Eur Spine J (2016) 25:2649–2656
DOI 10.1007/s00586-014-3484-7

ORIGINAL ARTICLE

Adult degenerative scoliosis: comparison of patient-rated outcome after three different surgical treatments

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Received: 2 November 2013 / Revised: 20 July 2014 / Accepted: 21 July 2014 / Published online: 8 August 2014

Abstract
Purpose Few studies have examined the effectiveness of surgical treatment for adult degenerative scoliosis (ADS) using validated patient-orientated outcome instruments. This study reports patient outcomes in a large, consecutive series of patients being treated for ADS by simple decompression (D), short fusion (SF), or long fusion (LF).
Methods Our local spine surgery database (part of the Eurospine Spine Tango Registry) was used to acquire the data from patients with ADS undergoing D, SF or LF. Preoperatively and at 12 and 24 months follow-up (FU), patients completed the multidimensional Core Outcome Measures Index (COMI; 0–10); at FU, satisfaction and global outcome were rated on a five-point Likert scale and dichotomised as "good" and "poor", and patient-rated complications were recorded.
Results 173 patients took part (81 D, 53 SF, 39 LF). Compared with the two fusion groups, the D group was significantly older, had more comorbidity, and had more leg pain than back pain (each $p < 0.05$). There were significant differences among the groups for operation duration, blood loss and general complications (each $p < 0.05$), in each case with the LF group showing the greatest values and the D group the lowest values. However, patient-rated complications were not significantly different between the groups ($p > 0.89$). Further surgery within the 2-year follow-up was required in 7 % of the D group, 15 % in SF and 28 % in LF. All groups benefited significantly from surgery with no significant differences ($p > 0.05$) between them: improvement in COMI after 24 months was 2.9 ± 2.8 points for D, 3.1 ± 3.3 points for SF and 3.2 ± 3.1 points for LF; a "good global outcome" was recorded for 69, 74 and 76 % patients, respectively.
Conclusions Despite the complexity of the disease, patient-orientated outcomes after surgery for ADS were similar to those previously reported using the same outcome instruments in patients with lumbar stenosis and degenerative spondylolisthesis. The use of D, SF and LF for ADS yielded similarly good results from the patient's perspective. This most likely reflects careful and appropriate patient selection. Further analyses are warranted to identify baseline variables predicting the 26–31 % cases in each group with a poor outcome.

Keywords Adult degenerative scoliosis · Patient-rated outcomes · Decompression · Fusion

Introduction

The treatment of de novo adult degenerative scoliosis (ADS) represents a challenge for the spine surgeon, with the demand for surgery rising but the indications and most appropriate treatment methods remaining controversial [1]. The criteria reported in the literature for the diagnosis of ADS are many and varied, but most rely on age, location in the lumbar spine, Cobb angle (minimum 10°), extent of degenerative changes and the absence of a history of scoliosis up to adolescence [1–3]. A recent overview of the various classification systems proposed for ADS concluded that no specific one was universally agreed upon [4]. The Scoliosis Research Society (SRS) describes ADS as a

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subgroup of adult deformities with a main curve in the lumbar spine [5]. Pritchett et al. [6] described ADS as an entity occurring in patients over 50 years old, having curves in the coronal plane not exceeding 60°, and involving the region from T12 to L5, with the apex of the curve at L2 or L3. Aebi reported that ADS often presents with subluxation of L3/4 and a tilt of L4 over L5 [2]. Grubb et al. [7] described characteristic differences between patients with this entity and those with adult idiopathic scoliosis that had degenerated further. In 2006, Schwab et al. [8] published a classification system for adult spinal deformity based on curve types with various modifiers. New onset lumbar degenerative scoliosis was a subgroup in this classification, represented by type V and, to a lesser extent, type IV. The same group recently published a new proposal for classification, which also included spino-pelvic parameters [9].

Adult degenerative scoliosis is commonly associated with some degree of foraminal stenosis, usually on the concave side, and less often with central canal stenosis. Progression over time is slow, and in some instances osteophyte bridging can lead to autofusion and stabilization. Clinical presentation in patients with ADS is very variable and ranges from simple radiculopathy and unilateral leg pain to severe mechanical low back pain with loss of sagittal and coronal balance. Treatment varies from decompression, through limited fusion, to attempts at full correction of the deformity with longer constructs. Patients with ADS are typically quite elderly, with a number of comorbidities, and the risk of complications when using extensive procedures rises markedly. The need to limit the extensiveness of surgery without compromising outcome is hence self-evident. However, there are no clear guidelines as to which procedure yields the best results in which patients, and there are few known predictors of outcome [1].

