In-Vivo Endoscopic Visualization of Patho-Anatomy in Painful Degenerative Conditions of the Lumbar Spine

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ABSTRACT

The degenerative processes in an aging spine have been defined traditionally only by our knowledge of the biology of disc and facet degeneration, as well as interpretation of post-mortem cryosections by forensic anatomist Wolfgang Rauschning, M.D. In this chapter, visualization of *in-vivo* patho-anatomy in a degenerating disc and spinal segment is demonstrated at surgery using the Yeung Endoscopic Spine System™ (Y.E.S.S.™), (Richard Wolf Surgical Instrument Company, Vernon Hills, IL, USA). An Institutional Review Board (IRB)-approved study of endoscopic treatment for degenerative conditions of the lumbar spine incorporated intraoperative probing under local anesthesia and endoscopic treatment of the visualized patho-anatomy. An intraoperative evocative chromo-discogram, using indigocarmine, was used to elicit discogenic pain and label the fissured and degenerative nucleus pulposus for surgical removal and thermal modulation. Painful patho-anatomy was probed in a conscious patient. The most common endoscopic finding was Inflammatory tissue in the disc and annulus. Inflammation was correlated with the presence of annular tears. Patho-physiologic changes that affect the exiting nerve, which contains the Dorsal Root Ganglion

(DRG), was associated with stenotic and chemical irritation. Unavoidable postoperative dysesthesia was associated with the presence of an inflammatory membrane, and removal or thermal coagulation of "anomalous" furcal nerves in the foramen that branched off of the exiting spinal nerve. Neo-angiogenesis and neurogenesis in the inflammatory membrane present in the foraminal triangle was a new finding not reported in traditional clinical studies. Visualization and treatment of pathologic findings inside (annular tears) and outside the disc in Herniated Nucleus Pulposus (HNP), synovial cysts, foraminal stenosis, central stenosis, spondylolisthesis, is demonstrated. The endoscopic foraminal approach to the spine and disc is a technique that provides access to patho-anatomy in the lumbar spine not usually feasible with traditional surgical methods. Favorable surgical results allow for continued evolution of the endoscopic method, concomitant with the continued evolution of endoscopic spinal surgery.

INTRODUCTION

The patho-anatomy and degenerative processes in an aging spine are clearly defined by Rauschning's cryosections of cadaveric specimens. Theories of pain generation are suggested by close examination of these specimens. If *in vivo* patho-anatomy can be studied by spinal probing of a conscious patient, rational treatment options can be developed, and the patho-physiology of spinal pain may be better understood.[1,2]

MATERIAL AND METHODS

An IRB-approved study on Selective Endoscopic Discectomy™ (SED™), (Oratec, Inc.; Mountain View; California; USA) and thermal annuloplasty for treatment of Herniated Nucleus Pulposus (HNP), as well as painful degenerative conditions of the lumbar spine, was initiated in 1997.[1,2] The painful conditions were confirmed by a positive response to Evocative Discography™, then incorporation of endoscopic treatment of the visualized patho-anatomy.[1-4] Patients with painful degenerative conditions of the lumbar spine (including HNP), who failed at least three months of non-surgical treatment, were enrolled in the study. An intraoperative chromo-discogram was used to stain and label the fissured and degenerative nucleus pulposus, along with any structural tissue in contact with the indigo-carmine dye. SED™ of the blue-stained degenerative nucleus pulposus followed. Foraminal normal and patho-anatomy were probed under local anesthesia. To differentiate this visualized endoscopic procedure from other endoscopic procedures in the literature, the technique was trademarked and dubbed the Y.E.S.S.® technique. Patients were followed at one month, three months, six months, and one year. The Modified MacNab Criteria, Oswestry Disability Index, visual pain analog scale, and a questionnaire evaluation were used to determine patient satisfaction.

RESULTS

Overall initial outcomes using the MacNab criteria for this study were excellent, 46%; good, 32%; fair, 11%; and poor, 11%.[1] The Oswestry disability index dropped an average of 39%, and the analog pain scale improved an average of 7 points. Two separate retrospective and independently reviewed studies of the Y.E.S.S.™ patient surgical results for HNP,[5] and HNP with radiculopathy,[5,6] disclosed more than 89% satisfactory results by the MacNab Criteria and more than 91% satisfactory results by patients who would recommend it to family and have the surgery again.[5,6]

DISCUSSION

As endoscopic foraminal surgery evolved, the initial study was extended to include studies on multi-level discogenic pain, discitis, synovial cysts, failed back surgery syndrome, spinal stenosis, spondylolisthesis, and degenerative conditions of the lumbar spine accessible through the foramen.[7-26] Especially satisfying were favorable results in selected patients with Grade I spondylolisthesis who experienced both back pain and sciatica. For discogenic pain, the most common endoscopic finding was inflammatory (granulation) tissue in the disc and annulus. Of the patients in the IRB study, 22/56 had an inflammatory membrane. Inflammation was correlated with the presence of Grades IV and V annular tears to the vascular and innervated outer annulus. Inflammation that affected the exiting nerve was associated with chemical irritation of the DRG and lateral recess stenosis. Usually temporary postoperative dysesthesia was associated with removal of the inflammatory membrane and identification of furcal nerves in the inflammatory membrane near spinal nerves.[23] Co-morbidities such as epilepsy, and systemic conditions such as diabetes or alcohol abuse that cause peripheral neuropathy, could result in residual numbness and motor weakness, especially when accompanied by severe dysesthesia. Delayed dysesthesia, days to weeks postoperatively, remains unexplained.[23]

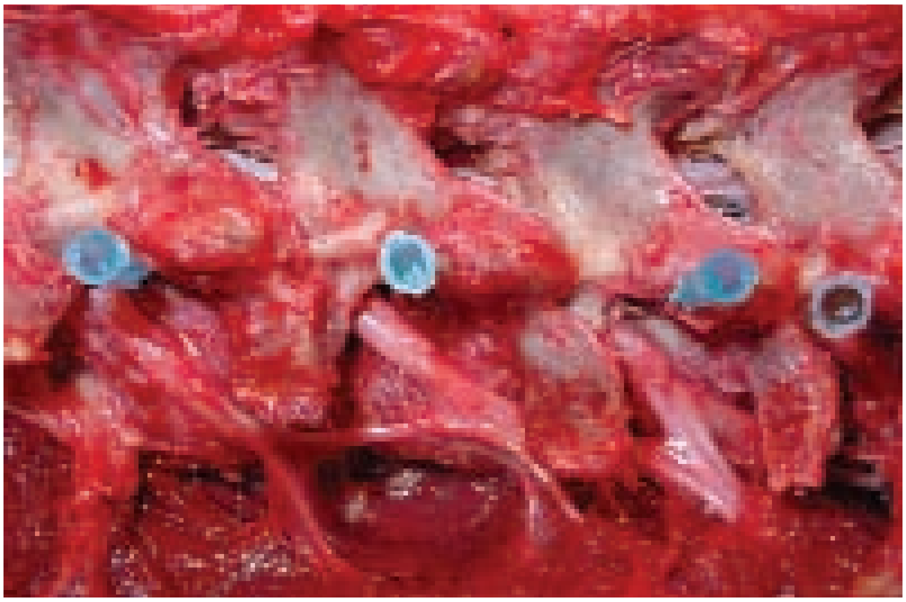


Figure 1. Cadaver dissection of the foraminal zone.

Neo-angiogenesis and neurogenesis are findings not reported previously in surgical clinical studies. To our knowledge, these "anomalous" nerves in the "hidden zone" of MacNab may be a source of pain and radiculopathy from the foramen that has not been reported previously in the literature.[23]

CONCLUSION

Successful visualization and treatment of HNP, along with degenerative conditions that involve synovial cysts, foraminal stenosis, and the painful annular tears that cause discogenic pain, are demonstrated. The endoscopic foraminal approach through MacNab's "hidden zone" to the disc is a technique that spares denervating and destabilizing the important multifidus, longisimus, and iliocostalis muscles, and allows access to patho-anatomy in the lumbar spine. Interventional diagnostic techniques, such as Evocative Discography™ and foraminal epidural injec- tions, also help with patient selection for surgical intervention.[20,21,23] Visualization of normal and patho-anatomy in the conscious patient provides valuable information in the continued study of discogenic pain. Favorable surgical results allow for continued evolution of the endoscopic method, concomitant with the continued evolution of endoscopic spinal surgery.[1-26]

These degenerative conditions of the lumbar spine can be visualized, decompressed, and treated endoscopically from the foramen without harming normal anatomy and creating the following paradoxical effects of surgery on the spinal segment:

1. annular tears associated with discogenic lumbar pain as determined by Evocative Discography™;
2. all disc herniations and protrusions accessible through the foramen whether primary or recurrent, contained, or extruded;
3. foraminal osteophytosis; and/or
4. Failed Back Surgery Syndrome (FBSS) (Fig. 1).

