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Progress in multislice-CT in lumbar pathology and dynamic lumbar myelography

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The considerable increasing number of people suffering from low back pain in western societies with a prevalence of 60 – 90% is challenging diagnostic imaging disposing of various imaging modalities. The following techniques are available:

Native diagnostic	Contrast material / diagnostic tools
<i>standard images</i>	<i>myelography</i>
<i>special projections</i>	<i>spinal arterio- and phlebography</i>
<i>functional projections</i>	<i>discography</i>
<i>layer images</i>	<i>computed tomography</i>
	<i>magnetic resonance</i>
	<i>PET scan</i>
<i>bone activity</i>	<i>"bone scan", skeleton scintigraphy (technetium)</i>

As well as modern digitised conventional equipment with a fully integrated PACS, we use a 16 row multislice helical CT-scanner (PHILIPS Multislice Brilliance CT) in our 200-bed-hospital; there are 6 (soon 7) MRI machines (up to 3 Tesla) available in the near surroundings.

The modern CT techniques, e.g. multislice scan technique with up to 64 row scanners, remain in many points competitive to MRI. Regarding accuracy, there is no difference, moreover, CT techniques are less expensive and the radiation dose is low by using dose modulating systems. We get optimal lumbar disc diagnostic results in using a combination of CT, CT-myelography and CT-discography.

Discography is indicated in patients who suffer from pain in the lower back, buttock and leg with negative or equivocal findings of nerve root or thecal sac compression by imaging techniques such as CT, MRI and myelography. In case of chronic lower back pain, with or without radicular symptoms, it is reported that up to 13% of abnormal discs as detected by MRI have a normal discogram appearance, while up to 7% of the normal discs as determined by MRI were abnormal in discography. Radial tears and often significant changes in the peripheral structure can be difficult to visualize reliably by a native MRI scan. Discography is also performed in an attempt to determine the presence of discogenic pain on a definite level, and so makes an integral part of different intradiscal therapy regime, e.g. chemonucleolysis.

CT myelography is used as a functional radiographic imaging technique and is indicated to clear up CT and MRI diagnostics together with complementary dynamic information. Myelography by itself is an excellent tool for dynamic and morphologic studies under almost natural conditions that can hardly be simulated under CT or MRI conditions alone - functional MRI scanners are available nowadays but are still rare. For spinal pain patients the still considerable exposure time in functional positions is often fostering movement artefacts with hence impaired image quality. Side effects of myelography are extremely rare and consists mainly in some headaches (about 1%), infectious or bleeding related problems could not be noticed in our large number of studies. Significant progress in CT hd/sw allow us to have a more and more accurate diagnosis and is related to progress in developing new multislice technique and image reconstructing process.

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MR imaging of the spine

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The actual presentation is based on investigations performed at our institution. Grading of MR findings, reliable diagnosis of nerve root compromise is possible with a relatively simple grading system (no compromise, contact of disk material with nerve root, deviation of nerve root, and compression of nerve root). Substantial intra- and interobserver agreement ($\kappa = 0.72 - 0.77$ and $0.62-0.67$, respectively) was found in 500 nerve

roots. Correlation of image-based grading with surgical grading was high (surgical confirmation available in 94 nerve roots, $r = 0.86$). Lack of clinical meaning of certain MR findings: At least one bulging disk was found in 62% and at least one disk protrusion in 67% of 60 asymptomatic volunteers (20 to 50 years old). Disk extrusion was not as common (18% of the subjects), and no disk sequestration was found. High intensity zones probably relating to anular tears were present in approximately 1/3 of the study population. In addition, endplate abnormalities were rarely found in the study population. MR findings versus provocative discography: End plate abnormalities seen on MR images predicted pain provoked by discography in 100% of the disks. Endplate abnormalities were far better predictors than discal high intensity zones (HIZ) (62% positive predictive value) and disk degeneration (72% positive predictive value). Normal MR images predicted a negative discogram. Positional MR imaging: 30 patients with chronic low back pain were examined in a double-doughnut scanner which allows to obtain images in the upright position. Changes between body positions were relatively subtle. In a single instance, nerve root compression was diagnosed solely in the positional (extension) position. 1H-spectroscopy: This method has become more widely available on new MR scanners and can be used for quantitative assessment of fatty degeneration of paraspinal muscles. 25 patients with chronic low back pain (LBP) were compared to 25 age-, gender- and body mass index (BMI)-matched asymptomatic control subjects. The mean fat content of the multifidus muscle was significantly higher in patients with chronic LBP with 23.6% (95% confidence interval [CI] 17.5%, 29.7%) compared to 14.5% (95% CI: 10.8%, 18.3%) in the asymptomatic control group ($p=0.014$). This difference was not recognized with a qualitative grading on standard spin-echo images.

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Anatomical considerations on instability: posterior pillar components and its influence

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Early stages of the lumbar motion segment degenerative cascade encompasses internal disc disruption, later disc dysfunction due to the delamination of the annulus fibrosus along with slackening of the outermost annulus fibrosus, longitudinal ligaments, inter- and supraspinous ligaments and instability/subluxation of the facet joints, all causing dysfunction of the spinal functional unit. The strong tendons of the longissimus dorsi muscles together with the tendinous insertions/origins of the multifidus muscles considerably reinforce the lumbodorsal fascia adjacent to the spinous processes. In the early stages of DDD these stabilizing structures are anatomically intact, although relaxed and therefore not functioning properly due to altered mechanics and insertion sites.

A "soft" dynamic stenosis typically also heralds "instability" or "dysstability" due to enthesopathy-type strains on the outermost annulus and ligaments on their insertion sites (inducing osteophyte and spondylophyte formation), and also by the slackening and infolding of soft tissues into the spinal canal, lateral recesses and root canals. Restoration of segmental height would afford re-engagement of the discoligamentous structures, joint capsules, and normalization of muscle action trajectories. Such distractive re-stabilization could conceivably normalize or at least improve segmental spinal mechanics, by itself eliminating undue and painful range-of-motion excursions, thereby taking painful strains off these structures, and also eliminate much of the soft tissue encroachment of bulging disc and ligamentum flavum on the central spinal canal, lateral recesses and neuroforamina. This concept of a staged reversal of pathologically altered segmental spinal mechanics would seem to be a prerequisite for future biological intradiscal therapy solutions such as gene therapy and/or disc cell culture reimplantation.

In selected early stages of painful segmental settling, abnormal and painful "dysstabilities" and soft spinal stenosis, especially in younger individuals, a (typically distractive) dynamic restabilization realigns the spinal segments (antero- and retrolisthesis) and also affords an "indirect decompression" since the inbulging and infolding disc and ligamenta flava and joint capsules are stretched and realigned, reestablishing the patency of the central spinal canal, lateral recesses and neuroforamina for the neural elements, arteries, veins and lymphatics. Contrary to non-reversible fusion operations, this staged approach would seem to offer multiple lines of defense, and also "buy time" until the biological regenerative therapy solutions have become a viable clinical options. Challenges in the development of dynamic stabilizing devices are choice of the distractive fulcrum, implantation of the device through a minimally invasive approach and, if not biodegradability of the implant, so at least explantability and thereby reversibility of the surgical procedure.

Anterior column reconstruction (ALIF, PLIF, TLIF and discovertebral arthroplasty) typically realigns and heightens the spinal segment, thereby also reengaging and tensioning the annulo-ligamentous structures. The same holds for pedicle screw based dynamic restabilizing systems, provided that the screw head (fulcrum, hypomochlion) is placed as far anteriorly as possible. Surgical-technical challenges with this system are a non-traumatizing surgical approach, obviating undue damage to the paraspinal muscles, correct positioning of the pedicle screws, optimized segmental distraction and also adequate "stiffening" of the implant by appropriate tensioning of the cord. Irreparable muscle debilitation, overdistraction and overstiffening of the system are serious technical issues.

Conceptually, interspinous distractive spacer devices should carry less surgery-related morbidity. Their relative ease of insertion (and explantation) must, however, be weighed against their less favourable geometrical trajectories and their relatively limited overall distraction force, in part due to the pleomorphology of the spinous processes and limited mobility and resilience of the functional spinal unit in intermediately degenerated situations (stiff segments). Erosion of the spinous processes over time along with bony remodelling is another potential hazard, especially with the less elastic and hard devices. To this end, diligent investigations of explanted devices would seem to be essential. Both pedicle-screw-based and interspinous distractive systems should be suitable for eliminating painful mechanical conflict of the posterior elements (kissing "spines", kissing laminae, subluxed, painfully impinged or impacted articular facets) and both types of dynamic stabilizers would seem to eliminate painful end range-of-motion "dysstability" and enthesopathy. The clinical indications for these systems remain to be determined as solid clinical data are becoming available. ◆

Anatomy of the triangular safe zone applied in lumbar percutaneous procedures

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To safely perform lumbar posterolateral percutaneous procedures in the treatment of lumbar intervertebral disc diseases (disc herniation or degeneration), the positioning and the diameter of working cannula in the triangular safe zone are important. The boundaries, the dimensions, the form of triangular safe zone and the maximal diameter of working cannula were investigated by the anatomic dissection of 100 foraminal levels in 14 human male fresh cadaver lumbar spines (L2 to S1). The average age was 52 years (28-75). The height of triangular safe zone was formed by the lateral border of the dura-mater, not corresponding to the medial pedicular border; the base, by superior endplate of the inferior vertebra body; and the hypotenuse by the spinal nerve. The average dimensions determined were: width 13.41 mm, height 21.68 mm, and hypotenuse 25.49 mm. In high lumbar spine (L2-L3 and L3-L4) were delineated approximately right-angled triangular safe zone, whereas in lower lumbar spine (L4-L5 and L5 e S1), obtuse-angled triangular safe zone. Based on this study, we concluded that the triangular safe zone admits progressively larger external diameter working cannula from L2-L3 to L5-S1. ◆

Dynamic Discography - A report on 1706 discs, on consequent cases

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With modern evaluation by CT Scan and particularly by the MRI, discography is controversial. But commonly the multiple MRI images do not tell us which of the demonstrated patho-anatomy is the symptomatic source of pain (April III 1997). For this reason, we have been routinely carried out discography at two levels, rarely at three levels and commonly, we operated at one level and exceptionally at two levels.

Since January 1990 to December 2004, discography was performed in 1,706 discs on 1030 patients as pre-operative routine test. 272 cases had neck 758 patients had low back pain and sciatica. The purpose of the test was: (1). To reconfirm the diagnose made by myelogram and CT Scan or MRI testing. (2). To identify the symptomatic disc by the dynamic discography. (3). To improve the result of Endoscopic minimal invasive Discectomy (Simmons J.W. 1988).

Technique and results: normal disc is not painful to pressure or to touch with a needle. The closed cavity of normal disc will not take more than 0.2-0.5ml. isovue 200mg/ml. The picture is round regular and rarely twin spots. Abnormal disc is very painful to touch, even with blind needle, reproduce the symptom; leaks and one may inject 1-3ml. dye and will be seen a irregular picture with bulged or herniated inside the spinal canal. Fissure lesion seen 30% of cases, because were painful, we considered positive. Frank herniation of the disc or bulging disc seen in 70%.

Conclusion: The patients with cervical spine symptoms all but one had a positive discogram, where as in lumbar spine, all had positive discogram. Discogram is in agreement with the Myelography, CT scan in 100% but 96% with MRI. We have recognized 10 patterns of discography on which one type is normal and nine form pathologic. The results of the percutaneous blind nucleotomy were satisfactory on 55-77 percent (Rezaian 1987) cases with out discography, whereas the result of minimal invasive. Universal Endoscopic Discectomy surgery with dynamic discography was good or excellent on 92% in those cases. ♦

Biological properties of intervertebral disc in spinal pathology

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Low back pain is the most common health problem for individuals between 20s and 50s of age. Evidence from the past decade indicates that inflammatory mediators - including metallo proteinase, prostaglandine E₂, interleukin-6, TNF-alfa and nitric oxide - are released by herniated intervertebral disc. Nerveroot compression itself does not always lead to pain unless the dorsal-root ganglion is also compressed. After nerve root compression or with no compression, numerous T cells and macrophages appeared among the demylinized nerve fibers. The dynamics of cytokine, NO and COX may be deeply involved into the appearance of radicular symptoms. Local application of autologus nucleus pulposus may induce injury of the spinal nerve root by mechanical or/and chemical mechanisms.

Local application of nucleus pulposus may induce a characteristic «inflammatory crescent», providing histologic confirmation of inflammatory reaction at the surface of dorsal root ganglion (DRG). It has been suggested that intervertebral discs may be invaded by newly formed blood vessels and nerve fibers following injury of the anulus fibrosus. The nerve fibers have been considered to induce low back pain. It seems that bioactive substances within the nucleus pulposus may be involved in the induction of neovascularization and neoinervation.

Such ingrowth seems to be reduced by doxycycline and inflixib, two cytokine inhibitors. The clinical importance of these data has yet to be elucidated. ♦

Should Doctors treat backage ?

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Doctors will always be asked for advice from people who have pain, be it spinal; abdominal, chest or facial. Serious disease needs to be excluded, by history examination and investigations.

All benign conditions seem to have 70% cure rate whatever the pathology and whatever the treatment; back pain without leg pain, irritable bowel syndrome, anterior knee pain, chest pain, tempero-mandibular. There are many more.

The Swedish Fusion Trial showed that fusion was better than no treatment; Similarly anterior knee pain treated by Arthroscopy is better than no treatment. But in both cases active interested physiotherapy or Osteopathy are equally as good as surgery (British Spine Trial)

The only people who have been successful in treating back pain have been politicians. In 1989 Sweden cut the financial benefit of sickness pay by 20% and lowered the Backache Sick Listing by 200%.

In the early 1990s Singapore attached Sick Benefit to pensions. If you used up your pension on Sick Benefit there was no pension or widows pension on retirement.

In 2004 Australia decriminalised Whiplash and Backache. Injuring a back in a car accident is treated no differently to the backache acquired mowing the lawn at home. There is no compensation merely the same treatment for both backaches. This returns to the 70% cure rate with all modalities. ♦

Mid-term results with percutaneous cryodeneration of lumbar facet joints

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Background: Lumbar zygapophyseal joints are a frequent source of pain in degenerative lumbar spine disease. In many cases, they may actually be the predominant source of pain. Amongst the minimally invasive therapies, efficacy has previously only been demonstrated for radiofrequency denervation. Study Goal: This study prospectively investigates the effects of percutaneous cryodeneration of lumbar facet joints.

Material & Methods: Our target criteria were low back pain (VAS 0 – 10), limitation in daily activities and general acceptance of the treatment method. Inclusion criteria: Deep-seated non-sciatic low back pain, failure of conservative measures, positive diagnostic medial branch blocks. Exclusion criteria: Previous spinal surgery, relevant spinal stenosis, activated osteochondrosis, radicular pain. Diagnostic blocks were performed under fluoroscopy, improvement in low back pain of more than 50% for more than 3 hours was considered a positive block. Cryodeneration was performed also under fluoroscopy at a separate appointment. Since June 2002, 57 patients (average age 55) were entered into the study. 2 Patients were lost to follow-up and 2 others had to be excluded, so that 53 patients were available for evaluation. At present, we have a 3-month follow-up for all 53 patients, a 6-month follow-up for 50 patients, a 12-month follow-up for 45 patients, an 18- and 24-month follow-up for 29 patients.

