A HISTORY OF SURGICAL TREATMENT FOR RADICULAR PAIN ASSOCIATED WITH INTERVERTEBRAL DISC DISEASE

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The paper presents an analytical review of the literature on the history of the development of clinical diagnostic approaches and methods of surgical treatment for intervertebral discs diseases in the lumbar spine.
Key Words: degenerative intervertebral disc disease, lumbar spine, clinical diagnosis, surgical treatment.

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In this article, we have tried to describe the development of surgical techniques for treatment of discoradicular conflict. The description of some classical surgical techniques may be interesting to both experienced and novice neurosurgeons. Because the domestic literature lacks translations of most classical descriptions, our article provides quite lengthy quotes.

Andreas Vesalius (1514–1564) was one of the first who described the intervertebral disc in his famous monograph "De humani Corporis Fabrica" (1543) where he depicted the spine and intervertebral discs (Fig. 1).

The progress in surgical treatment of spine pathology was promoted by achievements and discoveries in medicine at the turn of the XXth century. Studies by Joseph Lister (1827–1912) and his predecessors devoted to fighting infections made surgery safer. Macewen (1848–1924) described the laminectomy procedure, and Menard (1895–1934) described the costotransversectomy procedure. Weber (1827), Rauber (1876), and Messerer (1880) pioneered spine biomechanics studies. In 1895, the method proposed by Wilhelm Conrad Rontgen (1845–1923) became the gold standard in studying spine pathology. The myelography technique proposed in the 1930s became the logical continuation of radiography and significant progress in vertebrology [28]. However, the intervertebral disc was not a primary focus because nothing was known about the relationship between the disc and sciatica.

The development of a surgical technique to treat lumbar intervertebral disc diseases was one of the most interesting challenges for surgeons and neurosurgeons in the early 1900s. People always suffered from radicular pain, but it was very difficult to accurately diagnose and, in particular, treat severe cases associated with caudal syndrome and pronounced sciatica not only due to the lack of modern means of visualization but also due to an insufficient understanding of the pathophysiology of the process.

The neurogenic nature of leg pain (sciatica) was first described by an Italian doctor, Domenico Cotugno, in 1764 [29, 47]. He was the first who differentiated between arthritic sciatica associated with hip pain and neuritic sciatica, with the latter being further classified into posterior and anterior sciatica. Cotugno described in detail the characteristics of sciatica pain and associated muscle deficits. However, Cotugno related the cause of sciatica to an acrid matter deriving from the vessels of the nerve sheaths or brain itself, which was present in the sciatic nerve sheaths. His follower, Giovanni Petrini, differentiated neuritic sciatica into tibial (lateral), sural (posterior), and combined types [46].

In the XIXth century, intervertebral disc herniations were detected accidentally at autopsy [44]. A German anatomist, Hubert von Luschka (1820–1875), identified herniated nucleus pulposes. A German pathologist, Rudolf Ludwig Karl Virchow (1821–1902), discussed disc pathology and ruptured discs (known as Virchow's tumor). In 1896, a Swiss surgeon, Emil Theodor Kocher (1841–1917), reported on a traumatic disc herniation at the L1–L2 level in a patient who fell from a height onto his legs, suggesting that the herniation might cause spinal root compression, but he did not relate it to sciatica [38].

In 1911, a British doctor, George Middleton, and pathologist, John Teacher, described a case of a T12–L1 posterior disc herniation that developed due to fast weight lifting and was confirmed at autopsy. The patient died due to bedsores and septic cystitis 16 days later. Howev-

Fig. 1
The spine with the intervertebral discs depicted by Andreas Vesalius Bruxellensis in "De Humani corporis fabrica Libri septem" (1543)

er, they, like their predecessors, did not find a relationship between a hernia and radiculopathy [41]. The relationship was suggested by Joel E. Goldthwaite (1866–1961) from Boston in his article on the lumbosacral joint in 1911 [36]. Goldthwaite described a clinical case when reduction of spondylolisthesis resulted in caudal syndrome that was later treated by Harvey Cushing using laminectomy, but the treatment failed. Goldthwaite explained this by that the pain might be caused by repeated dislocation of the disc into the canal, but during surgery the hernia retracted. Goldthwaite demonstrated how weakening of the fibrous ring may lead to a displacement of the nucleus pulposus, which, in turn, according to his hypothesis, might cause back pain, paraplegia, and sciatica.