The foraminal approach to the lumbar spine is through the "hidden Zone" of MacNab. Using a biportal approach improves visualization and allows for more efficient removal of extruded and sequestered disc herniations. The blue-hubbed needles are positioned into the disc through the annulus where the endoscope is surgically placed to inspect the foramen and disc. The foramen of Kambin's triangle is readily accessible, including the lateral and subarticular recesses, epidural space, and superior and inferior pedicle of the spinal segment, by manipulation of the access cannula (Fig. 2).

Degenerative conditions from annular tears to spinal stenosis are visible through the foramen. In severe cases, the ligamentum flavum is pushed against the exiting nerve, which causes the normal perineural fat in the foramen to be absent, and then result in ischemic inflammation of the nerve. The absence of peri-neural fat and pulsation of the exiting nerve is an indirect, but more accurate, confirmation of lateral stenosis than computed tomography (CT)-myelogram and magnetic resonance imaging (MRI) (Fig. 3).

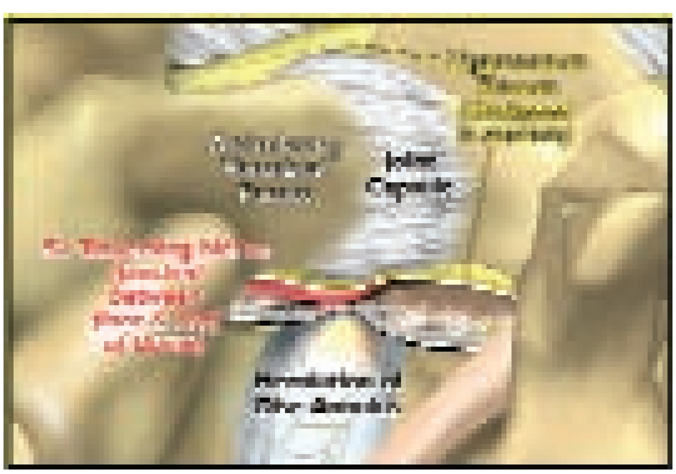


Figure 2. Close-up illustration of the foramen.

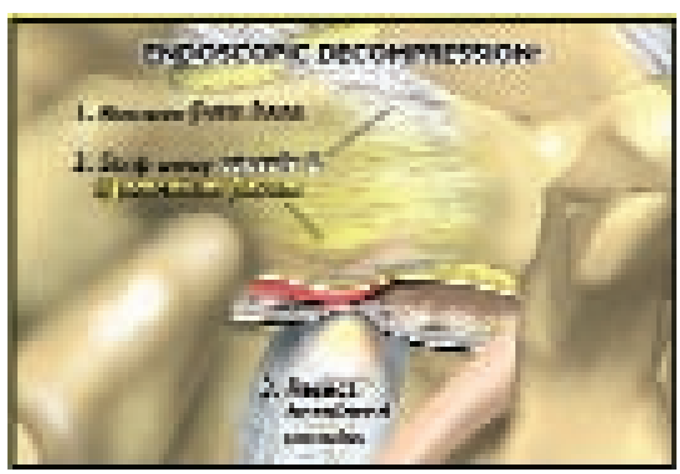
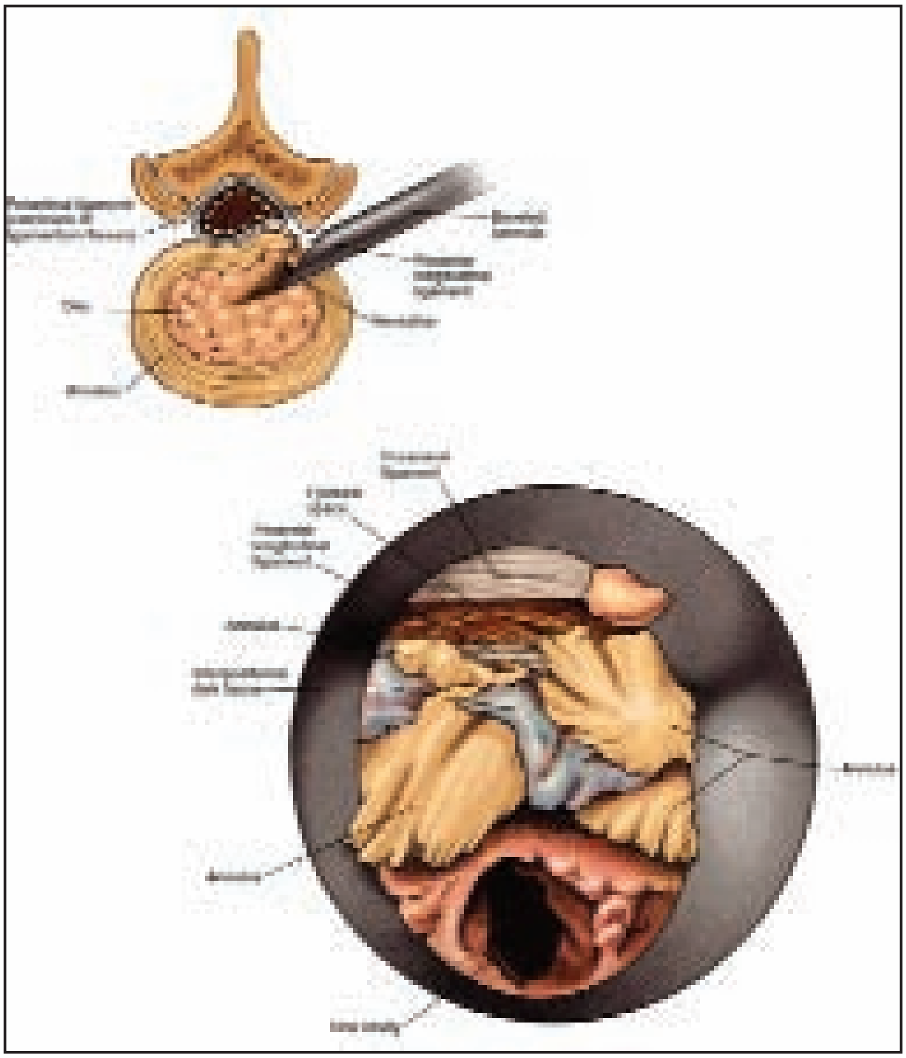


Figure 3. Endoscopic decompression.



4. Endoscopic approach for decompressing herniated discs.

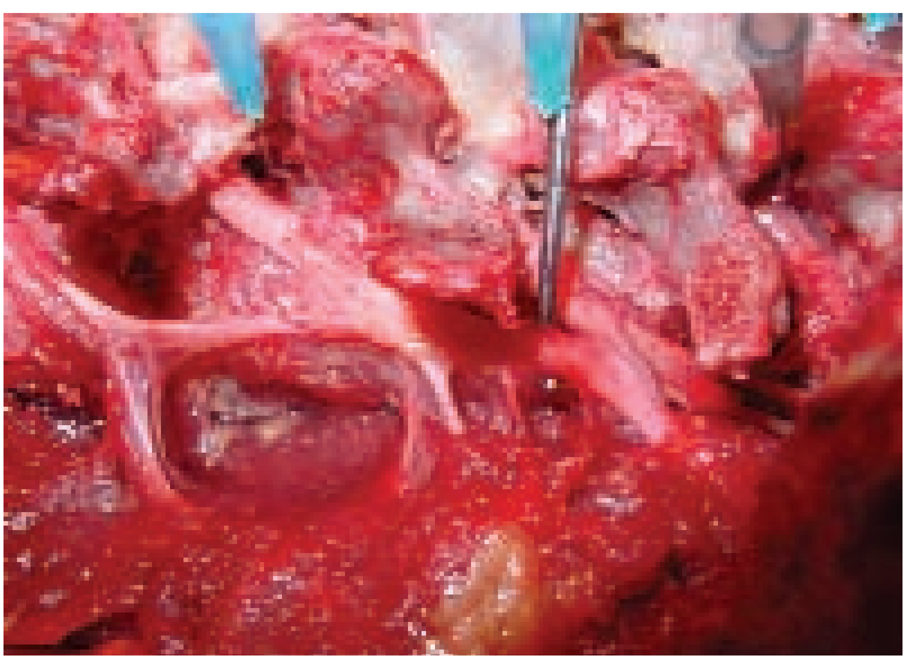


Figure 5. Cadaver dissection of furcal nerves.

Endoscopic surgery can address these conditions by decompressing the disc and enlarging the foramen, accomplished by resecting the inferior facet, a portion of the pedicle, and the ligamentum flavum through the foramen, thus decompressing the exiting nerve, traversing nerve, and DRG (Fig. 4). The recent development of a foraminal endoscope with a 4.2-mm working channel and accompanying instruments has made the technical aspect of the procedure easier, essentially expanding the indications for endoscopic foraminal decompression.

For decompressing and removing herniated discs, a beveled or slotted cannula is placed in the foramen at the base of the herniation. One half of the beveled or slotted cannula is in the disc and the dorsal one half of the cannula is positioned to view the epidural space lateral to the traversing nerve. Rotating and re-positioning the open end of the cannula laterally exposes the facet, epidural space that contains the traversing nerve, and exiting nerve while simultaneously protecting anatomy. Multiple cannula configurations designed to accommodate variable foraminal anatomy help the Endoscopic Surgeon with surgical exposure (Fig. 5).