Results: 2 weeks after treatment, 65 % of patients reported significant improvement, 35 % reported little or no change in pain. The average VAS of the complete study group dropped from 7.6 preoperatively to 3.5 at two weeks and to 3.2 at three, 3.1 at twelve, 3.5 at eighteen and 3.7 at twentyfour months, respectively ($p < 0.05$). Limitation in daily activities improved parallel to the reduction in low back pain and 35 out of 53 patients would have the procedure performed again while 4 remained undecided.

Conclusion: Percutaneous medial branch cryodeneration is a safe and effective means for the treatment of lumbar facet joint pain. Facet joint diagnostics should be performed ♦

Cryosurgical therapy of spinal tumors

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Introduction In-vivo studies as well as clinical practice have demonstrated that with modern miniature cryoprobes adequate tissue freezing of bone without major complications for the organism are possible. In the present in-vitro study on human vertebra we examined if the placement of the cryoprobe and the navigation-controlled pre-surgical planning of the cryoablation is possible. We will also demonstrate the first clinical experiences.

Methods We have performed cryoablations on 12 vertebra of 4 human spinal columns. CT images were obtained for planning. The transpedicular positioning of the cryoprobe was supported by CT-fluoronavigation so that the entire freezing zone (3cm) laid within the vertebra. With the help of the virtual planning of therapy fields we were able to control the ablation in a way that neural structures were not affected. Temperature measurements were recorded at the posterior part of the vertebral body, within the myelon and the spinal nerve and surrounding the cryoprobe. After satisfactory evaluation of this method we performed the navigation-controlled cryoablation of spinal tumors in 4 patients.

Results All in vitro and in vivo measurements were able to show that an iatrogenic harm of neural structures can be avoided. The virtual-planned and actual therapy fields during ablation showed a high correlation. The application of the microprobe through CT-fluoromatching ensured an accurate positioning. No major complications were observed in all 4 patients and especially no neurologic complications.

Discussion The cryoablation of vertebral bone tumors with navigation-controlled placement of miniature cryoprobes and virtual planning of therapy fields is well practicable. Pre-existing software for spinal navigation surgery can be used for planning of the therapy fields. A good local tumor control without major complications was achieved in all 4 patients. A minimal invasive application of this method is practicable.

Keywords Cryosurgery, in vitro study, bone tumor, navigation, cryoprobes. ◆

Clinical results of lumbar and cervical disc nucleoplasty (1200 cases)

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Aim of the study: The one year follow up results of 900 cases are reported.

Material & Methods: The Disc Nucleoplasty is a minimally invasive plasma discectomy. 900 patients, suffering from chronic lumbar back pain and radicular pain syndrome were treated by the percutaneous disc decompression procedure of Nucleoplasty. The Nucleoplasty is a new percutaneous disc decompression system, based upon the experience with Chymopapain, Nucleotome, Thermonucleolysis, Lase and IDET. The Nucleoplasty is a controlled therapy: low temperature and controlled ablation /coagulation. In one system you have two modes of action: ablation via plasma molecular dissection and coagulation via resistive heating. Nucleoplasty is an voltage mediated process. The temperatures in both modes between 40-70 °C. The tissue is broken down into elemental molecules and low molecular weight gases, i.e. oxygen, nitrogen, hydrogen, carbon, dioxide, etc.. The gases exit disc through introducer needle. The Nucleoplasty-electrode ("wand") is characterised by an small profile, bipolar, micro-machined tip and an s-curved tip of shaft. Design goal: no scar, decrease morbidity, out-patient-procedure. Outcome independent quantity of disc remove (average 0.5g-1,0g). Patient selection: Treatment of radicular / axial pain: Cases with leg and / or back pain has been treated. Important is MRI evidence of contained disc protrusion. Discography, if indicated, has been done. Disc height of 50-70% minimum is essential. Exclusion criterias: severe degenerative disc, spinal fracture or tumor, severe spinal stenosis, degenerative instability.

Results of the two year follow up examination: 67% of the patients were complete pain free, continues working regular duty. Complete relief of sciatica and parasthesias. 9% reported intermittend occasional low back pain, never in th intensity of the pre-op state. Temporarily occasional pseudoradicular parasthesia, low grade. 20% reported about increase of low back pain during havy lifting (over 15 kg) and progressive sciatica and intermittend parasthesias 8 month after surgery. Narcotics temporarily needet. Resurgery has been done in 36 cases (4%). 0 case of paresis. Examination 1, 3, and 6,12 and 24 month follow up: 78 % good to excellent results. VAS score decreased from 8-9 pre surgery to 1-2 post surgery in 2 weeks.. No medication after 2 weeks post op. 75% of these patients were completely pain free post operatively. 25% were pain free after 2-3 weeks after surgery. 18% acceptable: VAS score decreased from 7-9 pre surgery to 4-5 post surgery in 4 weeks, down to VAS 1-2 after 8 weeks. Medication needet 4-6 weeks after surgery. 4 % poor: No significant decrease of pre-operative back and / or pain. Open surgery (Microdiscectomy) was done in 4%. Complications: no bleeding, no perforation of the ventral ligaments, no infection. Conclusion: Nucleoplasty is a quick an safe procedure of minimally invasive disc-decompression with excellent clinical results. There is no significant

difference between male and female patients- Significant pain relief postoperatively during the first 4 weeks after the Nucleoplasty –procedure. Persistent pain relief in the follow up. No severe complications are reported. ◆

Percutaneous lumbar endoscopy : evolution and actual foraminoscopic concept

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After the first decade with clinical experience in percutaneous intradiscal applications for intradiscal decompression since 1979 and endoscopic biportal technique since 1982, the idea to combine simultaneous endoscopic control with direct extradiscal tissue elaboration across an uniportal approach arose in the later eighties. Experiments with modified urologic workings-scopes designed for cystoscopic applications demonstrated in 1990, that endoscopic applications are possible also in non-preformed anatomical spaces when some hyperpressive irrigation was used for local atraumatic tissue spacing. So we introduced endoscopic coaxial foraminoscopy clinically for the first time in February 1991 for the treatment of a foraminal sequestered herniation. Since then the technology became almost standardized for this specific range of indication. The posterolateral approach from 9-12 cm from the midline follows the same criteria as for intradiscal applications, but the working cannula is directed to the foraminal sequester, which is extracted under endoscopic control then with a special working scope. Our first clinical series of 160 cases brought successful results in 131 cases, including an initial learning curve. 22 patients needed later on conventional open surgery w/wo fusion. Here the initial results trend to "black or white" : or the sequester is removed or not. Relatively freshly sequestered fragments without local scar-adhesions are easier to remove. Anatomical limits can occur in L5/S1 when high iliac crests do not allow enough flat approach to medioforaminal sequestra. Detailed knowledge of foraminal anatomy is mandatory. Hospital stay could be reduced to 2 to 3 days, out-patient care is possible as well. ◆

Percutaneous endoscopic and microscopy-assisted lumbar nucleotomy

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For 15 years the percutaneous endoscopic nucleotomy of contained lumbar disc herniation has been in use in our department. Essential for the success of this method is a careful diagnosis to decide the correct indication. With the first 164 patients (1990 – 1997) the postoperative follow-up checks have been carried out for 5 to 13 years. The average age of patients operated on was 43 ½ years for male patients (n = 102) and 40 years for female patients (n = 62). The level of disc removal was mainly L4/5 (n = 126) and in 38 cases L3/4. 123 patients (75%) had got therapy-resistant low back pain and radiculopathy, and 41 patients (25%) had got therapy-resistant low back pain only. The patients suffered from relevant symptoms for six months on average (3 months – 2 ½ years) before consulting our department. The preoperative diagnosis applied consisted of standard X ray of lumbar spine and CT, in 95 cases (58%) additional MRI and in 37 cases (22.6%) a further myelography with subsequent myelo CT was applied. An intraoperative discography was the basis of our operating. The postoperative follow-up check was done 5 to 13 years later (7.7 years on average). It revealed very good results with 116 patients (70.7%) and fairly good results with 21 patients (12.8 %). 27 patients (16.5%) showed persistent neurological symptoms postoperatively. 12 out of them needed conventional microdiscectomy from 3 weeks to 6 months later, another 5 patients within 12 months and another 3 patients 2 or 3 years later. We have had no major complications. For cases of contained disc herniation this is a highly effective, minimal-invasive operation method.

For some time now we have been gaining experience with minimal-invasive microscope-assisted nucleotomy in lumbar herniation. We use conventional dorsal approach. The advantage of this method compared with the traditional microsurgical technique, is the smaller minimal traumatizing access required through transmuscular dilatation by offering optimal three-dimensional visualisation of the surgical field. Our most recent results are highly promising. ◆

Interlaminar endoscopic approach (Destandau technique/foraminoscopy): 6/2 y experience

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Many surgeons conserved conventional open surgical approach for the treatment of lumbar disc herniation because of the fright for the endoscopic procedure difficulties without évident and quick clinical benefits. In fact the limited exposure and twodimensional vidéodisplay could be a potential injury of the nerve root and prolonged surgical time. The author relates his 6 years' experience with a posterior paramedian endoscopic procedure (Destandau technique) for lumbar disc herniation. He describes his first technical difficulties during his own learning curve, and his actual experience after 500 procedures. He will describe particulaly:conversion to open surgery / surgical time / release of neural structures / injury of nerve root / hemostasis and draining /associated bone stenosis/disc space infection / use of standard instrumentation / the costs.

In our experience this minimally invasive surgical treatment, has a hight rate of succes without increasing surgical pitfalls.It shows better result with limited epidural scarring and less complaints due to segmental instability, and facilitated fonctional rehabilitaton. ◆

Full endoscopic interlaminar/lateral transforaminar operations in herniation/stenosis/instability

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The therapy of degenerative diseases of the lumbar spine involves both medical and socioeconomic problems. A surgical procedure may be necessary if conservative measures have been exhausted and states of exacerbated pain or neurological deficits persist. Despite good therapeutic results with conventional operations, there may be consecutive damage due to traumatization. Thus, it is important to continuously improve these procedures. Taking existing quality standards into account, the objectives must be to minimize operation-induced traumatization and negative long-term sequelae. Current research results and technical innovations must be critically applied in order to guarantee the best-possible treatment strategies.

Minimal-invasive techniques can reduce tissue damage and its consequences. Endoscopic operations under continuous fluid flow bring advantages which raise these procedures in many areas to the standard level. Lumbar transforaminar procedures with posterolateral access have been used for more than 20 years. The work area is predominately intradiscal and intra- and extraforaminar. In recent years, a new lateral transforaminar and a new interlaminar access have been developed to enable a full-endoscopic approach to disc prolapses located within the spinal canal. Problems arose technically from small and not actively-flexible instruments coupled with a small intraendoscopic work canal. Insurmountable difficulties could arise in the resection of hard tissue, the anatomic access, the mobility and the elevated recurrence rate. New optics with an intraendoscopic 4.2-mm working canal and corresponding instruments, as well as shavers and burrs were developed with the objective of permitting full-endoscopic operating under visual control.

Considering the indication criteria, now the combination of the new approaches with the new developed endoscopes and instruments provides sufficient full-endoscopic decompression under visual control of all lumbar disc herniations located within the spinal canal or intra- and extraforaminar. The results are equal to that of conventional procedures, but with all the advantages of a truly minimally-invasive procedure.

In addition due to the possibility of resect bone in a sufficient way with the new instruments and burrs the indication is broadened with respect to techniques for spinal canal decompression. Further indications can be facet cysts, fusions and infections of the disc. But the technical development has not yet been completed, and there remain clear indications and limitations.

However, total avoidance of known problems in spinal surgery can hardly be imagined. In addition, open procedures will remain as indispensable in the future as they currently are. At the moment we estimate the full-endoscopic procedures as a sufficient supplementation and alternative inside the complete spectrum of spine surgery. ◆

Minimally invasive approaches to the spine : personal experience

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The present spinal surgery requires, more than ever, that the greatest possible therapeutic result should be achieved with the least amount of iatrogenic effects. The stereotaxy was the first step towards minimally invasive technique. Subsequently, the introduction of the operating microscope permitted a reduction of surgical field with consequent improvement of surgical procedure. Furthermore, the development of neuroimaging methods, like CT and MRI, revolutionised radiologic diagnostics, permitting precise surgical planning and three-dimensional programming. The use of the computer applied to the surgery, the so called "navigator" has yielded high precision in surgical techniques. The endoscopes, optic flexible or rigid instruments transferring images from an area inside the body to the outside by microcamera system, allowed the development of spinal endoscopic microsurgery. Following this philosophy, keyhole surgery began, to the patient's benefit. Our personal experience in the minimally invasive spinal surgery started from 1989. Up to date we performed 5852 operations on the spine by this technique. We treated disc herniation, spinal stenosis, spinal instability, traumatic injuries, some benign tumor, and complications of previous surgery, such as epidural fibrosis, vertebral instability and others. In cervical spine we used anterior approach, sometimes posterior approach and, when required, transoral approach. In thoracic spine we used parapedicular-transforaminal approach, thoracoscopic anterior and anterolateral approach, when required, posterior approach. In lumbar spine we used posterolateral-transforaminal approach, posterior approach, laparoscopic retroperitoneal and transperitoneal approach, sometimes inferior approach and, when required, posterolateral transdiscal approach. This experience suggests that the endoscopic microsurgical technique on the spine is an extremely advantageous and safe method.

We think that the development and improvement of instruments, longer follow-up periods and a greater number of patients treated, will further confirm this minimally invasive spinal surgery. ◆

Endoscope decompression using high speed drill for lumbar canal stenosis

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Recently, spinal endoscopic surgery is gaining support among the orthoscopic surgeon community as a less-invasive surgery. We carried out our first case in the September of 1998 and have accumulated over 800 procedures using the MED system. Accordingly, we have also gained insight into the most common indications for the procedure. The most important advantages of the posterior endoscopic procedure are that the surgeon can gain a wider and a more clear view of the surgical field than in the conventional method. So, we can perform the operation more safely and accurately.

We will present the clinical outcomes of the surgical procedure for lumbar canal stenosis, in addition to clarifying the indications and problems that we saw.

Materials and Methods: From September 1998 to January 2005, 781 consecutive patients underwent posterior endoscopic surgery for lumbar radiculopathy and cervical radiculo-myelopathy. Among them, 220 cases of lumbar canal stenosis were investigated. The mean age was 64.3 y.

We investigated operation time, blood loss, inter and postoperative complications and clinical outcomes by using the Japanese Orthopedic Association scoring system (JOA score).

Summary of the surgical technique : By using of the air drill diamond burr, the inferior part of the L4 lamina and the medial part of the facet joint were removed. Following this step, the tubular retractor was moved caudally and the upper margin of the L5 lamina was removed. Upon confirming that the ligamentum flavum was completely detached from the bone, the remaining ligamentum flavum is then resected, ideally in one solid piece. Following the removal of ligamentum flavum on the ipsilateral side, the tubular retractor was angled at 30 degrees medially and was set up over the superior part of the L5 lamina on the patient's contralateral side. The ligamentum flavum and the medial facet joint on the contralateral side were then removed piece by piece. Finally, the tubular retractor was placed over the inferior part of the L4 lamina on the contralateral side. Then, the contralateral side was decompressed. Lastly, it was confirmed that the L5 nerve root on the contralateral side was able to move freely.

