



Review article

FUSION OF THE LUMBAR SPINE

A consideration of the indications

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Low back pain (LBP) is a common complaint with various studies indicating a point prevalence of from 12% to 33%, a one-year prevalence from 22% to 65%, and lifetime prevalence from 11% to 84%.¹

Most Western adults complaining of LBP do not seek professional treatment, but those with chronic spinal disorders have worse scores for measurement of physical function than those with most other conditions.² Some may be candidates for lumbar spinal fusion. There are different opinions concerning the indications for this procedure, which is reflected in the considerable regional variation.³ Countries with high rates of back surgery also have similar levels of other discretionary procedures such as tonsillectomy and hysterectomy.⁴ In an Australian investigation, the rates of surgery of the lumbar spine varied from 25/100 000 to 92/100 000. In a regression model, only the rate of unemployment correlated negatively with the variation in the rate of lumbar spinal surgery and accounted for 11% of this.⁵ In another study on lumbar disc herniation, outcomes for patients who had been operated on by surgeons in areas with low rates of surgery were better than those in areas with high rates. These latter generally had less severe preoperative symptoms.⁶

We do not know to what extent factors such as genetics, occupation, access to health care, and the opinions of the general population about spinal fusion explain regional variation. The differing opinion of surgeons concerning the indications, however, appears to play an important role and the complexity of this process is high. This review focuses on the most common problems and indications, and does not claim completeness. Particularly, conditions such as tumours, infections, trauma, lumbar Scheuermann's disease, kyphosis, severe lordosis, and degenerative scoliosis are not included.

The indications for fusion

The indications for lumbar spinal fusion are variable and not accurately defined.

The decision-making process involving surgeons and their patients is also poorly understood. The behaviour of the physician and the expectations of the patient have not been systematically studied. In the following paragraphs a personal opinion is given which cannot be based on empirical data.

Patient. There is almost no knowledge about the patient's opinion of lumbar spinal fusion. Why does the patient want to undergo this procedure? Does he perhaps want less care and less risk than surgeons offer? What does the general population think about the procedure and how does this knowledge affect the indications for surgery? In different countries there are different answers to these questions. No firm guidelines have been published in the orthopaedic literature. Recently, Weinstein⁷ has pointed out that patients have a preference for avoiding risk and for non-surgical treatment rather than operation.

Doctor-patient relationship. The legal concept assumes that the doctor informs the patient about his disease, the different options for treatment, with the possible benefits and adverse events, empowering the patient to make the decision himself. The everyday experience is that patients behave differently in this relationship. Many of them simply trust the doctor, do not wish to know anything about adverse events, and hope that a good outcome will occur without their own contribution. Such behaviour may be adequate for a straightforward procedure which may be life-saving, but in more complex circumstances there is some evidence that shared decision-making based on a fully-informed patient, perhaps helped by a video tape, can help to address the patient's requirements.⁷

Doctor. The doctor is the most important influence in decision-making and passes on his knowledge and beliefs to the patient. Carey, Garrett and Jackman⁸ followed 1246 patients with acute LBP: 96 (7.7%) had had continuous symptoms for three months, with unremitting pain for 22 months in 59 (4.7%); 46 underwent various surgical procedures. Patients initially seen by an orthopaedic surgeon were more likely to undergo surgery (5.2%) than those seen in an HMO (1.8%) or by a chiropractor (2.8%) or by a

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primary-care physician (4.4%). The decision to operate may also be influenced by the financial and personal interests of the doctor. Volinn et al⁹ found a nearly 15-fold variation in spinal surgery, which was weakly related to explanatory variables. Those related to the surgeon included: 1) variable diffusion of medical innovations (willingness to apply promising new *versus* well-established methods of treatment); 2) preconceptionalisation (knowledge learned during residency training, later acquired knowledge may be assimilated into a preconceived knowledge base); 3) tolerance of uncertainty (surgeons are inclined towards action and resolving of uncertainty); and 4) reaction to patient expectations (pressures exerted by the patient vary by ethnic group, class and locality).

The goal

The aim of spinal lumbar fusion is not to achieve fusion between two vertebrae but to improve pain, disability, quality of life and the working capacity of the patient or to alter an unfavourable natural course. The patient's main problem is pain and the disability due to it. Most are not threatened by a progressing deformity and the rates of fusion are therefore not an adequate measure of the success of the procedure.

Outcome measures. It is confusing and frustrating to compare the results of studies using different outcome measures. Penta and Fraser¹⁰ followed 125 patients who had had anterior lumbar interbody fusions for a minimum of ten years. Of these, 78% rated themselves as having complete or considerable relief from pain, but only 34% had a good or excellent outcome as judged by a low back outcome score.

Pain. This is best measured by a visual analogue scale for current and habitual pain.^{11,12} A short written explanation to the patient is sufficient; an oral explanation is not necessary.

