Predictors of outcome after decompressive lumbar surgery and instrumented posterolateral fusion

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Received: 15 August 2009 / Revised: 24 December 2009 / Accepted: 14 January 2010 / Published online: 5 February 2010
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Abstract There has been no agreement among different authors on guidelines to specify the situations in which arthrodesis is justified in terms of results, risks and complications. The aim of this study was to identify preoperative predictors of outcome after decompressive lumbar surgery and instrumented posterolateral fusion. A prospective observational study design was performed on 203 consecutive patients. Potential preoperative predictors of outcome included sociodemographic factors as well as variables pertaining to the preoperative clinical situation, diagnosis, expectations and surgery. Separate multiple linear regression models were used to assess the association between selected predictors and outcome variables, defined as the improvement after 1 year on the visual analog scale (VAS) for back pain, VAS for leg pain, physical component scores (PCS) of SF-36 and Oswestry disability index (ODI). Follow-up was available for 184 patients (90.6%). Patients with higher educational level and optimistic preoperative expectations had a more favourable postoperative

leg pain (VAS) and ODI. Smokers had less leg pain relief. Patients with better mental component score (emotional health) had greater ODI improvement. Less preoperative walking capacity predicted more leg pain relief. Patients with disc herniation had greater relief from back pain and more PCS and ODI improvement. More severe lumbar pain was predictive of less improvement on ODI and PCS. Age, sex, body mass index, analgesic use, surgeon, self-rated health, the number of decompressed levels and the length of fusion had no association with outcome. This study concludes that a higher educational level, optimistic expectations for improvement, the diagnosis of “disc herniation”, less walking capacity and good emotional health may significantly improve clinical outcome. Smoking and more severe lumbar pain are predictors of worse results.

Keywords Lumbar fusion · Risk factors · Predictor · Clinical outcome

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Introduction

Fusion procedure rates have increased dramatically in the past two decades and are being used routinely in many specialized centres for degenerative- and disc diseases. Fusion prevents segmental instability derived from the underlying disorder or decompression (postdiscectomy or postlaminectomy instability) [10, 29, 43] and allows surgeons to perform wider discectomies, laminectomies and facetectomies. Nevertheless, the published results on spinal fusion and on pedicle [8, 25, 26, 35, 49] and interbody implants [9, 24] differ depending on the authors and have been controversial in terms of efficacy, complication rates [17, 18] or cost-benefit ratio [35, 38]. However, these same reports point out the difficulty in drawing conclusions and

that present knowledge of the advantages and drawbacks of fusion is limited. Thus far, there has been no agreement among different authors on guidelines to help define the situations in which arthrodesis is not justified because of results, risk and complications [4, 5].

Therefore, it is interesting to review the reports that study and evaluate presurgical factors related to a better or worse clinical outcome. An attempted meta-analysis of surgery for lumbar spinal stenosis in 1992 could not identify predictors, probably due to methodological deficiencies in the bibliography published up to that time [45]. The quality of publications has subsequently improved and several authors have published studies on prognostic factors, especially in the diagnosis of lumbar spinal stenosis. Regarding the quality criteria, different experts and scientific societies recommend prospective designs and measuring outcomes in multiple dimensions [7, 16].

There is little data in literature published to date on prognostic factors in lumbar fusion [28]. The primary purpose of the current study is to identify preoperative predictors that may affect clinical outcome in patients who undergo a primary decompression procedure (laminectomy, discectomy, etc.) associated with instrumented posterolateral fusion.

Methods

Study population

This report is part of a prospective study [13] of the clinical results of 203 consecutive patients operated on by four surgeons in our Service between January 2002 and October 2006. All patients were treated with decompression, intertransverse process fusion, and segmental pedicle screw fixation. Patients operated on for decompression procedures without fusion or fusion without pedicular implants and those with high level spondylolisthesis (more than Level II on the Meyerding index) or scoliosis (greater than 15°), as well as patients who had undergone previous lumbar surgery were excluded.

In general, our group is in favour of performing a wide decompression, broad enough to bring relief to areas with MRI-confirmed neural compression. Thus, decompression often included complete discectomies, bilateral laminectomies, or total facetectomies. In most cases, fusion was performed using local grafts combined with calcium phosphate compounds.

