 1981 (**a**). Pain subsided immediately after PN but gradually increased again owing to infection of the intercorporal space. Spondylotomy (February 1982) achieved healing (**b**)

The preoperative clinical symptoms were affected by the procedure as follows: all 49 patients experienced some degree of pain relief immediately after surgery. At an average of 5–7 days postnucleotomy, 21 patients reported a feeling of tension on the affected side or mild pain in the leg, which subsequently improved. Radicular signs, particularly sensory disturbances in 40 patients and muscle weakness in 28 patients were eliminated postoperatively in 28 of the 40 and 16 of the 28 respectively. Improvements in mobility, weight-bearing capacity, and local symptoms were reported by 35 patients.

At the time of follow-up, 38 patients had already been rehabilitated; 23 were working full time, the rest part time (50%). Eight required further training for less physically demanding occupations, and five others are drawing disability pensions.

Reoperation

Conventional hemilaminotomy proved necessary in one patient due to recurrent disk herniation and in 11 patients due to unsatisfactory improvement of the subjective complaints and clinical symptoms, although no recurrence could be demonstrated. Spondylotomy had to be performed in one 53-year-old female patient because of postoperative spondylodiskitis (Fig. 5), and sacral cystoplasty was necessary in a 41-year-old female patient with a painful sacral cyst. The clinical result of the hemilaminotomy was good in seven patients, while the clinical status remained unchanged in the rest.

Weight of the Removed Disk

It is generally rather difficult to pick the small fragments of disk off the forceps, collect them in physiological saline, and then weigh them together. This introduces several errors. We always use the same method of weighing, solely for the comparison of collected material. The minimum weight of the disk substance was 1.5 g and the maximum 13 g, the average being 4.5 g. No correlation between the weight of the excised material and the clinical result could be made, owing to the small number of patients operated upon.

Accessibility of the Lumbosacral Region

In two cases which are *not included* in this series, the disk at L-5 was not accessible owing to the deep position of the L-5/S-1 intercorporal space. One of these patients was a 41-year-old woman whose symptoms could be attributed to a mediolateral disk herniation at L4–5 in combination with a medial disk herniation at L-5/S-1. Nucleotomy at the L4–5 level alone produced good clinical results. The other patient with mediolateral disk herniation at L-5/S-1 had had to be operated on in the conventional manner, by hemilaminotomy.

Case Reports

L.W., male, 49 years old: Following a symptom-free period of 17 years after a diskectomy of L4–5, intensive sciatica that proved to be resistant to conservative therapy developed (Fig. 6). Myelography showed recurrence of disk herniation at the L4–5 level and relative narrowing of the spinal canal between L-3 and L-5. (The widest sagittal diameter measured 14 mm immediately below the pedicle. The dural sac was constricted to a width of 9 mm at the level of the disk.) Percutaneous nucleotomy of L4–5 brought instant relief to the patient, who has remained trouble free up to now, 3 years after intervention.

M.G., male, 19 years old: The patient suffered from sciatica on the right side due to disk herniation at L4–5 with clinical L-5 nerve root symptoms. CT-scan showed a mediolaterally herniated disk at the level of L4–5. In November 1983 percutaneous nucleotomy was performed at this level under local anesthesia. A postoperative CT-scan exhibited a decrease of disk volume at the operated level (Fig. 7). The patient has no pain and no objective symptoms and works full time.