The description of sciatica (pain along the sciatic nerve) as well as the relationship between the pain and a disc herniation also has its staging. A representative of the French school of neurology, Ernest Charles Lasegue (Fig. 2), used a neurological straight leg test, but never described it. There are references to his paper of 1864, but there Lasegue just described in detail the symptoms of sciatica. The first description of the straight leg test used to differentiate sciatica was provided in the thesis of a Lasegue's student, J.J. Forst, in 1881 [35, 55]. At the same time, this test was known to a Serbian doctor, Lazar K. Lazarevic, who indicated the relationship between sciatic nerve compression and a positive straight-leg-raising sign in 1880; however, his article published in Serbian did not rise to international fame [32].

Later, in 1927, Putti wrote that sciatic nerve inflammation developed due to irritation of the nerve root in a foramen. This irritation resulted from arthritis of the posterior intervertebral joints. However, he did not write about a relation to intervertebral disc prolapse [50].

Before the relationship between intervertebral disc prolapse and sciatica was reliably identified, the medical community had believed for a long time that canal lesions to be of a tumorous nature. In 1930, an American neurosurgeon and neuroanatomist, Paul C. Bucy (1904–1992), wrote in his clinical observation of lumbar sciatica that a disc problem was due to a typical cartilage neoplasm [24] and referred to cases of cervical and thoracic extradural chordomas reported by a respected neurosurgeon from New York, Byroon Stookey (1887–1966), in 1928 [54].

In this regard, we should consider a patho-anatomical, but clinically very important, study by a German pathologist, Christian Georg Schmorl (1861–1932), who routinely studied the intervertebral discs at autopsy (Fig. 3). Before Schmorl turned his interest toward the spine pathology, there had been few publications on this subject in the literature. Most pathologists avoided investigating the spine because of cosmetic and technical problems associated with its removal and subsequent isolation of the intervertebral discs. In contrast, Schmorl removed the intact spine using a band saw. In the period from 1928 to 1932, he studied more than 10,000 spinal columns [57]. Schmorl found intervertebral disc abnormalities, the most common of which were disc prolapses into the adjacent vertebral bodies (approximately in 38 % of all examined spines). In addition, Schmorl found small prolapses beneath the posterior longitudinal ligament (about 15 % of cases), but concluded that they rarely, if ever, caused any clinical symptoms. Schmorl associated these changes with weakening of the fibrous ring caused by degenerative changes, with a minor trauma as a second factor causing fissures in the annulus and release of the semifluid contents of the disc nucleus [57]. Schmorl published a number of advanced patho-anatomical studies on the intervertebral discs, which, unfortunately, have remained available only to German readers.

In the US, the first laminectomy was performed by a little-known surgeon, Alban G. Smith (Danville, Kentucky). In 1828, he operated on a male who developed paraplegia after falling from a horse. Smith noted that the patient not only survived serious (for that time) surgery but also achieved a partial improvement of neurological symptoms. Smith published the surgical technique and surgery outcome in 1829 [52]. The Smith's surgery technique comprised a midline

Fig. 2
Ernest-Charles Lasegue (1816–1883), a French doctor of nervous and mental diseases; Lasegue was immortalized by his student, J.J. Forst, who called, in his thesis, the straight leg raising test in sciatica as the Lasegue test

incision, multilevel laminectomy, resection of the damaged spinous processes and depressed laminae, and exploration of the dura mater, followed by closure of the soft tissue incision. This publication placed Smith among the pioneers of the early modern period in spinal neurosurgery.

Half a century after the historical Smith's operation, the indications for laminectomy included mainly spinal injuries; in the XIXth century, the indications were extended to tumors and infections. In 1887 in England, Sir Victor Horsley (1857–1916) performed laminectomy for a tumor. The indications for surgery were made by a neurologist William R. Gowers for an English army officer who lost his wife and was injured in a carriage accident. After injury, the captain Gilbey suffered severe back pain, urinary retention, paraplegia, and loss of sensation below the thoracic level. Seeking for a doctor capable of identifying the cause of the disease, Gilbey was fortunately referred to the eminent London neurologist, Gowers, who located the lesion in the thoracic spine. Despite the fact that nobody had previously performed surgery for intraspinal tumors, Gowers referred the patient to Victor Horsley for surgery. As early as 2 h after consultation, Horsley performed a skin incision. The surgery was held at a hospital, and, although experiments on vertebrate animals to attain manual skills were prohibited in England at that time, Horsley was familiar with the procedure. Despite initial surgical difficulties in locating a tumor, Horsley found an intradural lesion at the thoracic level that caused compression of the spinal cord, which was successfully resected. The pathological diagnosis was a "fibromyxoma of the theca". An examination one year later revealed complete regression of the neurological symptoms; the patient walked without assistance and returned to his previous job. He remained in the same good condition until his death from another cause 20 years later [37, 58].