Disability. Restricted function or "the limitation of a patient's performance compared to that of a fit person of the same age and sex"¹³ is measured by a disability scale. The Roland and Morris scale¹⁴ includes 24 items and an indication of pain. The patient is asked to tick each sentence which describes his present status and the score ranges from 0 (no disability) to 24 (severe disability). It can be completed in five minutes. The Oswestry disability scale which includes ten items¹⁵ is also often used. It offers six answers for each item ranging from 0 to 5. A percentage of the total score divided by the total possible score is calculated. It ranges from 0 (no disability) to 100 (severe disability). The Waddell and Main disability index¹³ is a short nine-item scale requiring answers with high reliability ranging from 0 (no disability) to 9 (severe disability). All these disability scores are condition-specific for LBP. Kopec and Esdaile¹⁶ have compiled a list of more than 40 scales, most of which have been developed for a single study and have not been properly validated. The Roland

and Morris scale has been the most frequently cited back pain scale in the medical literature, followed by the Oswestry questionnaire and the Waddell disability index. It is also validated for the German language.¹⁷

Quality of life. This is most often measured by the SF-36¹⁸⁻²⁰ questionnaire. It contains 36 items and generates a profile of eight dimensional scores (physical functioning, social functioning, role limitations (physical), role limitations (emotional), pain, mental health, vitality, and general health perception) ranging from 0 to 100, in which high scores indicate good health. It can be completed by most patients within ten minutes. The Euroqol²¹ is also increasingly in use. It is a brief two-page questionnaire; the first page contains five items describing health status across five dimensions (mobility, self-care, usual activity, pain/distress and depression/anxiety: EQ-5D) and the second displays a 20 cm visual analogue rating scale on which the respondent marks an assessment of their overall health ranging from 100 (best imaginable health state) to 0 (worst imaginable state) (EQ-VAS).

Work loss. This is the hardest measure of outcome to determine objectively, but it has some limitations. It may be less important to the individual patient and is only applicable to the working population. It addresses only one specific aspect of functional disability and is a dichotomous variable with limited statistical power in comparison with continuous measures. Work loss and return to work are very dependent on non-health-related socio-economic variables such as general economic conditions and the labour market.²²

Outcome scores. These were developed by Greenough and Fraser²³ and the North American Spine Society (NASS).²⁴ The Greenough low back outcome score ranges from 0 (worst) to 75 (best) and includes four items scoring nine points (current pain, employment, domestic chores, sport), four items scoring six points (resting, treatment, analgesia, sex life), and five items scoring three points (sleeping, walking, sitting, travelling, dressing). The NASS outcome instrument can be completed in 20 minutes and includes six subscales: pain and disability (11 items), neurogenic symptoms (6 items), job dissatisfaction (3 items), job exertion (5 items), expectations (6 items), and satisfaction (3 items). The NASS instrument is also validated for the German language.²⁵

Natural course and alternatives to lumbar spinal fusion.

In a prospective study patients who were seeking treatment in a primary-care office for LBP for the first time were followed up. Half who had a self-defined poor outcome at seven weeks also had a poor outcome at one year.²⁶

The efficacy of our commonly used methods of conservative treatment is strongly related to disability. In a prospective trial patients with LBP were invited by advertisement in the press to undergo one of three methods of conservative treatment: physiotherapy, isoinertial training devices, and aerobic exercises. The result was a long-lasting reduction of pain from 6.5 to 5 on a 10 cm visual

analogue scale, and from 8 to 6 on the Roland and Morris disability scale.^{27,28} In patients undergoing lumbar spinal fusion, the Roland and Morris disability score is usually about 16, decreasing to 9 at follow-up at two years.⁸ This illustrates that disability is important in characterising a study population. Most papers on conservative treatment deal with a totally different study population compared with those on lumbar spinal fusion and are therefore difficult to compare.

Lumbar spinal fusion. In a meta-analysis of 47 articles published on lumbar spinal fusion from 1966 to 1991,^{29,30} no randomised trials were found. On average, 68% of patients had a satisfactory outcome after fusion, but the range was wide (16% to 95%). The rate of satisfactory outcome was lower in prospective than in retrospective studies. The most frequently reported problems were pseudarthrosis (14%) and chronic pain at the donor site of the bone graft (9%). Clinical outcome did not differ by diagnosis or fusion technique, but anterior interbody fusions had lower rates of solid arthrodesis. Reoperations had a worse outcome. There is some evidence that discogenic pain may persist after solid posterior fusion^{31,32} and therefore an unfavourable result in a study on posterior fusion for the treatment of discogenic pain should be interpreted with caution. A bad outcome can be related to the wrong indication as well as the choice of the wrong technique.

Complications of fusion are relatively common.^{29,30} In the studies reporting specific complications, an average of 3.7% of patients had deep-vein thrombosis, 2.8% had neurological injury, and 8.7% developed chronic pain at the donor site. Pseudarthrosis averaged 14% overall. Deyo et al³³ studied 27 111 Medicare patients who had had spinal surgery, of whom 5.6% had fusions. The rate of blood transfusion was 5.8 times greater than in surgery without fusion; the six-week mortality was increased 2.0 times and hospital charges were 1.5 times more. Rates of reoperation at four years were not lower for patients who had undergone fusion. The authors concluded that there was an urgent need for a uniform definition of spinal instability and the indications for fusion. In a comparison of 1041 fusions and 5335 other surgical procedures of the lumbar spine, Malter et al³⁴ have shown that lumbar fusion is associated with a higher rate of reoperation (18% v 15%) and of complications (18% in fused v 7% in unfused patients).

Comparison of outcomes. In a prospective cohort study⁸ of 1246 patients with acute back pain, 46 had surgery. The operated patients had more disability initially (Roland score 16 v 11) and at 22 months (9 v 5). The rates of satisfaction with care (57% v 51%) and employment (72% v 79%) were comparable. In another study of 507 patients, 133 were receiving workers' compensation.³⁵ Of the latter, 65 had been treated surgically and 68 non-surgically. The patients treated surgically were more likely to have had preoperative imaging, worse leg pain and decreased physical function than the non-surgically-treated patients. At six months

disability was less in patients treated surgically than in those treated non-surgically. Return to work was also greater (60% v 40%). These studies, however, do not differentiate between different surgical procedures and include many more cases of decompression of a herniated disc than lumbar spinal fusion. It is not known whether the more favourable result of surgical treatment is caused exclusively by decompression of the disc.

