



Surgical training in spine surgery: safety and patient-rated outcome

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Abstract

Purpose The aim of this study was to investigate the difference in patient-reported outcomes and surgical complication rates between lumbar procedures carried out either by experienced board-certified spine surgeons (BCS) or by supervised spine surgery residents (RES) in a large Swiss teaching hospital.

Methods This was a single-center retrospective analysis of data collected prospectively within the framework of the EURO-SPINE Spine Tango Registry. It involved the data of 1415 patients undergoing first-time surgery in our institution between the years 2004 and 2016. Patients were divided into three groups based on the surgical procedure: lumbar single-level fusion (SLF), single-level decompression (SLD) for lumbar spinal stenosis and disc hernia procedures (DH). Patient-reported outcome measures (primary outcome) included the multidimensional Core Outcome Measures Index (COMI) preoperatively and 3 and 12 months postoperatively plus single items concerning satisfaction with care and global treatment outcome (GTO). Secondary outcomes included surgical variables such as blood loss, duration of surgery, complication rates and length of stay.

Results There were no significant differences between the RES and BCS patient groups for most of the demographic and baseline clinical variables with the exception of age in the SLD group ($p=0.012$), BMI in the DH group ($p=0.02$) and leg pain in the SLF group ($p=0.03$). COMI scores improved significantly after all three types of procedure ($p<0.0001$) without significant difference ($p>0.05$) between the patients of RES and BCS. There was no significant difference ($p>0.05$) between RES and BCS patients with regard to satisfaction and GTO. There were no significant differences between RES and BCS ($p>0.05$) in the surgical or medical complication rates.

Conclusion In the given setting, surgical training of spine surgery residents under guided supervision by board-certified spine surgeons was shown to be safe, as it was not associated with greater morbidity or mortality. Furthermore, it had no detrimental influence on patient-reported outcomes. The findings can be used to give reassurance to prospective patients that are to be operated on by supervised spine surgery residents.

Graphical abstract

These slides can be retrieved under Electronic Supplementary Material.

Key points

[surgery training, lumbar decompression, lumbar fusion, patient reported outcome]

1. The influence of resident participation in spinal surgical cases is controversial.
2. Active involvement in surgical procedures is regarded a key feature for a thorough and efficient training of spine surgery residents.
3. Concern over resident inexperience can also be reflected in a reluctance among patients to have residents involved in their care.

Table 3: Global treatment outcome and satisfaction with care one year postoperative

Variables	Single level decompression (SLD)			Single level fusion (SLF)			Disc herniation (DH)		
	RES	BCS	<i>p</i> value ^a	RES	BCS	<i>p</i> value ^a	RES	BCS	<i>p</i> value ^a
Mean (SD)	49.88 (23.12)	49.82 (23.12)	0.91	47.52 (27.22)	47.52 (27.22)	0.91	49.88 (23.12)	49.82 (23.12)	0.88
Median (IQR)	49.88 (23.12)	49.82 (23.12)	0.91	47.52 (27.22)	47.52 (27.22)	0.91	49.88 (23.12)	49.82 (23.12)	0.79

^a%, percentage within the group; SD, standard deviation; SLD, single level decompression; SLF, single level fusion; DH, disc hernia operation; RES, patients operated on by residents as primary surgeons; BCS, patients operated on by board certified surgeons; GTO, global treatment outcome.

Take Home Messages

1. Surgical training of spine surgery residents under guided supervision by board certified spine surgeons was shown to be safe, as it was not associated with greater morbidity or mortality.
2. Furthermore, surgical training had no detrimental influence on patient reported outcomes.
3. The findings can be used to give reassurance to prospective patients that are to be operated on by supervised spine surgery residents.

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Extended author information available on the last page of the article

Keywords Surgical training · Patient-reported outcome · Complications spine surgery · Lumbar spine surgery

Introduction

Surgical education of spine surgery residents in the operation room represents the essence of surgical training. However, patient safety is of paramount importance and must not be sacrificed in favour of education. As residents are less experienced than their supervising counterparts, reaching the educational goal might present a dilemma, as residents' involvement may theoretically result in increased morbidity and less satisfied patients. Concern over resident inexperience can also be reflected in a reluctance among patients to have residents involved in their care [1]. In addition, the possible increase in operation time and prolonged hospital stay due to greater morbidity might have an economic burden.