R.R., female, 42 years old: Percutaneous nucleotomy was carried out in May 1980 at the level of L-5/S-1 because of therapy-

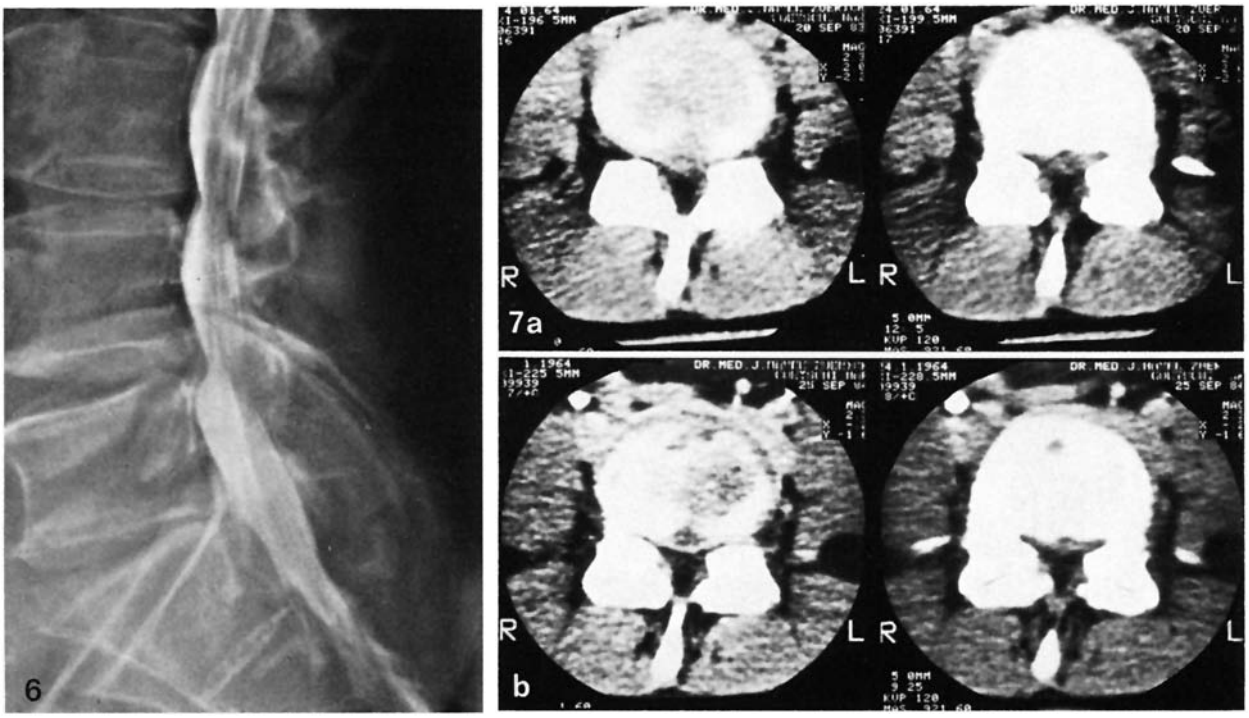


Fig. 6. L.W., 49-year-old man with sciatica due to recurrence of operated disk herniation at the L4–5 level. Myelography showed relative narrowing of spinal canal between L-3 and L-5 in addition. Percutaneous nucleotomy at L4–5 brought relief from the sciatica. Patient remains symptom free 3 years following operation

Fig. 7a, b. M.G., 19-year-old man with sciatica due to disk herniation on the left at L4–5 and narrow lateral recess at same level. CT scans showing mediolateral disk herniation before (**a**) *(9/83)* and 1 year after (**b**) *(9/84)* percutaneous nucleotomy. Patient is still symptom free 1.75 years after operation