Data collection

Non-health-care staff members were responsible for contact with patients, sending questionnaires by mail and making

reminder calls. Questionnaires measured pain intensity in the last 4 weeks for back and leg pain independently by means of a visual analogue scale (VAS), and included the Spanish versions of medical outcome study-short form-36 (MOSS-SF-36) [2, 46] and Oswestry disability tests [23]. Data reflecting personal and work situation as well as several questions about presurgical expectations and post-surgical satisfaction with results were also included.

Data description

Outcomes (dependent variables)

Four different measures of outcome (dependent variables) were selected to evaluate the improvement in different clinical aspects between “before surgery” and 1 year post-surgery: VAS of back pain, VAS of leg pain, standardized physical component score (PCS) on SF-36 and the Oswestry disability index (ODI). The value of each dependent variable was obtained by calculating the difference between presurgical value and that obtained 1 year after surgery.

Independent variables

A large number of variables (Table 1) were selected as potential predictors based on results of previous studies [1, 28, 31, 37].

Sociodemographic variables included age, sex, body mass index (BMI), education level and smoking.

Tobacco smoking (at the time of surgery) was divided between “smokers” (active smokers and patients that had stopped smoking less than 6 months before) and “non-smokers”.

Educational level was divided into primary or elementary education and secondary or higher education.

Diagnosis

Univariate analysis (ANOVA with post-hoc multiple comparison Tukey test) was performed to test the differences in outcomes depending on the presence of degenerative spinal stenosis, isthmic or dysplastic spondylolisthesis or disc herniation. This analysis concluded that only patients with disc herniation presented different values of outcomes (better results) when compared with other diagnostic categories (Table 3). Therefore, we decided to dichotomize the diagnosis into “disc herniation” and “other lumbar spine disorders”. The diagnosis of disc herniation was established if it appeared as such in the surgeon’s post-operative written report, even if in addition to discectomy, decompression included other procedures such as foraminotomies or contralateral decompression. In all cases, the diagnosis of “disc

Table 1 Baseline characteristics. Preoperative values

Continuous variables	Mean (SD)
Age at time of operation (years)	52.00 (14.83)
VAS Lumbar	73.48 (22.71)
VAS MMII	77.14 (23.13)
ODI	44.62 (17.53)
	29.27 (7.94)
PCSs scale-00	43.34 (13.98)
MCSs scale-00	35.37 (23.01)
SF-36 physical functioning (0–100)	10.52 (24.63)
SF-36 role physical (0–100)	22.82 (17.40)
SF-36 body pain (0–100)	54.76 (19.97)
SF-36 general health (0–100)	41.87 (21.99)
SF-36 vitality (0–100)	49.73 (29.65)
SF-36 social functioning (0–100)	54.39 (45.03)
SF-36 emotional role (0–100)	56.88 (21.18)
SF-36 mental health (0–100)	
BMI (kg/m ²)	26.68 (4.07)
Categorical variables	N (%)
Sex	
Male	79 (42.9)
Female	105 (57.1)
Self-rated health	
Good–excellent	71 (40.3)
Fair	81 (46.0)
Poor	24 (13.6)
Analgesic use	
Daily	125 (69.4)
Moderate use/not needed	55 (30.6)
Expectations (symptom relief)	
Optimistic	137 (75.7)
Moderate/no previous expectations	44 (24.3)
Walking capacity	
Unlimited	86 (47.5)
Somewhat limited	75 (41.4)
Severely limited	20 (11.0)
Education	
Primary or lower	126 (68.5)
Secondary or higher	58 (31.5)
Smoking	
Non-smoker/ex-smoker	113 (62.4)
Smoker	68 (37.6)
Diagnosis	
Lumbar disc hernia	51 (27.7)
Other lumbar spinal disorders	133 (72.3)
Surgeon	
1	47 (25.5)
2	21 (11.4)
3	60 (32.6)

Table 1 continued

Categorical variables	N (%)
4	56 (30.4)
Decompressed levels	
1 level	95 (51.6)
2 levels	55 (29.9)
3 or more	34 (18.5)
Length of fusion	
Short-segment	142 (77.2)
Long-segment	42 (22.8)

VAS visual analog scale, BMI body mass index, ODI Oswestry disability index, PCSs SF-36 physical component summary, MCSs SF-36 mental component summary

herniation” was verified by evaluating MRIs, confirming that the criteria defined by Fardon [20] had been met. The group labelled with the diagnosis “other lumbar spine disorders” includes patients with radicular compression produced by degenerative or constitutional disorders such as degenerative stenosis, degenerative spondylolisthesis, isthmic or dysplastic spondylolisthesis or degenerative scoliosis (less than 15°).