Most spine surgery is carried out for lumbar degenerative disorders [2]. Key procedures for these degenerative pathologies include decompressive techniques for spinal stenosis and herniated disc as well as segment fusion for various underlying diseases. In the coming years, the ageing of the population is expected to be accompanied by an increase in the number of spine surgical interventions carried out, especially in developed countries [3–5]. For this reason, trainee spine surgeons will have to become familiar with these procedures and the acquisition of adequate skills will be crucial to provide high-quality treatment in the future.

The influence of resident participation in spinal surgical cases remains controversial. In the study of Pugely [6], both operative time and length of hospital stay were greater when residents were involved in spinal fusion cases. In addition, resident involvement was associated with greater 30-day reoperation rates. Longer operative times were also reported in a study evaluating the impact of resident participation on morbidity in 1136 patients who underwent fusion surgery for adult spinal deformity. Possible negative effects associated with longer operative times such as increased blood loss and longer hospitalization were reported [7]. In contrast, outcomes and complications in scoliosis surgery were found to be comparable when residents were involved, with only marginally increased operative times and estimated blood loss (EBL) without an increase in transfusions or complications [8]. No significant risk of postoperative morbidity or mortality was detected for lumbar spine surgery carried out by residents in a study investigating a total of 4558 cases of discectomy [9]. In addition to these American studies, a recent Swiss study showed comparable complication rates and outcomes between patients undergoing lumbar disc surgery by supervised residents and board-certified surgeons [10]. The aforementioned studies focussed mainly on morbidity and related parameters such as length of hospitalization, while

patient-reported outcomes were addressed in just one of them [10].

In Switzerland, training of surgery residents in the operation theatre is an integral part of the curriculum and trainees usually perform procedures commensurate with their level of experience and competence, under constant supervision of a board-certified surgeon, present at all times. The aim of this study was to investigate the influence of surgical resident performance on outcomes in patients undergoing lumbar procedures. To our best knowledge, this is the first study to assess the impact of supervised resident surgical performance in both neurosurgery and orthopaedic surgery trainees, enrolled at the same teaching facility, on patient-reported outcomes and morbidity after different spinal procedures. The evaluation is based on three of the most common procedures in degenerative lumbar spine surgery: decompression for spinal stenosis, sequesterectomy or microdiscectomy for disc herniation, and single-level lumbar fusion.

Methods and materials

Residents (RES) and board-certified surgeons (BCS)

Spine surgery residents were typically between their fourth and sixth years of training and were participating in the education programs of the Swiss national board for either orthopaedic surgery or neurosurgery. The teaching and training of residents focuses on the day-to-day care of patients with spinal disorders during outpatient consultations, the presenting and discussing of cases in a board review committee, and the postoperative management of operated patients. Clinical and scientific knowledge is also acquired by the resident by means of participation in journal clubs and internal workshops. Most importantly, surgical skills are acquired via active participation of the resident in the operation room.

In the case of a potential indication for surgery in the setting of the consultation, the case was discussed as described below. Patients from the resident's consultation that were selected for surgery were operated on by the respective resident, provided the patient consented, and surgery was done under the supervision of a dedicated BCS.

Patients

This was a single-center retrospective analysis of data collected prospectively in connection with the EUROSPINE Spine Tango Registry [11], between the years 2004 and 2016.

All patients with degenerative disease as their main pathology that had undergone a single-level, procedure on the lumbar spine by supervised residents (RES) or board-certified surgeons (BCS) were included. To avoid selection bias between the study groups due to the health insurance status (patients with private health insurance were always referred directly to BCS), patients with private and semi-private health insurance were excluded. Only single-level procedures were included in order to minimize differences between the groups in the severity of the pathologies treated. For the same reason, cases with previous surgery at the index level were excluded. Surgery cases were classified as follows: one-segment lumbar fusion with or without decompression (SLF); single-level decompression alone (SLD); or disc hernia-related procedures such as sequestrectomy and microdiscectomy (DH).

Patient assignment to either BCS or RES was based on the primary consulting surgeon. The patients were informed, accordingly. The decision for surgery was case-related and heterogeneous. Patients were generally selected for surgery by a case review committee based on the clinical symptoms, radiological findings, response to prior conservative treatment, degree of suffering and comorbidities.