Advances in anesthesia and aseptic techniques made laminectomy an affordable approach. Twenty four laminectomies for vertebral osteomyelitis were reported as early as 1896 [40]. An increasing number of patients underwent surgery using this approach, but concerns about potential postoperative instability raised by the end of the XIXth century. Laminectomy techniques were also gradually improved.

For example, Dawbarn in 1889 [31] described an osteoplastic laminectomy technique to resolve the problem of postoperative segmental instability. A more traumatic approach used two paramedian incisions up to the transverse processes, which were connected in an H-like fashion at the center, with superior and inferior flaps, including the skin, muscles, fascias, and bones, being reflected sidewards. When closing the wound, the flaps were re-approximated, and the wound was sutured in layers. Despite the fact that this technique was not extensively used, many surgeons tried to improve laminectomy.

The most successful technique was hemilaminectomy developed in Italy [19] and the United States. In 1910, A.S. Taylor of New York described unilateral resection of a hemilamina using a Doyen saw [56]. Despite the Taylor's arguments that this surgery less affected the spine biomechanics, a famous spinal neurosurgeon of New York, Charles Elsberg, noted that hemilaminectomy provided a very narrow field of view, and the effect of laminectomy on the biomechanics was negligible.

It should be noted that, unlike a herniated disc, spinal stenosis as a cause of paraplegia was described and defined by A. Portal relatively early in 1803 [48]. In 1893, William A. Lane used laminectomy for degenerative spondylolisthesis [39]. Elsberg in his monograph on spinal surgery (a basic book for spinal neurosurgeons at that time) noted that surgical treatment may be necessary in some arthritis and spondylitis cases responsible for compression of the nerve roots or spinal cord by a newly formed bone [33].

Herman Oppenheim and Fedor Krause were among the first who used lumbar laminectomy and a transdural approach (separating the roots) for an intervertebral disc herniation in December 1908 (Fig. 4) [43]. They called the lesion as "enchondroma".

Fig. 3
Christian Georg Schmorl (1861–1932), a German pathologist, who is known to spine specialists by the same name hernia. In his papers, Schmorl described not only the normal anatomy of the vertebrae and intervertebral discs but also age-related degeneration with appropriate changes in the vertebra (deforming spondylosis), spinal stenosis due to degeneration, morphology of circular annular ruptures and radial, posterior, and vertical disc protrusions, ballooning of the disc in osteoporosis, pathological anatomy of discitis, juvenile kyphosis, and spondylolisthesis. He combined pathological anatomy with X-ray and was one of the first who performed discography with barium sulfate. Schmorl died of septicemia developed due to chronic finger injury occurred during spine dissections [57]

In 1929, one of the founders of American neurosurgery, Walter E. Dandy (Fig. 5), published the first case report under the title "Loose cartilage from intervertebral disk simulating tumor of the spinal cord" where he described, based on two cases, the cause of pathology as follows: "The pathological substrate is a completely loose cartilage fragment (disconnected) from the intervertebral disc and surrounded by serum. It protrudes backwards into the spinal canal, like a tumor, and compresses the cauda equina roots, causing motor and sensory paralysis as well as loss of the anal and visceral reflexes. The lesion undoubtedly has a traumatic nature" [30].

Dandy concluded that decompressive laminectomy may be indicated for intervertebral disc diseases associated with compression of the nerve roots. This paper was published 5 years before a study by Mixter and Barr.

The most well-known and cited paper is "Rupture of the intervertebral disc with involvement of the spinal canal" by a neurosurgeon at the Harvard College, William J. Mixter (Fig. 6), and his colleague, an orthopedist Joseph Barr, in which they described the pathophysiology of lumbago and sciatica [42]. In 1932, Barr treated a patient with degenerative intervertebral disc prolapse that was not amenable to 2 week conservative treatment. Barr consulted with Mixter, and the latter recommended myelography that revealed a filling defect. Mixter carried out surgery, and Barr performed a histological study. Shortly before this case, Schmorl published his monograph "The Human Spine Health and Disease", for which Barr prepared a review. Barr remembered histologic specimens in a recent Schmorl's publication in German and realized that the specimen from his patient was the nucleus pulposus. After this finding, Mixter, Barr, and a pathologist Mallory retrospectively investigated all cases of chordoma at the Massachusetts General Hospital in recent years and found intervertebral disc fragments in most of the cases [22]. Mixter and Barr, having combined the results of Schmorl's patho-anatomical studies with previously published clinical reports of chordoma (Oppenheim, Goldthwaite, Elsberg, Bucy, Dandy, Petit-Dutallis, et al.) and analyzed their own 11 cases, presented a study that later became the key one for the diagnosis and treatment of many millions of patients with low back pain and sciatica around the world. They proposed a surgical technique that was not minimally invasive and comprised extended laminectomy, opening of the dura mater, and an approach to the intervertebral disc via an intradural access. This technique had been used in the US and Europe for several years during the "Cold War" of the 1960s, until less invasive techniques were proposed.