Results : Predominately, the L4-L5 levels were the most affected sites. Surgery was performed for two segments in 67 cases, and three segments in 5 cases. Mean op. time was 86.5 min. Mean blood loss was 47.7g per segment. The JOA scores of the operative results were 14.4 preoperatively, improving to 24.6.1 at the final follow-up.

Complications were seen in 14 cases (6.3%). These were as follows; 5 cases of dural tears, 4 cases of postoperative hematoma, 2 cases of misjudgment of operative locations, and 2 cases of facet fracture. As of this presentation no cases of permanent neurological deficits have been recorded in our series.

In conclusion, the MED system allowed for not only removal of herniated disc, but also decompression of the nerve root and dural tube in cases of lumbar canal stenosis. This method achieved excellent clinical results. Intertranslaminar endoscopic decompression by high speed drill minimizes resection of pathologically compressed tissues and provides added margins of safety. ◆

Endoscopic decompression in lumbar spinal stenosis

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Objective: Microsurgical decompression of spinal stenosis today is a standard. Different approaches, such as bilateral access or unilateral access with bilateral decompression, are currently practiced.

The endoscopic video-assisted decompression of spinal stenosis via unilateral or bilateral access – achieved through a modified unilateral approach – will be presented, as well as the complications and results.

Methods: Endoscopic video-assisted operations – employing the METR'x-system – were performed on 323 patients (149 women and 174 men).

The stenosis was enlarged on 100 patients without discectomy through a unilateral or bilateral resection of medial facet joints and of the ligamentum flavum as well as a foraminotomy.

Results: 60 patients were decompressed unilaterally without discectomy, and in 40 patients the bilateral decompression occurred with a modification across the midline to the opposite side. In 7 cases a bi-segmental and in 3 cases a tri-segmental operation was performed. In one of those cases the dura was injured, and in another case microsurgical techniques had to be employed due to a venous hemorrhage. Neither nerve damage nor infections occurred.

Conclusion: Endoscopic decompression of spinal stenosis is a practicable and low-risk alternative procedure which, however, cannot supplant microsurgical techniques. ◆

Selective cervical percutaneous endoscopic decompression with a new instrumentation

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There is a high incidence of cervical discogenic pain symptoms in the population. It is estimated that one person in five in Germany who visits an orthopedist presents with the symptoms of a cervical disc syndrome (Krämer 1994). The treatment of cervical discogenic diseases makes high demands in terms of both diagnostics and therapy. Diagnostics has been made easier by improved imaging and the enhancement of neurological measuring methods. Consequently, there is now interdisciplinary consensus that the principal pathologic causes can be reliably identified.

With the aid of appropriate conservative therapy, approximately 80 percent of all cervical syndromes can be cured. Only once all the conservative and semi-invasive procedures have been exhausted should surgery be considered.

As a bridge between open and percutaneous therapy, endoscopy of the cervical spine started to be used at the beginning of the 1990s, following good experiences on the lumbar spine (Lee, Chiu, Fontanella). The principle of microsurgery is combined with the minimally invasive principles by bringing the optical level to the forefront of pathology. Access morbidity has been significantly reduced by the percutaneous access technique. Furthermore, a large proportion of the intervertebral disc, in particular most of the fibrous ring, is preserved. The pathology is only removed selectively in the area of the nucleus pulposus and on the dorsal fibrous ring. This preserves the remaining biomechanical function of the degenerated intervertebral disc. By means of tried and tested minimally invasive methods under vision, such as the use of a laser to ablate and shrink tissue, the risk of complications has been further reduced, at the same time as enhancing efficiency. The advancement of the endoscopic technique with increased miniaturization of the telescope and working options led to a restriction of use (e.g. LASE system). Our objective was to create an adequate working space in front of the telescope while preserving the minimally invasive approach. This was achieved by the use of dilation sheaths, which force the base plate and upper plate apart in the manner of a Caspar retractor and permit a working field of 5 mm or 6 mm. Here the visualization is sufficient to expose the ventral epidural space. A swiveling maneuver of the endoscope (fan sweep, Chiu) enables the dorsal section of the intervertebral disc to be visualized from one uncovertebral joint to the other. Removal of disc material is limited to the pathologic part, in a similar way to arthroscopic meniscus surgery. Equally, the surgeon has to become accustomed to the fact that limited viewing fields are lined up, rather as in joint arthroscopy. An irrigation system is used to rinse the ablated disc material out of the viewing field and to achieve partial hemostasis. Endoscopic cervical discectomy can also be performed using a gas medium. In this case, it is advisable to use a familiar view, such as through a microscope, to facilitate differentiation of the individual structures.

The indications for selective percutaneous endoscopic cervical decompression are neck pain radiating into the arm (radicular pain), symptoms of segmental dysesthesia, and motor deficits matching the pathologic segment, conservative therapy-resistant vertebrogenic headache with reliable imaging, disc herniation confirmed by MRI or CT, with associated clinical picture, damage in adjoining segments after preceding fusion, with corresponding clinical picture, and multisegment disc herniations.

This method cannot be used in cases of serious cervical spinal stenosis, migrated free sequestra, pronounced spondylosis with large osteophytes, and calcifications of the posterior spinal ligament.

As further instruments for endoscopic intervertebral disc surgery are developed, the scope of application can undoubtedly be extended.

The results of this method display a success rate of 80% - 95% for good to very good outcomes (Lee, Fontanella, Chiu, Wang, Hoogland). This includes various work techniques of endoscopic cervical decompression, such as laser (Chiu, Lee) or endoscopically assisted chemonucleolysis (Dekkers, Hoogland). Our experience also confirms this success rate. Unfortunately, the controlled cases to date are not sufficient to draw a definitive, statistically evidence-based conclusion.

The complication rate of percutaneous cervical decompression is extremely small, as is the case with non-endoscopic percutaneous procedures. In our patients, there have been no complications to date. Various complications have been discussed in the literature. In a multicenter study, 1,750 cervical endoscopic interventions on the cervical spine, employing different techniques, have been recorded around the world. In four cases discitis occurred, in one case there was a permanent sensory deficit, and in 5 cases nerve lesions with motor damage. This corresponds to an average incidence of complications in 0.6 percent of cases. Other, rare events to be found in publications are vessel injuries with hematoma, in one case a carotid injury, damage to vegetative nerves with Horner syndrome, and two cases with recurrent laryngeal nerve lesion out of 1,200 interventions (Chiu). Inadequate decompression when using the endoscopic technique is reflected in the incidence of secondary operations. The multicenter study quotes 28 relevant cases, which represents 1.6 percent.

Summary: Selective percutaneous endoscopic decompression and nucleotomy is a safe and efficient alternative to conventional anterior cervical discectomy, with or without fusion, for the treatment of discogenic syndromes of the cervical spine. It entails less surgical trauma, and considerably reduces surgery-related stress for the patient, while also shortening the period of hospitalization and the operating time. With the new devices for this procedure we got further possibilities in the current treatment of cervical disc disease and for development of new opportunities. ◆

Twelve year experience with cervical endoscopic discectomy : 100 cases

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Study Design: A retrospective clinical case study of patients who underwent anterior cervical endoscopic discectomy. **Objective:** To evaluate the outcome in 100 patients who underwent an anterior cervical endoscopic discectomy for the treatment of a cervical disc herniation using an anterior approach.

Methods: Both pain levels and disability were evaluated in one hundred patients who underwent an anterior cervical endoscopic discectomy at one or more levels during the period of time from March, 1996 to June, 2001. The patients completed questionnaires to determine their subjective findings before and after surgery. They were asked to rate their neck and arm pain on the Visual Analogue Scale (VAS) from zero to ten both before and after surgery. The neck disability index (NDI) was used to measure improvements in self-rated disability.

Results: In regards to arm pain, using VAS scores, patients reported a decrease in their pain scale from an average of 6.1 to an average of 1.8. In regards to neck pain, patients using the NDI, reported a decrease in their disability from an average of 6.4 to an average of 2.7. 77% of the patients in this study were satisfied overall with their outcomes.

Conclusions: Anterior cervical endoscopic discectomy using an anterior approach is a safe and efficacious alternative to traditional cervical discectomy for the treatment of cervical disc herniations causing radiculopathy and myelopathy. It offers an alternative to traditional open surgery and entails a lower risk for complications, less difficulty in the post-operative recovery period and fewer expenses.

*Our experience with patients undergoing this procedure from June of 2001 to present will also be discussed.



The technique of foraminoplasty in PED and MED procedure

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Japanese Society for the study of Endoscopic and Minimally Invasive Spine Surgery (JESMISS) has been founded in 1998 and operated educational, scientific purposes or to do assist all those involved with health care and so on. In 1995 endoscopic surgery was introduced for the first time. At first laparoscopic spine surgery, retroperitoneoscopic spine surgery has been tried. At September 1998 MicroEndoscopic Discectomy (MED) was introduced in Japan. The number of posterior Endoscopic approach to the lumbar spine have gradually increased. So far about 12000 cases of posterior Endoscopic approach have already performed. On 13 May 2005 Japanese government has approved the application of endoscopic procedure to lumbar disc herniation. The controversy in applying the use of PED (Percutaneous Endoscopic Discectomy) and MED to treat the lumbar disc herniation remains an issue of discussion. But we try to use original PED system with foraminoplasty since 2002 for the first time in Japan.

But the cause of intraoperative complications during this sophisticated surgery must be attributable to unrealistic and unpractical training system, shortage of experienced surgeons and no appropriate credentialing system. To overcome these problems, the Committee of Endoscopic Surgical Skill Qualification System was gained in JOA with 6 members who fulfill the requirements that are to be a councilor of JOA, a surgeon represents their Mother Society, a holder of certification by an appropriate specialty board and has established the credentialing system to encourage the surgeons to be trained to obtain privilege of endoscopic surgery. They shall serve for a 3 years term. As to the number of cases necessary to certify that the applicant must have a competence to be able to complete popularized endoscopic surgeries by his or her own efforts, surgeons must have an experience with over 30 cases in posterior lumbar discectomy or 20 cases in endoscopic anterior approach experience of some advanced endoscopic surgeries in the field of spine surgery.



A retrospective review of failed percutaneous transforaminal endoscopic discectomy

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Recent advances in minimal invasive techniques have generated a great deal of interest in the percutaneous transforaminal endoscopic lumbar discectomy (PTELD) and have had spine surgeons consider it as being less invasive than the conventional posterior lumbar microdiscectomy.

Object: There are few published studies describing the experiences in patients with failed PTELD. The author conducted a retrospective review to determine the causative factors in 66 patients with failed PTELD.

Methods: Eight-hundred patients underwent a PTELD in our hospital between 1999 and 2003. Of them, according to the outcome criteria proposed by Macnab, 66 patients (8.3%) were classified into fair and poor outcome, which were considered as 'treatment failure'. The ratio of male to female patients was 1:2.6. The patients' ages at the time of PTELD ranged from 18 to 54 years with a mean age of 35 years. All patients had regular clinical or imaging follow up for a minimum of 12 months (range: 12-59 months, mean = 33 months). Postoperative radiologic evaluation was performed using magnetic resonance imaging (MRI) to determine the postoperative status. In some cases, computed tomography (CT) was obtained to supplement the MRI findings.

Results: Of them, who were considered as 'treatment failure' following PTELD, 20 patients (30%) had inadequate indications for PTELD. Nineteen of the 20 patients had combined spinal canal stenosis. One patient had a wrong diagnosis preoperatively. Seventeen patients (26%) were classified into treatment failure due to the procedural problem during endoscopic discectomy. Twelve of the 17 patients displayed incompletely removed disc herniations in the follow-up imaging, and fascicular damage of spinal nerve root was observed in five patients. The treatment failures were noted to be caused by delayed reherniation following endoscopic discectomy in fifteen patients (23%). Postoperatively, three patients had discitis at the index level, which required antibiotic treatment, and eleven patients experienced extremity dysesthesia longer than 8 weeks. The reoperation rate following endoscopic discectomy in our series is 5.75%.

Conclusions: PTELD offers the major advantages of minimally invasive surgery such as less postoperative pain and earlier functional recovery. However, we believe PTELD should be performed under strict surgical indications following enough learning periods of this procedure. ◆

Microdecompression of the nerve root in patient with lumbar spondylolysis

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Purpose : The main source of pain in patient with spondylolysis is a compression of the nerve root which pass through lytic isthmus. We reported acceptable results after microsurgical nerve root decompression in young to middle- aged patients. However, micro-decompression in elderly patients have not been reported. The purpose of this report is to present clinical feature and an efficacy of microsurgical decompression in elderly patients with spondylolytic spondylolisthesis.

Clinical feature of elderly patients with spondylolytic spondylolisthesis:

They showed mainly root compression symptoms accompanied with or without cauda equina compression. The intermittent claudication was identified in 83 % patients. The pain or numbness was not always improved with bending posture like degenerative canal stenosis.

The neuroradiological characteristic image in elderly patients was a scream canal sign (a new CT and MRI sign in spondylolysis). The wide canal sign is well known as a MRI sign that remind a physician spondylolysis even if conventional x-ray films show no clear discontinuity in the isthmus. Posteriorly displaced detached lamina made an enlarged spinal canal. We can detect a large oval transsectional image of dural tube in both T2 weighted axial MRI and CT scan at isthmus level. In elderly patients, the enlarged dural tube was compressed from both sides by osteo-cartilaginous process which was growing as degenerative proliferative changes in isthmus spondylolysis. We named bilaterally compressed large axial image of dura "scream canal sign" after famous art – The Scream- by Edward Munch. The dura image just looks like the face of man painted in The Scream.

Instability in slipped segment has not clearly seen in functional x-ray. Percentage of slippage was less than 30% and lumbar lord was preserved in elderly patients. From the x-ray finding, we think that the number of patients who need spinal fusion is very few.

Elderly patients have a lot of systemic diseases. It is sometimes very difficult to perform the conventional operative method because of complications those they had. Recently a delirium becomes major problems as a postoperative complication in elderly patient with prolonged bed rest. Minimally invasive surgery will be primarily indicated in patient with spondylolytic spondylolisthesis who failed conservative therapies.

Patients: There were 14 men and 4 women with a mean age of 68.7 years. The level of spondylolysis was L5 in 14 cases and L4 in four. The mean duration of the symptom is 3.8 years. In spite of over than 3 months conservative treatment all patients showed no improvement. Mean preoperative JOA score was 13.5 point. The nerve root block is useful for establishing the diagnosis of nerve root compression at the isthmus. The scream canal sign was identified in both MRI and CT. A pedicular spur and proliferating osteo-cartilaginous mass were demonstrated around the lytic isthmus in lumbar CT.

Operative Methods: A 2-3 cm midline incision was enough to access the isthmus under the microscopic control. By cutting cranial edge of floating lamina with cutting bur, the caudal aspect of lytic lesion of the pedicle was clearly identified. The pedicular spur and proliferating osteo-cartilaginous mass was totally resected to achieve nerve root decompression.

Results : Unilateral decompression was performed in 5 cases and bilateral in 13. The mean operation time was 56 minutes. Blood loss was minimum. The mean follow-up period was 16.5 months (28-6). Preoperative JOA score 14.8 point postoperatively improved to 23.6 in average.

