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Comparison of surgical procedures for degenerative lumbar spinal stenosis: a meta-analysis of the literature from 1975 to 1995

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Abstract Therapy for spinal stenosis remains difficult. The possibilities for conservative management are limited and not satisfactory in the more severe cases. Various surgical procedures are possible, such as decompression, decompression and fusion without instrumentation and decompression and fusion with instrumentation. The aim of our meta-analysis was to compare the postoperative results of these three surgical techniques in the literature and, thus, to establish a treatment of choice for degenerative lumbar spinal stenosis. Via Medline, 30 articles met the inclusion criteria for our study, leading to a total number of 1668 cases being included in the meta-analysis. The evaluation was made according to our own definition of outcomes, based on criteria most commonly used in the studies reviewed. We found that in patients suffering degenerative spinal stenosis for up to 8 years, decompression without fusion showed the best results. For a dura-

tion of symptoms of 15 years or more, decompression with instrumented fusion had the best results. Analysing all postoperative outcomes, decompression is the surgical procedure with the highest rate of success and the fewest complications, followed by decompression with instrumented fusion. In surgery for degenerative lumbar spinal stenosis, decompression and fusion without instrumentation was the least successful procedure. As patients suffering from a degenerative spinal stenosis often are elderly, operations are risky and place a strain on them. This review of the literature shows that the least invasive surgical procedure can obtain the best results if the correct diagnosis is made and if the operation is carried out within the first years of the disease.

Key words Meta-analysis · Degenerative lumbar spinal stenosis · Decompression · Fusion

Introduction

Spinal stenosis of the lumbar spine is described as one of the end processes in the pathogenesis of low back pain [27]. The initial concept of spinal stenosis was developed in 1911. However, it was only after 1954, when Verbiest [26] set out definitive clinical and pathological findings, that spinal stenosis could adequately be diagnosed [18]. Lumbar spinal stenosis has been defined as a condition in-

volving any type of narrowing of the spinal canal, nerve root canals, or tunnels of intervertebral foramina [1]. The most common form is the degenerative lumbar spinal stenosis due to hypertrophy of the facet joint, with or without developmental changes, leading eventually to protrusions of the intervertebral discs resulting in a narrowing of the spinal canal [17].

The therapeutic choices remain difficult and controversial. The possibilities for conservative therapy are limited

and their effect is lasting only in mild cases [2, 27]. Surgical intervention should be considered when medical management fails or in cases of initial signs of cauda equina dysfunction or progressive neurologic deterioration [3]. Many surgical techniques have been described [5, 8, 10, 13, 15, 20–23, 29], all based on the principles of decompression alone or decompression and fusion with or without instrumentation. These different surgical techniques show a wide range of good, fair and poor results and they all have specific complications; spinal instability after decompression operations and pseudarthrosis after lumbar fusions are particular problems. However, a reference procedure has not yet been established.

One way to compare the different surgical techniques described in the literature is to conduct a meta-analysis. The aim of our meta-analysis was to compare the postoperative outcomes for the following three surgical techniques: decompression; decompression and instrumented fusion; and decompression and fusion without instrumentation.

Materials and methods

A Medline database search was conducted using the key words:

1. Lumbar spinal stenosis
2. Fusion/decompression of the spine
3. Claudicatio spinalis
4. Radicular signs

Literature included in our study fitted the following inclusion criteria:

1. Published between 1975 and 1995 in English, French or German
2. Reported cases of degenerative lumbar stenosis with no precedent operations of the lumbar spine ("virgin backs")
3. Covered a minimum of seven patients in the original study

We did not include degenerative spondylolisthesis with resulting spinal stenosis in our study because it has a different etiology from pure degenerative spinal stenosis. Furthermore, there is already a therapeutic concept for the treatment of the degenerative spondylolisthesis with good results.

Each article selected was read independently by two clinicians with training in research methods. The raters extracted specific information concerning the study morphology, preoperative patient

characteristics, surgical methods and patient outcomes, recording these data on standardised coding forms. They then met to review information from each paper, and all disagreements were discussed until a consensus could be reached. When agreement could not be reached, the article was sent to a third rater for arbitration. This was particularly necessary regarding the evaluation of the postoperative patient clinical outcome. Our literature review revealed a wide range of definitions of "good", "fair" and "poor" overall outcome. We therefore used our own definitions. This procedure is usual in meta-analyses [16, 24, 25]. We used outcome rating criteria similar to those of Turner et al. [24] (see Table 1). Whenever enough information was provided in an article, we classified the outcomes according to our own criteria so that we could compare outcomes across studies. We also rated outcomes for each of the measured variables separately, such as leg pain, back pain, job functioning, functional disability and preoperative duration of symptoms. Finally, we recorded the authors' own overall ratings of good, fair and poor outcome.