The "hidden zone" of MacNab contains branches of the spinal nerves as "furcal" or "forked" nerves. Most of these branches come off of the exiting nerve as it passes or enters the psoas muscle to the lower extremity. Autonomic nerves have been visualized, which anatomically may demonstrate a sympathetic component to sciatica is present, especially dysesthesia. Combining a sympathetic therapeutic block with a foraminal epidural block provides the best relief of clinical pre- or postoperative dysesthesia (Fig. 6).

This 3-mm myelinated furcal nerve is identified in the annular fat adjacent to an extraforaminal disc protrusion. The nerve is being decompressed safely by discectomy adjacent to the nerve branch with a 2.5-mm endoscopic pituitary forceps in "Kambin's Triangle." Stimulation of the nerve with the bipolar radiofrequency Ellman bipolar probe re-creates the patient's concordant sciatica when probed (Fig. 7).

This furcal nerve is determined to be coming from a stenosed exiting nerve following lateral foraminal endoscopic decompression. The inferior surface of

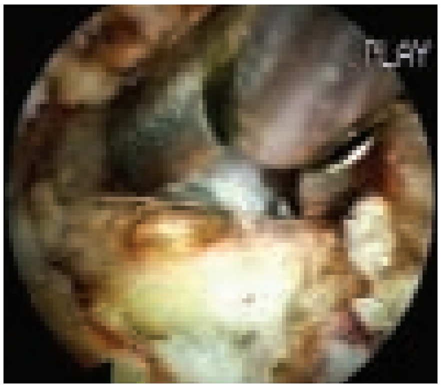


Figure 6. Furcal nerve.

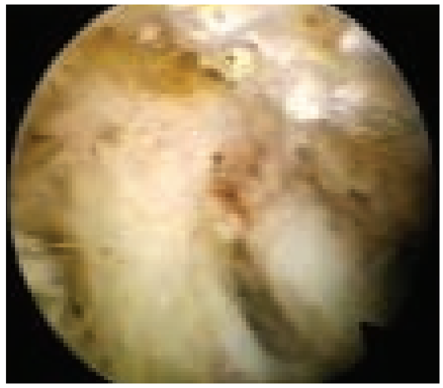


Figure 7. Furcal nerve from stenosed exiting nerve.

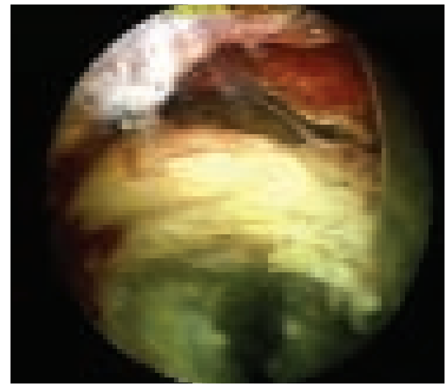


Figure 8. Autonomic nerve.

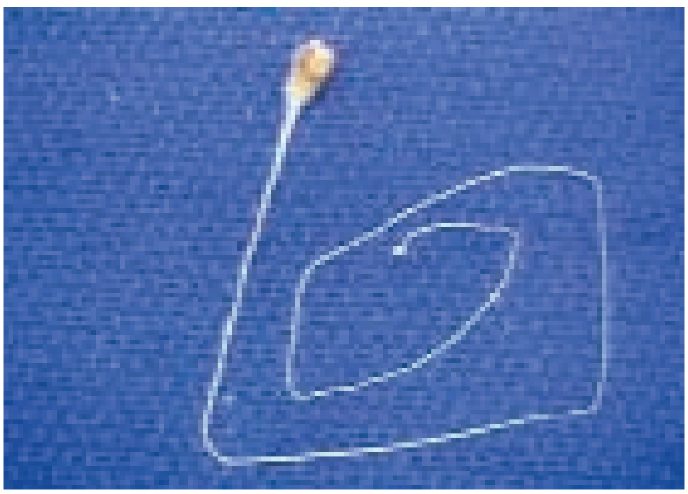


Figure 9. Biopsy of autonomic nerve.

Figure 10. Picture of Wolfgang Rauschning, M.D.

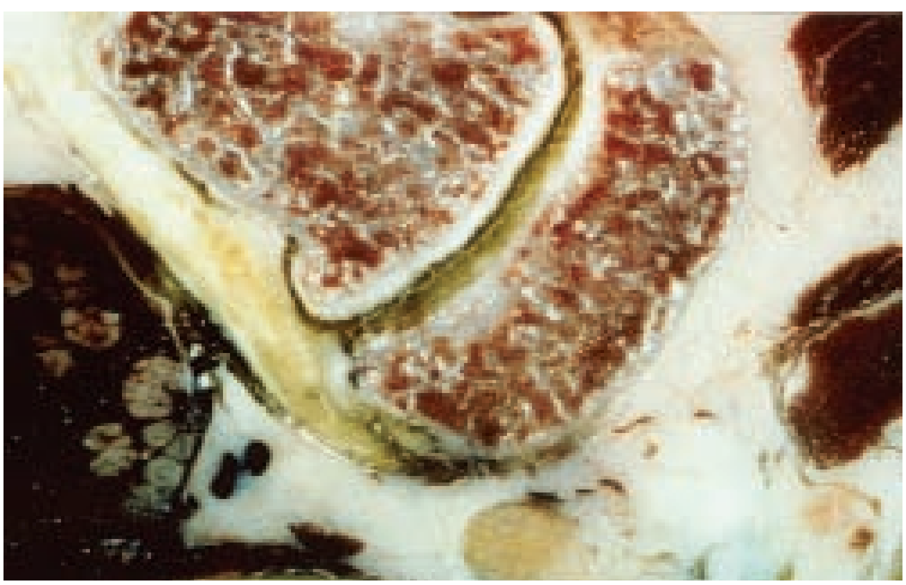


Figure 11. Relationship of the normal facet with the annulus , thecal sac, and dorsal root ganglion. The facet joint surface is contoured (courtesy of Wolfgang Rauschning, M.D.).

the lateral facet is seen at 1:00 o'clock. It is sometimes difficult to differentiate a furcal from a conjoined nerve when the nerves are adjacent to each other (Fig. 8).

This nerve structure in the foramen can be mistaken for a foraminal ligament, the "door to the foramen." The foraminal ligament is often resected to gain access to the epidural space. When stimulated with the Ellman Bipolar Trigerflex® probe (Ellman International, Inc.; Hewlett, NY, USA) this structure produces atypical leg pain. A biopsy of the structure discloses the presence of an autonomic nerve with a ganglion (see Fig. 8). If pain is reproduced by probing or radiofrequency stimulation, the foraminal ligament may have a furcal nerve next to it. Painful structures should be excised or ablated with caution, as they can cause severe, but usually temporary, dysesthesia (Fig. 9).

Biopsy of this "structure" in the vicinity of the foraminal ligament shows an autonomic nerve with its ganglion, diagnosed and confirmed by the Pathologist who made slides of the specimen (Fig. 10).

Wolfgang Rauschning, M.D. defined normal and patho-anatomy with his cryosections of the human spine.[27] He has contributed tremendously to the understanding of discogenic pain with his description of microscopic patho-anatomy (Fig. 11). This cryosection of normal anatomy by Rauschning demonstrates the close relationship of the DRG to the disc annulus, lumbar facet,

Figure 12. Sagittal section of a degenerative disc and facet.

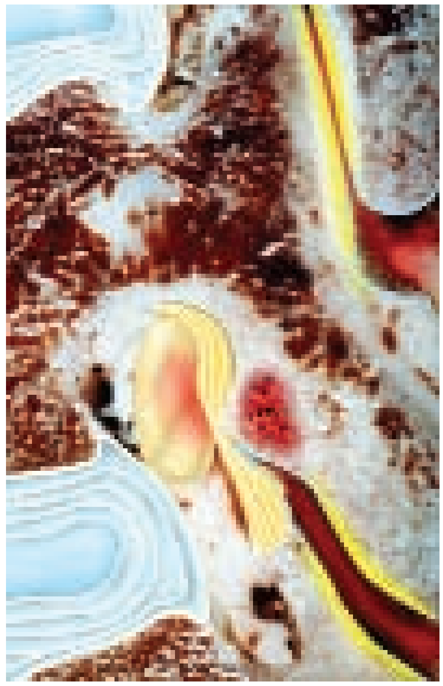


Figure 13. Illustration of a facet osteophyte.

and ligamentum flavum (Fig. 12).

In a painful spine, disc degeneration is associated with annular tears, facet synovitis, synovial cysts, and osteophytosis. All can inflame and irritate the DRG. A facet osteophyte is illustrated as it compresses or tethers the DRG in this enhanced illustration of the degenerative spinal segment (Fig. 13).