Discussion and Conclusion: Invasive surgeries such as Gill operation, direct repair or spinal fusions were indicated for painful spondylolysis. But microsurgical decompression to the nerve root that passing beneath the lytic isthmus is effective for the improvement of patient symptoms as a minimally invasive spinal surgery. We have already reported preferable results in young and middle-aged patients. We also indicate this technique to elderly patients. We believe the pain in elderly patients with spondylolysis comes from compromised nerve root passing just ventral of lytic isthmus as well as younger patients. Slipped segments were always stable and lordotic curvature was preserved. Consequently there were quite few cases to need spinal fusion. I believe that the microsurgical nerve root decompression is useful technique to improve the pain in patient with spondylolytic spondylolisthesis. ◆

The lumbar spine in medical history : concepts and treatments

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Medicine and politics have a common sense : you hardly understand the present state when you do not know the evolution in the past. So historically investigating our actual understanding of today available sources, spinal surgery, in comparison to trauma-related or septic surgical procedures, due to its relatively short evolution, demanding nature in invasivity and complicative potential, is a relatively young discipline. It is only seventy years ago that a clear correlation between rupture of an intervertebral disc and possible involvement of the spinal canal with its nervous structures and its surgical therapy had first been established by MIXTER & BARR in 1934. So degenerative spinal surgery took its upraise from this moments. However, our knowledge of the vertebral disc on the one hand, and of myelo- and radiculopathies on the other, is older. Some of the main steps from greco-roman classics leading to the final "discovery" of the disc herniation are pointed out and illustrated. ◆

The continuum of indications in non-fusion technologies

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The main targets of therapy in DDD and also the ideal goals of surgery are the decompression of neurogen structures, pain relief, preserving the range of motion, segmental stabilization and replicating the natural function of the disc. At least the last two goals cannot be achieved with the classical surgical techniques. As there is at that time no treatment with "restitutio ad integrum", not the maximum possible, but the most adequate treatment should be applied.

A compromise is the treatment with little and increasing invasive therapy steps, according to the "Step Algorithm for Treatment for Spinal Disorders". The three classical steps are Percutaneous Surgeries, Open Disc Surgeries and Fusion Surgeries. The Step Algorithm of the third millennium is extended to six surgical steps with Arthroplasty Surgeries (Partial Disc Replacement, Total Disc Replacement [TDR]) and Posterior Dynamic Stabilization, e.g. Dynesys. With Disc Arthroplasty and Dynamic Stabilization new concepts of restoring segmental stability without definite irreversible destruction are introduced in Spine Surgery. In contrast to loss of motion with fusion, with TDR motion and spinal balance are restored. A relatively neutral and more physiological stress flow to the adjacent levels can be achieved, despite to progressive damage to these segments after fusion surgeries. Another treatment step and the future of TDR could be the biological disc repair e.g. with Autologous Disc Chondrocyte Transplantation (ADCT) or gene transfer.

Nevertheless fusion surgeries cannot totally be replaced by Arthroplasty. Nowadays the real instabilities (e.g. fractures, tumors) and deformities (e.g. scolioses, kyphoses) remain for fusion surgeries. ◆

Thoracoscopic interventions in deformities of the thoracic spine

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Aim of the study : Scoliosis is a complex deformity of the spine with an abnormal shape in all different planes. In scoliosis over 40° progression is fast and the possibilities for successful conservative brace treatment are reduced during the growth period. Curve escalation depends on the degree of the frontal and sagittal deformity, vertebral rotation, rigidity of the curve, the skeletal age, the age and sex of the patient, the familial frequency of scoliosis and the location of the curve. Corrective loads are divided in forces of distraction, compression, translation and rotation. In the case of high rigidity of the curve the deformity is complicate. A thoracoscopic release helps to improve a better correction. Since 2001 13 patients with deformities of the thoracic spine underwent thoracoscopic surgery. The perioperative data including complications were collected and a radiographic analysis concerning curve correction was carried out to evaluate the benefits and limitations of thoracoscopy.

Methods/results : The average age was 21 years, the follow-up was 18 months with a minimum of 12 months. The scoliotic curves measured preoperatively 85 degrees on average with a Cobb angle of 62 degrees on the traction films and were corrected by 57% to averagely 36 degrees at follow-up. Between 4 and 6 discs were excised with a blood loss between 50 and 360 ml. A conversion to open thoracotomy was not necessary in any case. There were no intraoperative neurovascular complications.

Conclusions : Thoracoscopic procedures in deformities of the thoracic spine are technically demanding, however, it is a minimally invasive procedure with a reduced approach-related morbidity compared to open thoracotomy. The indications for a thoracoscopic release are rigid kyphosis and scoliosis with rigid curves between 70 and 100 degrees Cobb angle in which a posterior correction and instrumentation alone is not considered. ◆

Minimal invasive surgery of thoracolumbar compression fractures

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It is common knowledge that surgery of compression fractures of thoracic and thoracolumbar parts of the spine is still an important issue. There is an ongoing research into methods that will enable to reduce time of an operation, its traumatic effects and blood loss.

For an operation on one vertebral body fractured to the half of its height, we suggest using methods that comprise a minimal anterior lateral transthoracic approach and a minimal invasive surgery on vertebral bodies.

Surgical indications:

1. Vertebral fracture to the half of the vertebra height;
2. Neural disorders;
3. Spinal cord compression by a fractured vertebral segment (without a clinical picture of neurological deficits).

Principles of surgical interference:

1. An approach level is chosen considering the patient's body type (an asthenic person, a hypersthenic person);
2. The approach should approximate the surgical action axial tilt angle to 90 degrees.
3. When operating on the level Th12-L1, the medial crus of the diaphragm is, as a rule, not transected. It may be partially incised.
4. During an operation on the level of one vertebra-motor segment, segmental vessels on vertebral bodies are not transected and paravertebral issues are only coagulated above the interference region.
5. The spine cord decompression begins with an extirpation of a ruptured disk, followed by a resection of the body upper segment dislocated into the spinal canal.
6. Anterior lateral spine fusion is performed with the help of 3-6 fragments of the patient's rib and grafts made of the vertebral bodies under operation.

In all patients, operations included anterior lateral decompression of the spine cord and spine fusion. The approach length was 6-10 cm. The average time of an operation was 1 hour 45 minutes (60-120 minutes). The average blood loss was 143 ml (50-350 ml, less than 200 ml – 87.5%). The patients were able to stand up within 2-7 days after the operation.

Results: 94 (98.9%) patients have been recorded to have synostosis of operated vertebral bodies within 4-6 months. 45 (86.5%) patients have shown a neurological deficits improvement registered within the first hours after the operation. The improvement can be explained by the decompression method with little traumatic effects. The method that we have developed has enabled us to stabilize the spine and improve a neurological state, significantly reducing time of anesthesia, the time of the operation itself, its traumatic effects and blood loss. ◆

Technique/1st results of perc. plates/postero-lateral fusion (cages/plates) PEPLIF

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The aim of this paper is to present a percutaneous technique of fusion. In 1987 the team of Balgrist led the way by describing the technique for percutaneous posterior grafting under endoscopy, publishing their results with 50 cases. The technique is bilateral, and can be done without endoscopy if it is limited to osteosynthesis by plates. An endoscopy under local anaesthesia and neuroleptanalgesia is necessary for root control when cages are placed. The osteosynthesis material is provided by pedicular cannulated screws inserted in specially made plates with two or three holes. Surgical technique is particularly simple, necessitating a simplified ancillary set familiar to every spine surgeon. It involves the standard pedicular aiming by a percutaneous approach; the patient is prone on a spine frame, under general anaesthesia or sedation completed by a systematic local anaesthesia with 2% adrenalined lidocaïne. This reduces muscular bleeding. A C-arm gives live control of AP and lateral views. The skin incision needed is about 15 mm for each screw down to the dorsal fascia. Pedicular aiming is convergent with a trocar making a better screw anchoring. A Kirschner wire is pushed through the trocar; then two dilators of increasing diameter are guided by the wire; then a working tube. The plate-dilator is introduced along the wire, perpendicular to the spine, until bone contact. Small and progressive rotation movements of the dilator insure progress, stripping soft tissues away. The definitive plate is introduced on the wire with an adapted plate holder, following the path of the dilator

The trocar is then positioned, through the plate in place, onto the pedicle of the next vertebra. A cannulated screw is pushed on a wire through the working tube, and placed under X-ray control; other pedicles follow the same process.

Results: of 22 patients operated on from September 2004, ranging in age from 28 to 78 years old, sex ratio 13/10, 16 presented with degenerative disc disease localized to one or two segments, associated in one case

with a scoliosis, in another case with a spondylolisthesis, and one following an open surgical procedure; 3 presented with an isolated degenerative spondylolisthesis, 2 with a fracture (74 and 75 years old). The osteosynthesis involved one level in 17 cases (9 L5S1, 6 L4L5), and two levels in 5 cases (3 on L4L5S1). With the same approach, cages were put in place for a spondylolisthesis L4L5. Mean preoperative visual analogical scale (VAS) was 6.45, and post operative 1.59, otherwise 75% of improvement. Post operative Prolo score was 8.22, 10 being the maximum.

Discussion: Although patient follow-up is short (below one year), the technique gives good results. The cages can restore the intersomatic space. The learning curve is relatively steep, and a rigorous patient selection is necessary.

As far as we know, as percutaneous plates became usual overseas, there is only one paper about intersomatic cages put in place by a posterior percutaneous approach until now, and the operation is done under direct vision with the Medtronic system under general anaesthesia.

Conclusion: This technique of percutaneous pedicular screwing, including the possibility of interposing intersomatic cages by the same approach, is very promising.

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Development of the golden section idea at PLIF and first experiences

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Now PLIF technologies are most intensively developed in modern minimally invasive vertebrology, including with usage of a new generation of expandable cages.

In many respects, the implementation of main cage functions depends on features of its form, geometry of bearing areas, cage elements' material and coating material. At new designs searching for, the variety of the marked above cage parameters results in necessity of the solution of a problem of multicriteria optimization, the main aim is the definition of optimum ratio between parameters, when performing which, the stabilizing cage properties are provided to the best advantage.

The collectives of our two chairs have worked on improvement of prismatic non-full-contact cages with the concept of the "open window" during last four years. During creation of new models, we put forward an idea about cage creation with parameters made in the ratio of the "golden proportion" or "golden section". "Golden section" is such proportional segmentation of a distance into unequal parts, at which one, the minority pertains to greater, as the large part to the whole distance and is 1,618. From the mathematical point of view, classical "golden section" characterizes a non-Euclidean symmetry of two unequal objects.

We offered, founding on principle of the "golden section":

- Fixing cage members in pyramidal form;
- Four versions of cogs distribution on cage bearing areas;
- The way of cage coating and filling by hydroxylapatite ceramics (a ratio of calcium and phosphorus are 1,6 in "Golden proportion").

We studied stressedly-deformed states of new designs on 3D-models by a finite elements method for analysis of its stabilizing properties, its analysis allows to judge about positive restabilizing cage properties in the comparison with the known analogues.

20 cages were implanted to the patients with different versions of lumbar spine degenerative instability for restabilization on PLIF technology. 1,5 year follow-up of PLIF outcomes demonstrates efficiency of cage interbody stabilization in "golden section" proportion. ◆

Endoscope assistance in pedicle screw placement

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Insertion of pedicle screws in the thoracolumbar spine can be challenging. Incorrect placement can lead to significant neurologic morbidity. Techniques for intraoperative monitoring and stereotaxis have been developed to achieve proper screw placement. While these techniques are accurate, they are expensive and require significant additional operative time. We have studied the use of endoscopic monitoring of pedicle screw placement by two different methods as an alternative to these more complex strategies. The first method entailed integrating endoscopes into modified pedicle probes so that the interior of the pedicle could be monitored while the probe was advanced. The second method utilized small malleable endoscopes to explore the outside of the pedicle while the pedicle probe was being advanced.

Both techniques achieved their goals in laboratory studies. The modified pedicle probe allowed the inside of the pedicle to be easily viewed as the probe was being advanced. Likewise, the malleable endoscope provided a superb view of the outside of the pedicle during advancement of the probe. The only disadvantage of the malleable endoscope was the necessity to perform a laminotomy to provide access to the spinal canal.

In the operative cases the endoscopic pedicle probe had limited use. The images were poor due to bleeding within the pedicle that rapid irrigation through the endoscope could not clear. Because the endoscope was located slightly distal to the point of the probe, the immediate action of the point could not be adequately monitored.

The malleable endoscopes proved to be superior to the endoscopic probe. They easily showed the anatomy and any violation thereof. The only situations where the malleable endoscopes were limited were in the cases where there was scarring. We will discuss the use of both of these techniques and the ultimate utility for accurate placement of pedicle screws. ◆

Incorporation of intraoperative computed tomography in spinal navigation technique

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Background: Pedicle screw fixation is an established technique for vertebral fusion. However, it is important to ensure that the pedicle screws remain in the main axis of the pedicle, and do not invade the vertebral foramen or spinal canal.

Despite the various benefits of spinal navigation in pedicle screw insertion, there is still a high rate of screw misplacement, which ranges from 2.7% to 14%. Thus, we cannot recommend that navigation with registration based on anatomical landmarks and surface matching as a standard technique particularly in cases of unstable spinal fracture. The term 'screw misplacement' is taken to mean a perforation of the pedicle and vertebra by the pedicle screw of more than 2 mm. This presentation illustrates an improved method of intraoperative navigation, using marker screws for registration implanted in the vertebrae at the beginning of surgery, before acquisition of the data set used for intraoperative navigation. This has become a practical possibility due to the availability of intraoperative CT, and provides better application accuracy than techniques based on anatomical landmarks.

Methods: All of the operations were performed with the aid of a Tomoscan M mobile CT system (Philips Medical Systems, Eindhoven, the Netherlands). The system comprises a mobile gantry, a mobile patient examination table and a mobile workstation. A infrared sensor navigation systems were used: the SurgiGATE (Medivision, Oberdorf, Switzerland). All of the surgical operations were performed with the patient positioned on the mobile table of the CT system or on a fixed carbon table. Following dorsal preparation of the vertebral region, the surgeon implanted small titanium screws in the vertebrae. The screws served as fiducial markers. Image data acquisition and image-to-patient registration were performed after implantation of the marker screws. The pedicle screws were inserted using the navigation system, and the position of all implants was confirmed by intraoperative CT scans.

Results: The combination of intraoperative computerized tomography and spinal navigation allows easy navigation with a high application accuracy of $0.8 \text{ mm} \pm 0.4 \text{ mm}$ (SD) at the target point (measured in experiments with a plastic spine model). In a experimental study of percutaneous spinal navigation we reached an application accuracy of $1.2 \text{ mm} \pm 0.6 \text{ mm}$ (SD). 304 patients with various spine disorders have been operated upon using the technique described, and 1438 pedicle screws have been inserted. The pedicle screw misplacement rate was only 0.9% but using the navigation technique without CT (n=21) we achieved a misplacement rate of 9.2%

Conclusions: Pedicle screw fixation using intraoperative CT and fiducial marker screws provides much better application accuracy than the previous technique using anatomical landmarks. The possibility of performing an intraoperative quality check on demand markedly improves the safety of these procedures. We presume that the minimally invasive navigation-guided percutaneous technique will become increasingly important in the future and will certainly be employed in combination with the application of robots working more precisely than by free-handed navigation. ♦

CT-controlled endoscopic surgery in foraminal/far lateral lumbar disc hernia

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Purpose of the research: to define the efficiency and capabilities of CT controlled endoscopic surgery of foraminal / far lateral lumbar disc hernia.