A recent systematic review assessed the available data on clinical and radiographic outcomes in adult scoliosis surgery [10]. The authors concluded that surgery for adult scoliosis was associated with improvement in radiographic and clinical outcomes at a minimum 2-year follow-up, but they highlighted the lack of routine use of standardized outcomes measures in the adult scoliosis literature. In a subsequent retrospective study of 85 patients, Transfeldt et al. [11] presented their patient-based outcomes for ADS patients undergoing three different types of treatment: decompression alone, limited fusion, or full curve correction with long fusion. They used several outcome instruments, including the Roland Morris disability questionnaire (RM), the Oswestry Disability Index (ODI), the Short Form 36 (SF36) and various satisfaction questions. However, there were contradictions in the findings, depending on the outcome instrument used. For example, in the decompression alone and limited fusion groups, significant improvements in scores were seen on the ODI but not on the RM or Physical Component subscale of the SF36; and despite the lack of change in ODI or RM in the long fusion group, 75 % of them said surgery was a success (compared with just 64 % in decompression alone and 74 % in limited fusion). Moreover, the proportion of the original group included in the questionnaire analysis was low [e.g., for the change in ODI from preoperative to follow-up, just 58/85 (68 %)] and the authors failed to control for potential confounders such as comorbidity, age, etc., when conducting their multivariable analyses.

The purpose of the present study was to evaluate prospectively collected patient-rated outcomes in a large, uniform, consecutive series of patients being treated for ADS by simple decompression, limited fusion, or full correction with longer constructs.

Methods

Inclusion criteria

The study was carried out using the framework of the Eurospine Spine Tango Registry together with our own in-house spine surgery outcomes database. It comprised a retrospective analysis of prospectively collected data of consecutive patients who had undergone surgery by qualified, specialized spine surgeons in our own Spine Center (part of an orthopedic hospital) from Feb 2005 to Feb 2011. To be included, patients had to: have a good understanding of written German or English or (after 2006) French, Spanish, Italian or Portuguese; be at least 2 years' post-operative; and fulfill the study's surgical admission criteria. The latter made use of the options ticked in relation to the given fields on the Spine Tango surgery form and were as follows: no previous surgery of the lumbar spine; surgery in the lumbar or lumbosacral region of the spine; degenerative deformity as the main pathology. The diagnosis of ADS (registered on the Tango form) had originally been made based on the normal clinical workup, as per everyday practice. Plain films of the lumbar spine in a–p and lateral standing positions were taken in all patients. Where available, whole spine films were used instead. ADS was defined as a coronal Cobb angle $\geq$10° [12], limited to the lumbar spine, with no known history of adolescent scoliosis. Review of patient charts and X-rays together with the Spine Tango surgery data allowed for categorization of the treatment undertaken into decompression (D) or fusion (F) with or without decompression as the operative procedure. Fusion was further sub-divided into short fusion of 1–2 levels without curve correction (SF), and longer fusion ($\geq$3 levels) with attempted curve correction (LF). All

comprised posterior fusion with pedicle instrumentation, with the majority also including interbody fusion [TLIF (mostly) or PLIF (occasionally)]. In the long fusion constructs, a 360° fusion at the lower levels was typically combined with posterior only in the upper levels. In short fusion constructs, a 360° fusion was usually performed.

The individual surgeon's decision whether to perform D or F reflected his/her routine decision-making process used in daily clinical practice, and typically considered factors such as the patient's leg pain, back pain, neurological symptoms and radiological findings, as well as their age, general health status, activity level, and willingness to undergo additional fusion.