Patho-Anatomy of Discogenic Pain

Figure 14 shows a typical MRI with High Intensity Zone (HIZ) that represents an annular tear. Figure 15 shows a CT-Discogram of a single quadrant annular tear to the dorsal annulus. Figure 16 is of Rauschning's demonstration of granulation tissue in the annulus from incomplete healing of annular tears. Figure 17 is an endoscopic foraminal view of granulation tissue in the outer annulus. Painful discs are associated with the presence of granulation tissue *in vivo* in the annulus.

An inflammatory membrane is seen in Figure 18 as a vascular covering over

Figure 14. MRI of high-intensity zone.

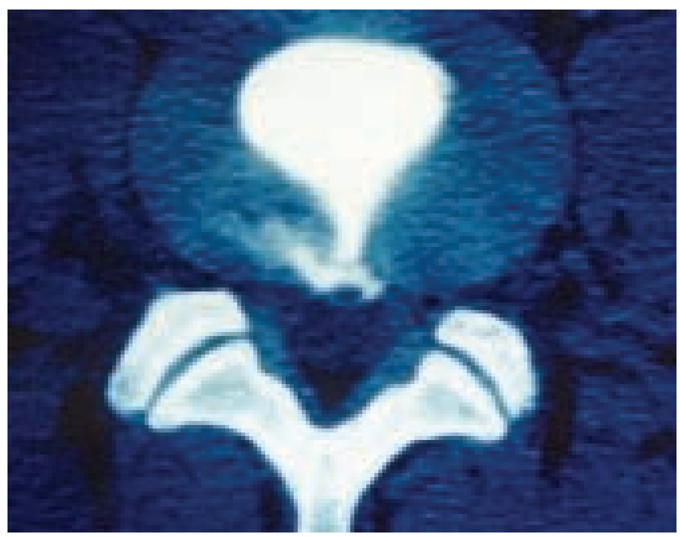


Figure 15. CT discogram.

Figure 16. Granulation tissue in the annulus (courtesy of Wolfgang Rauschning, M.D.).

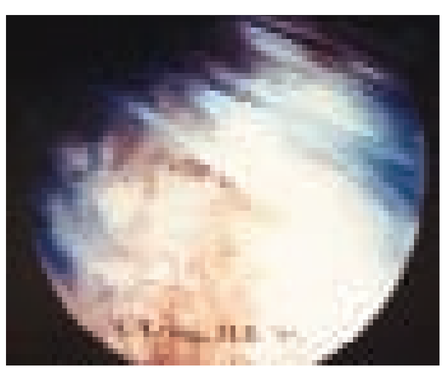


Figure 17. Granulation tissue *in-vivo.*

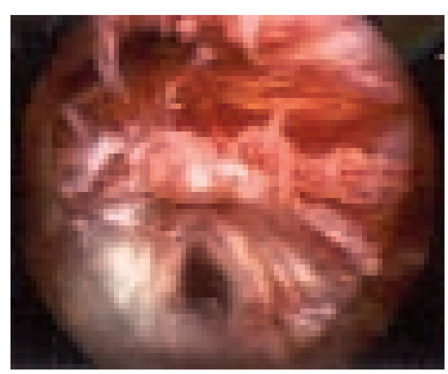


Figure 18. Endoscopic view of inflammatory membrane.

Figure 19. Neoneurogenesis.

the annulus and epidural space. It often demonstrates an absence of epidural fat.

Neo-neurogenesis can be seen in the inflammatory membrane (Fig. 19). Annular tears may cause inflammation and sensitize pain nociceptors in the annulus. Neo-angiogenesis and neurogenesis can be visualized as part of the healing response. If the annulus does not heal, the inflammatory membrane causes axial and neuropathic pain out of proportion to a similar annular tear without inflammation. Only endoscopic visualization can differentiate and confirm the difference between a sensitized tear (low-pressure positive discography) or non-sensitized tear (mildly painful or non-painful abnormal discogram).

Figure 20 Illustrates an example of a Grade IV annular tear. Annular tears can be graded, sized, visualized, and treated with radiofrequency, laser, and in the future, possibly with biologics for tissue healing.

Evocative Discography™ and Annular Tears

An endoscopic classification for the intraoperative chromo-discogram without post-discogram CT was adopted for this Y.E.S.S.® procedure[1-4,11] (??Fig. 21??). The Grades I-V are based on the combined works of Adams et al.,[28] Sachs et al.,[29] and Osti et al.[30] The basic patterns are according to Adams and colleagues.[28] The radial extensions are as described by the Dallas Discogram Description,[26] and the circumferential extension is as described by Osti et al.[30] divided into the quadrants of involvement seen in the posterior-anterior (PA) and lateral C-Arm views.

This description and grading eliminates the need for preoperative CT scanning. The revised discogram classification for endoscopic description is as follows:[1-4,11]

Grade I. Cotton ball nucleus.
Grade II. Oval or bilobular nucleus with painless radial extension.
Grade III. Radial extension to the inner fibers of the annulus. With minimal circumferential extension. (Axial back pain may be elicited under pressure, no sciatica).
Grade IV. Radial extension to outer annulus with circumferential extension to 1, 2, 3, or 4 quadrants.
Grade V. Radial tear past the outer annulus with or without circumferential extension.

Grades IV and V tears are often seen in the low-opening pressure, low- volume, highly sensitive tears. Granulation tissue is seen in this Grade IV single-quadrant radial annular tear. This type of tear causes severe pain elicited with low-pressure Evocative Discography™.

This large Grade V painful annular tear was seen after removing a central disc protrusion (Fig. 22). A large, high-intensity zone on the MRI was associat-

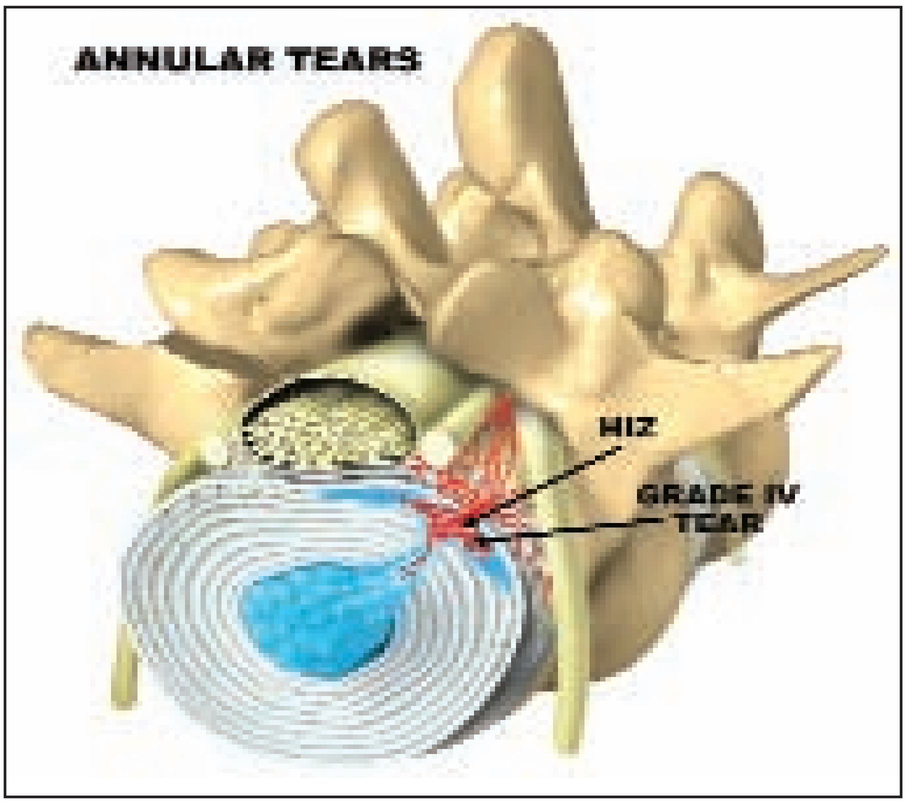


Figure 20. Illustration of annular tear.

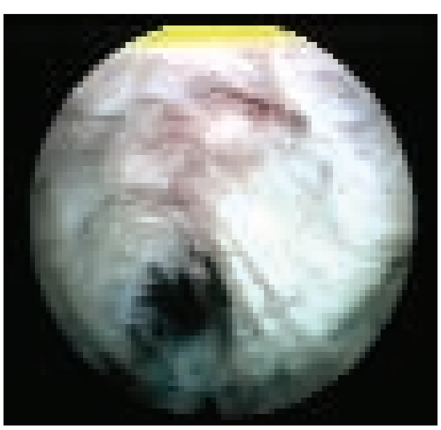


Figure 21. Endoscopic view of granulation tissue in an annular tear.