Unlike Turner et al. [24], we maximized the total number of studies available for the meta-analysis with the use of a weighting factor. In studies including a wider set of preoperative diagnoses than our study, where an overall outcome was presented for all the different diagnoses, we first weighted the whole study as follows:

$$wf = \frac{\text{relevant patients of the } (i)\text{th study}}{\text{all patients of the } (i)\text{th study}}$$

with the weighting factor wf calculated by dividing the number of relevant patients of the (i) th study by the total number of patients in that study.

The meta-analysis was performed according to the procedures described by Mosteller and Chalmers, Glass et al. and Fleiss [6, 7, 19]. To calculate simple proportions $p(i)$ for each study, the number of patients with a certain surgical procedure and the number of patients with satisfactory results in the (i) th study were divided by the total number of patients $n(i)$ in that study. The standard error $SE(i)$ for a proportion $p(i)$ was computed using the binomial distribution:

$$SE_i = \sqrt{\frac{p_i(1-p_i)}{n_i}}$$

The weighting $w(i)$ for a proportion $p(i)$ is the reciprocal of the squared standard error for the proportion:

$$w_i = \frac{1}{SE_i^2}$$

For combined estimate based on all studies, the weighted pooled proportion P , was calculated as follows:

$$P = \frac{\sum w_i p_i}{\sum w_i}$$

where $p(i)$ is the proportion for the i th study and $w(i)$ is the weight for $p(i)$.

The variance of P was computed as follows:

$$\text{var}(P) = \frac{\sum w_i^2 SE_i^2}{(\sum w_i)^2}$$

The Z value for comparing two weighted pooled proportions $p(1)$ and $p(2)$ based on two different sets of studies is computed according to the formula:

$$Z = \frac{P_1 - P_2}{\sqrt{\text{var}(P_1) + \text{var}(P_2)}}$$

The Z value indicates whether there is a statistically significant difference between the two different sets of studies.

The comparison of the different factors predicting patient outcome was made with the Student t -test, the level of significance was fixed at $P < 0.01$.

Table 1 Outcome rating criteria of the meta-analysis

Outcome	Criteria
Good	No or occasional mild pain Able to work at usual job No or minimal restriction of physical activity
Fair	Mild persistent back/leg pain; occasional moderate pain Able to work with some restrictions Able to perform most normal activities
Poor	Persistent moderate and/or occasional severe pain Little or no pain relief from surgery Persistent root symptoms Unable to work Severe activity restrictions

Table 2 Preoperative symptoms of the patients. The third, fourth and fifth columns indicate the maximum and minimum values of each study and the average value for all studies, respectively

Symptoms	% of the articles reporting symptom	Minimum value	Maximum value	Average value
Duration	38	3 months	30 years	7.9 years
Leg pain	50	18%	100%	51%
Claudication	54	14%	74%	28%
Back pain	54	1%	92%	47%
No root signs	19	0%	0%	0%
Paresis	46	9%	38%	22%
Dysaesthesia	35	12%	73%	29%
Bladder dysfunction	19	1%	6%	3%
Straight leg raising pain	23	8%	19%	11%

One of the general problems when conducting a meta-analysis is that one has to deal with the data that is provided from the authors of the original article. Only in a very few cases is it possible to find data about every single patient. Thus, we sometimes had to integrate all the patients of the original article into our meta-analysis, so that individual outcomes were not noted. For example, in the case of the patient age – which is mostly reported as an age range – exclusion of single patients of an inappropriate age was not possible.

The reason for the number of original papers included in our study being so small is that most authors reported on patients suffering from low back pain, but with different diagnoses such as spondylolisthesis, degenerative spinal stenosis, disc herniation and others. As outcomes are mostly not differentiated for the different primary diagnoses, inclusion in our meta-analysis was not possible for statistical reasons in these cases.

Results

Using the above-mentioned key words for the Medline search, 247 articles were identified. Only 30 of these articles met all the inclusion criteria, so we conducted the meta-analysis with these studies (see Appendix).

The sample sizes ranged from 8 to 184 patients (mean 67.5 patients), leading to a total of 1668 patients. The youngest patient was 19 years old and the oldest 87, with a mean age of 55.7 years. The sex ratio varied a lot, from 29% to 85% male patients (mean 58.2%). The time of follow-up ranged from 1 to 32 years (mean 4.7 years).