Surgical procedures

Spinal fusion was performed via posterior transpedicular screw insertion and rod fixation. When indicated for providing anterior support, surgery included a complete discectomy and interbody cage placement through either a posterior or a transforaminal approach (PLIF, TLIF). Indications for fusion surgery included degenerative disc disease, spondylolisthesis and spinal stenosis [12, 13].

Simple decompression procedures were executed micro-surgically in most cases. The surgical technique depended on the underlying pathologic characteristics as well as the surgeon's preference and included laminectomies, hemilaminectomies and unilateral as well as bilateral interlaminar fenestrations. The indication for surgery was spinal stenosis with uni- or bilateral leg pain, and claudication with or without neurological deficits.

Disc hernia cases were addressed via standard microscopic sequestrectomies with and without microdiscectomies as indicated. Patients were generally referred to surgery based on radicular pain and/or neurologic impairment.

The operation techniques were based on the case itself and were dependent on the experience and preference of the BCS.

All cases including indication and consenting were discussed prior to surgery with the corresponding BCS. Residents usually performed the whole case without major intervention of the BCS. However, if difficulties arose, the BCS intervened. The study sought to evaluate the relative

safety and outcomes of RES training in practice, rather than to compare the performance of RES and BCS per se, hence if assistance was required this was not considered to invalidate the analysis. Procedures carried out by BCS served as controls.

Outcome variables

Clinical and surgical data on our spine surgery cases are documented prospectively in our Spine Center using a customized, in-house database linked to the EUROSPINE Spine Tango registry system (<http://www.eurospine.org/spine-tango.htm>) [14]. For the time-period under investigation (Jan. 2005–March 2016), 98% of all surgeries were documented in the system. Documentation on the Spine Tango Surgery form includes information about pathology, prior treatment, morbidity status, demographic characteristics, surgical details and complications. Forms are filled out by the surgeon from admission to discharge for each case (Follow-up forms are filled in by the surgeon 6 weeks, 12 weeks and 12 months after the procedure.) Since the Spine Tango Surgery form uses only categories (with ranges of values) for the assessment of blood loss and operation duration, the data for these variables were exported from the clinic information system (by linking with the patient's operation ID code in the in-house database) to provide more exact values of blood loss (in ml) and operation duration (in minutes).

Preoperatively, and at 3-month and at 12-month follow-up, patients complete the Spine Tango Patient Self-assessment form. The latter includes the Core Outcome Measures Index, which is a short, validated, multidimensional outcome instrument, particularly suited for use in registries for monitoring the outcome of spinal surgery from the patient's perspective [15, 16]. The questionnaire contains questions covering the domains of pain (back and leg/buttock pain intensity, measured separately on 0–10 graphic rating scales), and function, symptom-specific well-being, general quality of life, social disability and work disability (each on a 5-point scale). At follow-up, the Self-Assessment form enquires about the global treatment outcome (GTO) evaluated with the following question "Overall, how much did the treatment you received help your back problem?", answered on a 5-point Likert scale, ranging from "1—helped a lot" to "5—made things worse". It also enquires about satisfaction with medical care in the hospital, evaluated using a 5-point scale (1—"very satisfied" to 5—"very dissatisfied"). Preoperative questionnaires were sent to the patients at home and returned complete at admission. Follow-up forms were dispatched and returned via post.

Statistical analysis

Descriptive data are presented as means and standard deviations (SD). Differences between groups of patients operated by RES or BCS for continuous, normally distributed data were analysed using analysis of variance: one-way ANOVA for the differences between BCS and RES for variables such as age, baseline scores; and repeated measures ANOVA for differences between BCS and RES for the changes in COMI scores over time of follow-up (baseline to 3-month to 12-month follow-up). Contingency analyses with chi-squared were used to analyse associations between the groups (BCS and RES) and categorical variables, e.g. ASA grade, complication rates, etc. The global treatment outcome (GTO) was dichotomized as “good” (operation helped or helped a lot) and “poor” (operation only helped a little, did not help, made things worse) for some analyses. Similarly, patient-rated satisfaction with care was dichotomized as

“satisfied” (satisfied and very satisfied) and “not satisfied” (neither satisfied nor dissatisfied, somewhat dissatisfied and very dissatisfied). The data were analysed using StatView 5.0 (StatView, SAS Inc., Berkeley, CA), and statistical significance was accepted at the $p < 0.05$ level.