The influence of the preoperative clinical situation was evaluated according to different variables: back pain VAS (0–100), leg pain VAS (0–100), ODI and the 8 subscales of the MOSS (SF-36): physical function, physical role, body pain, general health, vitality, social functioning, emotional role, mental health and both standardized components: PCS and mental component summary (MCS).

Use of analgesics was evaluated as a dichotomized variable (daily use vs. sporadic or no use).

Walking ability was registered considering the answer to the ninth item on the Oswestry questionnaire. It was defined as “not limited” if the pain did not keep the patient from walking more than a kilometre, “severely limited” when the patient’s capacity was limited to bed and chair or by the need to use crutches and “somewhat limited” for intermediate states.

Preoperative expectations were defined according to the answer to the question “What results do you expect from the operation in terms of symptom relief (pain, weakness, contracture, cramps, etc.)?” The options were defined as “optimistic” for the high or very high expectations (“I believe that I will improve a great deal” or “spectacularly”) and “nonoptimistic/without previous expectations” otherwise.

The patient’s perception of his or her health was obtained from the answer to the first question of the MOSS (SF-36): “How would you rate your health?” considering three possibilities (good–excellent, fair, and poor).

Surgical aspects considered were principal surgeon, number of decompressed levels (1 level, 2 levels, 3 or more) and length of fusion (short segment: 1 or 2 fused levels vs. long segment: 3 or more).

Data analysis

Data distribution was tested against normality using the Kolmogorov–Smirnov goodness-of-fit test.

A previous *univariate analysis of outcome predictors* was performed to find the relationships between potential predictors and the four principal continuous dependent variables considered: back and leg pain relief (on VAS), PCS improvement and ODI improvement. Spearman correlation coefficients and the Kruskal–Wallis test were used for continuous and categorical variables, respectively.

Multivariate analysis

Four multivariable linear regression models corresponding to the different outcome measures (dependent variables) were developed to identify predictors. Backward variable selection was used for modelling, with the standard significance level for contrasts $P < 0.05$. Independent variables associated with an outcome of $P < 0.20$ in univariate analysis were included in the corresponding multivariate model.

All maximum models included preoperative back and leg pain VAS scores, SF-36 PCS, ODI, age, sex, SF-36 General Health and SF-36 Vitality scores, use of analgesics, optimism, walking capacity, diagnosis, number of decompressed levels and length of fusion. Besides, all but the back pain VAS model included SF-36 MCS and education level as well. Smoking status only was included in the ODI maximum model.

The collinearity of the maximum models was assessed with the criteria proposed by Belsley [6]. Normality and homocedasticity assumptions in each final model were assessed by analysing model residuals. Model validation was evaluated by bootstrap techniques and leave-one-out cross-validation. Data analysis was performed using SPSS software (version 11.5, SPSS, Inc., Chicago, IL, USA).

Results

Subject characteristics

Patients had a mean age of 52 years, a majority were women (57.1%) and 68.5% rated their educational level as “elementary” or lower. The diagnosis was “disc herniation” in 51 (27.7%) and “other lumbar spinal disorders” in 133 (72.3%).

Of 203 patients, 1-year follow-up was available for 184 patients (90.6%). In four cases, contact was lost because of change of address and telephone number; one patient was reoperated and one patient died due to causes unrelated to the surgery. The rest of the patients preferred not to answer or sent back incomplete questionnaires.

There were no significant differences between patients who dropped out at 12 months ($n = 19$; 9.4%) and those who remained in the study with respect to preoperative age, BMI, back and leg VAS, PCSs, MCSs and ODI.