Questionnaires

Before and 12 and 24 months after surgery, patients were requested to complete the Core Outcome Measures Index (COMI) questionnaire [13, 14]. On each occasion, the questionnaires were sent to the patients to complete at home, to ensure that the information given was free of care-provider influence. The COMI is a multidimensional index consisting of validated questions covering the domains of pain (leg/buttock and back pain intensity, each measured separately on a 0–10 graphic rating scale), function, symptom specific well-being, general quality of life, and social and work disability. Patients also indicated by means of a multiple-choice question what they considered their "main/greatest problem" to be: back pain, leg/buttock pain, neurological disturbances. In addition to the above questions, at the 12- and 24-month follow-ups there was a further question inquiring about the global outcome of surgery "how much did the operation help your back problem?", with five response categories: (1) helped a lot, (2) helped, (3) helped only little, (4) didn't help, and (5) made things worse. The global outcome was dichotomised into "good" (1 and 2) and "poor" (3, 4 and 5) for the purposes of some of the subsequent analyses. A second item at follow-up inquired about the patient's overall satisfaction with the treatment of their back problem in our hospital, also with five response categories: (1) very satisfied, (2) satisfied, (3) neither satisfied nor dissatisfied, (4) dissatisfied, and (5) very dissatisfied. These were similarly dichotomised into "satisfied" (1 and 2) and "dissatisfied" (3, 4 and 5) for some subsequent analyses. Patient-rated complications were enquired about with an open-field question, and then categorized as described by Grob et al. [15]. Reoperations since the index surgery were also enquired about, including whether they were at the same or a different level of the spine. Reoperations declared by the patients themselves were cross-checked against our in-house outcomes database, and further enquired about if there were discrepancies.

Comorbidity was assessed using the American Society of Anesthesiologists Physical Status Score (ASA Score), and was recorded on the Spine Tango Surgery documentation form, as were surgical and general complications occurring during the hospital stay.

Statistical analyses

Descriptive data are presented as mean ± standard deviations (SD). The significance of any differences between treatment groups (D, SF, LF) in their baseline variables was analyzed using analysis of variance (ANOVA) (with post hoc Fisher's PLSD tests) for continuous data and contingency analyses with Chi-squared/Fisher's exact P test for categorical variables.

Repeated measures analysis of variance [one "between-measures" (treatment group) and one "within-measures" factor (time of assessment)] was used to compare the reduction in COMI score from preoperatively to the 12-month follow-up and preoperatively to the 24-month follow-up in the three treatment groups (D, SF, LF).

Multivariable linear regression analyses were used to determine the significant statistical predictors of the 12- and 24-month postoperative COMI scores. The baseline COMI score, age, gender, and comorbidity were entered as control variables (since they are recognized potential confounders in analyses of outcome in such patients), followed by treatment group (D, SF, LF) as potential predictors of outcome.

Multivariable logistic regression analysis was used to predict the 12- and 24-month outcome category (good or poor, based on dichotomisation of the "global treatment outcome" item, as described above), using the same control variables and predictor variables as described above.

Logistic regression analysis was also used to identify the factors most likely associated with a patient having undergone decompression only as opposed to fusion (either SF or LF).

Statistical significance was accepted at the $p < 0.05$ level.

Results

Patients and follow-up rates

In relation to the registry data collected within our Spine Center, the average compliance rate for the surgeons' completion of the Surgical Forms after the initial work-in phase was 85 % (i.e., 85 % of all spine surgeries carried out in the Spine Center had an accompanying Spine Tango Surgery Form). Hence, potentially, up to 15 % of eligible patients were not included in the present study (the exact

Table 1 Baseline demographic, radiographic, comorbidity, and self-reported clinical data (mean ± SD, or % values) for the three treatment groups

Variable	Decompression (D) ($N = 81$)	Short fusion (SF) ($N = 53$)	Long fusion (LF) ($N = 39$)	p value (among groups)
Age (years)	75.8 ± 7.4*	66.3 ± 11.6	66.4 ± 10.5	**<0.0001**
Gender				
Female	54 (67 %)	36 (68 %)	29 (74 %)	0.69
Male	27 (33 %)	17 (32 %)	10 (26 %)	
Cobb angle (°)	20.4 ± 10.0	19.1 ± 6.9	21.5 ± 8.4	0.41
Comorbidity, ASA score (%)*				
I	3 (4 %)	8 (15 %)	5 (13 %)	0.08
II	40 (49 %)	32 (60 %)	22 (56 %)	
III	37 (46 %)	13 (25 %)	12 (31 %)	
IV	1 (1 %)	0 (0 %)	0 (0 %)	
Preoperative main problem (%)*				
Back pain	22 (28 %)	30 (59 %)	22 (59 %)	**0.002**
Leg pain	42 (53 %)	13 (25 %)	10 (27 %)	
Neurol. disturb	15 (19 %)	8 (16 %)	5 (14 %)	
Back pain intensity (0–10 scale)	5.1 ± 2.9*	6.9 ± 2.3	6.2 ± 3.0	**0.002**
Leg pain intensity (0–10 scale)	6.9 ± 2.2*	5.5 ± 2.8	5.6 ± 3.0	**0.003**
Leg pain minus back pain intensity	1.8 ± 3.4*	−1.4 ± 3.1	−0.6 ± 3.1	**<0.001**
Intensity of worst pain, back/leg (0–10 scale)	7.4 ± 1.8	7.5 ± 1.9	7.0 ± 2.4	0.47
COMI summary score (0–10 scale)	7.6 ± 1.6	7.6 ± 2.0	7.2 ± 2.1	0.56