Material and method: 32 patient (19 male, 13 female), the average age 47 years have undergone endoscopic nucleotomy concerning foraminal (22 cases) and far-lateral (10 cases) intervertebral disc hernia. The level L3-L4 was observed in 9 cases, L4-L5 in 19 cases, L5-S1 in 4 cases. The manipulation were undertaken in the operating room equipped by CT using spinal navigation system. The operation included the following stages: CT discography, the working tube control, endoscopic nucleotomy, post-operation CT.

Results: assesment was done in 4 years after the operation. Exellent and good results were observed in 20 cases, satisfactory in 5 cases, poor ones requiring conversion to microdiscectomy by paraspinal approach in 7 cases. The average hospital stay was 3 days.

Discussion: the frequency of foraminal/far lateral lumbar disc hernia is 0,7 to 11,7% of all intervertebral disc hernia of the lumbar spine. Usage of transspinal, paraspinal or retroperiotenar approaches requires very often bone and faset jonts resection, impairs the function of paraspinal musculature, increases the time of the patient's stay in hospital, makes the operations more expensive.

Described above CT controlled endoscopic nucleotomy allows us to avoid possible complications. Conclusion: CT controlled endoscopic nucleotomy of foraminal/far lateral lumbar disc hernia is a safe and effective method. ◆

The transvertebral herniotomy in cervical spine

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This study analyzed results of anterior transvertebral herniotomy for cervical disc hernia in order to assess the usefulness of this procedure and possibility of removal of thoracic disc hernia using same technique. The advantages of this method are the simplification of postoperative management and less risk of degeneration of the neighboring spinal segments, because the operated segments retain a variable degree of mobility.

Materials : Anterior transvertebral herniotomy was performed in 30 patients who had cervical disc herniation without spinal canal stenosis. The treated disks were C3/4 in 4 patients, C4/5 in 6 patients, C5/6 in 12 patients, C6/7 in 4 patients, C4/5 and C5/6 in 1 patient, and C5/6 and C6/7 in 3 patients.

Methods : With the patient in the supine position, the side of the neck opposite to the herniated disc was incised for standard exposure of the anterior surface of the spinal column. If the herniated disc deviated cranially or caudally, the vertebral body on the side of deviation was exposed. Likewise, if there was lateral deviation of the herniated disc, the skin incision was made on the contra lateral side to the herniated mass, and the anterior surface of the vertebral body was exposed. Drilling was started with an air turbine drill at the center of the anterior surface of the adjacent cranial or caudal vertebral body. Drilling proceeded posteriorly or posterolaterally toward the herniated mass, and was stopped when the drill bit penetrated the posterior bone cortex. An operating microscope was introduced, and after checking the drilled-out posterior bone cortex, herniotomy was done through the drill hole, which was about 7 mm in diameter. The previously injected blue dye provided a good delineation of the herniated disc, especially if the mass had been extruded into the space between the superficial and deep layers of the posterior longitudinal ligament.

Results : In most patients, a good result was obtained, but simultaneous or subsequent anterior intervertebral fusion was necessary in 4 patients. In 1 patient, the two adjacent vertebrae had fused spontaneously.

Discussion : In patients with cervical disc hernia, not only radiculopathy but also myelopathy can be treated by this operation. However, in most patients with myelopathy the spinal canal is narrow relative to the spinal cord, so radiculopathy patients accounted for about a half of our series. The best indication for this treatment judging from our postoperative results is a large hernia associated with either myelopathy or radiculopathy in a patient without spinal canal stenosis. The most important points are that this procedure should be limited to localized soft disc hernias, and that bulging of the annulus fibrosus should be excluded. Recently Demura et al reported herniotomy between T2/3 using this technique. Usually sternal splitting approach is necessary for this level, therefore, this kind of approach may be useful if surgeons would like to treat patients minimally invasively.

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Sacroplasty: a mini-invasive procedure in treating sacrum fractures with bone cement

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Introduction : The incidence of osteoporosis and osteoporotic fractures has clearly increased with elderly population. A further increase is even expected during the next years. Vertebral compression fractures are frequent and common in osteoporosis. As a minimal invasive operative treatment percutaneous cement augmentation (vertebroplasty) has become more and more popular in recent years. 80-90% of the patients treated in this way obtain a prompt and persistent reduction of their pain. In addition a progress of the kyphotic deformity of the augmented vertebra is prevented. Another localisation of osteoporotic fractures are sacrum insufficiency fractures. These fractures were treated mainly conservatively with bed rest and analgetica. Recently the technique of percutaneous cement augmentation has been described for minimal invasive treatment of these fracture.

Surgical technique : The principle of the surgical procedure is quite similar to vertebroplasty. The patient is in a prone position on a radiolucent table. After stab incision k-wires and bone biopsy cannals (8 ga) are inserted percutaneously into the lateral mass of S1 keeping under control of an image intensifier. After verification of a correct position of the cannals in the center of the S1 body, PMMA cement of high viscosity is injected into S1 with permanent C-arm control. After setting of the bone cement the cannulas are removed.

In case of a bilateral fracture in terms of suicidal jumpers fracture additional stability is provided by one or two percutaneous sacro-iliac screws.

Results : Up to now we performed a sacroplasty procedure in 14 patients (13f, 1m) with an average age of 77,4 (49-87) years. The patients sustained a Sacrum insufficiency fracture without an adequate trauma or had a banal fall. All sacroplasties were performed bilateral. An additional stabilisation with one or two percutaneous sacro-iliac screws was performed in 4 patients. The patients had a relevant relief of their low back pain after the operation and during their stay in the hospital. The results of an ongoing clinical and radiological follow-up examination will be presented at the meeting.

Conclusion : This sacroplasty procedure is a minimal invasive procedure for stabilizing sacrum insufficiency fractures. Depending on the type of the fracture an additional percutaneous sacro-iliac screw fixation is reasonable and can be performed with minimal extra effort. The technique is safe in practise. In the early follow up the clinical results remain promising. ♦

Biomechanical/clinical study on vertebroplasty with various composite materials

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Based on the complex investigations including clinical, experimental, morphological, biomechanical researches and also mathematical modeling the new method of minimal-invasive vertebroplasty of osteoporotic compressive fractures with usage of composite materials and designed device was created.

During the mathematical analysis it was determined that the composite containing bone cement approximately 80-90% had elastic modulus most similar to the cortical bone. To define the best composite structure the experimental researches on material samples with different component correlation was carried out. The test results showed that the best strength characteristics had the composite material consisting of 80% bone cement and 20 % ceramic component. Ceramic component contained HA and TCP in ratio 2:8.

To study the characteristics of the obtained composite material the experiments on 15 laboratory animals (Vistar line white rats) was completed. The vertebrae filled with composite material of preliminary determined composition could sustain the loading much more bigger than the vertebrae filled with bone cement and osteoporotic vertebrae under control.

During the morphological analysis the effectiveness of composite material consisting 80% bone cement "Osteopal^R-V" and 20% calcium phosphate ceramics (20% HA and 80% TCP) for bone repair at osteoporosis was proved.

The method and device for minimal-invasive vertebroplasty of the vertebrae osteoporotic compressive fractures was worked out. 24 patients having vertebrae osteoporotic compressive fractures were treated with developed method and using composite material in accordance with fracture type and compression level. The follow-up after 6 month showed no compression increase in the operated vertebrae in all 24 patients. Only 3 patients were found to have deformation of the L5 vertebra after L3 and L4 vertebra vertebroplasty. The results of the usage of the worked out method of vertebroplasty, organization and composite material proved its clinical effectiveness. ◆

Percutaneous vertebroplasty for vertebral body fractures in multiple myeloma

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Purpose. Assessment of the efficacy of percutaneous vertebroplasty (PV) for vertebral body fractures in patients with multiple myeloma (MM).

Material and methods. We performed percutaneous vertebroplasty in 19 patients (10 men and 9 women, age range 47 to 61 years, mean age 52.4). Two patients had a diffuse type of MM, 11 patients a diffuse-local type and in 6 patients the plasmocytoma (local vertebral lesions) was revealed. Preoperative investigation included clinical examination, CT, MRI and SPECT bone scan with technetium-99m being performed in 5 cases. Back pain due to replacement of vertebral body bone tissue by plasma cells was the major symptom in all cases. The quality of life was evaluated based on the following criteria: back pain (VAS), social activity and dependence on medication. On CT data we evaluated the stage of vertebral fracture, involving vertebral body posterior wall, osteopenia pronouncement and lytic lesion size. MRI (C1 to S1) was made for all patients. According to MRI findings, our patients were divided into three groups suffering from: local MM (plasmocytoma), diffuse-local MM and diffuse MM.

Technique. Procedures were performed under local anaesthesia. In the patients with diffuse and diffuse-local MM with small lytic foci, we chose the unilateral transpedicular approach; while in the cases of solitary plasmocytoma and diffuse-local form with big lytic foci we applied the bilateral transpedicular technique.

In the 1st group, a needle was introduced into vertebral body center with intraoperative biopsy and cement injecting. In the 2nd group we applied filling of undamaged spongiosa of the vertebral body followed by composite injection into lytic lesion. Venospondilography was done in MM localized in a posterior one-third part of the vertebral body or, in the cases of posterior wall destruction, for the purpose of extravertebral bone cement leakage risk determination. The duration of PV was 19 - 120 min. Average stay in hospital - 1.4 days.

Results. Postoperative control was made for the following parameters: pain severity (Pain Score Scale), social activity and dependence on medication; CT and MRI characteristics and degree of cement filling were assessed. Postoperative assessment of clinical symptoms was carried out at 3 weeks, 6 weeks, 6 months, 12 months, 18 months and 24 months. The patients with diffuse-local MM displayed pain regress, analgetic reduction and life quality increase. After operations, the patients continued receiving chemotherapy according to general standards. Two patients with diffuse MM had a reduced pain syndrome, but due to tumor process spreading, no improvement of life quality occurred. In 3 weeks after operation, one MM patient had a hip fracture. Another patient died from pneumonia in 5 weeks. For patients with solitary plasmocytoma, the intraoperative biopsy data served a major principle of diagnosis. After complete pain regress had been noticed, all of the patients were then referred to a haematological department. Mean volume of filling per vertebra was 4.1 ml of bone cement (2-7 ml). Extraosseous cement leakages were noted in 3 patients (15.9%): one into the paravertebral soft tissue (5.3%), one insignificant epidural leakage (5.3%) and one into the intervertebral disc (5.3%). All of these cases remained without any clinical sequelae. The patients continued receiving hematological treatment according to accepted hematological standards of MM treatment.

Our experience and literature data show that PV is efficacious in treating osteolytic vertebral compression fractures resulting from MM. Significant pain relief was obtained in 18 of 19 MM cases treated with PV.

The use of PV for MM management is reasonable in cases of diffuse-local and local MM. In the cases of diffuse MM with multiple bone involvement, despite back pain lessening, the life quality cannot be improved due to character of the process.

Conclusions: PV is a safe operation for pain relief after vertebral body fractures in MM. PV improves life quality of patients with MM. Indication for PV is vertebral body fractures in diffuse-local and local forms of MM. PV does not influence adjunctive medical treatment and hematological treatment standards in MM. ◆

Percutaneous vertebroplasty for metastasis

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The vertebral column is recognized as the most common site for bony metastasis in patients with systemic malignancy. The thoracic vertebra is usual site for metastasis from thyroid, breast, and lung cancer; however, the lumbar spine is the site for from prostate, bladder, and colon cancer.

It is common to recommend percutaneous vertebroplasty (PVP) using a unipedicular approach because of the characteristic involvement of the pedicle in cancer metastasis with respect to osteoporosis.

The applied pressure during the injection of cement in metastasis is much higher than in osteoporosis due to the higher bone mineral density (BMD). The risk of cement leakage is increased with PVP. Thus, kyphoplasty could be an alternative method.

Facet joint block is necessary in the patients who complain of facet joint pain coming from losing the weight-bearing capacity of the vertebral body regardless of benign or malignant process.

PVP can be undertaken either before or after radiotherapy or chemotherapy because of the low risk of bleeding from PVP. Alendronate may have some anti-cancer effects and may reduce pain.

Even though PVP in metastasis has some difficulties such as the possible poor general condition of the patient, possible shortened remained life span, and a high risk of cement leakage, PVP has various advantages such as immediate pain relief and mobilization, avoiding the complications from prolonged bed rest, and possible increasing of immunity and life span. ◆

Spine Pearls - fills bone defect after internal reduction of osteoporotic fracture

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Aim of the Study: Spine Pearls are implants designed for the treatment of osteoporotic compression fractures. The Spine Pearls are small bodies, which are pressed in the vertebrae through transpedicular cannulas. The Spine Pearls are designed to be self interlocking and in order to stabilise the fracture. The aim of the present study was to investigate the stabilising effect of various Spine Pearls geometries in fractured osteoporotic vertebrae and compare them to bone cement.

Materials and methods: The vertebrae of six cadaver specimens T10-L5 were analyzed with CT for form/size and bone density. They were separated in 5 groups with matching age and bone density each containing 6 vertebrae. The 5 test groups were: Spine Pearls round (large (a) and small (b)), Spine Pearls hexagonal (large (c) and small (d)) and bone cement (e). After weakening the lateral and anterior body wall, a controlled vertebral compression fracture was created by applying a displacement controlled eccentric axial compression force. The vertebrae were compressed to 50% of their intact vertebral body height. The axial compression force was measured for the initial fracture and after treatment. The treatment included transpedicular reduction with an expandable device (SkyBone Expander, Discotech, Israel) and filling of the created cavity with either bone cement or Spine Pearls in two different forms and sizes.

Results: The mean compression force for all 30 vertebrae was 1157 N. For all groups the mean absolute compression force after treatment was lower than for fracture. The treatment mean relative compression forces (normalised to the fracture) were 85% for Spine Pearls round (large and small) and for bone cement, 90% for small hexagonal Spine Pearls and 106% for large hexagonal Spine Pearls.

Conclusion: The in vitro tests showed differences in relative strength to eccentric axial loading depending on the geometry and material used to fill the bone defect after internal reduction. The best relative stability was found for large hexagonal Spine Pearls. ◆

Novel techniques for VCF treatment

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Vertebroplasty is the injection of acrylic bone cement (PMMA), used to reinforce the structure of a compressed vertebral body. This technique was originated in France, in 1987, to treat vertebral lesions. It is assumed that the pain relief mechanism associated with Vertebroplasty is the achievement of mechanical stabilization of the vertebra, which likely prevents micromotion at the fracture site. Other suggested pain relief mechanisms include thermal necrosis (due to the temperature reached during PMMA polymerization) and chemo-toxicity of the intraosseous pain receptors. However, while Vertebroplasty is an efficient method of stabilizing VCFs, it fails to restore vertebral height and angle, and presents a relatively high incidence of cement leakage, posing a neurological risk to the patient.