Multivariate models

Table 2 presents data of the multivariable models and predictors significantly associated with outcome. To avoid collinearity problems, both SF-36 PCS and MCS were centered at their mean before including them in the multivariate models.

Sociodemographic predictors

A higher *educational level* was predictive of less leg pain (VAS) and a better postoperative Oswestry score. The predictive value of education in the PCS model turned out to be borderline (0.051). Smoking was predictive of less leg pain relief. Age, sex and body mass index (BMI) had no predictive value in any outcome measure models.

Diagnosis

Both patients with “disc herniation” and those with “other lumbar spinal disorders” improved significantly on all studied outcome measures (Table 3). Patients who underwent surgery for disc herniation had greater back pain relief (on VAS), and a better PCS and ODI.

Preoperative symptoms

The presurgical value of each studied dependent variable predicted outcome within its model. Nevertheless, the intensity of lumbar pain (back VAS) had a negative association with the outcome of other dependent variables. Greater preoperative lumbar pain predicted less ODI and PCS improvement.

Better emotional health (presurgical MCS) predicted greater ODI improvement.

Patients with less preoperative walking capacity had greater leg pain relief (VAS).

Expectations

Optimism (high expectations for improvement) was predictive of less post-surgical leg pain (VAS) and better functional capacity (ODI).

Table 2 Multivariate models and predictors significantly associated with outcome

Predictor	Back VAS improvement, $R^2 = 0.23$	Leg VAS improvement, $R^2 = 0.39$	OSWESTRY improvement, $R^2 = 0.49$	PCSs improvement, $R^2 = 0.27$
Back VAS 0–100	0.44 [0.23; 0.63]		−0.21 [0.08; 0.35]	−0.13 [−0.22; −0.05]
Leg VAS 0–100		0.67 [0.45; 0.89]		
ODI			0.95 [0.78; 1.12]	
PCSs	−0.89 [−1.46; −0.30]			−0.82 [−1.06; −0.59]
MCSs			0.20 [0.00; 0.40]	
Diagnosis				
Other lumbar spinal disorders versus herniated disc	14.08 [4.50; 23.69]		10.06 [3.92; 16.21]	5.53 [1.78; 9.29]
Expectations				
Moderate/no expectations versus optimistic		12.48 [1.47; 24.03]	6.28 [0.12; 12.44]	
Education				
Primary or lower versus secondary or higher		19.51 [9.19; 29.84]	7.55 [1.65; 13.46]	
Smoking				
Non-smoker/ex-smoker versus smoker		−10.09 [−20.10; −0.08]		
Walking capacity				
Not limited versus somewhat limited		18.83 [8.31; 29.36]		
Not limited versus severely limited		23.82 [7.65; 40.00]		

Values are given as β coefficient [95%CI]

VAS visual analog scale, BMI body mass index, ODI Oswestry disability index, PCSs physical component score, MCSs mental component score

Table 3 Preoperative values, and outcome improvement in diagnostic groups

Variable	Other lumbar spinal disorders			Herniation		
	Preoperative [Mean (SD)]	Improvement [Mean (SD)]	Significance (<i>P</i> value) ^a	Preoperative [Mean (SD)]	Improvement [Mean (SD)]	Significance (<i>P</i> value) ^a
VAS lumbar	74.8 (22.3)	24.3 (31.9)	<0.001	70.2 (23.5)	35.3 (28.7)	<0.001
VAS MMII	75.0 (24.3)	33.5 (38.7)	<0.001	82.4 (19.0)	48.4 (33.5)	<0.001
ODI	44.1 (17.5)	14.7 (21.3)	<0.001	46.0 (17.7)	29.2 (22.0)	<0.001
SPC-SF-36	29.3 (8.1)	6.3 (11.6)	<0.001	29.1 (7.5)	12.3 (13.4)	<0.001

Improvement difference between preoperative and after 1 year values with positive clinical significance

SPC-SF-36 standardized physical component

^a Non parametric Wilcoxon test (preoperative vs. after 1 year)

Surgical aspects

Principal surgeon, number of decompressed levels and length of fusion had no association with outcome in any model.

Preoperative self-rated health (1st question of MOSS-SF36) had no association with any outcome measure.