Patient-rated data (main problem, pain, COMI, etc.) from $N = 167$ baseline questionnaires (97 % completion rate)

Bold highlighted p values indicate $p < 0.05$

* D significantly different from SF and LF ($p < 0.05$)

number is unknown, because a completed Tango surgery form was a prerequisite for identifying patients who fulfilled the study's surgical inclusion criteria).

Of all the patients in our local spine surgery database (operated between Feb 2005 and Feb 2011, and having reached 24 months follow-up), 173 patients satisfied the study's admission criteria. A patient-rated questionnaire was completed by 167/173 (97 %) patients at baseline, 156/173 (90 %) at 12 months follow-up, and 150/173 (87 %) at 24 months follow-up.

The baseline data of the three treatment groups are shown in Table 1. Compared with the two fusion groups, the group undergoing decompression was significantly older, had more comorbidity, and had more leg pain than back pain (each $p < 0.05$); however, neither the worst pain (either leg or back) or the COMI score at baseline differed between the groups.

Logistic regression analysis confirmed that patients were significantly more likely to have undergone decompression alone (as opposed to either of the types of fusion) if they were of a greater age (OR per year older 1.1; 95 % CI 1.1–1.2); had greater leg pain than back pain (OR per unit difference in pain intensity 1.3; 95 % CI 1.2–1.5); and had a greater number of levels to be decompressed (OR per additional level to be decompressed 1.6; 95 % CI 1.1–2.3). The baseline COMI score (severity of symptoms/function), comorbidity, lumbar lordosis and Cobb angle had no significant association with treatment group ($p > 0.05$).

Surgical data

The Spine Tango data pertaining to the surgery and the period up to discharge are shown in Table 2. There were significant differences ($p < 0.05$) among the groups for operation duration, blood loss and general complications; for each of these, the long fusion group showed the greatest values and the decompression group the lowest values.

Reoperation rate

In total, 25/173 (14 %) patients underwent further surgery within 2 years of their index operation: 6/81 (7 %) in the decompression group (2 fusions due to recurrence of symptoms, 1 osteoporotic fracture needing vertebroplasty, 1 infection and wound-healing problem, 1 dural repair, and 1 adjacent segment problem); 8/53 (15 %) in the short

Table 2 Surgical data for the three treatment groups

Variable	Decompression (D) ($N = 81$)	Short fusion (SF) ($N = 53$)	Long fusion (LF) ($N = 39$)	p value (among groups)
Number of levels decompressed	2.2 ± 0.8	1.3 ± 0.8#	1.9 ± 1.5	**<0.0001**
Number of levels fused	0*	1.6 ± 0.5#	4.0 ± 1.2	**<0.0001**
Operation duration (%)				
<1 h	3 %	0 %	0 %	**<0.0001**
1–2 h	75 %	6 %	0 %	
2–3 h	14 %	26 %	0 %	
3–4 h	7 %	41 %	18 %	
4–5 h	1 %	19 %	13 %	
5–6 h	0 %	4 %	51 %	
>6 h	0 %	4 %	18 %	
Blood loss (%)				
<500 ml	89 %	43 %	10 %	**<0.0001**
500–1,000 ml	10 %	44 %	38 %	
1,000–2,000 ml	1 %	13 %	31 %	
>2,000 ml	0 %	0 %	21 %	
Surgical complications [no. (%)]	6 (7 %)	2 (4 %)	6 (15 %)	0.12
General complications [no. (%)]	4 (5 %)*	9 (17 %)	8 (21 %)	**0.02**