Möller and Hedlund³⁶ carried out a prospective, randomised study on lumbar spinal fusion *versus* non-surgical treatment in 111 adults with isthmic spondylolisthesis. The surgical group had a better outcome than the non-surgical group, as assessed by a VAS and a disability index. In the exercise group, the disability rating index did not change at all.

Non-organic predictors of outcome

In chronic LBP, and especially in patients who have been on sick leave for more than a month, resumption of work can be predicted almost exclusively by psychosocial factors, disability, and comorbidity.³⁷ In a recent Swedish study,³⁸ quality of life was found to be the best predictor of return to work in patients with LBP. In another study⁸ a high level of disability and sciatica, defined as radiation of pain to the level of the knee or below, were the most powerful predictors of developing a chronic back problem. Unfortunately, a Roland and Morris disability score of 11 was 86% sensitive, but only 50% specific in predicting a patient's ability to perform activities of daily living at three months, resulting in a positive predictive value of only 13%. Even when a Roland and Morris score of 19 was used as a cut-off point for predicting chronicity, this resulted in a positive predictive value of only 22%.

In severely disabled patients on sick leave most conservative methods of treatment have no proven efficacy. Hansson and coworkers³⁹ investigated 2080 subjects in six countries who had been on sick leave for a minimum of 90 days because of LBP. All had been treated in a relatively uniform way. Almost none of the most frequently practised procedures had a positive effect on recorded health measures or on resumption of work. The only exception was back surgery, which had some beneficial effect on return to work in some of these countries.

Psychological and social predictors of the outcome of operative treatment are better evaluated in disc herniation than in degenerative disc disease. Hasenbring et al⁴⁰ found that persistent pain six months after discectomy was best predicted by a combination of somatic (the degree of disc displacement), psychological (depression, pain-coping strategies, endurance strategies, non-verbal pain behaviour, search for social support) and social parameters (social status, sitting position).

Tandon, Campbell and Ross⁴¹ performed posterior lumbar interbody fusion in 55 patients. They used the Distress and Risk Assessment Method (DRAM) and the Oswestry

disability score before surgery and after a mean follow-up of 2.7 years. The mean Oswestry score was reduced from 51 preoperatively to 39 at follow-up. In the DRAM groups 'normal' and 'at risk' disability was reduced from 48 to 37 and 'distressed depressive' and 'distressed somatic' from 56 to 42. There was a strong association between psychological distress and Oswestry disability. There is no clear opinion as to how to treat a patient with a marked organic as well as a psychological disorder. The strong relationship between both, and the possibility that psychosocial distress can also be ameliorated by organic treatment as in the study of Tandon et al,⁴¹ suggests that both organic and psychological disorders should be treated independently. The sequence of treatment will depend on the underlying condition.

Psychosocial comorbidity. The intention of lumbar spinal fusion is to treat an organic disease not a psychological or social problem. Such problems should be clearly defined before spinal fusion is undertaken since they are strongly related to disability and outcome. Disability is associated with coping strategies, depression and belief in avoidance of fear.^{28,40} In herniation of a lumbar disc it was shown that psychosocial and work-related factors played a much more important role than morphology, as indicated by the MRI findings, in predicting outcome.⁴²

Childhood psychological trauma is reported to be associated with a worse outcome in spinal fusion. Physical abuse, sexual abuse, alcohol or drug abuse in a primary care-giver, abandonment (not uncomplicated divorce) and emotional neglect with abuse were identified. In a retrospective study of 86 patients, those with poor surgical outcome had an incidence of such trauma of 75%.⁴³

Occupation. Several studies showed that LBP is strongly associated with occupation. Machine driving with whole-body vibration⁴⁴ and prolonged sitting were notable factors. The outcome of lumbar fusion is worse in those receiving workers' compensation. Franklin et al⁴⁵ carried out a population-based study on 388 such patients; 68% reported that back pain was worse and 23% required further lumbar spinal surgery two years after fusion.

Short screening tools

Pain drawings. These can demonstrate radicular pain but they are not suitable as a screening method to detect psychosocial distress.

DRAM (Distress and Risk Assessment Method). This was developed by Main et al⁴⁶ and is based on the Modified Somatic Perception Questionnaire (22 items) and the Modified Zung Depression Index (23 items). Threshold values of both questionnaires are used to define four types of patient: normal, at risk, distressed depressive and distressed somatic. The method is not time-consuming and can be applied by an orthopaedic surgeon.

Behavioural responses to examination. These are often recognised by orthopaedic surgeons. Signs like overreaction or a better performance of the straight-leg raising test when the patient is distracted are often overinterpreted. The

non-organic signs are not a test of credibility or faking.⁴⁷ Waddell et al⁴⁸ developed a standardised assessment of inappropriate non-organic signs, but their interpretation is difficult. Multiple signs suggest that the patient does not have just a physical problem, but that psychological factors also need to be considered.⁴⁹

Organic indications, general considerations

The indications for lumbar spinal fusion should be based on an organic condition. In clinical practice there are sometimes different methods of verifying a particular condition. It is helpful therefore to consider which conditions can be helped by lumbar spinal fusion and how their presence be confirmed.