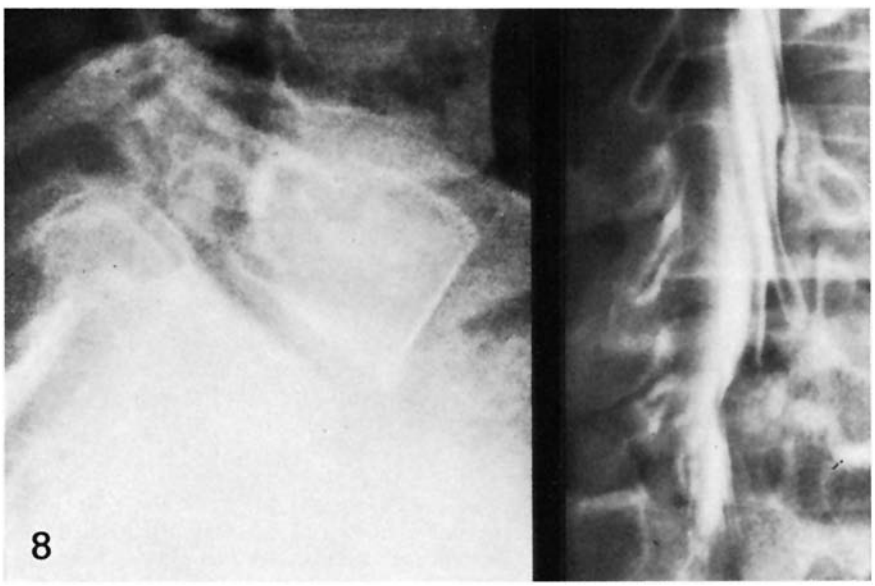


Fig. 8. R.R., 42-year-old woman, myelograms. Sciatica on right side due to mediolateral disk herniation and spondylolisthesis at level L-5. Patient underwent percutaneous nucleotomy under general anesthesia in 1980; sciatica disappeared immediately. She is still symptom free 5.5 years later

resistent sciatica due to disk herniation with spondylolisthesis of L-5 of about 15% (Fig. 8). The patient is symptom free.

C.G., female, 28 years old: The patient suffered from recurrent sciatica for a long time; this increased severely in the summer of 1980. Lumbar myelography showed a filling defect of nerve root S-1, with not only severe osteochondrosis and retrolisthesis but also a narrowing of the spinal canal in the area of L3–5 (Fig. 9). The clinical results of hemilaminotomy in the presence of a narrowed spinal canal are not always good. Because

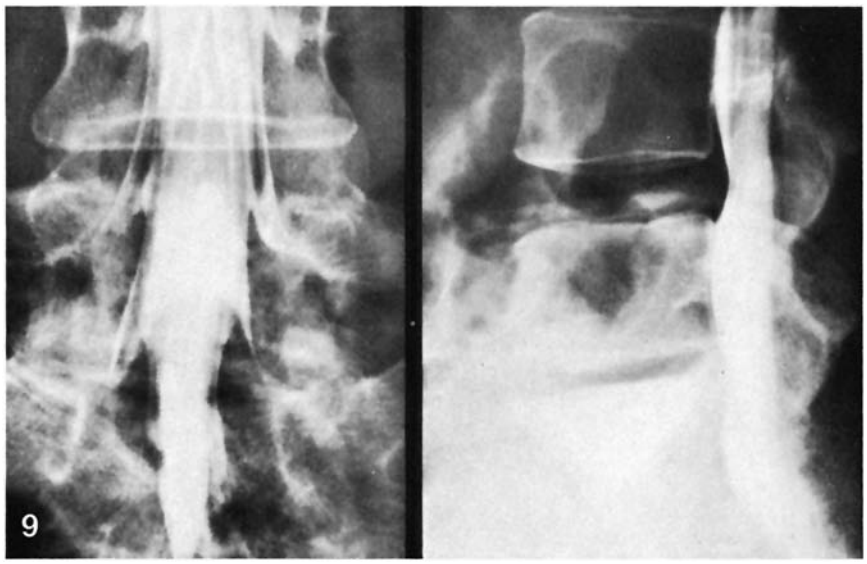


Fig. 9. C.G., 28-year-old woman with sciatica. Myelograms show mediolateral disk herniation *(left)* with unstable osteochondrosis at L-5/S-1 and a narrow spinal canal with disk protrusion at level L4–5. Percutaneous nucleotomy was performed in 1980, and the patient was symptom free 4.5 years later