Results

Patient and surgical characteristics

A total of 1415 patients were identified for analysis: 321 patients (RES $n = 60$, BCS $n = 261$) had undergone SLF, 318 (RES $n = 72$, BCS $n = 246$) had been treated with SLD and 776 (RES $n = 247$, BCS $n = 529$) had undergone surgery for DH (Table 1).

There were no significant differences between the RES and BCS patient groups for most of the demographic and

Table 1 Patient demographics and baseline (preoperative) characteristics

Variable	Group (procedure and surgeon experience level)								
	Single-level decompression (SLD)			Single-level fusion (SLF)			Disc herniation (DH)		
	RES	BCS	<i>p</i> Value*	RES	BCS	<i>p</i> Value*	RES	BCS	<i>p</i> Value*
Mean age in years (\pm SD)	73 (\pm 11)	69 (\pm 11)	0.012	59 (\pm 15)	56 (\pm 13)	0.12	45 (\pm 13)	45 (\pm 13)	0.91
Sex			0.29			0.84			0.30
Male (<i>N</i> , %)	40 (56)	119 (49)		21 (35)	95 (36)		132 (53)	303 (57)	
Female (<i>N</i> , %)	32 (44)	126 (51)		39 (65)	166 (64)		115 (47)	225 (43)	
BMI (<i>N</i> , %)			0.71			0.27			0.02
< 20	1 (1)	11 (5)		2 (3)	18 (7)		14 (6)	37 (7)	
20–25	24 (33)	88 (36)		22 (37)	101 (39)		105 (42)	240 (45)	
26–30	27 (38)	81 (33)		18 (30)	75 (29)		65 (26)	157 (31)	
31–35	7 (10)	31 (13)		9 (15)	34 (13)		20 (8)	38 (7)	
> 35	2 (3)	7 (3)		1 (2)	16 (6)		16 (6)	10 (2)	
Unknown	11 (15)	28 (11)		8 (13)	16 (6)		27 (11)	47 (9)	
ASA (<i>N</i> , %)			0.07			0.38			0.37
n/a	2 (3)	1 (< 1)		0 (0)	1 (< 1)		0 (0)	2 (< 1)	
1	10 (14)	20 (8)		18 (30)	52 (21)		150 (61)	292 (55)	
2	29 (40)	137 (56)		28 (47)	153 (59)		83 (34)	206 (39)	
3	30 (42)	84 (34)		14 (23)	54 (20)		14 (5)	29 (5)	
4	1 (1)	4 (2)		0 (0)	1 (< 1)		0 (0)	0 (0)	
Current smoker (<i>N</i> , %)			0.45			0.93			0.96
Yes	8 (11)	42 (17)		17 (28)	80 (31)		75 (31)	156 (29)	
No	49 (68)	160 (65)		35 (58)	146 (56)		127 (51)	278 (53)	
Not known	15 (21)	44 (18)		8 (13)	34 (13)		45 (18)	95 (18)	
COMI (mean \pm SD)	7.5 (\pm 2.0)	7.4 (\pm 1.9)	0.49	7.7 (\pm 1.6)	7.8 (\pm 1.5)	0.92	7.8 (\pm 1.7)	7.8 (\pm 1.7)	0.54
Leg pain (mean \pm SD)	6.7 (\pm 2.6)	7.0 (\pm 2.4)	0.40	5.4 (\pm 3.0)	6.2 (\pm 2.7)	0.03	6.7 (\pm 2.4)	6.9 (\pm 2.4)	0.39
Back pain (mean \pm SD)	5.3 (\pm 3.1)	4.9 (\pm 3.1)	0.34	6.3 (\pm 2.4)	6.5 (\pm 2.5)	0.69	4.7 (\pm 2.9)	4.7 (\pm 2.9)	0.84

N number, % percentage within the group, *SD* standard deviation, *SLD* single-level decompression, *SLF* single-level fusion, *DH* disc hernia operation, *RES* patients operated on by residents as primary surgeons, *BCS* patients operated on by board-certified surgeons, *BMI* body mass index, *ASA* American Society of Anesthesiologists score, *COMI* core outcome measure index

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

baseline clinical variables (Table 1) with the exception of age in the SLD group (RES patients were slightly older than BCS, $p=0.012$), BMI in the DH group (slightly more RES than BCS patients were “obese” (BMI > 30 kg m⁻²), $p=0.02$) and leg pain in the SLF group (slightly higher in BCS than in RES patients, $p=0.03$).