Kyphoplasty, a variant of Vertebroplasty, entails device expansion within the collapsed vertebra prior to cement injection. The void, created within the vertebra using an Inflatable Bone Tamp (Kyphon Inc, USA) or the SKY Bone Expander (Disc-O-Tech Ltd, Israel), is filled with cement after removal of the device. In addition to the stabilization intended to reduce the pain, it may provide in some cases a relative vertebral deformity correction. The Confidence Cement System (Disc-O-Tech Ltd, Israel), an innovative system, has been presented recently as an alternative to Vertebroplasty and Kyphoplasty for the treatment of vertebral compression fractures. It comprised of a unique high viscous bone cement (PMMA), a delivery system and an access instrument. Mixing the 2 components of the cement (liquid and powder) results in a constant high viscosity texture, which enables its immediate and safe injection. The cement maintains its high viscosity for up to eight minutes at a 20°C. The Confidence System may present the benefits of minimizing the risk of extravasation and reducing the procedure time as, after mixing its components, the cement is ready for immediate injection. The author will present the system, his initial experience and data from cadaver experiments. ♦

Kyphoplasty versus vertebroplasty; our advanced indications and results

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From the first applications in 1984 by Deramond and Galibert introducing the vertebroplasty with acrylic cement for the treatment of the osteoporotic fractures, it has been an explosion of this admirable mini-invasive technique. In the 1990s the limits of this technique (extra-vertebral cement leak, cement pulmonary embolism, for high pressure cement injection, the absence of biomechanical improvement due to cement without fracture's reduction, induced Mark Reiley, to conceive a new technique: the kyphoplasty.

This mini-invasive procedure, used from 2001 in our hospital restores the vertebral body's height, stabilizes the fracture and reduces the spinal deformity in these patients. It's possible, with this technique to cancel the possibility of leakage with creation of a cavity in the vertebral body. This can reduce the pain in more than 90% of cases.

Our casuistic is about of 40 patients. There are reduction in early fractures or reduction in osteoporotic patients fifty days from fracture. In some case we only introduce the traumatic fracture to high energy in lumbosacral column reduced by combination between kyphoplasty and traditional stabilization. This solution can improve consolidation and fracture's reduction. We didn't use this technique in metastatic localizations.

We practice preventive kyphoplasty in adjacent fractured levels when we can see a risk of one new possible fracture. The bursting wedged vertebra is not an absolute contraindication, it can be treated in a good outcome. ♦

The direct reduction effect of balloon kyphoplasty in osteoporotic vertebral fractures

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Balloon Kyphoplasty yields direct reduction on fractured vertebra segment. Restoration of anatomy is possible after PMMA cement augmentation. It stabilizes the fractured segment and leads decrement in pain. However we observed that among patients undertaken into kyphoplasty operation due to vertebral fractures of osteoporotic or osteolytic vertebra tumors at least some cases experienced a recurrent pain in a moderate time period following the surgery. The reason for this recurrent pain was thought to probably be related with the adjacent vertebral micro fractures, consequently this study was designed. Briefly, we planned to evaluate the correlation between reduction effectivity and pain decrement following balloon kyphoplasty. ♦

Less invasive lumbar spine fusion: a comparison study

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The aim of the prospective study was to examine advantages and disadvantages of less invasive spine fusion in comparison with traditional fusion technique. In the literature there exists no comparison study of less invasive fusion technique with traditional fusion technique. In the prospective comparison study 3 groups were compared: Group I, percutaneous fusion with VIPER technique, group II a less invasive Wiltse approach with long arm pedicle screw titanium MOSS ® Miami, and group III a traditional medial approach to the lumbar spine. In all three groups monosegmental or bisegmental fusions in the lumbar spine were performed. From April 2000 to September 2005 58 patients with osteochondrosis or spondylolisthesis according to Meyerding I or Failed Back Surgery Syndrom were operated. In all cases a anterior fusion with autogenic or allogenic bone graft was performed. The mean age at operation was 48 years (range from 35 to 63). Group I, 16 patients (7 women, 9 men), group II 20 patients (12 women, 8 female), and in group III 22 patients (13 women, 9 men). All patients were operated by one surgeon. For the clinical examination VAS and SF 36 were used. The mean follow up was 26 months (range from 3 months to 48 months). The mean time of operation was in group I 65 minutes (55 to 125); blood loss was in mean 75 ml (10 to 150), skin incision 4.5 cm (4 to 8cm), In group II mean time of operation 110 (95-125), blood loss 250 (150-900), skin incision 6cm (5-9). In group III mean time of operation 75 (50 -120), blood loss 600 (350-900), and skin incision 12 cm (9-15) There was none infection, none neurological complication. In one case we found a misplacement of pedicle screw lateral outside of the pedicle. The preliminary results have shown that percutaneous pedicle screw instrumentation with VIPER is a reliable technique and seems better in monosegmental cases as a traditional open procedure. However more prospective comparison study of a open and minimal percutaneous procedure with long time follow up are necessary. ♦

Minimal invasive surgery in spinal instability caused by cervical osteochondrosis

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Kyphotic spinal deformity plays a crucial role in the development of backbone instability. Most frequently, cervical kyphotic deformity is caused by intervertebral disc degeneration, which inevitably leads to secondary microsubluxation and instability. This suffering is accompanied by both vertebrogenic pain syndrome and neurovascular manifestations and can even lead to myelopathy.

The influence of kyphotic deformity on backbone stability has been studied with the help of the mathematical model of a three-vertebrae complex. The data show that kyphosis increased up to 30 degrees causes 200% growth of the forces shifting the three-vertebrae complex into the spinal canal - which is apparently a chief mechanic reason for the subluxation of Kovach. This is why, pathogenetically, solution for this problem can be found in liquidating the kyphosis by way of restoration of the intervertebral space height. Porous cages used in combination with the minimal invasive approach are a simple solution way to deal with the problem.

Surgery was done to 10 patients suffering from backbone instability, brought about by kyphotic deformation caused by intervertebral disc degeneration. The minimally invasive approach (up to 3 centimeters) in combination with endoscopic assistance allowed us to reduce the hospital stay time to 5-7 days. The cage size was calculated for complete elimination of kyphosis. The height of the cage was determined as the average height of the disc situated between the upper and the lower vertebrae. 2-year's clinical observations show that 9 out of 10 operated patients have not had any neurological manifestations since they underwent surgery. Our tentative conclusions, therefore, are as follows:

1. Kyphotic spinal deformity plays a crucial role in the development of cervical backbone instability because the horizontal displacement forces may cause secondary subluxations of the vertebra. The greater is the angle of the kyphosis, the greater are the displacement forces.
2. The problem of instability with kyphotic deformities caused by intervertebral degeneration can be efficiently tackled by way of restoring the geometry of the disc thus approaching its natural parameters. This can be achieved with the help of porous cages.
3. The use of minimally invasive techniques in combination with endoscopic assistance allows to minimize the patient's stay in hospital. ◆

Minimal invasive transforaminal technique for spondylodesis in deg. lumbar instabilities

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The initial degenerative changes in the disc, with a reduction of the disc's water-binding capacity and hence a decrease in its ability to act as a buffer, lead to a loss in intervertebral height with decrease in the neuroforaminal width and compression of the small vertebral joints with resulting arthrosis. Finally, compaction of the segment occurs, with a loss of mobility and extremely reduced stress absorption.

This biological aging process is not initially associated with much pain, but in each phase it may lead to serious and long-lasting problems requiring treatment. In the early stages, a disc herniation may occur in isolation, with all the well-known clinical consequences; the treatment of choice here, apart from conservative treatment, is microscopic nucleotomy. However, in later stages, the disc nucleus deteriorates and compaction of the intervertebral segment occurs, which is usually asymmetrical. As a result of this, in addition to the decrease in intervertebral height, there is also a rotation component, and the uneven load on the facets therefore also leads to displacement of the vertebral bodies in both: the sagittal and frontal plane. This results in so-called degenerative spondylolisthesis. L4/5 is the segment most commonly affected, but the process continues, and the segments above therefore become similarly affected. As a result of degenerative spondylolisthesis in several segments, the spine becomes curved, which can affect the entire lumbar region and is referred to as degenerative lumbar scoliosis. As can be expected, in addition to the curve, changes also occur that affect the nerves: as a result of facet hypertrophy and slippage with a rotation component, the spinal nerves become compressed or elongated. As patients are usually older than 60 and more likely to be women, problems concerning bone density may occur, and osteopenia causes additional pain.

The clinical symptoms of degenerative lumbar scoliosis are pain in the lumbar region and the typical signs of neurogenic claudication; the distance patients are able to walk is limited, and they suffer ischialgia-like tearing pain, with or without radicular deficits. In addition to neurological and orthopaedic examinations, clinical evaluation also includes standard radiographs of the lumbar spine, whereby functional myelography seems to be mandatory in order to plan surgical treatment. This allows us to determine exactly which nerves are compressed at which level and also documents mobility, which influences the surgical concept. Magnetic Resonance Imaging (MRI) with a myelogram-effect can also provide useful information, but MRI without functional images provides only limited information.

In patients with degenerative scoliosis, decompression of the nerves alone is not likely to be successful, because instability increases as a result of decompression, which leads to increase in the curvature and worsening of symptoms. Decompression combined with restoration of the correct spinal balance in the lumbar region is the best way to achieve good results in the long term. In many cases, open decompression can be avoided by restoring the proper axial alignment.

In the course of preoperative planning, three questions need to be answered:

- Do we need perform corrective surgery using instrumentation?
- Which route should be used for this instrumentation?
- Which approach should be used for surgical correction: anterior, posterior, or a combined approach?

On the basis of the comments made above, the answer to the first question is YES, as spinal balance can only be restored using instrumentation. A three-dimensional corrective procedure should be carried out to create the necessary conditions for fusion. The answers to the other questions vary from patient to patient, although we aim to achieve as much fusion as necessary, but as little as possible. The way fusion is achieved certainly depends to some extent on the surgeon's personal preference, whereby a ventrodorsal or combined ventro-dorso-ventral approach used to be regarded as the method of choice. However, new implants and techniques have been developed that allow almost all surgical steps to be performed from posterior. We are familiar with three techniques to stabilize the intervertebral segment:

- Posterior Lumbar Interbody Fusion (PLIF), in which an cage implant is inserted into the intervertebral segment through the spinal canal, which in this case has to be opened up.
- Transforaminal Lumbar Interbody Fusion (TLIF), in which the implant is inserted through the foramen without the need to open up the spinal canal to any great extent.
- Anterior Lumbar Interbody Fusion (ALIF), in which the implant is inserted using anterior approach.

In our department, we have now begun to favor a combined TLIF and PLIF approach, as this allows us to perform the procedure using a posterior approach only and the spinal canal is only decompressed where necessary in the compressed regions; a PLIF technique is used at these points and a transforaminal approach elsewhere, thus obviating the need for decompression over large sections of the spinal canal.

The steps required to achieve adequate correction are as follows:

-The first step involves segmental distraction in the frontal plane in order to compensate for the curve in this axis. This can be obtained by using an intervertebral implant on the side that the vertebral interspace has collapsed.

-Derotation, which is performed using an inserted pedicle screw with the rod bent forward, subsequently rotating the axis in the sagittal plane.

Modern implants and materials have now been developed that allow us to obtain good primary stability while at the same time creating the necessary conditions for the segments to fuse. There are now a large number of pedicle screw/rod systems on the market, which allow stabilization over both short and long sections of the spine. A whole range of intervertebral implants have been created in recent years, most of which can be inserted using PLIF or TLIF techniques. We make a basic distinction between cylindrical implants, which are screwed into the vertebral interspace, and square ones, which are designed to support the intervertebral segment after insertion until subsequent fusion occurs. However, experience with cylindrical implants has shown that the area of contact between the implant and the dorsal plate or the vertebral body is small, and the capacity for fusion thus appears to be limited here. In addition, as a result of screwing the implant into the vertebral endplates, these plates are partially destroyed, and in some cases the segment has been observed to compact into the vertebral body, which led to loss of correction.

In our Spine Center, we therefore prefer square implants, which are press-fitted into the vertebral-interspace and which, due to their PLASMAPORE coating, lead to bone induction and growth around the implant, thus ensuring good integration of the implant. A further advantage of square implants is that they are thin and can therefore easily be inserted through a small transforaminal approach. As a result of the Plasmapore coating and the special design of the surface, there is an effective surface enlargement of 1:16,2 – which provides a very large contact area between the bone and the implant.

We have been using the transforaminal approach for 6 years now, an approach recently favored by Harms, among others. However, we modified this approach and adapted it to suit the requirements associated with the implant. The transforaminal approach can be performed both via a paraspinous approach according to Wiltse or via a classical medial approach. The Wiltse approach is chosen if we want to avoid opening the spinal canal. This approach also has the advantage of sparing the paravertebral muscles and their blood supply; in addition, incisions are small, which leads to better cosmetic results and quicker mobilization of the patient. The pedicle screws serve as important landmarks; after they have been placed, the cranial part of the facet concerned is removed using a small chisel or drill. The facet capsule is initially left in place. The surgeon can then proceed further ventrally using a punch and a ball-reamer and can perform decompression of the nerve exit located here from the outside inward. Complete removal of the facet is not necessary. Care must be taken not to destroy the pedicle lying beneath it in order to maintain screw stability. The joint capsule is then opened and the nerves exposed. There are usually small congested veins here, which can be coagulated using bipolar forceps and then cut. The disc is usually very well exposed, and the annulus is typically incised. Distraction can be performed using both the pedicle screw and the intervertebral distractor in order to restore balance in the frontal axis and at the same time to allow the segment to be prepared for insertion of the implant. If the segment has collapsed asymmetrically, we usually opt for unilateral implantation of the spacer in order to thus correct the curve, as studies by Bronsard and Tropiano have shown that, due to Plasmapore induction, stable spondylodesis of the entire intervertebral segment still occurs even after unilateral cage insertion. In patients with spondylolisthesis in one segment, however, we insert the implants bilaterally.

After correcting the frontal axis, the rod is then adjusted to the curvature and put on the pedicle screws. Derotation is then performed, which is usually easy as a result of the release already carried out.

We studied 204 patients who received this surgical treatment during the past 6 years. Of these, 68 were men and 136 women. The mean age of the patients was 64,3 years, the oldest was 91, the youngest 47 years.

The following segments were fused:

One to two segments in 71 patients, three to four in 119 patients, five segments in 23 patients and 6 segments in one case. The approach was chosen as a TLIF in 92 cases, as PLIF in 73 cases, as ALIF in 28 cases and combined in 11 patients. According to a PROLO-Score and VAS, a total of 84 % of the patients was satisfied with operation. Leg pain had eased in 92%, but back pain had decreased to bearable pain in only 61% of the cases. The following complications were observed:

- Neurological complications in 12 cases (a spinal nerve lesion as a result of over-distraction with transient palsies)
- Spacer-dislocation in 5 cases (4 posterior and 1 anterior)
- Nonunion in 8 patients
- Pulmonary embolism (this patient died)
- Intraoperative stroke in one case (infarction of the basilar artery).

In summary, on the basis of our experience and the results found in a review of the literature, most patients were able to walk further and had less pain in their legs as a result of sufficient decompression. The lower back pain should no doubt be seen in the context of lumbar instability, but is also in many ways connected with the soft tissues and muscles and the neighboring joints, particularly the iliosacral joint, but also the hip joints. Many of the older patients have considerable insufficiencies as well as arthrosis of the aforementioned structures, which also leads to persistent postoperative pain.

Osteoporosis should also be considered as an important factor in this context, particularly since the majority of patients are postmenopausal women. However, marked osteoporosis should also be considered a contraindication to cage insertion.