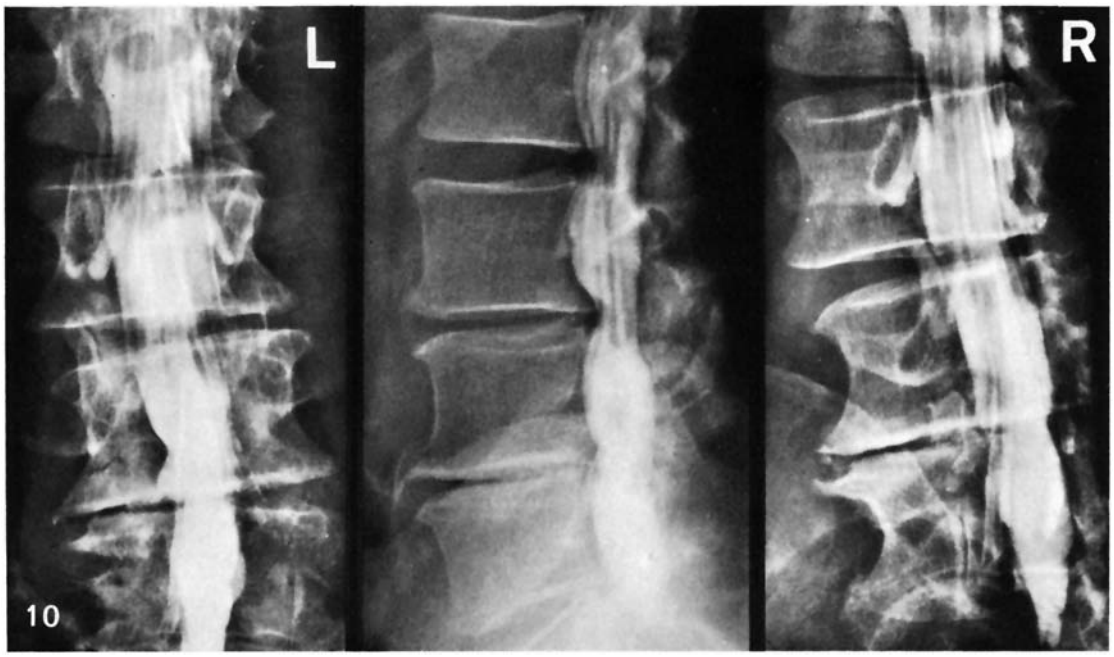


Fig. 10. F.S., 71-year-old man, suffered a sudden attack of sciatica, in particular on ventral side of thigh, and numbness in region of innervation of L2–3. Myelograms show narrow lateral recess at L-4 *(right)* and multiple disk protrusions, at L2–3, L3–4, and L4–5. Percutaneous nucleotomy was performed at only one level, as indicated by pain and numbness arising from L2–3. Pain disappeared immediately. Two weeks after operation lower-back pain recurred; long-term physiotherapy cured it

of this tendency, we performed percutaneous nucleotomy in September 1980. The sciatica disappeared immediately after the surgical treatment. At the most recent check-up she was absolutely pain free.

F.S., male, 71 years old: The patient, with a long history of lower back pain, suddenly suffered a severe attack with radiating pain on the right thigh initiated by the movement of stretching himself (Fig. 10). The sciatica failed to respond to various conservative treatments, so that percutaneous nucleotomy had to be resorted to at the level of L2–3. Clinically, he had hypoesthesia arising from the L-3 level. Location of the pain was also traced to the L-3 level on the right side. Lumbar myelography exhibited a filling defect of the nerve root at the L-3 level through herniation of the L2–3 disk on the right side. The myelography further showed narrowing of the spinal canal at multiple levels. After percutaneous nucleotomy had been performed we observed a dramatic decline of the sciatica and disappearance of the hypoesthesia. However, because of per-

sisting pain in the lumbar region, postoperative physiotherapy was necessary.

Discussion

The clinical results of the standard operation for disk herniation, with or without microscope, can in most cases be characterized as good. Very good to satisfactory results are reported in about 70% to over 90% of operated patients, depending on the author [1, 5, 9, 10, 11, 14, 22].