Which conditions can be altered by lumbar spinal fusion? A recent study has shown that positive discographic pain was found in 50% of discs with a high-intensity zone (HIZ) as an MRI sign of a tear of the annulus. In patients with abnormal testing and/or chronic pain, however, 100% of discs with an HIZ were positive on discography.⁵⁰ A tear of the annulus is a particular condition, and we shall therefore focus on the question as to whether lumbar fusion for the treatment of such a tear has a desirable outcome. This is only valid under the premise that an organic painful condition can be treated efficiently by lumbar spinal fusion. This statement is too general to be used as a premise. On the other hand, the argument is valid

in the opposite direction. Many studies have compared a series of individuals with and without LBP and tried to demonstrate that a particular condition causes pain or is not likely to be painful. A condition occurring with the same frequency in patients with and without pain is likely not to be the cause of pain, and should therefore not be treated by fusion. Disability seems to play a role in the assessment by most surgeons, as preoperative disability in patients treated operatively is much greater than in those treated conservatively.⁸

These questions can best be answered by prospective, randomised trials evaluating whether lumbar spinal fusion compares favourably with conservative treatment or surgical treatment without fusion in a defined particular condition and with regard to a defined outcome measure.

Which diagnostic method is the best to find a particular condition? There are many studies on the accuracy and reliability of diagnostic methods and on confounding variables which influence the results of a diagnostic test. The diagnostic method should be reliable so that several repetitions will give the same result. Much more important, however, is the accuracy, that is the capability of the method to find the real condition. Investigations on accuracy are much more difficult to perform than those on repeatability, and can often only be determined by comparison with a much more accurate method. The diagnostic method should be as least invasive and expensive as possible.

Diagnostic methods are used to find or define a particular condition (diagnosis, severity), to determine whether this condition is painful or relevant to the patient's symptoms (e.g., by provocative discography) and as an outcome measure.

Table I. Successful outcome as estimated by the patient

	Number	Successful outcomes (%)
Painful degenerative disc disease	89	56
Internal disc disruption	8	50
Pseudarthrosis	17	82
Spondylolisthesis	15	80
Stenosis	4	50

Indications

Slosar et al⁵¹ found a strong correlation between diagnosis and outcome (Table I). In this study, there were no statistical differences in outcome between primary or revision procedures, and between workers' compensation and non-workers' compensation groups. Remarkably, 'instability' did not occur in the list of indications.

Disc degeneration

The disc is a source of pain. Even pain referred distally below the knee can originate from the disc. In a study of 33 patients with LBP a heating coil was placed within the disc. When the coil was heated, 66% of the patients had an exact reproduction of their presenting symptoms. Since normal temperatures were recorded adjacent to the disc, it was assumed that the provoked pain was produced by stimulation of annular nociceptors.⁵²

Degeneration of the disc is assumed to cause discogenic pain. There is a sequence in degeneration of the disc which is described in various grading systems. The most important step in defining a clinically relevant lesion is the occurrence of a radiating annular tear. These were first described by Schmorl and Junghanns, and investigated in more detail by an Australian research group.⁵³ They can be classified as peripheral lesions, circumferential tears and radiating clefts. Experiments on sheep showed that a stab wound produced in order to simulate a peripheral tear lesion does not heal, but slowly develops to a radiating cleft.⁵⁴ Degenerated discs with a radiating cleft behave differently. Axial rotation is considerably increased.^{55,56} As

soon as the cleft has reached the surface of the annulus, the height of the disc decreases and flexion/extension and sidebending are reduced. Signs of tears of the annulus as seen on MRI such as the HIZ correlate with provoked discographic pain. Nevertheless, not all discs with a radiating tear are painful.

Radiography and CT. These are not always indicative of disc degeneration. Degenerative changes are often found in radiographs⁵⁷ and CT scans⁵⁸ individuals who are free of symptoms. CT is not able to elucidate disc abnormality adequately.

MRI. This corresponds well to the underlying pathology. Unenhanced T2-weighted MRI is usually sufficient. Gadolinium contrast-enhanced examination may give useful additional information for the differentiation of formation of a scar and disc herniation.⁵⁹ In MRI, the Thompson grading of disc degeneration⁶⁰ can be delineated reproducibly, but special coils are necessary. There is currently no technique which has enough quality to categorise disc degeneration other than MRI.⁵⁵ In conventional MRI, the first sign of degeneration is inhomogeneity of the intranuclear cleft followed by bulging of the disc. Late signs are decreased signal intensity and reduced disc height. In a Finnish study of 151 men aged from 40 to 45 years in whom MRI was performed twice with a four-year interval, a clear sequence of these signs was shown.⁶¹

Boden et al⁶² have shown that degenerative changes in the disc are common in normal individuals (Table II).

Jensen et al⁶³ also found in their MRI study of 98 asymptomatic individuals and 27 patients with back pain that there was a high prevalence of bulges (52%) and protrusions (27%) in asymptomatic subjects. Only 36% of the asymptomatic individuals in the age range of 20 to 80 years had normal discs at all levels. Buirski and Silberstein⁶⁴ have classified patterns in the disc with increasing pathology from 1 (normal) to 6 (severely reduced disc height).

The pattern of distribution was not significantly different between 115 symptomatic patients and 63 control subjects (Table III).⁶⁵ None of these studies has separately addressed the appearance of the bone-marrow (Modic changes).