Graphical analyses of model residuals were compatible with model assumptions.

Validation of final models resulted in good calibration. Bootstrap techniques showed that the choice of variables in final models was the most frequently selected in repeated samples, and leave-one-out techniques ensured

minimal changes (<0.05) in the determination coefficient (R^2).

Discussion

Our group considers lumbar fusion an adequate procedure for a great variety of lumbar problems. In our study, both patients with disc herniation and those with “other lumbar spinal disorders” improved significantly on all studied outcome measurements (Table 3). Nevertheless, in the past few decades several authors have reported on the lack of scientific evidence of efficacy and cost-effectiveness of

fusion [8, 25, 26]. These facts and the fear of adjacent level syndrome have encouraged the development of dynamic implants or disc prosthesis. Regarding lumbar fusion procedures, several studies report on notable regional differences in the number of patients operated, depending on surgeons' beliefs or on other subjective factors, such as organization and financing of health services [18, 47], rather than on clinical or demographic criteria.

Several studies emphasize the importance of an adequate selection of patients to undergo surgical lumbar interventions [11, 12, 14, 39]. Thus far, there has been no agreement among different authors on guidelines to specify the situations in which arthrodesis is justified in terms of results, risks and complications.

The indication of any surgical procedure is made weighing social, psychological and clinical factors, and the presence or absence of these factors can help the doctor and patient make appropriate decisions. In a systematic review of lumbar spinal stenosis surgery Aalto et al. [1] concluded that depression, cardiovascular comorbidity, disorders influencing walking ability and scoliosis predicted poorer subjective outcome and male gender and younger age predicted better postoperative walking ability. Though we currently have more information on prognostic factors in decompressive surgery, present knowledge of lumbar fusion surgery is limited [28]. In a multicentre-controlled study of predictors in patients with low-back pain but no signs of radicular compression that underwent fusion, Hagg et al. [28] concluded that the best candidates were those with severe disc disease, a personality characterized by a low degree of neurosis and short preoperative sick leave periods.

This report is a prospective study destined to identify preoperative factors predictive of clinical outcomes after the performance of a decompression procedure associated with instrumented posterolateral fusion.

The *educational level* of the patients was a determining factor in clinical results in two of the four models and in a third, the relationship reached borderline significance (Table 2). A high educational level (secondary or higher education) has turned out to be an independent aspect that influences positively on alleviation of symptoms, especially radicular pain and functional disability (ODI).

We have not found other prospective studies detecting association between education and outcome in the literature on lumbar surgery. Several studies reported a significant association between a low educational level and the presence of health problems in general and lumbar pathology in particular [32, 42], but this relationship is yet to be explained. A propensity to report diffuse physical symptoms (somatization) may mediate in patients with a lower educational level [19]. Perhaps a good education may provide better psychological mechanisms for coping

with surgery and interpreting postoperative symptoms positively.

Optimism (greater expectations for improvement and pain relief) predicted less leg pain (VAS) and better functional capacity (ODI). It is interesting that this effect is independent of patients' assessment of their own health, their educational level, emotional state and the intensity of the symptoms, since these factors have been controlled in the study. The research on patients' expectations regarding surgical outcomes in spinal surgery literature is limited, but others have found a relationship between preoperative expectations and the clinical outcome in spinal stenosis [27, 31] and disc herniation [40]. It would seem logical that if a patient has lower expectations prior to the surgery; in general, he or she would express higher levels of satisfaction and better clinical results afterwards. Nevertheless, just the opposite occurs. Since patient expectations may be formed by the information provided by their surgeons, they may be able to influence outcome if they provide their patients with realistic information and enough confidence to face surgery with a positive attitude.

Katz et al. [34] found the answer to the first question of the MOSS (SF-36) "How would you rate your health?" to be a powerful predictor. These authors believe that the answer may tap into a sense of optimism that may, in turn, bode well for a favourable prognosis. In our study, after ruling out associations, the answer to this question was rejected in the preliminary phases of the statistical analysis.

In this study smokers had less leg pain relief. Several reports document the influence of smoking on lumbar fusion rates [3, 27, 33, 44], attributing the possible negative effect of nicotine to revascularization of bone grafts. The interaction between smoking and degenerative lumbar pathology has also been reported.