Bold highlighted p values indicate $p < 0.05$

* Significantly different from SF and LF ($p < 0.05$)

Significantly different from D and LF ($p < 0.05$)

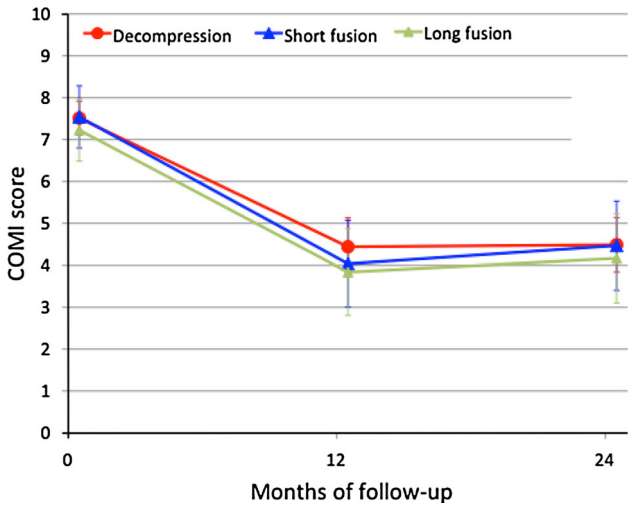

Fig. 1 Change in COMI score over the course of the study for the three treatment groups (decompression, short fusion, long fusion). Mean values ± 95 % CI

fusion group [1 revision for sagittal balance correction, 2 further decompressions after recurrence of symptoms, 1 revision due to pseudarthrosis, 2 infection (one of which also later had extension of the fusion), 2 fusion due to adjacent segment problems]; and 11/39 (28 %) in the long fusion group (7 adjacent segment problems, 4 pseudoarthrosis and 3 infections; >1 diagnosis per patient possible). The difference in reoperation rates among the groups was statistically significant ($p < 0.01$).

Outcomes at 12 and 24 months postoperatively

At both the 12- and 24-month follow-ups, the distribution of patient-rated global outcomes did not differ significantly between the treatment groups ($p > 0.05$). At 12 months, % "good" outcomes were D 68 %, SF 79 %, LF 78 %; at 24 months, the corresponding figures were D 69 %, SF 74 %, LF 76 %.

Similarly, there was no significant difference between the groups for the reduction in COMI score at 12 months (D 3.1 ± 2.9 points, SF 3.5 ± 3.1 points and LF 3.2 ± 3.2 points; $p = 0.78$) or at 24 months (D 2.9 ± 2.8 points, SF 3.1 ± 3.3 points and LF 3.2 ± 3.1 points; $p = 0.94$) (Fig. 1).

Satisfaction with care was also similar amongst the groups: at 12 months, % satisfied were D 82 %, SF 85 %, LF 84 % ($p = 0.90$); at 24 months, the corresponding figures were D 79 %, SF 72 %, LF 91 % ($p = 0.10$).

Patient-rated complications did not differ significantly among the groups: at 12 months, the proportions who self-reported a complication of some type after the index surgery were D 31 %, SF 34 %, LF 30 % ($p = 0.89$); at 24 months, the corresponding figures were D 23 %, SF 24 %, LF 21 % ($p = 0.93$).

In multivariable regression analysis controlling for possible confounders (age, gender, comorbidity), surgical treatment group [decompression alone or fusion (either SF or LF)] was not a significant predictor of either the 12- or 24-month COMI score or the 12- or 24-month global outcome (all $p > 0.45$).

Discussion

General considerations

There is a wide range of treatment options for ADS, ranging from non-operative care all the way up to full curve correction with long fusion [1]. Since patients with ADS represent a very heterogeneous group, with a relatively wide age range, differing symptoms, and varying amounts of comorbidity, etc., the specific treatment to be applied must be considered for each patient on a very individual basis [2].