Boos et al⁶⁶ have shown in 46 asymptomatic individuals followed for a mean of five years that herniations of the disc and neural compromise did not become significantly worse at follow-up, whereas degeneration of the disc pro-

Table II. Incidence of MRI findings in individuals who had never had LBP according to Boden et al⁶²

Age (yrs)	Number	Herniated disc (%)	Spinal stenosis (%)	Bulging disc (%)	Disc degeneration (%)
20 to 39	35	21	1	56	34
40 to 59	18	22	0	50	59
60 to 80	14	36	21	79	93

Table III. Degeneration patterns according to Buirski.⁶⁵

Pattern type	Intranuclear cleft	Prolapse/bulge	Disc intensity	Disc height	Asymptomatic (n = 63) (%)	Symptomatic (n = 115) (%)
1	Thick	-	No	No	0	0
2	Thick	-	Reduced	No	5	4
3	No	Yes	No	No	4	4
4	Thick	Yes	Reduced	Reduced	42	29
5	Thick/incomplete	Yes	Focal signal voids (HIZ)*	More reduced	31	47
6	Not seen	Yes	Severely reduced	Severely reduced	18	16

* high-intensity zone

gressed in 19 individuals (41%), six of whom had to seek medical treatment with another five having to stop work temporarily. Nevertheless, medical consultation for LBP was predicted with higher accuracy by listlessness, job satisfaction, and working in shifts. Work incapacity was best predicted by physical job characteristics, job disaffection, and working in shifts. Another study⁴⁴ found an association of LBP with MRI signs of degeneration of the disc and of sciatic pain with posterior bulging of the disc. The adjusted odds ratios for the 12-month prevalence of LBP were 2.7 for a posterior bulge, 3.4 for an anterior bulge, and 2.0 for a dark nucleus. The adjusted odds ratios for a four-year prevalence were 1.7 for a posterior bulge, 1.9 for an anterior bulge, and 2.1 for a dark nucleus.

There is no strong correlation between MRI changes in the intervertebral disc and LBP. In most studies, however, disability was not assessed. Perhaps the incidence of degenerative lesions is much higher in a severely disabled population. Further studies are required to evaluate whether there is a correlation between degeneration of the disc and the degree of disability.

High-intensity zone (HIZ). This was first described in the lumbar spine by Aprill and Bogduk⁶⁷ and is a high-intensity signal on MR scans in the substance of the posterior nucleus pulposus. It is surrounded by a low-intensity black signal of the annulus, and is appreciably brighter than that of the nucleus. Provocative discography revealed that the HIZ represented painful internal disruption of the disc with a positive predictive value of 86%. Schellhas et al⁶⁸ and Lam, Carlin and Mulholland⁶⁹ confirmed these findings, whereas Ricketson, Simmons and Hauser⁷⁰ found that the HIZ is not necessarily associated with a painful disc. Carragee, Pragioudakis and Khurana⁷¹ performed provocative discography and MRI in 42 symptomatic patients and 54 asymptomatic individuals. The prevalence of an HIZ was 59% in the symptomatic and 24% in the asymptomatic group. Provocation discography was undertaken. In the asymptomatic group, 73% of the discs with an HIZ were positive on discography compared with 38% of those without an HIZ. In the symptomatic group, the respective values were 69% and 10%. The nature of the HIZ is

unclear. It may represent an area of secondary inflammation as a result of a tear in the annulus.

Discography. This has also been used for grading degeneration of the disc. Buirski⁶⁵ has shown that the signal characteristics of MRI can accurately depict the early stages of nuclear degeneration as revealed by discography. Once protrusion of the disc occurs, MRI and discography do not correspond so well. With the current trend to perform more provocative discography, grading of the disc degeneration can be carried out using, for example, the classification of Adams, Dolan and Hutton.⁷²

Provocation discography. This is an attempt to reproduce symptoms. Since damage to the intervertebral disc can be seen in both asymptomatic and symptomatic individuals, the intention is to distinguish painful from painless disc disease, and also to localise the painful disc. Colhoun et al⁷³ followed 137 patients in whom discography had provoked symptoms; in 25 the discs showed morphological abnormality but had no provocation of symptoms. Patients underwent anterior or posterior fusions and occasionally a laminectomy. Of the 137 with provoked symptoms, 89% derived significant and sustained clinical benefit from operation as measured by subjective improvement, resumption of work and/or normal duties and no intake of analgesics, compared with 52% of patients in whom symptoms had not been provoked by discography. Carragee et al⁵⁰ performed provocation discography of the lumbar spine in 26 patients with no history of LBP. Significant positive pain responses were found in 10% of those who were pain-free, 40% of those with chronic cervical pain and in 83% of those with a somatisation disorder. The incidence of false-positive discography therefore may be low in subjects with a normal psychometric profile. This may also explain the high rate of 65% of fair and poor results of single-level fusions in a workers' compensation group.⁷⁴ Carragee et al⁷¹ also found that provocation discography in discs demonstrating an HIZ was positive in only 50% of patients with normal psychometric testing, compared with 100% in those in which testing was abnormal. Although provocation discography is an instrument for assessing discogenic pain, Leufven and Nordwall⁷⁵ reported excellent

Table IV. Types of Modic change as defined by signal intensity (SI) patterns in T1- and T2-weighted MR sequences, underlying pathology according to de Roos et al⁷⁸ and Modic et al⁷⁹, and their relation to reproduction of pain at provocative discography in the series of Braithwaite et al⁸⁰

Type	MRI		Pathology	No pain*	Pain*
	T1-weighted	T2-weighted			
I	SI reduced	SI increased	Fissures of the cartilaginous endplate, increased vascularity within the subchondral bone	0	5
II	SI increased	SI increased or isotense	Fatty replacement of the marrow, perhaps a result of marrow ischaemia	2	16
III	SI reduced	SI reduced	Subchondral sclerosis	0	3
None				60	69

* numbers of patients

and good results in 52% of patients with a positive provocation test who had only a posterior fusion.