The diagnosis of lumbar spinal stenosis was established in the studies with the help of physical examination, CT (reported in 23% of the studies), myelography (50% of the studies) and electrophysiological neurologic investigations (3% of the studies). The diameter of the spinal canal was reported in 27% of the original articles, with a range of 10–15 mm found to be the limit for a diagnosis of spinal stenosis. The preoperative symptoms of the patients were reported only in some of the articles (see Table 2). Most of the patients had back or leg pain (47% and 51%, respectively), but only about 30% of patients, on average, were reported to have any neurologic deficits. Straight leg raising was abnormal in an average of 11% of subjects.

We divided the different surgical techniques performed into three groups in order not to have too few patients in

Table 3 Postoperative results of the patients with decompression. The third, fourth and fifth columns show the good, fair and poor results of the patients of all the articles that reported on these symptoms (second column)

Symptoms after decompression	% of articles reporting symptom	Good results (%)	Fair results (%)	Poor results (%)
Leg/back pain	42	72	19	9
Neurologic symptoms	37	78	14	8
Ability to work	11	45	22	33

Table 4 Postoperative results of the patients after decompression and fusion without instrumentation

Symptoms after decompression and fusion without instrumentation	% of articles reporting syndrom	Good results (%)	Fair results (%)	Poor results (%)
Leg/back pain	33	57	28	15
Neurologic symptoms	33	62	19	19
Ability to work	0	0	0	0

Table 5 Postoperative results of the patients after decompression and fusion with instrumentation

Symptoms after decompression and fusion with instrumentation	% of articles reporting syndrom	Good results (%)	Fair results (%)	Poor results (%)
Leg/back pain	29	67	28	5
Neurologic symptoms	29	72	21	7
Ability to work	14	69	20	11

each group. We included in the group of patients with decompression only, all patients with hemilaminectomies ($n = 299$) and those with complete laminectomies ($n = 1177$). Fusion without instrumentation was a posterolateral fusion in all cases ($n = 49$). The group of patients with instrumented fusion included those instrumented with pedicle screws and a rod ($n = 169$), with pedicle screws and a plate fixation ($n = 29$) or with various other techniques ($n = 45$). All patients with fusion of the lumbar spine had a

Table 6 Comparison of the results of the different surgical techniques. The Z value indicates whether there is a statistically significant difference between the two sets of studies

	Good	Fair	Poor
Decompression vs. decompression and fusion without instrumentation	Z = 2.033 (n. s.)	Z = -0.650 (n. s.)	Z = -0.735 (n. s.)
Decompression vs. decompression and fusion with instrumentation	Z = -0.854 (n. s.)	Z = -4.478 (n. s.)	Z = -0.917 (n. s.)
Decompression and fusion with instrumentation vs. decompression and fusion without instrumentation	Z = -2.312 (n.s.)	Z = -1.238 (n.s.)	Z = 0.176 (n.s.)

Table 7 Complications following the operations as reported in the articles

Complications	% of articles reporting symptom	Minimum total no.	Maximum total no.	Average no.
Deep vein thrombosis	19	0	4	1.6
Infections	27	0	8	1.7
Operative mortality	27	0	0	0
Neurologic disorders	31	0	13	3.8
Others, e.g. reoperation	23	1	16	5.8

Table 8 Comparison of the good versus the fair and poor postoperative outcomes for the different surgical techniques for all patients with a history of degenerative spinal stenosis of less than 7 years

Surgical technique	Good results	Fair + poor results
Decompression only	234	71
Instrumented fusion	78	61
	$P < 0.01$	
Uninstrumented fusion	66	49
Decompression only	234	71
	$P < 0.01$	
Instrumented fusion	78	61
Uninstrumented fusion	66	49
	$P < 0.78$	

Table 9 Comparison of the good versus the fair and poor postoperative outcomes for the different surgical techniques for all patients with a history of degenerative spinal stenosis of at least 15 years

Surgical technique	Good results	Fair + poor results
Decompression only	21	55
Instrumented fusion	62	45
	$P < 0.01$	
Uninstrumented fusion	32	69
Decompression only	21	55
	$P < 0.45$	
Instrumented fusion	62	45
Uninstrumented fusion	32	69
	$P < 0.01$	

complete laminectomy and none underwent anterior fusion of the spine.

The postoperative results were presented very differently in each study. We tried to assess the results presented in the articles with the help of the criteria mentioned in Table 1. This was only possible in cases where information additional to the authors' rating was provided, such as a description of the postoperative clinical symptoms of the patient in comparison to the preoperative clinical symptoms. Such information was provided in 0%–42% of the studies, depending on the criterion (Tables 3–5).