Most commonly, surgical treatment for ADS comprises decompression alone, limited fusion without any attempt at deformity correction (usually with decompression) or long fusion (with or without decompression) in an attempt to correct the deformity. It is generally believed that patients treated with decompression alone are those who present with predominantly stenotic symptoms and pain radiating to the buttocks and legs, but with the load-bearing component of the spine appearing adequate. And, indeed, these indications were confirmed by the findings of the present study where leg pain greater than back pain and more levels requiring decompression were each significantly associated with being in the decompression group. With short fusion, the indication is usually the need for restabilization to protect the decompressed segment from further collapse, and/or as a means of addressing pain localized to 1–2 segments, as identified by diagnostic injection studies. In contrast, long fusion with curve correction is indicated when there is progressive collapse with no single level identifiable as the pain source; pain associated with mechanical weight bearing, and loss of spinal balance, are typically the chief complaints.

In the present study, we categorized our patients into these three treatment subgroups and analyzed their outcomes. As in the previous study of Transfeldt et al. [11], the aim was not to compare the groups to examine the superiority of one treatment over another, but rather to examine the factors that led to the treatment decisions and to analyze the subsequent outcomes, in a larger and more uniform series than has previously been reported. The present study is solely focused on patient-based outcomes; the extensive radiological data that accompany the clinical outcomes, and their relationship to the latter, will be presented in a separate paper.

Clinical outcome and treatment modality

There is a paucity of studies that have examined patient-rated clinical outcomes in patients with ADS and even fewer examining these in relation to different treatment modalities [2, 10]. Transfeldt et al. [11] compared the same three treatment groups as those examined in the present study and noted that patients treated with decompression alone showed greater improvement in Oswestry scores yet less satisfaction compared with patients who underwent more extensive full curve correction. This contrasts with our findings, where all three groups appeared to benefit from treatment to a similar extent, whether expressed as the reduction in COMI score from baseline to 12 or 24 months, or as the global treatment outcome. There was a slight tendency for patients who underwent fusion to report slightly better outcomes all round, but this was not statistically significant.

The complication rates reported by Transfeldt et al. for their fusion groups were considerably higher (40 and 56 % for SF and LF respectively; no indication given in their paper as to whether these were surgical or general complications) than those reported in the present study (D 7 %, SF 4 % and LF 15 % for surgical complications and D 5 %, SF 17 %, LF 21 % for general complications). Longer constructs have been repeatedly associated with a longer duration of surgery, higher blood loss, and more complications, and this was also the case in the present study. However, none of these factors appeared to have any bearing on the overall ratings of treatment outcome or satisfaction, since these were similar in the three treatment groups.

The rates of reoperation reported by Transfeldt et al. [11] were 10 % for D, 33 % for SF and 37 % for LF, which were somewhat higher than in the present study, especially for the SF group (7 % D, 15 % SF, 28 % LF in the present study). Other authors have compared SF and LF (sometimes with differing definitions of each), but only in terms of radiological outcomes and perioperative clinical data [16]. Indeed, the paucity of outcome reports from the patient's perspective, using standardized outcome measures, was one of the main points of concern in the review of Yadla et al. [10].

Value of the COMI for the assessment of outcome in ADS

It has been shown that ADS is more closely related to other degenerative conditions of the lumbar spine than to adult idiopathic scoliosis (AIS) [2, 17]. As such, the current outcome instruments used in the assessment of AIS may not be appropriate for patients with ADS. The main complaints of patients with ADS are pain and disability; these are the very same domains of importance in other degenerative conditions of the lumbar spine and are the domains measured by the COMI. Transfeldt et al. [11] similarly used instruments that assessed pain and disability, i.e., Roland Morris, SF36, ODI, and various satisfaction questions. However, there were some discrepancies in their findings, dependent on the instrument in question, that could not be fully explained. This may have been a result

of their rather small group sizes and the subsequent lack of stability of the findings. The COMI has been in regular use in the Spine Tango surgical registry for many years now [18], and has proven to be a highly practical and responsive instrument in assessing outcome in painful degenerative entities such as lumbar disk herniation, spinal stenosis, and lumbar degenerative spondylolisthesis [14, 19–22]. The responsiveness to treatment shown in the present study confirms its usefulness also in patients with ADS.

This study reports for the first time (to the best of our knowledge) complication rates in ADS surgery as assessed from the patients' perspective. Approximately 20–30 % patients across the three different treatment arms reported complications at the 1 and 2-year follow-ups, without any significant differences among the groups. The incidence of complications after surgery as rated by the patient is typically much higher than the incidence reported by the surgeon [15, 23, 24], and the same was generally true in the present study. Interestingly, however, even our patient-based complication rates were still much lower than those reported from the surgeon's perspective in some previous surgical studies [11, 25].