Derby et al⁷⁶ investigated 96 patients in a retrospective study. They categorised provocative discographic pain according to the pressure required to trigger the pain: chemical, <100 kPa; mechanical, 100 to 350 kPa; and indeterminate, normal, 350 to 600 kPa. Chemical pain was associated with a better outcome after interbody or combined fusion. Hanley, Phillips and Kostuik⁷⁷ recommend the diagnosis of discogenic LBP by discography reproducing the patient's symptoms, and showing advanced degeneration, especially extravasation of dye to the side of the leg symptoms.

Provocation discography is perhaps one of the rare techniques which is helpful in indicating the need for lumbar spinal fusion in patients with degenerative discs. It is, however, invasive, and a small amount of antibiotics should be added to the dye to protect against iatrogenic discitis. Provocation discography should be combined with psychometric testing. The painful disc should be fused and a 360° fusion is perhaps better than a posterior fusion in patients with positive provocation discography.

Vertebral bone-marrow changes. These changes, sometimes called vertebral endplate or Modic changes, were first described by de Roos et al⁷⁸ and Modic et al⁷⁹ (Table IV, Fig. 1).

Type-I changes often progress to type-II, but they can also resolve. Marrow oedema may also be seen in discitis, penetrating Schmorl's nodes, and following chemonucleolysis. The prevalence of Modic changes in asymptomatic individuals has not been investigated.⁶²⁻⁶⁴ Braithwaite et al⁸⁰ found an additional HIZ in 7 of 23 discs with Modic changes, and Modic changes in 7 of 27 discs with an HIZ. Toyone et al⁸¹ studied 500 MRI scans and identified 74 patients with bone-marrow changes, 37 with increased (type A, Modic II) and 37 with decreased (type B, Modic I and III) signal intensity; 73% of those with type-A changes and 11% of those with type-B changes had pain.

Lang et al⁸² evaluated 33 patients with a lumbar spinal fusion, in 30 posterolaterally, in whom segmental instability was suspected at the site of the fusion; 16 of 19 patients with a solid fusion had bone-marrow changes

comparable with Modic type-II changes. In ten of the 14 patients with segmental instability, subchondral bands of low intensity in T1-weighted and increased signal intensity in T2-weighted MRI were found. It remains unclear whether the bone-marrow changes in solid fusion were also present before surgery, and whether a 360° fusion should be undertaken in all patients with bone-marrow changes, if surgical treatment is considered. In the opinion of the author this is the correct procedure.

The specificity of Modic changes for identification of a painful disc at discography is high, but sensitivity, however, is low.⁸⁰ The presence of Modic changes is therefore perhaps an indication for lumbar spinal fusion, although the literature is not very conclusive. Both T1- and T2-weighted MR scans are necessary to distinguish between the different types of Modic change.

Facet joint degeneration. The facet joint usually degenerates later than the disc. Butler et al⁸³ performed CT and MRI of 330 discs; in 108 there was degeneration without changes in the facet joint, in 40 both the disc and the facet

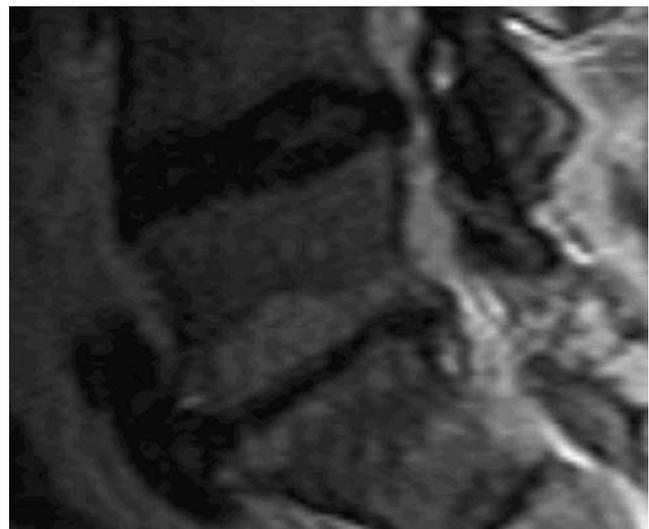


Fig. 1

Increased signal intensity in T2-weighted MRI in a Modic type-I lesion of the presacral disc.

joints were degenerate, and in only one was there isolated facet joint degeneration without corresponding changes in the disc. Fujiwara et al⁸⁴ have confirmed this finding recently, whereas Videman et al⁸⁵ showed that osteoarthritis of the facet joint preceded degeneration of the disc in 20%.

Facet joint blocks. Several studies have shown that these are not predictive in the selection of patients for lumbar fusion. In 126 patients Esses and Moro⁸⁶ failed to find any significant correlation between the outcome of fusion and the result of facet blocks.

Lovely and Rastogi⁸⁷ studied facet blocks prospectively; 28 of 91 patients had pain relief of more than 70% for more than six hours on three separate occasions. These patients underwent fusion and 19 of 23 described pain relief of 90% at follow-up. The authors applied 3 to 5 ml of a combination of 1% xylocaine, 40 mg of Depo-Medrol, and 0.5% marcaine. The facet blocks were not selective because of the amount of local anaesthetic.

Facet blocks may help to determine the location of posterior facet pain; 0.5 ml of local anaesthetic per facet is adequate, otherwise the block will not be sufficiently selective.