Problems do frequently develop, however, when additional unfavorable factors are involved such as medial disk herniation, herniated disks at multiple levels, narrowing of the spinal canal, spondylolisthesis and/or spondylolysis or lumbosacral assimilation. Patients with these combined findings often complain of chronic lumbalgia, which cannot be adequately treated conservatively but which would also be very problematical to treat surgically.

Statistical evaluation of our more than 600 patients with operated disk herniation shows interesting results, as follows:

In about 80% of the patients with only a herniation at one level the clinical results obtained were very good or good, whereas in patients with disk herniation combined with other causes of sciatica or lower back pain – spondylolisthesis, spondylolysis, narrowing of the spinal canal or lumbosacral assimilation – clinical results that might be described as very good or good were achieved in only about 30% of cases [24].

The disadvantages of the hemilaminotomy approach understandably lead to the consequence that the above-mentioned unfavorable factors become prominent as causes of low back pain. The following sequelae are particularly detrimental: weakness of segmentary back muscles resulting from lesion of the dorsal ramus; damage to the ligaments, lamina, and the vertebral joints; irritation of the dural sac or nerve roots, or of neighboring segments as well, due to postoperative hematoma or indirect soft tissue injury during intraoperative mobilization that can cause the formation of scar tissue in the immediate environment of the nerves. In such cases, we regard percutaneous nucleotomy as being a more suitable, more sparing operative measure.

The concept of relieving the symptoms of disk herniation by reducing the volume of the disk was probably first described by Hult and Olsson [8, 15]. In 1950, Hult treated lumboischialgia successfully in 22 of 30 patients by fenestrating the anulus fibrosus via a ventral approach. Olsson likewise successfully performed disk fenestration in dogs with herniated disks. At that time, both methods were "bloody", or open. At the same time, others attempted a closed approach to the prolapsed disk: in 1956, Feffer first reported his results after intradiskal injections of corticosteroid preparations [2].

Mechanical Action of Percutaneous Nucleotomy

Hijikata succeeded in performing percutaneous nucleotomy, the removal of the nucleus pulposus with a small forceps via tubes, in 1975 [6]. It is known that both changes in the volume of the herniated disk and changes in the intradiscal pressure irritate the associated pain receptors. The converse also applies, namely that slowly growing, hard herniations, or spondylophytes, often cause substantially less problematic symptoms. Variations in volume and pressure are decreased by diminishing the quantity of nucleus pulposus and by creating a passage through the anulus fibrosus, which may explain the effectiveness of percutaneous nucleotomy. In fact, contrast medium can be seen extravasating through the dorsolateral aspect of the anulus fibrosus on diskography even several months after successful percutaneous nucleotomy [7]. Persistence of such an opening reduces or even totally abolishes intradiskal pressure. The prevention of pressure buildup makes it difficult for a recurrent disk herniation to develop. The creation of an opening in the anulus fibrosus – external to the vertebral canal – thus proves to be especially favorable with regard to the long-term prognosis.

The question of how much nucleus pulposus should be removed is, however, still open. In our patients, the minimum we removed was 1.5 g, the maximum 13 g. There is, as yet, no correlation with the clinical results, however. From a theoretical standpoint, it would seem desirable to remove as much nucleus pulposus as possible, but, on the other hand, massive extirpation might cause rapid narrowing of the disk, thus leading to reduction of the intervertebral foramen space and to possible irritation of the pain receptors.

Even after a successful disk operation, symptoms of a relatively narrow spinal canal may become clinically manifest in the neighboring segment. This procedure ensures a direct cure of the disk herniation, but at the cost of surgical trauma to the surrounding tissues. Percutaneous nucleotomy, on the other hand, completely avoids such complications by virtue of its tissue-sparing character.