The value of 1- or 2-year follow-up

To be published in the peer-reviewed literature, most clinical studies are required to have at least 2 years follow-up. In a previous study in patients with degenerative spine disease, it was reported that the 3-month outcome is a good predictor of the 1- and 2-year outcome [14]; however, it was not known whether this was also the case in the specific subgroup of patients undergoing larger deformity surgery. Glassman et al. [26] showed that, in patients with degenerative deformity, the 2-year results mirror the 1-year results. This was confirmed also in the present study. There were no major differences in the findings at the 1-year compared with the 2-year follow-up. Given the nature of the disease affecting the entire lumbar spine, one might assume that progression would take place; however, this could not be demonstrated in the present study, certainly as far as patient-based outcome was concerned. In a community based cohort study, Jimbo et al [27] examined the epidemiology and progression of ADS over time and identified certain risk factors such as L4 tilt and smaller vertebral size as predictors of progression. It remains to be seen whether such factors might influence the longer-term outcomes in the present series.

Reoperation rates

The reoperation rates in the present study varied between the treatment groups, showing a progressive increase from 5 % in decompression alone, 9 % in short fusion and 21 % in long fusion over the course of the 2-year follow-up. Hence, the reoperation rate appeared to be related to the degree of invasiveness/extensiveness of the surgical procedure. Again, it is interesting that, despite the higher reoperation rate in the LF group, the overall 2-year outcome from the patient's perspective was similar in all three groups.

Shortcomings of our study

Our study was not without its limitations. It was a retrospective, observational study and there were hence no a priori criteria detailing how patients were selected for the different treatments. In deciding which treatment is most suitable for which patient, factors such as age, comorbidity, presenting symptoms, and the patient's expectations are typically taken into account. For patients in the decompression group, fusion procedures may sometimes have been indicated, but were not chosen because of other contraindications. Thus, decompression was not always the treatment of choice but of circumstance. In fusion arms, it was usually the treatment of choice. This may underlie the slightly (but not significantly) poorer results in the "decompression only" group. Our study reflects the current way that patients with ADS are evaluated at our institution and the selection criteria used in decision making, and it seems to indicate that relatively favorable outcomes were obtained in all three treatment arms. It is not possible to state which procedure would have been the most appropriate for any given individual, or indeed whether a different procedure from the one used would have resulted in a better or worse outcome. This is a known limitation of observational studies. This study deals only with surgically treated patients, and it is not known how the patients would have fared had they received non-operative management rather than surgery. However, all our patients had had extensive conservative management prior to surgery, without achieving their goals, and hence opted for surgery. ADS was defined as per the SRS glossary of terms on the basis of a coronal Cobb angle of $\geq 10°$; however, some groups suggest that the clinical relevance of deformity starts at 20° or higher. In a secondary analysis of a subgroup of patients with a coronal Cobb angle $\geq 20°$, we found no notable differences from any of the whole group findings with the exception of somewhat higher complication rates and reoperation rates in the fusion groups, especially the short fusion group (results not shown). However, since for that analysis the sample size was approximately halved, the findings would require confirmation in larger studies. All the patients in the present study had adult de novo degenerative scoliosis, and hence the majority had only mild to moderate deformity; the findings cannot be generalized to patients with significant degenerative deformity ($\geq 40°$) typical of that resulting

from degenerative scoliosis subsequent to adolescent idiopathic scoliosis.

The study shows that, based on careful selection criteria, even extensive surgery in this population can yield satisfactory results similar to simple decompression and fusion procedures, when looked at from the patient's perspective. Future studies should analyze more closely the factors influencing outcome in each of the treatment groups and the correlation between patient-based outcomes and radiographic parameters.

Conclusion

The surgical treatment of ADS poses several challenges in terms of choosing the most appropriate procedure. In the present study, the use of patient-based clinical outcome measures showed satisfactory results in all the three treatment groups examined: decompression only, short fusion without correction, and long fusion with correction. Fusion procedures were associated with with significantly more general (systemic) complications, but still resulted in similarly favorable outcome compared with decompression alone.

Acknowledgments We are grateful to Dave O'Riordan, Gordana Balaban, Nora Aziz-Toth, Julian Amacker, and Kirsten Clift for their valuable assistance in collecting the questionnaire data.

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