Instability. Segmental instability has been recognised as a cause of LBP for some time. Knutsson⁸⁸ was the first to discuss the significance of instability or abnormal mobility between two lumbar vertebrae. He introduced flexion-extension radiographs to determine instability. Morgan and King⁸⁹ drew attention to the association between annular tears, radiographic instability, and LBP. Kirkaldy-Willis and Farfan⁹⁰ focused on anteroposterior lateral bending radiographs, from which rotational deformity and lateral translation were interpreted as indicators of instability.

Flexion-extension radiographs. These were often found to be inconsistent. Shaffer et al⁹¹ found in experiments that only relatively large translations (± 5 mm) could be observed in flexion-extension radiographs in a reproducible way. Leivseth et al⁴⁷ compared roentgen stereophotogrammetry and distortion-compensated sagittal plane radiographs and came to a similar conclusion, recommending a threshold value of ± 5 mm.

Hayes et al⁹² examined 59 flexion-extension radiographs obtained from asymptomatic individuals undergoing routine pre-employment examination. Angular motion was 7° to 14° and translational motion 2 mm to 3 mm at each intervertebral level. Of the asymptomatic individuals in the study 20% had 4 mm or more of translational movement at the L4-L5 interspace. Boden and Wiesel⁹³ studied 40 normal individuals using special x-ray equipment. They found that only 5% had a dynamic AP translation of 4 mm or more. Mayer et al⁹⁴ found that the test-retest reliability of flexion-extension radiographs of 14 examiners and 18 healthy volunteers was 4.9°.

It appears that instability can be assumed when dynamic AP translation is 5 mm or more.

Lateral bending films. Their use is not as well documented as that of flexion-extension films. Haas et al⁹⁵ found that

the inter-rater reliability was poor at L5, but acceptable at levels above. Jayaraman et al⁹⁶ observed that the range of lateral bending was reduced by 43% for symptomatic patients when compared with painfree individuals. Dvorak et al⁹⁷ examined healthy volunteers and found a large variation in rotation, which may limit the clinical usefulness of functional lumbar analysis. There are no reports in the English medical literature after 1990 which show a predictive value of lateral bending radiographs with regard to the outcome of lumbar fusion.

Lumbar orthosis. This restricts gross movement of the trunk rather than intervertebral mobility as has been demonstrated by roentgen stereophotogrammetry.⁹⁸ A corset test was carried out in 50 patients; 31 experienced significant pain relief of more than 50%. The clinical outcome after solid fusion did not correlate with the preoperative results of the corset test.⁹⁹ A lumbar orthosis is not of value when selecting patients for lumbar fusion.

External transpedicular fixation test. This is an invasive method in which 5 mm Schantz screws are driven into the pedicles by a closed technique and using an image intensifier. The screws are connected by bars. Pain is then assessed using visual analogue scales with locked and unlocked bars. Roentgen stereophotogrammetric analysis gave a significant reduction in sagittal intervertebral translations, in half of the cases below the accuracy of the measuring method.¹⁰⁰

Soini et al¹⁰¹ carried out a prospective study on 42 patients with chronic LBP; 29 had relief from pain in the external fixation test. At one and two years, they had significantly better pain and performance scores than the other patients. Van der Schaaf, van Limbeck and Pavlov¹⁰² followed 133 patients, all of whom had had an external fixation test in three positions: neutral, slight distraction, and non-fixation. After two to three days for each position, pain was assessed by means of a visual analogue scale. Those patients who experienced adequate pain relief in fixation and considerably less pain relief in non-fixation were considered to be suitable candidates for fusion and, of these, 55 had the operation and 78 were treated conservatively. The subjective end result was good in 35 of the 55 fused patients (64%) and in 10 of 78 control subjects (13%), fair in 16 of the fused patients (29%) and in 23 of the conservatively-treated patients (29%), and poor in 4 (7%) of the fused and 45 (58%) of the conservatively-treated group. The VAS of the fusion group was 77 before operation, 26 during test fixation, 69 in non-fixation, and 40 at follow-up. The corresponding figures for the control group were 75, 53, 44 and 71.

There are no reports of a higher rate of infection in lumbar spinal fusion after the external fixation test, possibly because of the small numbers of patients in the studies. The method requires an additional operation. In difficult cases, however, the external fixation test seems suitable for proper selection of patients and segments (Fig. 2).

Other methods. Steffen et al¹⁰³ have developed a three-

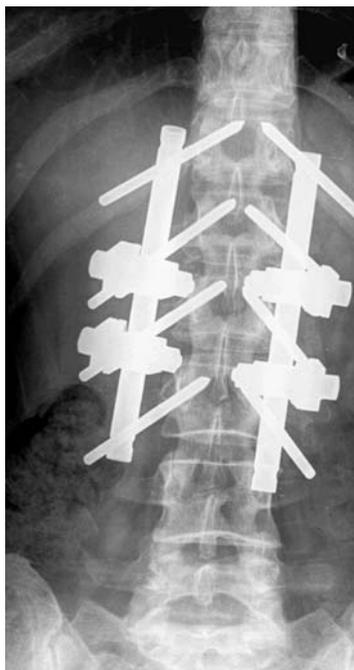


Fig. 2a



Fig. 2b

External transpedicular fixation test in a 38-year-old woman with several inappropriate signs, but severe pain at L1/L2. At intervals of two days other movement segments are fixed. At this stage only L1/L2 is fixed.

dimensional method based on the use of Kirschner wires inserted into the spinous processes to assess flexion-extension, lateral bending and axial rotation. Studies using videofluoroscopy¹⁰⁴ and cinéradiography¹⁰⁵ showed a step-wise occurrence of segmental movement and different patterns of movement in the lumbar spine. It remains unclear whether a thorough analysis by these methods will lead to reliable techniques for the assessment of instability.