Noteworthy, in 1934, a French neurosurgeon, Vittorio Putti, who operated on a patient with a sequestered herniation, was surprised when found a strange fragment of whitish material inside the spinal canal. Understanding that he dealt with interesting and perhaps previously unknown pathology, Putti sent the specimen for analysis to one of the famous European pathologists, Professor Erdheim in Vienna. The answer was: "If you could not assure me that you found this material free in the canal and not inside a disc, I would say that it is disc material" [27]. Shortly thereafter, a paper by Mixter and Barr was published.

It is also worth mentioning an Italian surgeon, Bonomo, who proposed in 1902 a technique similar to the Mixter and Barr procedure [23]. In the period between 1937 and 1939, Love implemented an intralaminar extradural approach for discectomy [28].

The first two papers on a less invasive approach and surgery using a microscope were published in the same issue of "Advances in Neurosurgery" (1977) by Yasargil during his work in Switzerland and Caspar from Germany.

Yasargil [58], being one of the pioneers of using an operating microscope during neurosurgical operations, could not shy away from spinal surgery. It might be supposed that the spine was not a part of his favorite interests, but he could leave a significant footprint with one page describing experience of the cranial surgery maestro in spine surgery. In 105 patients, whom he operated on between 1967 and 1977, Yasargil reported 100 % success, the absence of recurrences, and only one infectious complication. It should be noted that the description of microsurgical removal of the disc almost completely corresponds to modern protocols: "A midline incision is made between the spinous processes over the involved disc space, generally a length of 2.5 to 3 cm. Paraspinous muscles are freed from the spinous processes and lamina in the subperiosteal plane and retracted with a self-retaining retractor. The deep narrow blades of the retractor provide enough mobility that the disc space above and below can be also inspected if this should prove necessary. If one centimeter space exists between the adjacent lamina, the procedure is

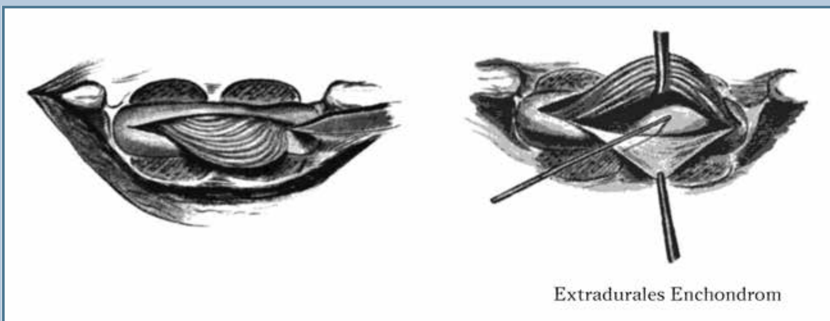

Fig. 4
The transdural approach to a tumor during laminectomy depicted by Oppenheim and Krause [43]

Fig. 5
Walter Edward Dandy (1886–1946), an outstanding American neurosurgeon, whose name is associated with significant advances in cranial surgery. After some professional relationships with another well-known neurosurgeon, Harvey Cushing, Dandy approved himself as an outstanding neurosurgeon, researcher, and organizer. He was the first who organized a unique residency in neurosurgery as well as a special unit "Brain Team", the prototype of modern neuro-reanimation. Dandy organized his work so efficiently that he could perform up to 1000 neurosurgical operations a year, apart from ventriculography. The most known his studies were devoted to the circulation of cerebrospinal fluid, Dandy-Walker syndrome, and surgery for brain aneurysms and cerebellopontine angle tumors [45, 51]

Fig. 6
William Jason Mixter (1880–1958). Mixter was born in Austria. In 1906, he received a medical degree from the Harvard University (USA), and after a surgical internship joined his father's private neurosurgical practice in Boston. In 1915, he left for France as a civil surgeon to assist victims of World War I; he headed a military hospital in England. He turned his interest to neurosurgery in 1911 when he and his father succeeded in implementing neurosurgical procedures recently described by Horsley and Cushing. By the 1930s, he was considered one of the most authoritative spinal neurosurgeons; he was a member of various neurosurgical societies and President of the Society of Neurosurgeons. In 1933, Mixter was appointed head of the Neurosurgery Department at the Massachusetts General Hospital, which had been established under his guidance. In 1941–1946, he served as a principal consultant in neurosurgery with the US Army chief surgeon [44]

entirely interlaminar. If osteophytes are present on the lamina or the lamina overrode, a small laminectomy is made using a high-speed electric drill to avoid injury to the articular facets. A U-shaped is made in the ligamentum flavum, and this flap is sutured laterally.