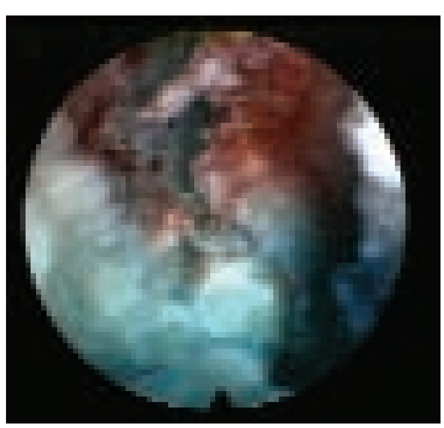
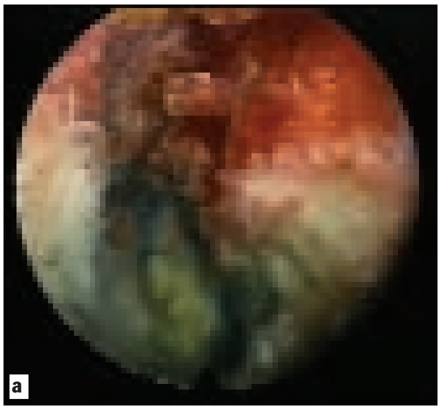


Figure 22. Endoscopic view of large annular tear.

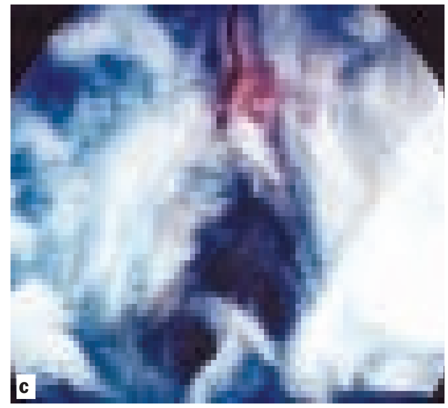


a

Figure 23a is an inflamed disc associated with a painful Grade IV tear.

b

Figure 23b is an interpositional disc tissue embedded in annulus.

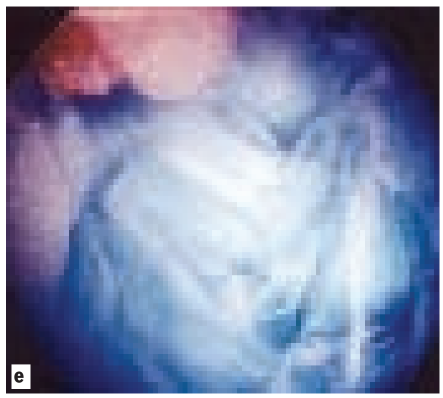


c

Figure 23c are Grades IV-V single quadrant annular tears. (Note bleeding coming from the outer annular fibers and epidural space.)

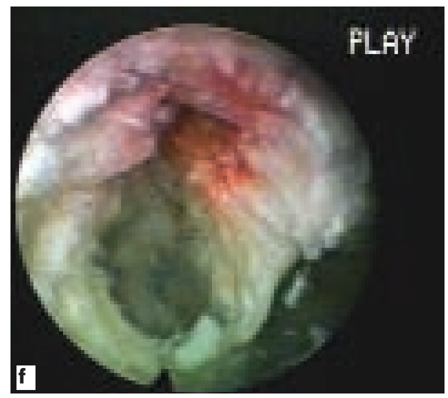
d

Figure 23d is a Grade III stained annulus.



e

Figure 23e is the same annulus visualized from the foramen before nucleotomy.



f

Figure 23f shows a Grade V annular tear, extending past the outer annulus.

ed with central disc protrusion, which caused bilateral sciatica. Note the inflammation around the tear. Nuclectomy not only decompresses the protrusion, but also removes degenerative inflammetogenic nucleus and exposes the tear for visualized thermal treatment. Visualization is important because sometimes the tear enlarges rather than contracts. By removing the degenerative nucleus, inflammetogenic degradation by-products are removed. Annuloplasty with radio-frequency ablates the granulation tissue, closes some fissures, and can ablate pain nociceptors in the annulus.

Examples of Annular Tears

Following are Examples of Tears (Figures 23a-23f)

Figure 23a shows an inflamed disc associated with a painful Grade IV tear. This pressure-sensitive annular tear corresponds to a benign-looking MRI, whereas in a small HIZ on the sagittal view, the annular tear was not associated with any disc protrusion, yet the pain was intense with low-pressure, low-volume Evocative Discography™. A clear abnormality was visualized in the form of inflammation at the site of the annular defect.

Figure 23b shows an interpositional disc tissue embedded in the annulus. Evocative Discography™ identified a Grade V annular tear that produced severe concordant back pain. The tear did not heal because nucleus pulposus was lodged in the annular layers, which prevented the tear from healing. Axial back pain was more severe than sciatica because the traversing nerve continued to be protected by the posterior longitudinal ligament.

Figure 23c shows Grades IV-V single quadrant annular tears, with bleeding coming from the outer annular fibers and epidural space. The hole in the annulus may not close with thermal modulation, and the long-term clinical success of thermal annuloplasty depends on the size and configuration of the annular tear and its ability to heal. Tears associated with inflammatory tissue improve with SED™ and tears that close with thermal annuloplasty provides longer-lasting pain relief.[9]

Figure 23d shows a Grade-III single-quadrant annular tear that demonstrates a stained annulus. This Grade-III tear demonstrates the stained collagen of the inner annulus after nuclectomy. Grade III tears may not be associated with granulation tissue and inflammation. This type of tear is theorized to have a better chance of healing, because the outer annulus is not sensitized nor disrupted. These tears are painful with larger-volume, moderate-to-high pressure discography.

Figure 23e shows the same annulus visualized from the foramen before nuclectomy. This same annulus is visualized from the foramen before nuclectomy. Note the peri-annular fat at 9-11 o'clock.

Figure 23f?? is the same annulus visualized from the foramen before nucleotomy.

Figure 24. A Grade V annular tear preoperative thermal annuloplasty.

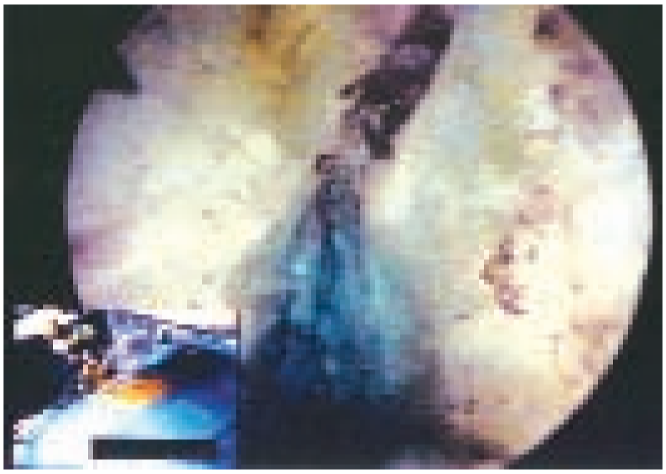


Figure 25. A Grade V annular tear postoperative thermal annuloplasty.

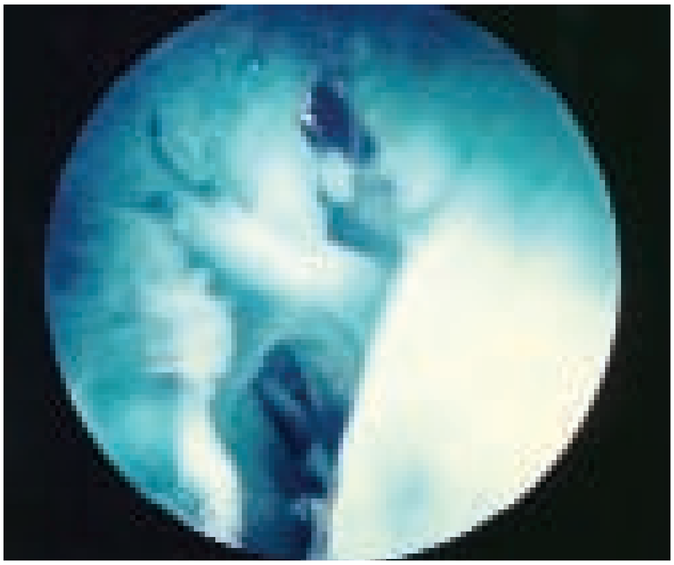


Figure 26. Grades III-IV tear perioperatively.

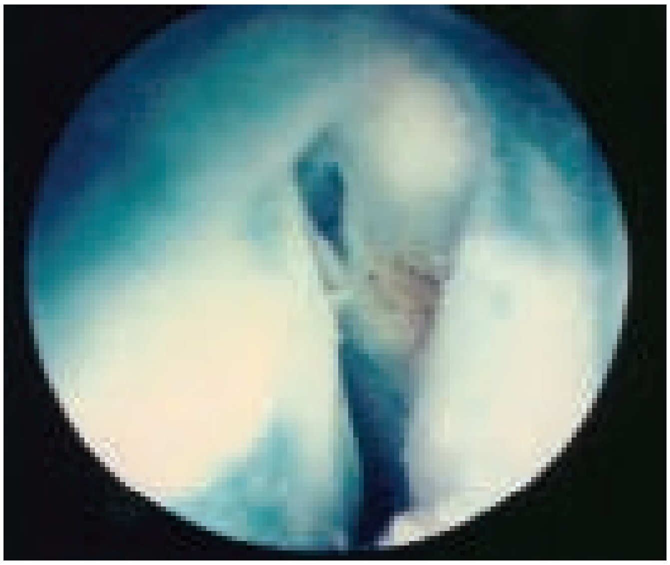


Figure 27. Grades III-IV annular tears postoperatively.