Patient-rated outcome

81% of patients [SLF 284/321 (88%), SLD 267/318 (84%), DH 591/776 (76%)] completed a Spine Tango Patient Self-assessment form at all three time-points, i.e. preoperatively and at 3- and 12-month follow-up. There was a statistically significant ($p<0.001$) and clinically relevant reduction in the multidimensional COMI score from preoperatively to 3 and 12 months postoperatively for all groups, with no significant difference between RES and BCS cases (SLF, $p=0.31$; SLD, $p=0.44$ or DH $p=0.39$) for the extent of the reduction (Fig. 1). Satisfaction with care revealed no significant differences between the surgeon groups (RES vs BCS) for any of the surgical procedures (see Table 2). One year postoperatively, between 81 and 89% patients were satisfied with their medical care in the hospital, with the highest values being recorded for DH patients (Table 2). A good GTO was reported by almost 80% of the patients in the SLF (both RES and BCS), between 72% (RES) and 76% (BCS) in the SLD groups and by over 80% (both RES and BCS) in the DH group. There were no significant differences between RES and BCS groups (Table 2).

With regard to the surgical outcomes, the duration of the operation was significantly longer in both SLD and DH cases when performed by RES (SLD $\Delta 9$ min, $p=0.0594$; DH $\Delta 6$ min, $p=0.0054$; SLF $\Delta 5$ min, $p=0.5107$). Blood loss was higher in RES than BCS for SLD cases only ($\Delta 55$ ml, $p=0.0017$; DH $\Delta 13$ ml, $p=0.1017$; SLF $\Delta 34$ ml, $p=0.05619$) (Table 3).

Compared with patients operated by BCS, patients operated by RES had a non-significant tendency for a longer hospital stay after SLF ($p=0.18$) and a shorter stay after DH surgery ($p=0.14$) (Table 3). There were no significant differences between RES and BCS cases for the % complications of either a surgical or general medical nature (Table 3). The most common surgical complication, dural tear, occurred with slightly but not significantly lower frequency in RES than in BCS cases, for all types of surgery, respectively, 1.5% versus 3.0% for DH, 1.9% versus 6.0% for SLD and 2.4% vs 3.4% for SLF.

Discussion

In addition to acquiring theoretical knowledge, performing inpatient and outpatient care, and taking on emergency duties, an active involvement in surgical procedures is