Thus, we have chosen this method for the treatment of disk herniation at our clinic since 1979, as mentioned in a preliminary report [25]. Since 1982 we have also made use of a viewing arrangement

(diskoscope) as reported by Suezawa et al. [23] and Schreiber and Suezawa [17]. Through our supplementary instruments and the use of a diskoscope, we can now achieve a far more effective excision of the nucleus pulposus in a shorter operating time.

In ten of the 49 patients operated on we diagnosed a combined narrow spinal canal with disk herniation or protrusion, which could have unfavorably influenced the outcome of a standard disk operation. Decompression and dorsal spondylodesis would have been unavoidable in all cases. Another six patients had medial herniations, which would have had to be removed via bilateral intervertebral windows.

When a disk is displaced beyond its corresponding level, hemilaminotomy is the procedure of choice. In six patients with poor clinical results after percutaneous nucleotomy, extensive dislocations were found at the subsequent necessary operations. Once the herniation is no longer in contact with the anulus fibrosus, therapeutic success is highly unlikely with percutaneous nucleotomy.

In 1963, Smith injected the enzyme chymopapain into the nucleus pulposus. His chemonucleolysis remained controversial, as central nervous system irritation resulted from extravasation of the chymopapain into the vertebral canal.

Smith et al. [20, 21], Finneson [3], and Graham [4] reported the occurrence of anaphylactic shock, which is a known side effect, after the use of chymopapain. Various studies, particularly animal experiments, showed that chymopapain can cause subarachnoid bleeding or nerve damage [16, 19, 26].

The effectiveness of chemonucleolysis is due mainly to a certain degree of reduction in disk volume, while the action of corticosteroids on the disk has not yet been conclusively determined. Numerous studies have been published, but the clinical results recorded vary. Double-blind studies [4, 12, 18] using both methods did not reveal any significant differences in effectiveness.

Ever since the use of chymopapain has been reallowed in the United States, positive reports have become increasingly frequent, and a growing number of patients are being treated with this procedure.

McCulloch and McNab [13] maintained that good clinical results of chemonucleolysis were observed in 60%–80% of over 7000 patients who had been selected according to particular indication criteria.

The indications and contraindications for percutaneous nucleotomy as well as for chemonucleolysis are listed in Table 2. A contraindication for percutaneous nucleotomy is a very large disk herniation – such as causes subtotal blocking of contrast agent in the spinal canal – or one that has become displaced beyond the level of the disk itself. Contraindications for chemonucleolysis could be allergy towards chymopapain, a previously performed chemonucleolysis, or a case of disk herniation where considerable leakage is present in the anulus fibrosus.

Table 2. Indications and contraindications for percutaneous nucleotomy (PN), chemonucleolysis (CN) or classical hemilaminotomy (HL)

	PN	CN	HL
Mediolateral DH			
Sequester at one level	–	–	+
Without sequester at one level	+	+	+
Leakage or communication between spinal canal and disk	+	–	+
Medial DH	+	+	+/–
Recurrence of operated DH	+	–	+/–[a]
DH at multiple levels	+	+/–[b]	+/–
DH combined with other causes of lumbago/sciatica	+	+	+/–[a]
Repetition of the same treatment			
At same location	+	–	+/–[a]
At other side, same level	+	–	+
At other levels	+	–	+
Allergy against chymopapain	+	–	+
DH L-5/S-1, with obstructed approach	–	–	+

DH, Disk herniation; +, good indication; +/–, limited indication; –, not advisable or contraindication

[a] Can be performed combined with spinal fusion

[b] Two segments are possible because of maximum permissible dosis of chymopapain.

A combination of both methods would permit treatment of a larger number of patients suffering from therapy-resistant sciatica due to disk herniation, either with or without additional causes of sciatic trouble. At present, we are using either percutaneous nucleotomy or chemonucleolysis with due restriction, depending on the intraoperative diskography observations and on the given accessibility of the affected region.