SED™ and Thermal Annuloplasty Provides Visual Confirmation of Surgical Alteration of the Annulus

The following four figures (Figs. 24-27) show:

Grade V annular tear preoperative thermal annuloplasty.
Grade V annular tear postoperative thermal annuloplasty.
Grades III-IV tear preoperative.
Grades III-IV annular tear postoperative.

Example of What is Visualized in a Uni-Portal Endoscopic Extraction of a Paracentral Extruded HNP at L4-5

An intraoperative C-arm view of the forcep's position when extracting a paracentral HNP from the foramen is shown in Figure 28. Figure 29 shows an endoscopic view of extruded herniation through the annulus obscuring the traversing nerve. The patient reported leg-pain resolution immediately upon removal of this collagenized disc fragment, as shown in

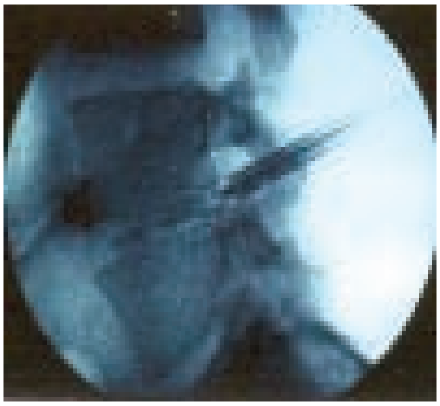


Figure 28. An intraoperative C-arm view of forceps' position extracting a paracentral HNP from the foramen.

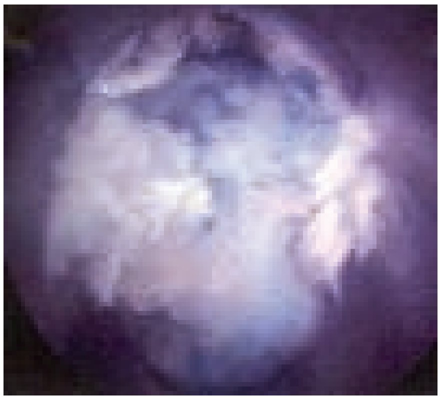


Figure 29. An endoscopic view of extruded herniation through the annulus obscuring the traversing nerve.

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Figure 30. Patient reported leg-pain resolution immediately upon removal of this collagenized disc fragment.

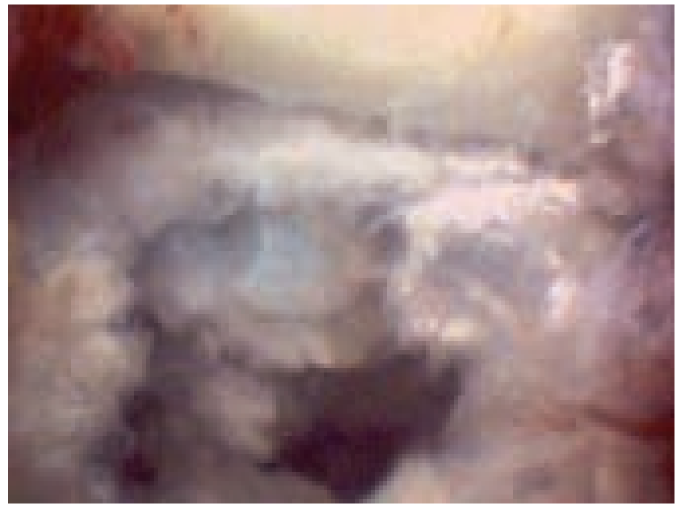

Figure 31. Traversing nerve confirmed to be decompressed adjacent to herniation defect.

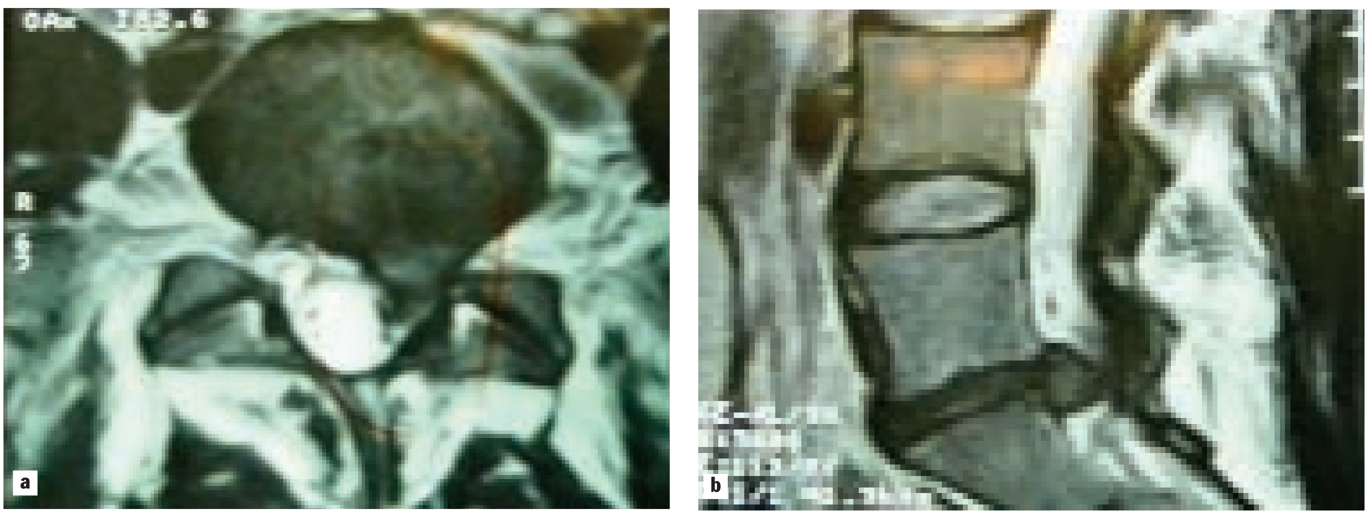

Figure 32a & 32b. MRI of a classic large paracentral HNP at L5-S1 that causes back pain and radiculopathy lack of containment suspected due to size of HNP.

Figure 30. Figure 31 shows traversing nerve confirmed to be decompressed adjacent to the herniation defect.

Biportal Technique Allows for a More Completely Visualized Approach, Especially for Extruded and/or Sequestered Fragments That May Require Probing the Nerve and Sequestered Disc Fragment

MRI of a classic large paracentral HNP at L5-S1 that causes back pain and radiculopathy lack of containment suspected due to the size of HNP is shown in Figures 32a and 32b.

Figure 33 shows an endoscopic view of the base of herniation from the ipsilateral portal. The indigo-carmine dye and Iso-vue discogram also stains the annulus.

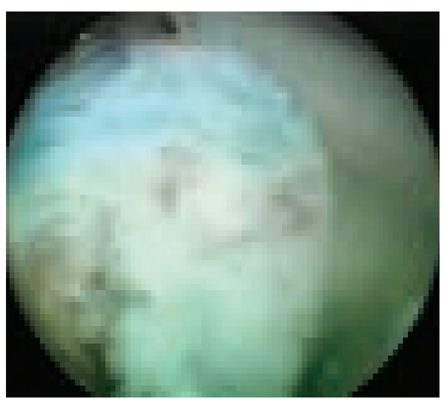

Figure 33. Endoscopic view of the base of herniation from the ipsilateral portal.

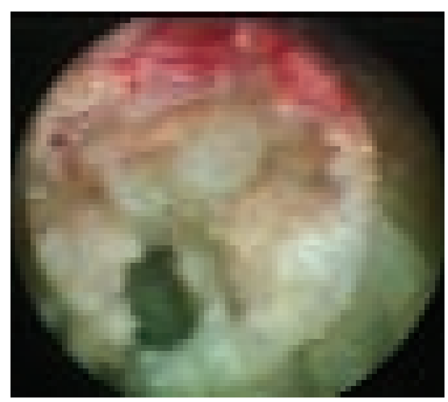

Figure 34. Collagenous sequestered subligamentous fragment under the traversing nerve, which prompted the decision to establish a biportal approach to probe the nerve and extract the fragment under direct visualization.

A collagenous sequestered subligamentous fragment under the traversing nerve caused the decision to establish a biportal approach to probe the nerve and extract the fragment under direct visualization (Fig. 34).

A probing, sequestered subligamen-

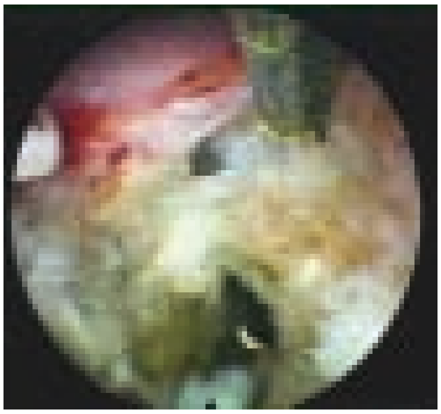

Figure 35. Probing sequestered subligamentous fragment from ipsilateral portal.