We hope that in the future surgeons will be offered courses and the relevant training more frequently to encourage intense debate on planning operative procedures and postoperative care. In view of the fact that patients are becoming older, the number of surgeries is likely to increase in the near future. It is thus particularly important to develop surgical concepts that are as standardized as possible. ◆

B-Twin, an endoscopic rescue for difficult cases

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Some collapsed discs cause severe low back pain, in many cases associated with sciatica secondary to foraminal stenosis. This stenosis causes leg irradiated pain in one side or in both sides. Endoscopic surgery done by transforaminal approach helps against foraminal stenosis doing a laser and burr foraminoplasty. Unfortunately this is not enough for the associated low back pain, probably due to the collapse of the posterior articular processes. Expansion of the collapsed disc means a B-Twin expandable implant helps to heal the chronic low back pain in a simple way. Through the posterolateral approach, the implant can be pushed and expanded under endoscopic control. No other incisions are necessary and it doesn't require general anesthesia, as a light sedation is sufficient. The author shows some cases as an example of this rescue technique. ◆

Minimal access fusion with X-tube

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Between May 2004 and January 2006 we have used the X-tube [38 patients] and Quadrant [12 patients] minimal access systems on 50 consecutive patients when performing a one or two level posterior instrumented lumbar fusion +/- decompression. The operations have been performed for the following conditions: lytic spondylolisthesis 9 cases; degenerative spondylolisthesis 24 cases [7 previously treated by decompression]; post-decompression/discectomy 10 cases; degenerative motion segment 7 cases. The clinical problems were Low Back Pain and Sciatica in 40 patients, spinal claudication in 4 patients and mechanical Low Back Pain only

in 6. 17 of the patients had previously undergone a total of 27 previous operations at the affected levels, all decompressive except for one non-instrumented fusion.

The age range of the patients lay between 18 – 85, with a mean of 58. The operations performed were 26 TLIF's at a single level, 5 TLIF's at two levels, 17 single level pedicle screw fusions [PSF], one two level PSF and one hybrid [TLIF at L4/5 and PSF at L5/S1].

The mean operating time was 148 minutes for a PSF, 172 minutes for a TLIF, rising to 225 minutes for a 2 level TLIF. The mean blood loss for a TLIF was 341 mls for a single and 860 mls for a 2 level fusion, compared to 556 mls for a single level PSF.

The mean post-operative stay for a single level TLIF was 5.8 days, for a 2 level TLIF was 6.3 days, and for a single level PSF was 6.6 days. This compares favourably with historical controls by the same surgeon. We are as yet unable to comment on the fusion rate. The main complications were as follows : dural tears in 5 patients, one requiring a revision operation to repair the tear. Malpositioned screws in 4 cases. 2 were symptomatic and were revised. Residual or recurrent radicular pain in 8 patients, with 4 settling spontaneously and 3 requiring [successful] revision surgery due to cage migration in one case, a fracture subluxation in another, and ossification within the neuroforamen in the third. A further patient has persistent neuropathic pain.

There were no haematomas, delayed wound healing or superficial or deep infections.

The most notable post-operative feature is the lack of local pain associated with the surgical exposure, with 22% of patients taking no analgesia by the time of discharge from hospital, and 46% taking only simple Paracetamol as required. In the majority we have avoided harvesting graft from the pelvis. Of the 14 patients who have returned to work so far, the mean is at 8 weeks.

We believe the minimal access compromises the ability to satisfactorily prepare a posterior bone graft bed, particularly if a wide decompression is required, and we prefer to use a TLIF approach in these circumstances.



Long term follow up after OP-1 fusion : 4-6 years

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INTRODUCTION: This case series review the longer term safety, efficacy and durability of the OP-1 (Osteogenic Protein-1) fusion in a group of eight patients having a posterolateral fusion combined with decompression laminectomy for neurogenic claudication due to lumbar stenosis with degenerative spondylolisthesis.

METHOD: Eight patients, all female aged between 56 and 79 years at enrolment into the pilot study from 1999 to 2002. Carboxymethylcellulose (CMC) Putty with OP-1 was used on one side and autogenous iliac crest bone on the other to perform a posterolateral fusion at a single level. Each patient was their own control. Patients were reviewed clinically, with SF-36, Oswestry Disability Index and imaging with CT scan. The patients are now aged 63 to 86 years. All patients continued with excellent relief of neurogenic leg pain, living independently. The exuberant bone growth seen in one case did not increase. No case had encroachment of the spinal canal in the area of fusion.

CONCLUSION: OP-1 is a safe and effective long term agent for producing posterolateral fusion in the lumbar spine. ◆

Anterior and posterior restabilization....Where are we ?

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How much motion is necessary? A biomechanical study of combined anterior and posterior motion preservation techniques.

BACKGROUND: Fusion is thought to be the gold standard for stabilization of symptomatic degenerative disk disease and vertical instability. Concerns over adjacent level degeneration due to increased motion and altered stress have suggested the need for dynamic stabilization to offer differing degrees of freedom and modes of constraint to more normalize spinal alignment, motion, and forces. Motion preservation and restabilization using

anterior nucleus stabilization, posterior dynamic stabilization, and combination 360 restabilization will be assessed biomechanically in a motion preservation cadaveric model.

The Satellite™ intradiskal stabilization sphere is an elliptical implant made of cobalt chrome used to provide stabilization and hold end plates in alignment while they heal and restabilize the motion segment. CD horizon peek rods provide immobilization and stabilization of spinal segments and provides a stiffness close to that of cancellous bone with a fatigue life over twice that of titanium with radiolucency to assess healing (radiolucent). The purpose of this study is to assess anterior column restabilization alone with Satellite™, in conjunction with peek rods posteriorly creating 360 restabilization, and posterior peek rods alone in the intact and surgically destabilized cadaveric model.

METHODS: The motion of L1, L2, L3, L4, and L5 vertebrae relative to the sacrum were measured (Optotrak, Northern Digital, Waterloo, Ontario). A six component load cell measures the applied compressive preload and moment in this biomechanical study. Adjacent level pressures were measured with pressure transducers in the L3-4 and L5-S1 disk space. Adjacent level facet loads were measured with the lamina of L3 instrumented with strain gage rosettes in the vicinity of each facet in order to monitor load sharing through the anterior and posterior columns. In each condition, the specimens will be subject to the following loads: 1. Flexion/extension moments with compression preloads of 0 newtons and 450 newtons, via follower loads as prescribed by Pat Wardhan. 2. Lateral bending with compressive preloads of 0 newtons and axial rotation with compression preloads of 0 newtons.

RESULTS: The cadaveric specimen of a 50-year-old female with a healthy lumbar spine was analyzed in flexion and extension. Partial discectomy resulted in a small amount of additional range of motion. The Satellite™ alone shows range of motion similar to the destabilized state. Addition of peek rods result in less than 2 degrees of range of motion. Significant reduction in motion is noted when posterior instrumentation is added.

In lateral bending, partial discectomy resulted in a small amount of additional range of motion. The Satellite™ nucleus prosthesis alone shows range of motion near the intact state. Addition of peek rods resulted in a stiff spinal segment with very little motion. The Satellite™ peek combo resulted in more range of motion than the Satellite™ titanium rod at the instrumented level.

Partial discectomy resulted in significantly larger range of motion and axial rotation. The Satellite™ alone shows range of motion near the intact state. Addition of peek rods resulted in a stiffer segment.

Load versus displacement showed the quality of Satellite™ motion to be similar to the intact disk. Satellite™ takes more energy to move over range of motion and the addition of posterior instrumentation results in much stiffer segments compared to the vertical axis of the load displacement curve.

CONCLUSION: Flexion/extension, axial rotation and lateral bending range of motion results after partial discectomy are similar to the intact spine using the Satellite™ nucleus stabilization prosthesis. The addition of peek rods significantly stiffen the spinal segment compared to the intact spine. Peek rods were slightly less stiff than a 5/5 titanium rod, however provided stiffness and diminished range of motion compared to testing of the satellite along specimen. The addition of posterior stabilization rods may provide too much stability to a nucleus stabilization prosthesis. The addition of posterior stabilization rods with an anterior column stabilization nucleus device has to be questioned unless significant posterior load sharing is required. ♦

Dynamic neutralization system (DYNESYS) : experience /actual concepts

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In a prospective multicenter study, patients with a primary diagnosis of symptomatic lumbar spinal stenosis with instability underwent posterior dynamic stabilization with the DYNESYS spinal system (Zimmer GmbH) and were followed for 2 – 10 years.

The purpose of this study was to assess the performance of DYNESYS (Dynamic Stabilization System for the Spine) in alleviating symptomatic lumbar spinal stenosis and instability through radiological and patient outcome evaluation and to compare the findings with results reported for other treatment methods.

115 patients with a mean age of 63 (31-87) years were operated by three surgeons. 79 patients (68.7%) had a single level procedure, 36 patients (31.3%) were treated on multiple segments. Additional to the dynamic stabilization a decompression was performed in 93 % of the patients.

Some early complications (n=4, 1 dural tear, 1 seroma, 1 early infection, and 1 scar neuroma) resolved without reoperation. There were 2 reoperations at the index vertebral levels that have been instrumented with

DYNESYS in the original procedure, representing 1.7% of patients. Additional procedures at adjacent or other non-index levels were eventually performed in 12.2% of patients. Oswestry disability index as well as visual analog scale (VAS) for leg and back pain improved significantly. 88.4 % of patients would repeat the surgery. 15 out of 446 totally implanted screws (3.4%) in 10 patients (8.7%) evidenced some radiolucency during radiological follow up.

We conclude that dynamic stabilization with DYNESYS combined with appropriate decompression can achieve excellent outcomes in the treatment of spinal stenosis combined with instability. Complication and reoperation rates are comparable to other treatment methods. ◆

Dynesys stabilization in degenerative lumbar dysstability – over 4 years follow-up

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In spinal stenosis with degenerative spondylolisthesis, decompression and fusion is widely recommended. However, the main drawback of fusion remains pain at the bone donor site. A novel dynamic transpedicular system (Dynesys™) was introduced to stabilize the spine without adding bone graft for fusion. Two years results reported earlier were excellent.

Objective: To test whether dynamic stabilization in situ can maintain enough stability to prevent progression of spondylolisthesis in long term follow-up.

Methods: 26 consecutive patients (mean age 71 years) with lumbar spinal stenosis and degenerative spondylolisthesis underwent interlaminar decompression and stabilization with Dynesys™. Patients were re-evaluated clinically and with plain and functional radiographs after a minimum follow-up time of 4 years.

Results: A total of 21 patients could be evaluated (81%). Pain on VAS as well as walking distance improved significantly ($p < 0.01$) at 2 years and remained unchanged at 4 years follow-up. Radiographically spondylolisthesis did not progress and the motion segments remained stable. Implant failure in terms of screw-loosening (3 patients) or breakage (1 patient) seen after 2 years did not increase. At 4 years follow-up 7 out of the 21 patients (35%) showed some degeneration at an adjacent level. Overall, patient satisfaction remained high as 95% would undergo the same procedure again.

Conclusions: In elderly patients with spinal stenosis and degenerative spondylolisthesis, decompression and dynamic stabilization leads to sustained excellent clinical and radiological results. It maintains enough stability to prevent progression of spondylolisthesis. Since no bone grafting is necessary, donor site morbidity is eliminated. The degenerative disease however is progressive and degeneration at adjacent motion segments remains a problem. ◆

Perspectives of further minimizing approaches for Dynesys procedures

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The presentation gives a practical guideline for up-to-date Dynesys application and future extensions of the system which is currently the only pedicle screw based dynamic system with reasonably long enough follow-up for comparison with fusion. General aim should be to further minimize collateral damage and comorbidity from pedicle screw based procedures.

For years, the classical midline approach with wide detachment of paraspinal muscles has been the standard gateway to the dynamic stabilization of the spine. Now that the Dynesys L.I.S. armament is available the trend has gone to posterolateral muscle splitting incisions between multifidus and longissimus muscle. This was made possible by the extracorporeal tensioning instruments developed for that purpose.

A true Dynesys M.I.S. is now feasible by combining the L.I.S. instruments with commercially available spreaders mounted to the bedrail, thus allowing for a 24 mm insertion portal for 1-segment instrumentation which will be demonstrated in the presentation.

Since in our department the first semiautomatic (computer-guided) insertion of Dynesys pedicle screws worldwide has been recently carried out with good success the technique of this procedure will also be outlined.

Some caveats, however, have to be kept in mind: percutaneous insertion over stab incisions is possible but does not reach its possible potential since the spacers can only be attached under visual control. One perspective could be cannulated Dynesys screws plus dedicated measuring gauges and cord guides to overcome this limitation. Wide iliac crest, steep lumbosacral angle and obesity can render a patient not suitable for such an M.I.S. procedure.

The possible skin incisions in case of combination of Dynesys with spinal decompression are reflected also under cosmetic and functional aspects. Sometimes the necessity for posterolateral placement of the screws which is very safe in respect of the spinal canal is seen as a disadvantage in concomitant spinal stenosis. This limit can be overcome by different strategies which are described with their pros and cons in detail. More than 10 years after its introduction Dynesys is a reliable, yet still evolving system with a lot of potential for future applications. ◆

Flex./ex.-kinematics in posterior dynamic lumbar stabilization : in vitro/vivo/clinical

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The main objectives of dynamic stabilization are to restore disc height, normal kinematics and to minimize stress on the adjacent segment by maintaining the segmental mobility. This contribution compares parameters that influence the mobility before and after Dynesys® implantation from in vitro and in vivo data and to investigate how they reflect the long term situation in patients. Several in vitro studies applied different loading regimens to compare the range of motion (ROM) using DYNESYS® on the intact, the unstable and the fused spine [1,2,4]. A baboon model was used to measure kinematics immediately, as well as 6 and 12 months after implantation [3]. In an in vivo study, Kirschner-wires were implanted into the spinous processes of DYNESYS® patients to measure motion pre- and 6 months post-operatively. Furthermore, the ROM of 96 patients was analyzed by means of dynamic x-rays after a mean follow up time of 44 months. In vitro, DYNESYS® restored motion after destabilization to an intact level in extension and reduced ROM in flexion [2]. It was also noted that increased spacer length increased ROM [4]. In the animal model, motion increased after 6 months compared to the acute state [3] and remained constant between 6 and 12 months. A stabilization effect remained when the tests were performed after removal of DYNESYS®. Kirschner-wire measurements showed unchanged, decreased and increased ROM in different patients. The ROM measured by dynamic x-rays was unchanged in 48% of segments, decreased in 44% and increased in 6 % compared to the preoperative condition. In vitro studies suggest that in extension, DYNESYS® allows for a ROM near intact, while it stabilizes in flexion. The mobility of the segment is sensitive to the length of the device.

The differences between in vivo and in vitro results may suggest that in vitro testing represents the immediate postoperative situation and/or the stiffness of the device changes predictably within the first months. Dynamic x-rays demonstrated that DYNESYS® can either maintain the preoperative ROM over a long period of time or effectively stabilize a segment.

1. Freudiger 1999 ; 2. Schmoelz 2003; 3. Cunningham 2004; 4. Niosi 2004. ◆

Positional MRI findings: dynesys stabilization versus interspinous distraction device

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Introduction: Symptoms of neurogenic intermittent claudication in spinal stenosis are explained by the narrowing of the spinal canal in the extended (upright) position and widening in the sitting (flexed) position. The XStop inter-spinous process distraction device is a new product that is designed to hold the affected segments in a flexed posture. It can be inserted under local anaesthetic as a day case. This prospective study looks at the changes in the lumbar spine in a variety of postures from pre- to post insertion.