The influence of tobacco on outcome after lumbar surgery has been less studied. Aalto et al. [1] could not find any association between smoking and outcome in lumbar spinal stenosis. The causes of the association between smoking and the clinical results are diverse and hard to define. On the one hand, nicotine exercises a central effect in the modulation of pain [22], and this might lead to increased tobacco smoking in patients with chronic pain. It is also likely that personality or psychological traits which may influence outcome distribute differently among smokers and non-smokers.

Walking capacity has been studied in pertinent literature as an outcome measure [37] and less often as a predictor [27, 31]. A better preoperative walking capacity predicted greater postoperative satisfaction and improved walking capacity as an outcome in the systematic review of preoperative predictors in lumbar spinal stenosis [1]. Conversely, in our results a more limited preoperative walking capacity is associated with greater leg pain relief even after

the intensity of preoperative leg pain (VAS) has been adjusted. A limitation in this study is that walking capacity has not been studied as a measure of outcome.

The influence of psychological aspects on clinical outcome after lumbar surgery has been demonstrated using different psychological tests [30, 41, 44]. Interestingly, our study seems to verify the predictive utility of questionnaire SF-36 [15], easier to apply than more complex tests, especially the MCS. The MCS (standardized component of the mental function) is a composite of the mental health subscales of the SF-36 (vitality, social functioning, emotional role and mental health). Patients with better psychological conditions achieved greater improvement in functional capacity (ODI). In a prospective study of patients who had undergone previous fusion, Trief et al. [44] also found that higher presurgical MCS (better emotional health) predicted less back and leg pain and better physical function after surgery. These authors considered that studies evaluating the role of psychological therapy in alleviating pain and improving post-surgical functioning of patients with poorer emotional status are especially interesting.

Logically, the preoperative clinical situation proved to have significant influence on post-surgical outcome. The worse the preoperative situation (more pain, less functional ability, etc.), the greater the improvements obtained. Nevertheless, it is interesting that the intensity of lumbar pain (back VAS) had a negative association with outcome (improvement) for other dependent variables. More preoperative severe lumbar pain predicted lower postoperative ODI and PCS scores. This finding is contrary to the opinion shared by several authors who assume that, since lumbar pain is attributed traditionally to the intervertebral mobility, fusion would be specially indicated in those patients with a predominance of backache over leg pain [21, 48]. It is interesting that this influence is independent, as it appears after being controlled by the preoperative values of ODI, PCS and length of fusion. Other authors have found a negative influence of back pain in patients operated on without fusion [36].

The current study was limited as it was carried out over a short period of time (1 year). However, while this period is insufficient for measuring definitive clinical results, studies of predictors only try to identify tendencies and influences on outcome, so 1 year may be sufficient. Answers to questions about satisfaction were not used as dependent variables because the proportion of dissatisfied patients was very low, so the study was not feasible. We believe that future studies evaluating predictors on satisfaction will be of special interest, as the subjective patient's opinion, influenced by personal beliefs and feelings, is ultimately the main outcome measure. The findings have implications for practice. Surgeons should talk with

patients about their expectations and pay attention to factors like education, tobacco use, emotional health and intensity of back pain before performing a fusion procedure.

Conclusions

The educational level of the patients is a determining factor in clinical results after decompressive and posterolateral fusion with pedicle screw fixation. Preoperative optimistic expectations for improvement and emotional health may significantly improve clinical outcome. Smokers and patients with more severe preoperative lumbar pain have a less favourable outcome.