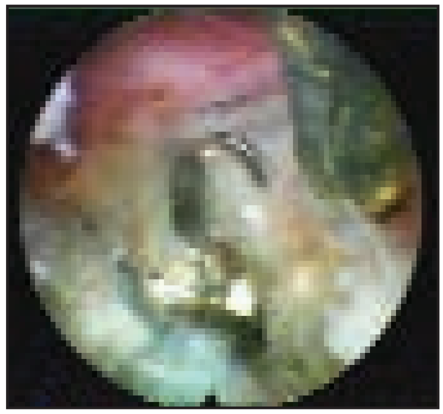

Figure 36. Biportal manipulation technique with Ellman Bipolar Triggerflex® probe and endius flexible pituitary for visualized manipulation of traversing nerve and removal of sequestered HNP fragment.

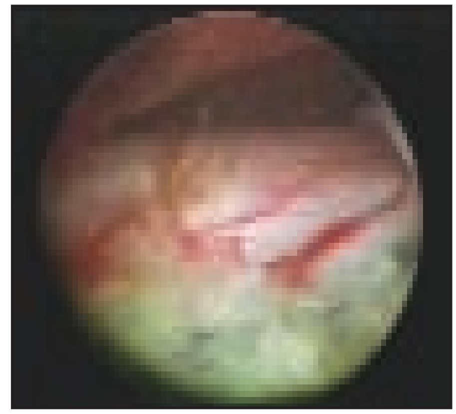

Figure 37. Confirmation of completely decompressed traversing nerve pulsating freely in the epidural space.

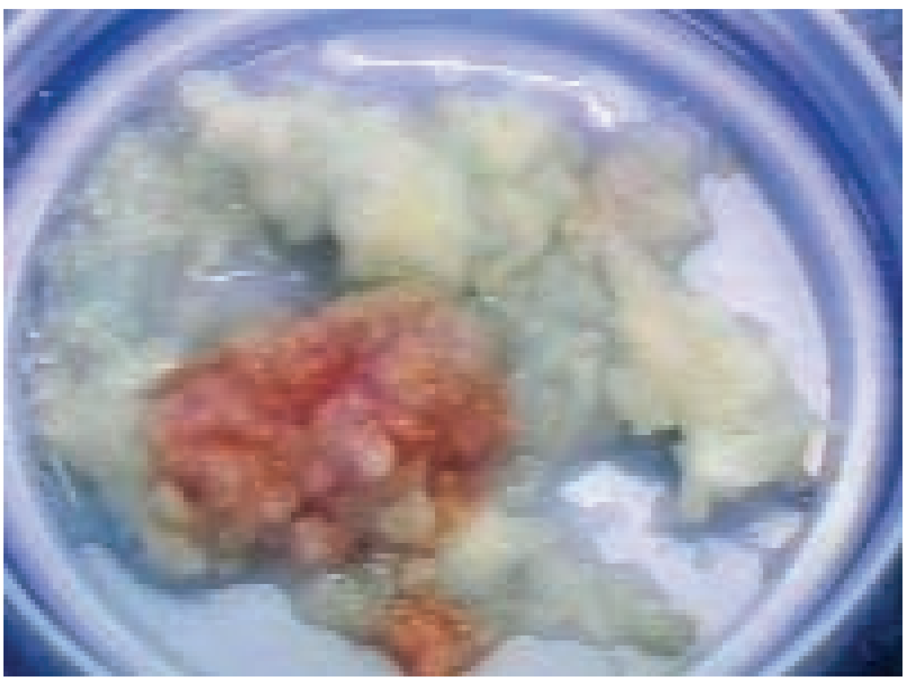

Figure 38. Pathologic specimen of extracted disc fragments.

tous fragment from ipsilateral portal is shown in Figure 35. Note the presence of a contralateral access cannula at 5 o'clock.

A biportal manipulation technique, with Ellman Bipolar Triggerflex® probe and endius flexible pituitary for visualized manipulation of traversing nerve and removal of sequestered HNP fragment, is shown in Figure 36.

Figure 37 shows a confirmation of completely decompressed traversing nerve pulsates freely in the epidural space. A pathology specimen of extracted disc fragments is shown in Figure 38.

Spondylolisthesis: Degenerative and Isthmic

When a patient with spondylolisthesis is first seen with back pain and sciatica, non-operative treatment remains the first line of care. After failure of non-surgical treatment, surgical options are numerous. The option of minimal de-compression and no fusion is championed by Epstein in 1998.[31] In her series of 290 patients, only 2.7% required stabilization. Some patho-anatomical conditions respond to endoscopic decom- pression, especially if the patient's sciatica is worse than their back pain. Most patients are able to tolerate the back pain of spondylolisthesis, but not leg pain. Degenerative spondylolisthesis may be asymptomatic or it may cause low back pain with or without moderate radicular pain. When degenerative spondylolisthesis is associated with the relative recent onset of sciatica, endoscopic treatment of the painful disc, as determined by Evocative Discography™, provides relief of sciatica similar to the results of the treatment of discogenic pain from annular tears.[9] When radicular pain is poorly tolerated, surgical decompression without fusion can be indicated for SED™. Patients have been endoscopically decompressed in this manner with satisfactory and good results that allow a majority so treated to avoid fusion. The patho-mechanism of slippage is not entirely known, but abnormal sagittal orientation of the facet joints,[32] disc degeneration,[1] and hyperlaxity of the spinal ligamentous structures all have a role. Lateral stenosis may depend on orientation of the facet joints. Forward slipping of the facet may directly compress the nerve root.

The patient shown in Figures 39a-39c had a bulging degenerative disc, as well as foraminal stenosis; two lateral MRIs and one axial MRI.

Epidurography Outlines the Bulging Disc (Fig. 40)

Discography and epidurography may identify a bulging disc that causes discogenic pain, and a therapeutic foraminal

Figure 39a-39c. Patient had a bulging degenerative disc, as well as foraminal stenosis.

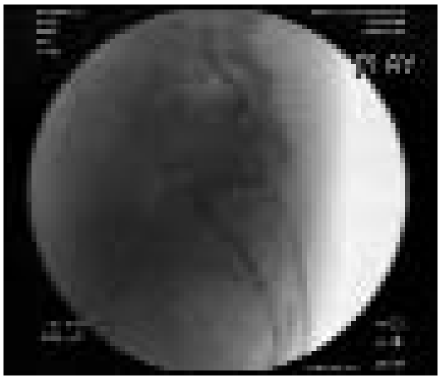

Figure 40. Epidurography outlines of the bulging disc.

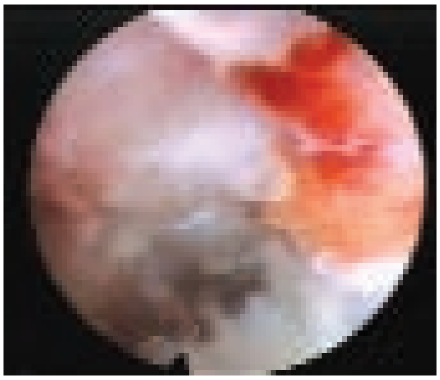

Figure 41. Endoscopic view of degenerative spondylolisthesis.

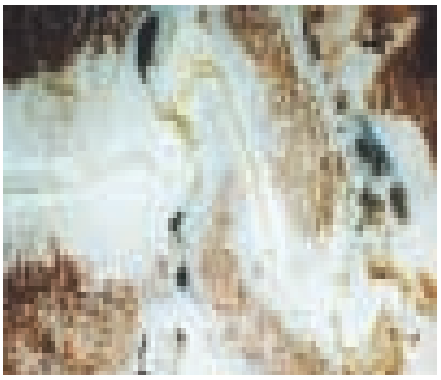

Figure 42. Contents of the cauda equine are constricted (Courtesy of Wolfgang Rauschning, M.D.).

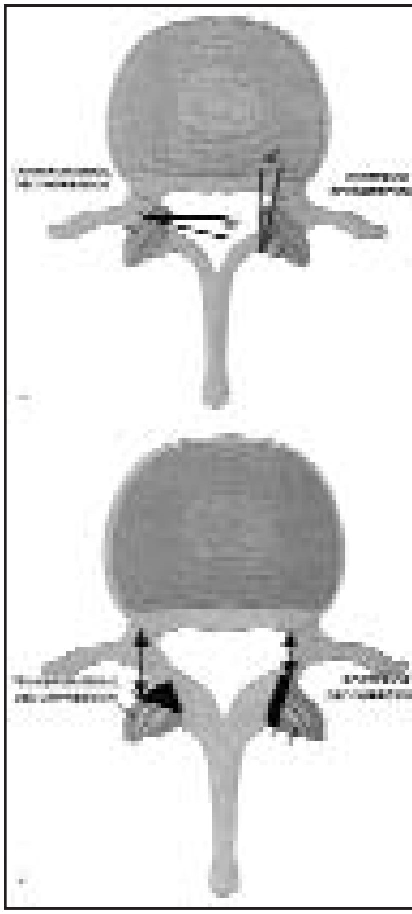

Figure 43. Lateral recess is not decompressed with the posterior approach.

epidural block may provide good temporary relief. If a painful bulging disc is present, patients can improve with SED™ and thermal annuloplasty. If there is evidence of impingement on the exiting nerve, as seen by inflammation and the lack of fat adjacent to the nerve, foraminal endoscopic decompression is sufficient to avoid fusion. The clinical examination may disclose that extension of the back accentuates the effect of the bulging disc, and impingement of the nerve causes increased leg pain. These patients can respond and improve with endoscopic decompression of the disc and foramen without fusion.[10,11,14]

Endoscopic View of Degenerative Spondylolisthesis

The tip of the superior facet of the inferior vertebra is shown impinging on the exiting nerve in the foramen. Impingement can occur from a thickened ligamentum flavum or bulging annulus. Annular thermal modulation, Laser foraminoplasty, or a high-speed diamond burr, frees the nerve and provides relief of sciatica (Fig. 41).