Identification of the dural sac, nerve root, radicular artery, and epidural veins is facilitated by use of the operating microscope. Epidural veins may be controlled with bipolar coagulation and are discernable from radicular arteries. The dural sac and nerve root may be retracted with an adjustable self-retaining retractor attached to the operating table although frequently adequate retraction is proved simply by the sucker.

If the annulus is ruptured, free disc fragments are located and removed. If the annulus remains intact, a U-shaped incision is made. Through this opening, disc contents are evacuated with curettes and rongeurs. Osteophytes from the rims of the vertebral bodies may block access to the disc space; these are removed with the electric drill. Following a reasonably complete removal of nucleus pulposus, the annulus is resutured with 7.0 suture. This may help prevent adhesions. The small flap of ligamentum flavum is positioned to restore normal anatomical planes and the lumbodorsal fascia and skin closed" [58].

On three pages of the same issue, William Caspar described in more detail the technique of microsurgical removal of a herniated disc. He prefaced the description of the technique with a warning about the complications after spinal surgery: "We believe that a considerable proportion of the complaints must be attributed to surgical trauma, in particular to muscle damage. This opinion is supported by the results of experienced surgeons such as Kuhlendahl, Lange, Love, Youmans and others, who have long advocated an intervention which is as accurate, restricted in extent and as gentle as possible. It is also based on our own observations over many years" [26]. Caspar noted that disproportionately extended approaches (sometimes, the length was 10-fold more than the surgical target area), which were common at that time (due to the lack of visualization tools and instrumentation), caused functional and morphological disorders in the muscular system, clearly associated with postoperative pain in the spine. Caspar described the surgical technique as follows (Fig. 7): "The operation is carried out with the patient in modified knee-elbow position

("Mecca positioning"). The segment to be operated on is marked by a puncture cannula with subsequent X-ray control. A midline cutaneous incision is made from about 3 cm from the upper limit of the cranial spinous process to the middle of the caudal one. The fascia lumbodorsalis is cut through 1 cm paramedially. The edge of the median fascial section is reflected to the midline and tied up by means of anchor threads. The musculature is detached obtusely with a tiny raspatorium from the midline down to the ligamentum flavum. It is advisable to start from the lateral surface of the cranial spinal process so not go beyond the midline unintentionally.

Further bloodless detachment is affected by firmly pressing in a drawn out compress. Muscle origins and insertions on spinous processes and midline ligaments are not detached but, at most, indented at their insertion. Digital palpation of the anatomical situation informs on the breadth and course of the vertebral arches, the position of the articular processes and the interlaminar space. The musculature lying on the vertebral arches is loosened with the fingers. A supraperiosteal detachment in the angle between the spinous process and arch by means of extremely fine incision is occasionally necessary. Under no circumstances is the musculature loosened by incision.

The special speculum-like retractor (various sizes are available) is introduced with the aid of a small modified Langenbeck hook, so that it can first be opened in the transverse direction. The interlaminar space is opened by spreading the musculature 2 cm. Residues of connective tissue and muscle fibers are pushed away from the ligamentum flavum with stem tampons. The retractor is closed, turned 90 degrees, the handle pointing towards the assistant, and then reopened, this time in a longitudinal direction. The branches must come to lie directly above the vertebral arches so that one can see the whole laminar space.

A cross-shaped incision is made in the ligamentum filum and fenestration is carried out. In the presence of difficult optical conditions, this phase can be performed under the microscope. The surgical microscope (focal length of the objective: 350 mm) is usually placed in position after fenestration. If necessary, the window can be readily extended and (exceptionally) hemilaminectomy carried out under the microscope. The root can be isolated and the slipped disc cleared in the usual way. The procedure is rendered significantly easier by special designed dissectors, various retractors, incision scalpels and coagulation forceps (Aesculap Company, Tuttlingen).

The advantages of the microscope (better illumination, variable magnification and depth sharpness, simultaneous possibility for the assistant to observe) allow more gentle manipulation of the dural sac and root. Besides, better differentiation of anatomical structures is possible. This reduces the risk of instrumental lesion and is advantageous in the loosening of adhesions as well as for hemostasis in the peridural space. Following removal of the retractor, the musculature immediately lies against the vertebral arches and the spinous processes since its insertions were not severed. The wound is closed in several layers as usual. A further advantage is the bloodlessness of the intervention (an average of 25 mL blood is lost). Transition to conventional procedure is easily accomplished at any phase, if required" [26].