References

1. Aalto TJ, Malmivaara A, Kovacs F et al (2006) Preoperative predictors for postoperative clinical outcome in lumbar spinal stenosis: systematic review. *Spine* 31:E648–E663
2. Alonso J, Prieto L, Anto JM (1995) The Spanish version of the SF-36 health survey (the SF-36 health questionnaire): an instrument for measuring clinical results. *Med Clin (Barc.)* 104:771–776
3. Andersen T, Christensen FB, Laursen M (2001) Smoking as a predictor of negative outcome in lumbar spinal fusion. *Spine* 26:2623–2628
4. Atlas SJ, Deyo RA, Keller RB (1996) The maine lumbar spine study, part II: 1-year outcomes of surgical and nonsurgical management of sciatica. *Spine* 21:1777–1786
5. Atlas SJ, Keller RB, Robson D (2000) Surgical and nonsurgical management of lumbar spinal stenosis: four-year outcomes from the maine lumbar spine study. *Spine* 25:556–562
6. Belsley DA (1991) Conditioning diagnostics: collinearity and weak data in regression. Wiley, New York
7. Bombardier C (2000) Outcome assessments in the evaluation of treatment of spinal disorders: summary and general recommendations. *Spine* 25:3100–3103
8. Bono CM, Lee CK (2004) Critical analysis of trends in fusion for degenerative disc disease over the past 20 years: influence of technique on fusion rate and clinical outcome. *Spine* 29:455–463
9. Chen L, Tang T, Yang H (2003) Complications associated with posterior lumbar interbody fusion using Bagby and Kuslich method for treatment of spondylolisthesis. *Chin Med J Engl* 116:99–103
10. Chen Q, Baba H, Kamitani K (1994) Postoperative bone regrowth in lumbar spinal stenosis: a multivariate analysis of 48 patients. *Spine* 19:2144–2149
11. Cherkin D, Deyo RA, Loeser JD (1994) An international comparison of back surgery rates. *Spine* 19:1201–1206
12. Ciol MA, Deyo RA, Howell E (1996) An assessment of surgery for spinal stenosis: time trends, geographic variations, complications, and reoperations. *J Am Geriatr Soc* 44:285–290
13. Cobo Soriano J (2008) Estudio prospectivo de resultados clínicos y de factores pronósticos en artrodesis instrumentada lumbar. Análisis económico y de relación de coste efectividad. <http://hdl.handle.net/10486/2099>
14. Davis H (1994) Increasing rates of cervical and lumbar spine surgery in the United States, 1979–1990. *Spine* 19:1117–1123