References

1. Bösch J (1969) Erfahrungen bei 1351 Bandscheibenoperationen aus 21 Jahren. Z Orthop 106:295
2. Feffer HL (1956) Treatment of low back and sciatic pain by the injection of hydrocortisone into degenerated intervertebral discs. J Bone Joint Surg [Am] 38:585
3. Finneson B (1973) Low back pain. Lippincott, Philadelphia
4. Graham CE (1976) Chemonucleolysis: a double-blind study comparing chemonucleolysis with intradiscal hydrocortisone. Clin Orthop 117:179

5. Gurdjian ES, Webster JE, Ostrowski AZ, Hardy WG, Linder W, Thomas LM (1961) Herniated intervertebral discs – an analysis of 1176 operated cases. J Trauma 1:158
6. Hijikata S (1975) Perkutane Nukleotomie – neue Behandlung der Diskushernie. J Toden Hosp 5:39
7. Hijikata S, Nakayama K, Yamagishi M, Ischihara S (1979) Percutaneus nucleotomie. Orthopedics Mook 11:246
8. Hult L (1950) Retroperitoneal disc fenestration in low back pain and sciatica. Acta Orthop Scand 20:342
9. LaMont RL, Morawa LG, Pederson MD (1976) Comparison of disc excision and spinal fusion for lumbar disc ruptures. Clin Orthop 121:212
10. Lenhard RE (1947) End-result study of the intervertebral disc. J Bone Joint Surg 29:425
11. Love JG (1947) The disc factor in low-back pain with or without sciatica. J Bone Joint Surg 29:438
12. Martins AN, Ramirez A, Johnston J, Schwetschenau PR (1978) Double-blind evaluation of chemonucleolysis for herniated lumbar discs. J Neurosurg 49:816
13. McCulloch JA, McNab I (1983) Sciatica and chymopapain. Williams & Wilkins, London
14. O'Connell JEA (1951) Protrusions of the lumbar intervertebral discs. J Bone Joint Surg [Br]:8
15. Olsson SE (1950) Observations concerning disc fenestration in dogs. Acta Orthop Scand 20:349
16. Rydevik B (1976) Effects of chymopapain on nerve tissue. Spine 1:137
17. Schreiber A, Suezawa Y (1984) Transdiscoscopic percutaneous nucleotomy for the treatment of lumbar disc herniation. First International Congress on Advances in Orthopaedic Surgery and Traumatology, April 16–19, Palmspring, California
18. Schwetschenau P, Ramirez A, Johnston J, Barnes E, Wiggs C, Martins AN (1976) Double-blind evaluation of intradiscal chymopapain for herniated lumbar discs. J Neurosurg 45:622
19. Shealy CN (1967) Tissue reaction to chymopapain in cats. J Neurosurg 26:327
20. Smith L, Brown E (1967) Treatment of lumbar intervertebral disc lesion by direct injection of chymopapain. J Bone Joint Surg [Br] 49:502
21. Smith L, Garvin PS, Gesler RM, Jennings RB (1963) Enzyme dissolution of the nucleus pulposus. Nature 198:1311
22. Spangfort EV (1972) The lumbar disc herniation, a computer-aided analysis of 2504 operations. Acta Orthop Scand [Suppl] 142
23. Suezawa Y, Blasbalg DT, Brandenberg JE (1983) Perkutane Nukleotomie und Diskoskopie. Z Orthop 121:394
24. Suezawa Y, Langlotz M, Schreiber A (1984) Klinik und Radiologie der Lendenwirbelsäule in bezug auf Operationsindikation und -wahl. 32. Jahrestagung der Vereinigung Süddeutscher Orthopäden e.V., Baden-Baden
25. Suezawa Y, Rüttimann B (1983) Indikation, Methodik und Ergebnisse der perkutanen Nukleotomie bei lumbaler Diskushernie. Z Orthop 121:25
26. Sussman BJ (1973) Treatment with chymopapain. J Neurosurg 39:793

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