In the USSR, the first operation for a herniated disc was carried out by I.S. Babchin (Fig. 8) in 1935. He described compression of the spinal cord in the cervical region by a Schmorl hernia [1]. Later, Soviet authors turned to the problem of discogenic lumbosacral pain, but it should be noted that most researchers considered an infectious theory of sciatica as the main one. Nevertheless, as early as 1938, A.K. Shenk and M.I. Kagan in their report "Lumbar ischialgia and its orthopedic basis in the light of current data" draw attention to the significance of intervertebral disc lesions in the etiology of this disease.

The first paper on surgery for posterior lumbar disc herniation was published by N.N. Popova in 1946 and reported data on nine operated patients. In 1949, at a meeting of the Leningrad Neurosurgical Society, A.A. Krivosheina presented a patient after removal of a lumbar disc herniation [1]. In 1966, Ya.L. Tsivyan (Fig. 9) and V.A. Shustin (Fig. 10) published a communication on treatment of discogenic radicular syndrome [14, 17].

In the late 1950s, Prof. Ya.L. Tsivyan chose spine surgery issues as a priority research area at the Novosibirsk Research Institute of Traumatology and Orthopedics. He founded domestic school of vertebrology that has confidently taken the leading position in the country. His name is also related to the widespread use of ventral fusion in the treatment of degenerative disc disease. In 1961, he proposed total discectomy and wedging corporodesis surgery. In this technique, the intervertebral disc was totally removed and replaced with a compact spongy autograft, which promoted restoration of the segment stability and intervertebral space height.

As early as the early 1960s, some Soviet neurosurgeons performed over a hundred of operations for intervertebral disc herniations [5]. In 1966, Ya.L. Tsivyan published the first guidelines for surgery of vertebral column diseases and injuries [14]. The guidelines focused on the issues of spinal injury treatment, with an emphasis on restoration of the normal shape and stability of the anterior support column of a damaged segment, including the vertebral bodies and intervertebral discs. Various anterior decompressive surgery options were developed; post-laminectomy syndrome was identified and described in detail; terms "posterior support complex" and "stable and unstable fractures" were refined.

The pioneer in the development of surgical treatments for complicated forms of lumbosacral degenerative disc disease is V.A. Shustin who, based on large clinical experience, prepared his doctoral dissertation "Discogenic lumbar radiculitis (clinical features, diagnosis, and surgical treatment)". The results of his study were published in the first Soviet monograph "Discogenic lumbar radiculitis" (1966) that remains of great value and is a handbook of modern neurosurgery [17, 18].