The comparison of the three surgical techniques did not reveal a statistically significant superiority of any one of them. Decompression only was the procedure with the highest rate of good postoperative results, followed by decompression and instrumented fusion. Decompression and fusion without instrumentation showed the lowest rate of good postoperative results (see Table 6).

Reported complications of surgery are shown in Table 7. The accuracy of these data are unknown. Typically, ar-

ticles did not report the absence of specific complications. If a particular complication was not mentioned in an article, it is unknown whether it occurred or not. None of the studies reported death as a direct result of the surgery.

We also analysed preoperative clinical symptoms as factors predicting the surgical outcome of the patients. None of the factors leg pain, back pain, claudication spinalis or neurologic symptoms showed any influence on the postoperative result for any of the symptoms. In patients with multiple symptoms surgery was less successful than in those with only few clinical symptoms prior to operation. This finding did not depend on which surgical technique was used and the difference in outcome between the different groups was not statistically significant.

The duration of preoperative symptoms had an important influence on the rates of success. In those patients that underwent surgery in the first 7 years of the disease, the best results were obtained by decompression only ($P < 0.01$, see Table 8); in those with a duration of symptoms of 15 years or more, instrumented fusion showed the best postoperative outcome ($P < 0.01$, see Table 9). For a dura-

tion of symptoms of 8–15 years none of the three analysed surgical procedures was superior.

Discussion

Conservative management of degenerative lumbar spinal stenosis is very seldom mentioned in literature [12, 27]. A randomised study comparing the surgical and the natural outcome of patients with degenerative spinal stenosis has not been reported so far, but would be highly interesting. We compared only the different surgical approaches to this disease.

For patients with degenerative lumbar spinal stenosis a treatment of choice has not yet been established. Therefore, which of the different possible forms of surgical interventions is used mostly depends on the progress and experience of the surgeon. Furthermore, most of the articles in the literature report on more specific problems and deal with few patients, so that information regarding a treatment of choice cannot be obtained. That is why we tried to evaluate the different surgical techniques used for degenerative lumbar spinal stenosis with the aid of a meta-analysis in order to give some orientation marks for the best possible treatment. A similar meta-analysis by Turner et al. was unsatisfactory because of the poor scientific quality of the literature and major deficits in study design, analysis and reporting [24]. We encountered the problem of quality as well, but with the help of a weighting factor for the studies we were able to incorporate more literature into our meta-analysis. Nevertheless some of the integrated articles did not provide enough information about the postoperative outcome of the patients, so we were obliged to use the authors' rating in the meta-analysis.

Like previous studies, we also analysed the clinical factors influencing the outcome after surgery for spinal stenosis. Some authors reported factors predisposing patients to worse outcomes as: female sex, greater severity and duration of symptoms before surgery, younger age (30–50 years), prior back surgery, compensation and litigation issues and multilevel decompression [4, 8, 9, 11, 14, 28].

We were unable to analyse whether previous surgery of the spine influenced the postoperative outcome, since these patients were not included in the analysis. In our meta-analysis we found none of the clinical symptoms to be a predicting factor for the surgical outcome where there was only one of the mentioned symptoms. In cases of severe illness with more severe and multiple symptoms the surgical outcome of the patients was less successful, but showed similar results for the three surgical techniques compared.

A difference was found in relation to the preoperative duration of the clinical symptoms, so that this was the only predicting factor for the postoperative outcome. These findings are probably due to the natural course of spinal stenosis leading to an increased instability of the spine and advanced facet joint degeneration. Therefore, different durations of symptoms may require different surgical techniques, and the decision of which technique to use should be made taking the duration of symptoms into consideration.

Improvements in the means of diagnosing spinal stenosis will surely lead to fewer patients with a long duration of symptoms before surgery, since the diagnosis can be established earlier. Patients will thus be operated at an earlier state of the disease, so that decompression only will be of increasing value for patients suffering from degenerative spinal stenosis. This is a benefit, since most patients undergoing surgery for degenerative spinal stenosis are aged over 60 years (in our study 901 patients = 54%), with many aged over 80 years (in our study 517 patients = 31%) and there is an increased morbidity associated with fusions [24].

In conclusion, we found that decompressive laminectomy only shows the best results for patients with degenerative spinal stenosis if the duration of symptoms is less than 8 years, so the clinician should aim to establish the diagnosis early and offer the operation to the patient early as well. Then patients can have maximum benefit from the operation, especially since it is associated with an acceptably low rate of complications.

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Appendix

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