Methods: Using a positional magnetic resonance imaging (pMRI) scanner, patients were scanned before and six months after the insertion of the device. Images were taken in sitting flexed and extended, and standing positions. The change in the total range of movement of the lumbar spine and in the individual operated segments was measured along with changes in the surface areas of the exit foramen, the dural sac, and the disc height.

Results : 26 patients with 37 levels distracted have been scanned and measured. The cross sectional area of the dural sac at the level of the stenosis has increased from a mean of 86.8 mm² to 101.4 mm² in the standing position (p=0.006) There were no statistically significant changes in the range of movement of the whole lumbar spine, or at levels adjacent to the device.

Discussion : This study demonstrates that the X Stop device increases the cross sectional surface area of the spinal canal and nerve root exit foramina at the stenosed level, without causing significant changes in the posture of the lumbar spine. ♦

Dynamic restabilization of degenerative lumbar instability : updated experiences

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Introduction: Between competing posterior (PLIF) and anterior (ALIF) fusion techniques and non-fusion techniques (disc replacement) in lumbar spine disorders, semi rigid stabilization techniques became more and more importance.

Material and Method : The Isolock^R device contains top-loading pedicular screws, which are connected with special semi rigid plates. These plates are laid between eccentric hemispheric washers, which guarantees another semi rigid element. Between March 2003 and November 2005 we have been used this device in 89 patients (41 males, 46 % and 43 females, 54 %) The average age was 47.7 years (ranged from 26 to 74 years). Most patients ranged in the age-group 51-60 years, but 15 patients were getting between 31 and 40 years of age. Mostly we stabilized both segments L4 and L5 (54 patients), and segment L5 only (26 patients). Our patients can be categorized into 4 indicative groups: 1. lytic spondylolisthesis with intact disc, 2. degenerative deformities and spondylolisthesis, 3. disc degeneration combined with instability of the adjacent segment, 4. Instability of the adjacent segment after previous surgery. In 30 cases PLIF technique (PROSPACE) were added in 1 segment, in 8 cases TLIF (TRAVIOS).

All patients are prospectively followed up. The results are impacted by the social and economical status of the patients. Only 25 patients of 53 who should back to work did return to work during the first year after surgery.

The results of a group of 19 patients, who underwent surgery two years ago, are presented. Ten patients sent back the questionnaire with evaluation of Proló score, Oswestry Low Back Disability Score and Visual Analogue Score. All patients improved I VAS, which was divided in pain level in rest and during activities (table).

Two-year results after dynamic restabilization in low-back disorders with IsoLock				
Patient	Proló	Oswestry	VAS in rest	VAS with activities
945/03	9	10	<10	<10
1500/03	4	44	<25	<50
1586/03	4	36	<25	<25
1952/03	9	10	0	<25
2081/03	4	42	<25	<50
2934/03	6	30	<10	<25
3335/03	10	2	<10	<10
4707/03	4	30	<25	<50
6404/03	4	44	<50	<75
6984/03	6	22	<25	<50

Complications: One deep infection occurred, which healed after irritation therapy without metal removal. In two patients with PLIF procedure a dura leak occurred. Root irritation after PLIF procedure we noted in 3 patients. Conclusion: To obtain objective results after lumbar spine surgery is not very auspiciously. Pain scores are individually affected and related to the patient's social status. Fluoroscopical results and pain descent in our semi rigid stabilized patients seem very encouraging. ◆

DIAM : principle and clinical experience

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BACKGROUND: The DIAM Spinal Stabilization System is an interspinous process device designed to provide dynamic stabilization to the lumbar spine. Given its unique mechanical properties and combination of materials, questions are still posed regarding the long term safety and efficacy of the device, despite many years of good clinical results.

PURPOSE: The purpose of this report is to demonstrate the long term safety and efficacy of the DIAM, as well as characterize the device's unique physical properties and explain its effect on the biomechanics of the treated spine.

METHODS: A variety of static and dynamic mechanical tests were conducted to evaluate the limits of the device, as well as biomechanical tests on human cadaveric lumbar spines. During fatigue tests, wear debris was collected and analyzed. Additionally, substantial biocompatibility testing was conducted for ISO 10993 approval, and a 12 month animal study was performed.

RESULTS: The DIAM satisfied the acceptance criteria for every mode of testing. The device withstood 2199 N and 480 N of static and 10M cycle runout fatigue compression before imminent spinous process fixture contact, with no sample breakage. The device withstood 565 N and 155 N of static and 10M cycle tensile fatigue before breakage of the cable (during static testing) and the silicone spacer (during fatigue testing). Minimal wear debris was found in the 10M cycle runout fatigue tests specimens, which was approximately 1/500th the amount used in biocompatibility testing. The recorded stiffness of the DIAM was 68 N/mm in compression and 15 N/mm in tension, which was comparable to physiological data from the literature. In biomechanical testing, the device stabilized the treated segment to below intact ROM for flexion-extension, with no change in ROM at the adjacent segments. During animal testing, both the 6 and 12 month sheep showed no signs of reaction to the materials of the device.

CONCLUSION: The DIAM is capable of sustaining a lifetime of physiological loads without losing its function. The materials in the DIAM, both independently and in combination, pose no significant threat of to the body. The unique design of the device, using silicone for its viscoelastic properties and polyester for strength, approximates the stiffness of tissues in the body, and is therefore appropriate for certain pathologies. In

summary, the DIAM, when used properly, should be safe and effective for treating various pathologies of the lumbar spine. ◆

Interspinous locker fixation/ligamentoplasty in stenosis or deg. Spondylolisthesis

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Introduction: Lumbar spinal stenosis is commonly seen in conjunction with degenerative spondylolisthesis and/or instability. Spinal fusion has been the most effective surgical procedure for lumbar spinal stenosis. But performing fusion in the elderly population has its own risks and disadvantages. Interspinous locker fixation (ILF) with ligamentoplasty is a new procedure designed to provide dynamic stabilization to the lumbar spine. The objectives of this study are to describe the surgical technique of ILF and to analyze the short-term clinical and radiological results.

Materials and Methods: Between January 2004 and January 2005, 28 patients underwent ILF with ligamentoplasty. After induction of general anesthesia, a midline skin incision is made over the spinous processes of the stenotic levels. Usually a 4 cm incision is needed for one-level surgery. The fascia is incised on the side of decompression about 1 cm laterally from the midline. The supraspinous ligament is detached from the spinous process with an osteotome. Under microscopic view, the interspinous ligament between adjacent spinous processes is removed, while preserving the spinous processes. Using a high-speed drill, decompressive foraminotomy is performed through the midline window. The entire laminar margins are retained while excising ligamentum flavum with a Kerrison rongeur. An appropriate sized titanium interspinous locker is then inserted into the interspinous space. Both spinous processes are tied with an artificial ligament woven in the form of figure-of-eight around the bases of spinous processes and passing through the hole of the interspinous locker. The wound is closed in layers.

Results: Mean follow-up was 17.1 months (range, 9 to 21 months). There were 15 men and 13 women with a mean age of 62.9 years (range, 41 to 85). A total of 35 levels were surgically treated: L3-4 in 7 patients, L4-5 in 13, L5-S1 in 1, and L3-4-5 in 7. The mean operative time and blood loss per level were 132.7 mins (range, 60-285 mins) and 302 cc (range, 150-750 cc), respectively. After surgery, lumbar lordosis was well preserved. Sagittal rotation angle in flexion was increased from -2.16 to 1.05 degrees, but it was not significant. Relative sagittal rotation angle was significantly decreased from 10.43 to 6.62 degrees ($p = 0.03$). Overall 25 (89.3%) postoperative patients were very satisfied or satisfied. Three cases developed a serous wound discharge, however there was no concomitant laboratory evidence of infection. These patients were managed by needle aspiration and responded well. There was no intraoperative neural injury.

Conclusion: Considering its less invasive and nonfusion nature, ILF seems to be an appropriate method for elderly patients with spinal stenosis with or without low grade degenerative spondylolisthesis. Retaining laminar margins minimizes blood loss and prevents embolic complications commonly seen in the elderly. Longer follow-up study is being continued to evaluate the true benefits of this procedure.

Keywords: Interspinous locker fixation, Spinal stenosis, Elderly patients ◆

Transpedicular elastic stabilization & prevention of junctional path. (Cosmic/Diam)

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We present our experience with "COSMIC" a new posterior dynamic system enables the non-fusion technique for disease of the lumbar spine. The decisive advantages of this system are:

- Dynamic stabilization without fusion
- Monoaxial mobility of the screws
- Maintains function and mobility

The possibility to perform the surgical procedure via mini-invasive approach reduces a surgical trauma and the post-operative pain. We have used this system in high grade discopathy and in grade 1 spondylolisthesis in combination with Optimesh technology (for interbody fusion) and DIAM (to prevent the junctional pathology). ◆

Prodisc lumbar total disc replacement : single center preliminary follow-up result

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There are several different models of artificial lumbar discs implanted in Korea and, of them, the SB Charite and the Prodisc remain in use most frequently.

Object. Symptomatic lumbar degenerative disc disease is a challenging entity to treat. Total disc replacement has numerous potential advantages to provide long-lasting relief to these patients, as well as the avoidance of pseudarthrosis, and the development of junctional degeneration. The purpose of this study was to present the preliminary clinical results following a Prodisc total lumbar disc replacement.

Methods. Twenty-five patients had single or multiple-level implantation of a total lumbar disc replacement. The subjects were 9 men and 16 women, with a mean age of 43 years, ranging from 29 to 53. The mean follow-up duration was 11 months, ranging from 6 months to 20 months. Clinical results were evaluated based on the criteria proposed by Yuan et al. Each patient completed a survey that measured pain (back and leg pain separately) and functional outcomes. The Oswestry Disability Index was also assessed.

Results. Seventeen (77%) of the 22 patients, who had leg pain preoperatively, achieved our definition of successful outcomes. Preoperatively, all patients had significant back pain, while postoperatively 92% of patients (n=25) achieved successful outcomes with regard to their back pain. Finally, functional improvement occurred in 88% of patients (n=25). The mean preoperative ODI was 53.0 ± 10.0 . At postsurgery one month, 6 months, 12 months, and last follow up visit, the mean ODI was decreased to 36.1 ± 11.2 , 28.4 ± 8.2 , 23.2 ± 7.7 , and 21.8 ± 8.7 , respectively. There were significant improvements ($p < 0.001$) in the Oswestry Disability Index. Radiographs did not demonstrate loosening, migration, or mechanical failure in any patient. Five patients had approach-related complications.

Conclusions. The Prodisc lumbar total disc replacement appears to be effective and safe for the treatment of symptomatic degenerative disc disease. The authors believe that longer follow-up of this cohort of patients are needed to determine the availability of total disc replacement in selected patients with symptomatic degenerative disc disease. ◆

Clinical application of lumbar TDR's - do we need centers ?

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The success of the treatment with Total Disc Replacements, including the degree of patient satisfaction postoperatively, depends on different influencing factors. The experience of the surgical team and the equipment of the operation unit are of essential importance. From the clinical point of view, the following aspects are to be considered:

1. The mental attitude of the patient regarding his/her postoperative professional, sportive and general utilizability and aims.
2. The quality of questioning and clinical evaluation as well as the accuracy of x-rays, MRI and discography including their correlation to different relevant findings.
3. The best suited indication for surgery especially in cases which show atypical findings.
4. The knowledge of contraindications versus advanced indications.
5. The ability to carry out the surgery including the dissection of the anterior spine to receive an expanded annulus fibrosus/longitudinal ligament.
6. The skill to prepare the intervertebral space in the matter as it is needed for the special type of prosthesis.
7. The experience to choose the proper size of prosthesis, the optimal angles of components and height of prosthesis.
8. The accuracy with respect to the ideal positioning of TDR within the intervertebral space.
9. The possibility for selective diagnostics and therapeutical methods in cases of postoperative complaints.
10. The experience in revision surgery regarding the above issues.

It is well known that implantations of lumbar TDR's have a learning curve which is more difficult than in most other orthopaedic surgeries. To minimize negative results it seems to be better to establish centers for implantation of lumbar TDR's under consideration of the above stated points amongst others. For this purpose the terminus center for lumbar TDR should be defined according to strict criteria, beginning with the minimal number of surgeries per annum. ◆

Questionnaires for routine use – the „pationnaire“^(tm)

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Construct validation of the "pationnaire"^(tm): a questionnaire to assess symptoms and disabilities of the musculoskeletal system

Introduction: The 'pationnaire' is a questionnaire to assess a person/patient with any disorder of the musculoskeletal system. The questionnaire consists out of four domains, with one page each to report: symptoms, disabilities, treatments and main complaint, socio-ethno-demography, morphometry and self-perception. It is an open questionnaire meaning that all symptoms and disabilities of a person/patient can be assessed and other symptoms included if necessary. For ease of understanding the questionnaire was designed with colors and pictograms. The questions were especially changed to "my symptoms are ..., my disabilities are ...". To improve simple utilisation and quick analysis the VCS (visual circle scale, Poster ECCEO 2005) was used ($r > 0.85$ to VAS, Likert Scale). The aim of this study was to test the construct validity of the 'pationnaire' with personal interviews (the agreement of symptoms and disabilities), and the ability and time to fill it out without help. Persons/patients and methods: The persons/patients were randomly selected by the interviewer. They signed an informed consent approved by the local ethical committee. After a short introduction about the 'pationnaire' and its aims, people filled out one directly without help. The time to completion was measured. The person/patient was then personally interviewed about items within the 'pationnaire' to assess their correlation with their symptoms and disabilities, and uncover any sources of misunderstanding or misinterpretation. At the end of the interview every person/patient was asked for a statement about their understanding, formulations, difficulties with the 'pationnaire', missing questions and general impression. Results: 78 persons/patients (50 women, 28 men) were included. Their average age was 46.3 years (range 12 - 93 years). 97% (76) could fill out the 'pationnaire' without help, 2 needed help and further explanations. Average time for completion was 9.9 min (range 3 - 45 mins) - the longest time being taken by those who needed help. Complete agreement between the questionnaire and the perceived symptoms/disabilities was found in 94% (n=73), it was partial in 3.8% (n=3), and "no agreement" occurred in 2.2% (n=2, persons, both of whom needed support). The understanding was rated very good in 98% and difficult in 2% (both elderly persons >80 years). The formulation 'my symptoms are' was preferred by everybody compared to 'which symptoms do you have'. In general the overall rating was good or very good for all persons, although older people with co-morbidities needed help.. Discussion: The 'pationnaire' accurately documented the symptoms and disabilities present in people with active musculoskeletal disorders; it also revealed the range of symptoms. The agreement between the answers in the questionnaire and the perceived symptoms/disabilities is high. Older people with co-morbidities may need help to fill it out, and this can markedly reduce the rate of misunderstanding and misinterpretation. The 'pationnaire' and the way to perform the interactive patient interview was welcomed by all persons. The chosen formulation was preferred by every person/patient. Conclusion: The 'pationnaire' can be used as an instrument to assess symptoms, disabilities, therapies, main complaint, sociodemography, morphometry and self-perception. Most people (>95%) can fill it out within 15 minutes. The agreement between individual perception and answer on the pationnaire is high. ◆