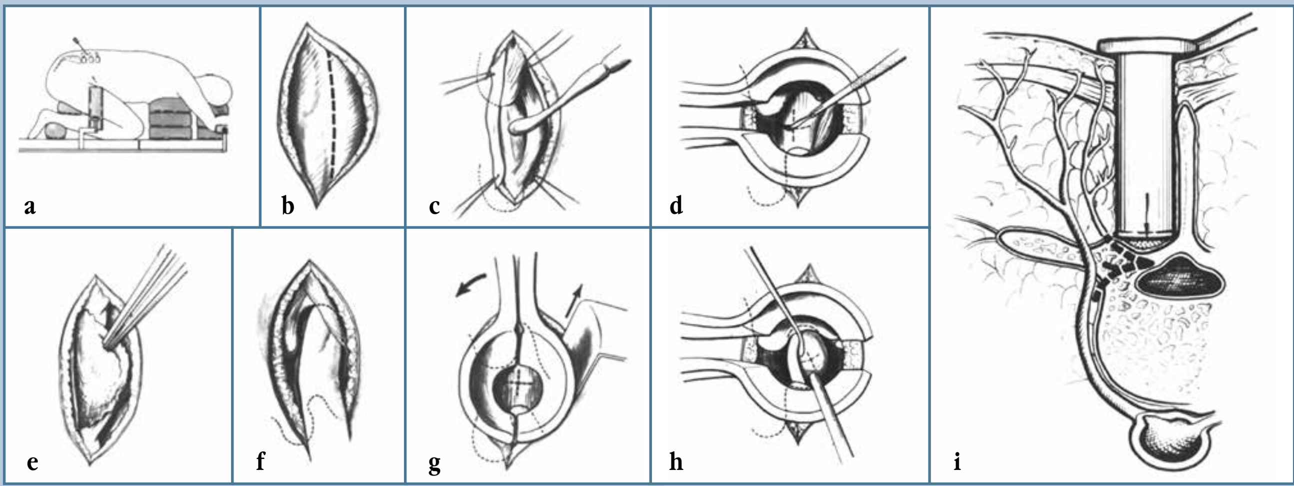

Fig. 7
The Caspar's microdiscectomy technique [26]: **a** – a segment to be operated is located and marked using a puncture cannula and X-ray control; **b** – a median cutaneous incision and a paramedian incision of the fascia (full size); **c** – medial reflection of the edge to the midline and attachment of the musculature to the supra- and infraspinous ligaments and lateral surface of the spinous process; **d** – extension through blunt bloodless detachment by pressing in a drawn out compress; **e** – topographo-anatomical palpation by moving the musculature aside from the vertebral arches; if necessary, a small periosteal incision is made in the angle between the spinous process root and the pedicle of the vertebral arch; **f** – a special retractor is introduced (various sizes; a modified Langenbeck hook is used; muscle are pushed away in a transverse direction, 2 cm); the ligamentum flavum is seen; the retractor is closed, turned 90 , the handle pointing towards the assistant, and then re-opened; **g** – extension in a longitudinal direction, the branches must come to lie directly above the vertebral arches so that one can see the whole laminar space; a cross-shaped incision is made in the ligamentum filum, and fenestration is carried out using rongeurs; if visualization is poor, a microscope is used; **h** – visualization of the root and herniation under the microscope; meningoradiculolysis; **i** – a cross-sectional view of the surgical field, with the introduced retractor; blood supply and innervation of the spinal musculature are preserved; a smooth surface and rounded profile of the tool do not cause any significant pressure-induced injury to the muscles; the arrow indicates the ligamentum flavum

The first use of microsurgical discectomy was reported by E.I. Zlotnik (Fig. 11) and co-authors of the Belarusian Institute in 1980 [5]. Since the early 1980s, microsurgical discectomy under general endotracheal anesthesia and a systems analysis of clinical results of its application have been actively used under his guidance. Later, V.A. Shustin and A.I. Prodan reported their experience and improvement of the method [11, 18].

A.I. Prodan (Fig. 12) performed the world's first total vertebrectomy of the cervical vertebrae and total resection of the sacrum in patients with tumors. He developed and implemented a number of new surgical techniques for treatment of degenerative disc disease, spondylolisthesis, and spinal injuries and tumors. The sphere of scientific and practical interests of A.I. Prodan involved vertebral surgery, spine biomechanics, and theoretical studies of the etiology and pathogenesis of degenerative and dysplastic diseases of the spine.

Among the prominent neurosurgeons of the Irkutsk region, engaged in the study of discogenic radicular pain, it is worth mentioning M.D. Blagodatskiy (Fig. 13), who defended his doctoral dissertation "Pathogenesis and surgical treatment of radicular syndromes of lumbar degenerative disc disease" in 1987 and substantiated a model of discogenic radiculitis [4].

Therefore, investigation of surgical approaches to the treatment of intervertebral disc herniations was developed in several directions ranging from identification of radicular pain causes and mechanisms of the herniated nucleus pulposus to the development of X-ray techniques for spine disease diagnosis and improvement of surgical techniques and instrumentation. The beginning of the XXth century was a revolutionary time in science and technology and significantly changed the course of life of people in Europe, America, and Asia. The emerged new global knowledge and experience of the interaction among adjacent fields of science promoted the development of medicine, including spinal surgery. The introduction of MRI at the end of the XXth century greatly expanded the opportunities for investigation and accurate diagnosis of discoradicular conflict, being the basis for a new phase in studying this issue [25].

At this stage of medicine development, there exists a multi-disciplinary approach to the treatment of patients with neurosurgical pathology using modern diagnostic and treatment methods based on the principles of evidence-based medicine. Because degenerative spine disease and degenerative dystrophic processes in the intervertebral discs are ones of the major causes of reduced quality of life and primary disability on the global scale, there is scientific and practical interest in comprehensive solving the problem of effective treatment for patients with this pathology [10, 15, 16]. The emergence and intensive introduction of new diagnostic neuroimaging techniques (MRI, CT, and PET) improved knowledge and ideas about the etiology and pathogenesis of neurosurgical pathology [3, 13]. MRI takes a special place in detailed investigation of the supporting elements of the vertebral motion segments; it determines in vivo diffusion of water and in vivo molecular transport across the intervertebral disc using diffusion-tensor images and diffusion coefficient maps. Mathematical modeling and a finite element analysis represent ones of the modern methods to investigate transport of fluid and metabolites through the intervertebral discs [7, 12, 20, 21].

Currently, a promising direction in medicine is to gain basic knowledge about the molecular and cellular mechanisms of regeneration and remodeling of a tissue or organ with restoration of their structure and function. This, along with investigation of the basic pathological processes, underlies the development of new methods for prevention and treatment of diseases [3, 6, 9].