Spinal Stenosis

The bulging and calcified annulus protrudes into the epidural space and the facets collapse and push the ligamentum flavum against the DRG. The contents of the cauda equine are constricted (Fig. 42).

Osman and colleagues, in 1997, published their findings on transforaminal decompression of the foramen versus posterior decompression.[33] They concluded that the transforaminal approach enlarges the foramen 45% versus 32% with medial facetectomy. The lateral recess is not decompressed with the posterior approach (Fig. 43).

The foramen can be decompressed with laser stripping of the facet capsule, and a high-speed burr developed specially for endoscopic decompression through a Wolf foraminal endoscope. The burr is shown removing the inferior surface of the superior facet. The decompression continues toward the exiting nerve. The cannula retracts and protects the nerve as the burr removes bone. Osteophytes impinging nerves can be removed in a similar manner (Fig. 44).

As the facet decompression moves toward the exiting nerve, the cannula is advanced to protect and retract the nerve from the burr. Note the lateral edge of the exiting nerve at 7 o'clock (Fig. 45).

The side-firing Ho:yag laser (Trimedyne) is shown decompressing the exiting nerve by resecting a portion

Figure 44. Cannula retracts and protects the nerve as the burr removes bone. Osteophytes impinging nerves can be removed in a similar manner.

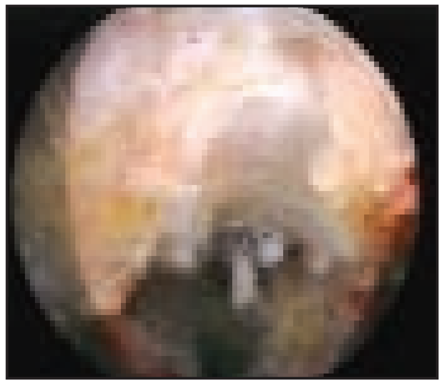

Figure 45. Cannula is advanced to protect and retract the nerve from the burr, as the facet decompression moves toward the exiting nerve. Note the lateral edge of the exiting nerve at 7 o'clock.

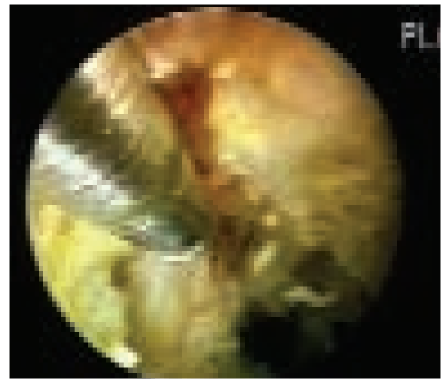

Figure 46. Side-firing Ho:yag laser (Trimedyne) is shown decompressing the exiting nerve by resecting a portion of the lateral pedicle and pedicle.

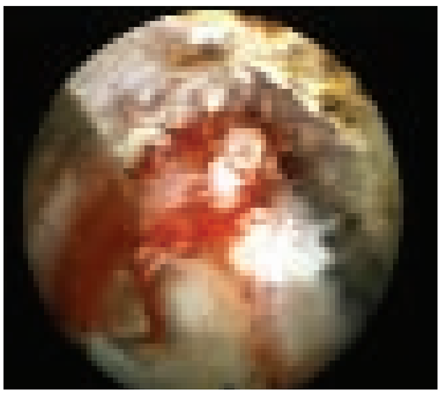

Figure 47. Scarred and inflamed exiting nerve is probed—note the lack of perineural fat. A freed nerve shows foraminal and perineural fat, and can be seen to pulsate after decompression.

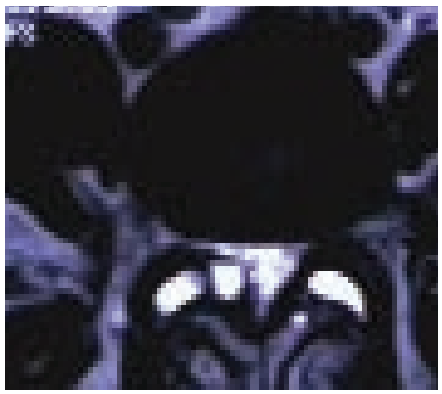

Figure 48. MRI demonstrating a juxta-articular cyst compressing thecal sac. These cysts can be decompressed endoscopically if sufficiently large to be visualized.

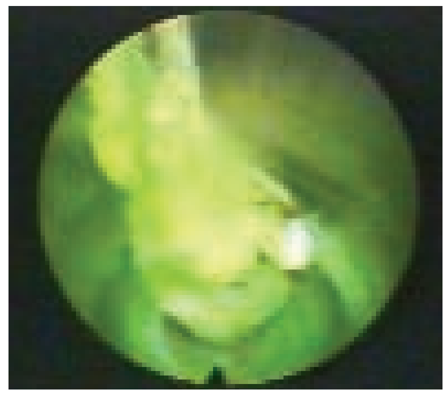

Figure 49. Cyst wall is suctioned into the cannula and extracted by endoscopic forceps.

of the lateral pedicle and pedicle (Fig. 46).

The scarred and inflamed exiting nerve is probed. Note the lack of perineural fat. A freed nerve shows foraminal and perineural fat, and can be seen to pulsate after decompression (Fig. 47).

Facet Juxta-Articular and Pedunculated Cysts

In Figure 48, this MRI clearly demonstrates a juxta-articular cyst compressing the thecal sac. These cysts can be decompressed endoscopically if sufficiently large to be visualized.

The cyst wall is suctioned into the cannula and extracted by endoscopic forceps (Fig. 49). This indigo-carmine stained cyst wall next to the exiting nerve is ablated with the Ellman Bipolar Triggerflex® probe (Fig. 50). This pedunculated cyst with a thick vascular wall is being extracted endoscopically (Fig. 51). STI

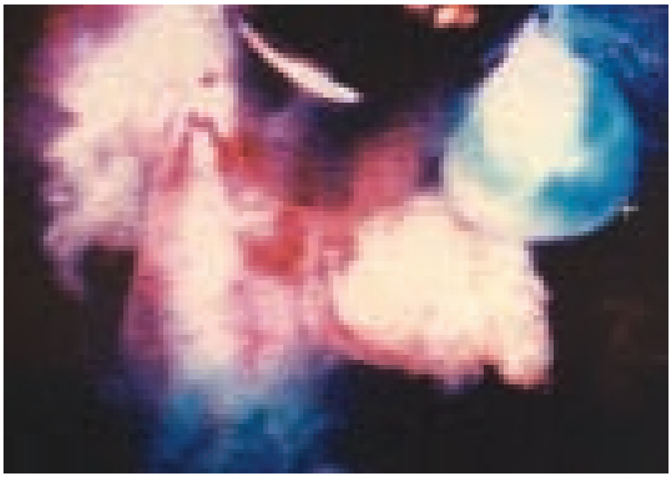

Figure 50. Indigo-carmine stained cyst wall next to the exiting nerve is ablated with the Ellman Bipolar Triggerflex® probe.

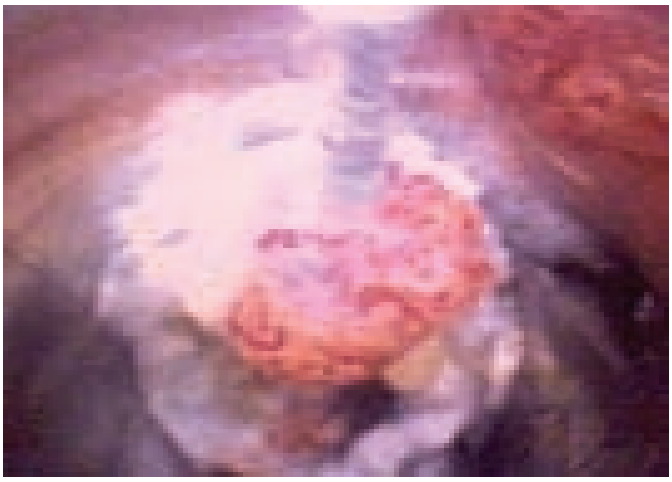

Figure 51. Pedunculated cyst with a thick vascular wall being extracted endoscopically.

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