15. Derby R, Lettice JJ, Kula TA (2005) Single-level lumbar fusion in chronic discogenic low-back pain: psychological and emotional status as a predictor of outcome measured using the 36-item short form. *J Neurosurg Spine* 3:255–261
16. Deyo RA, Andersson G, Bombardier C (1994) Outcome measures for studying patients with low back pain. *Spine* 19:2032S–2036S
17. Deyo RA, Cherkin DC, Loeser JD (1992) Morbidity and mortality in association with operations on the lumbar spine: the influence of age, diagnosis, and procedure. *J Bone Joint Surg Am* 74:536–543
18. Deyo RA, Ciol MA, Cherkin DC (1993) Lumbar spinal fusion: a cohort study of complications, reoperations, and resource use in the Medicare population. *Spine* 18:1463–1470
19. Dionne C, Koepsell TD, Von KM (1995) Formal education and back-related disability: in search of an explanation. *Spine* 20:2721–2730
20. Fardon DF (2001) Nomenclature and classification of lumbar disc pathology. *Spine* 26:461–462
21. Feldmann PH, Wittenberg RH (2003) Surgical treatment of spinal stenosis. *Orthopade* 32:877–888
22. Flood P, Daniel D (2004) Intranasal nicotine for postoperative pain treatment. *Anesthesiology* 101:1417–1421
23. Flórez García M, García Pérez MA, García Pérez F (1995) Adaptación transcultural a la población española de la escala de incapacidad por dolor lumbar de Oswestry. *Rehabilitación* 29:138–145
24. Fritzell P, Hagg O, Wessberg P et al (2002) Chronic low back pain and fusion: a comparison of three surgical techniques: a prospective multicenter randomized study from the Swedish lumbar spine study group. *Spine* 27:1131–1141
25. Gibson JNA, Grant TC, Waddell G (1999) The cochrane review of surgery for lumbar disc prolapse and degenerative lumbar spondylosis. *Spine* 24:1820–1832
26. Gibson JN, Waddell G (2005) Surgery for degenerative lumbar spondylosis: updated cochrane review. *Spine* 30:2312–2320
27. Glassman SD, Anagnost SC, Parker A (2000) The effect of cigarette smoking and smoking cessation on spinal fusion. *Spine* 25:2608–2615
28. Hagg O, Fritzell P, Ekselius L (2003) Predictors of outcome in fusion surgery for chronic low back pain: a report from the Swedish lumbar spine study. *Eur Spine J* 12:22–33
29. Herkowitz HN, Kurz LT (1991) Degenerative lumbar spondylosis with spinal stenosis: a prospective study comparing decompression with decompression and intertransverse process arthrodesis. *J Bone Joint Surg Am* 73:802–808
30. Herron LD, Turner J, Clancy S (1986) The differential utility of the Minnesota multiphasic personality inventory: a predictor of outcome in lumbar laminectomy for disc herniation versus spinal stenosis. *Spine* 11:847–850
31. Iversen MD, Daltroy LH, Fossel AH (1998) The prognostic importance of patient pre-operative expectations of surgery for lumbar spinal stenosis. *Patient Educ Couns* 34:169–178
32. Jacobsson L, Lindgarde F, Manthorpe R (1992) Effect of education, occupation and some lifestyle factors on common rheumatic complaints in a Swedish group aged 50–70 years. *Ann Rheum Dis* 51:835–843
33. Jenkins LT, Jones AL, Harms JJ (1994) Prognostic factors in lumbar spinal fusion. *Contemp Orthop* 29:173–180
34. Katz JN, Lipson SJ, Larson MG (1991) The outcome of decompressive laminectomy for degenerative lumbar stenosis. *J Bone Joint Surg Am* 73:809–816
35. Katz JN, Lipson SJ, Lew RA (1997) Lumbar laminectomy alone or with instrumented or noninstrumented arthrodesis in degenerative lumbar spinal stenosis: patient selection, costs, and surgical outcomes. *Spine* 22:1123–1131
36. Katz JN, Lipson SJ, Brick GW (1995) Clinical correlates of patient satisfaction after laminectomy for degenerative lumbar spinal stenosis. *Spine* 20:1155–1160
37. Katz JN, Stucki G, Lipson SJ (1999) Predictors of surgical outcome in degenerative lumbar spinal stenosis. *Spine* 24:2229–2233
38. Kuntz KM, Snider RK, Weinstein JN (2000) Cost-effectiveness of fusion with and without instrumentation for patients with degenerative spondylolisthesis and spinal stenosis. *Spine* 25:1132–1139
39. Larequi-Lauber T, Vader JP, Burnand B (1997) Appropriateness of indications for surgery of lumbar disc hernia and spinal stenosis. *Spine* 22:203–209
40. Lutz GK, Butzlaff ME, Atlas SJ (1999) The relation between expectations and outcomes in surgery for sciatica. *J Gen Intern Med* 14:740–744
41. Pheasant HC, Gilbert D, Goldfarb J (1979) The MMPI as a predictor of outcome in low-back surgery. *Spine* 4:78–84
42. Pincus T, Callahan LF, Burkhauser RV (1987) Most chronic diseases are reported more frequently by individuals with fewer than 12 years of formal education in the age 18–64 United States population. *J Chronic Dis* 40:865–874
43. Postacchini F, Cinotti G (1992) Bone regrowth after surgical decompression for lumbar spinal stenosis. *J Bone Joint Surg Br* 74:862–869
44. Trief PM, Ploutz-Snyder R, Fredrickson BE (2006) Emotional health predicts pain and function after fusion: a prospective multicenter study. *Spine* 31:823–830
45. Turner JA, Ersek M, Herron L (1992) Surgery for lumbar spinal stenosis. attempted meta-analysis of the literature. *Spine* 17:1–8
46. Vilagut G, Ferrer M, Rajmil L (2005) The Spanish version of the short form 36 health survey: a decade of experience and new developments. *Gac Sanit* 19:135–150
47. Weinstein JN, Lurie JD, Olson PR (2006) United States' trends and regional variations in lumbar spine surgery: 1992–2003. *Spine* 31:2707–2714
48. Wiltse L, Kikardy-Willis W, McIvor G (1976) The treatment of spinal stenosis. *Clin Orthop* 115:83
49. Zdeblick TA (1993) A prospective, randomized study of lumbar fusion: preliminary results. *Spine* 18:983–991