Active research is performed in the area of molecular and cellular aspects of intervertebral disc degeneration, molecular mechanisms of extracellular matrix catabolism and anabolism under the influence of specific factors, and changes in expression of genes associated with progression of disc degeneration and capable of modulating the balance of anabolism and catabolism in the extracellular matrix of the intervertebral disc [2, 21].

The basic biomedical technologies for treatment of the degenerated intervertebral disc are associated with the local use of various growth factors, morphogenic proteins, and transplantation of differentiated stem cells. However, the main problem of the avascular intervertebral disc is associated with modified transport of nutrients and drugs within the degenerated disc, which adversely affects the outcome of treatment [2, 3, 21].

Great attention is also paid to individualization of the tactics, a differentiated choice of surgical techniques, and personalization of surgical treatment options. Of great importance are assessment of long-term outcomes of surgical treatment, comparative analysis of surgical techniques, questionnaires, archiving of patient data, accumulation of experience, and analysis of postoperative complications [15, 16].

The priority direction in reducing pain and improving patient's quality of life after surgery is the use of mini-invasive surgical techniques to prevent excessive injury to the musculoligamentous apparatus and osteoarticular structures of the posterior support complex of spinal motion segments. This is necessary to prevent postoperative complications and reduce injuries to surrounding soft tissues during surgical access. For this purpose, modern instrumentation, microscopic or endoscopic magnification, intraoperative X-ray navigation with an electron-optical converter, and retractor and dilatator systems are used. This enables surgery at all clinically significant levels, with the minimal risk of intra- and

Fig. 8
Isaak Savel'evich Babchin
(1895–1989)

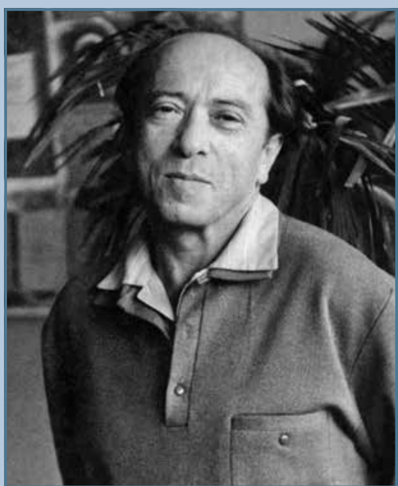

Fig. 9
Yakov Leont'evich Tsiv'yan
(1920–1987)

Fig. 10
Vladimir Anatol'evich Shustin
(род. 1924 г.)

postoperative complications and with earlier rehabilitation [8, 34, 49, 53].

Therefore, the level of modern surgical technologies enables highly efficient complex surgeries to remove lumbar intervertebral disc hernias in discoradicular conflict at the lumbosacral spinal level. Modern spinal neurosurgery is a system of therapeutic and diagnostic measures, which is based on an integrated approach to the treatment of patients with various pathological processes of the spine and is aimed at prompt and complete functional recovery and improvement of life quality of patients in the postoperative period, including rehabilitation and prophylaxis measures.

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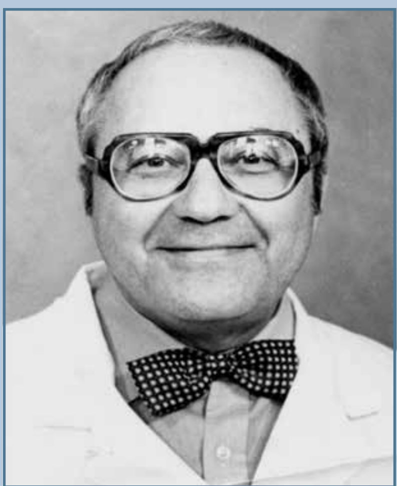

Fig. 11
Efraim Isaakovich Zlotnik
(1919–1993)

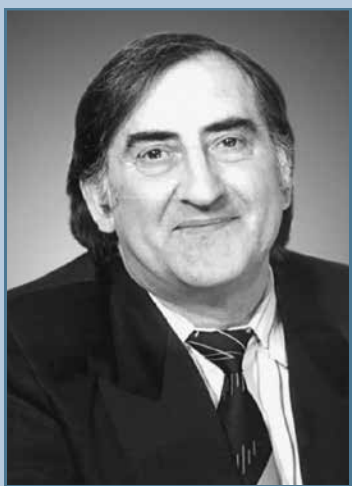

Fig. 12
Aleksandr Ivanovich Prodan
(1941–2010)

Fig. 13
Mikhail Dmitrievich Blagodatskiy
(1937–2009)

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