Spondylolisthesis. In 111 patients with painful adult spondylolisthesis, 62% reported LBP and sciatica, 31% LBP only and 7% sciatic pain only.¹⁰⁶ In a study on 936 asymptomatic soldiers and 662 with LBP, the incidence of spondylolisthesis was 5.3% in the symptomatic group, and 2.2% in the asymptomatic group.¹⁰⁷ Spondylolisthesis seems therefore to be associated with a higher incidence of LBP.

In a Swedish study, 111 patients with adult spondylolisthesis were compared with 39 with unspecific chronic LBP. The functional profile was strikingly similar for both groups.²⁸ Adult spondylolisthesis of minor degrees is therefore perhaps not very different from pure degenerative disc disease. Fusion in high grades of spondylolisthesis and of spondylolisthesis in children usually has a good outcome. Buttermann et al¹⁰⁸ used the Oswestry disability score to follow 165 patients after a mean period of five years. Children and patients with a high degree of slip (grade 3 and more) had mean preoperative Oswestry scores of 50 and at follow-up of about 10. Those with low degrees of

slip, degenerative disc disease and after discectomy had Oswestry scores of about 50 before operation and about 20 (low degrees of slip) and 30 (degenerative disc disease and post-discectomy) at follow-up. Patient satisfaction was 100% in the children and in patients with high grades of slip and 84%, 76% and 69% in the low grade, degenerative disc disease, and post-discectomy groups, respectively. The outcome did not differ between degenerative and isthmic spondylolisthesis, but was significantly worse in the presence of pseudarthrosis.

Painful spondylolisthesis in children and in patients with high grades of spondylolisthesis are the most accepted indications for lumbar spinal fusion.

Post-discectomy. Patients with psychosocial comorbidity have a less favourable result after operative treatment of lumbar disc herniation. Nevertheless, some studies report promising results of lumbar fusion in patients who had residual symptoms after discectomy,¹⁰⁹⁻¹¹¹ with the same rate of return to work when compared with a group after primary fusion, and rates of improvement of up to 82%. Tandon et al⁴¹ have shown that distressed patients had the same functional benefit from lumbar spinal fusion as normal individuals. Nevertheless, there is a need for more studies to establish clear guidelines for the selection of patients in those with failed back surgery.

Spinal stenosis. Spinal stenosis is outside the scope of this review. Some authors have recommended spinal fusion when decompression is done for spinal stenosis. Most agree

that fusion should be performed when more than two-thirds of one facet joint is removed, or more than 50% of a facet pair, or more than 50% of successive facets. These general guidelines are based on biomechanical studies, but their scientific basis is inadequate.¹¹² When a facet-joint-preserving technique is utilised, postoperative slipping does not occur in patients without a preoperative slip. Patients with a degenerative spondylolisthesis have a 30% risk of progressive slip after a four-year follow-up, but without associated clinical problems.¹¹³

Spinal stenosis associated with degenerative spondylolisthesis. This condition is often seen. Fischgrund et al¹¹⁴ studied prospectively 76 patients with this combination who were decompressed and fused by posterolateral intertransverse non-instrumented or instrumented fusion. The outcome was the same in both groups. Successful arthrodesis occurred in 82%. Successful fusion did not influence patient outcome. The disadvantages of this study, however, were the small statistical power and that it was not the primary intention to compare patients with successful and unsuccessful fusion.

Conclusions

The indications for lumbar spinal fusion are not well understood and there is not enough evidence for sound recommendations. A Cochrane review¹¹⁵ came to the following conclusions:

- 1) There is no acceptable evidence (strength D) of the efficacy of any form of fusion for degenerative lumbar spondylosis, back pain, or 'instability'.
- 2) There is limited evidence (strength C) that adjunct fusion to supplement decompression for degenerative spondylolisthesis produces less progressive slip and better clinical outcomes than decompression alone.
- 3) There is limited evidence (strength C) that fusion alone may be as effective as combined decompression and fusion for patients with grade-I or grade-II isthmic spondylolisthesis and no significant neurology.
- 4) There is strong evidence that instrumented fusion may produce a higher rate of fusion (strength A), but does not improve clinical outcome (strength A).

Lumbar spinal fusion should therefore be undertaken with caution. It should be borne in mind that there is little evidence to suggest that it has a beneficial effect on patients.

Psychosocial screening should be performed and if psychosocial distress is shown a thorough evaluation should follow. If both a psychosocial and organic disorder are found, both should be treated, with discussion between the psychiatrist and the surgeon as regards the sequence of treatment.

A high-grade spondylolisthesis, a progressive slip in an adult, and iatrogenic removal of the facet joints during decompression are good indications for lumbar spinal fusion. AP translation of 5 mm in a painful motion segment

may also be an indication, if the level of disability is high.

When a highly disabled patient has localised pain, no evidence of slip and imaging techniques show bone-marrow changes or an HIZ, provocative discography or a fixation test should be considered for further evaluation. When a highly disabled patient has localised pain, and when imaging techniques show severe degeneration of the facet joints, facet blocks should be performed to determine the location of pain. In a psychosocially-distressed patient provocation tests should be interpreted with caution. If provocation or pain relief tests clearly indicate that pain is related to a localised disorder, then lumbar fusion may be also indicated.

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