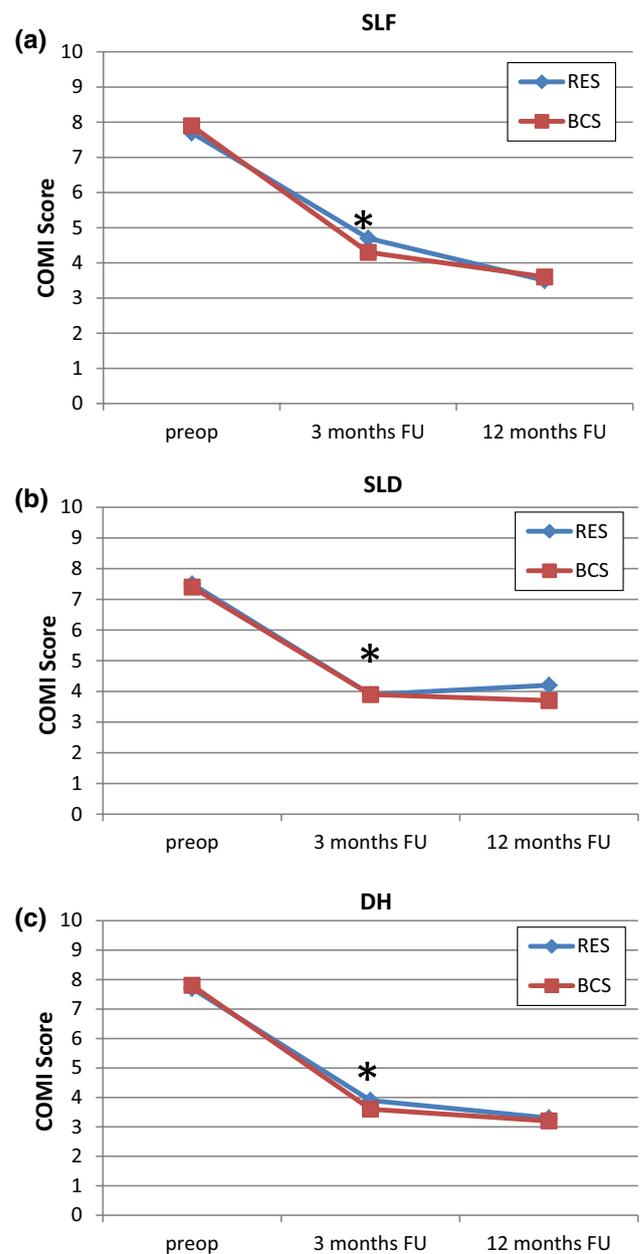


Fig. 1 COMI scores before surgery (preop) and at 3 and 12 months postoperatively (FU) for **a** SLF, **b** SLD and **c** DH procedures. *SLF* single-level fusion, *SLD* single-level decompression, *DH* herniated disc surgery. The asterisk indicates a statistically significant ($p<0.001$) and clinically relevant reduction in the multidimensional COMI score from preoperatively to 3 and 12 months postoperatively for all groups, with no significant difference between RES and BCS cases (SLF, $p=0.31$; SLD, $p=0.44$ or DH $p=0.39$) for the extent of the reduction. Standard deviations (SD) are omitted for clarity but ranged from ± 1.7 to 3.1 for SLF RES, ± 1.5 to 3.0 for SLF BCS; ± 2.0 to 3.0 for SLD RES and ± 1.9 to 2.8 for SLD BCS; and ± 1.7 to 2.9 for DH RES and ± 1.9 to 2.8 for DH BCS)

regarded a key feature for a thorough and efficient training of spine surgery residents. Surgical experience is essential for acquiring the best possible skills, and both the spectrum

Table 2 Global treatment outcome and satisfaction with care 1 year postoperative

Variable	Group (procedure and surgeon experience level)								
	Single-level decompression (SLD)			Single-level fusion (SLF)			Disc herniation (DH)		
	RES	BCS	<i>p</i> Value*	RES	BCS	<i>p</i> Value*	RES	BCS	<i>p</i> Value*
Good GTO (<i>N</i> , %)	49/68 (72.1)	168/221 (76.0)	0.51	44/57 (77.2)	193/243 (79.4)	0.71	183/221 (82.8)	391/481 (81.2)	0.63
Satisfied with care (<i>N</i> , %)	55/68 (80.9)	190/221 (86.0)	0.31	47/57 (82.5)	216/243 (88.9)	0.18	196/221 (88.7)	423/481 (87.9)	0.78

% percentage within the group, *SD* standard deviation, *SLD* single-level decompression, *SLF* single-level fusion, *DH* disc hernia operation, *RES* patients operated on by residents as primary surgeons, *BCS* patients operated on by board-certified surgeons, *GTO* global treatment outcome

Table 3 Perioperative surgical outcomes

Variable	Group (procedure and surgeon experience level)								
	Single-level decompression (SLD)			Single-level fusion (SLF)			Disc herniation (DH)		
	RES	BCS	<i>p</i> Value*	RES	BCS	<i>p</i> Value*	RES	BCS	<i>p</i> Value*
Mean estimated blood loss in ml (\pm SD) ⁺	166.80 (\pm 169.59)	114.74 (\pm 105.2)	0.0017	602.5 (\pm 482.79)	568.18 (\pm 395.2)	0.5107	98.29 (\pm 108.07)	85.47 (\pm 97.9)	0.1017
Mean operation time in min (\pm SD) ⁺	103.54 (\pm 35.4)	94.97 (\pm 33.32)	0.0594	220.32 (\pm 47.7)	225.4 (\pm 55.2)	0.5619	78.61 (\pm 28.4)	72.73 (\pm 26.9)	0.0054
<i>Complications N</i> (%)									
Any surgical complication	3 (4.1)	18 (7.3)	0.34	3 (5.0)	17 (6.5)	0.66	9 (3.6)	29 (5.5)	0.27
Dural tear	1 (1.9)	8 (6.0)	0.24	1 (2.4)	5 (3.4)	0.76	3 (1.5)	10 (3.0)	0.29
Any general complication	5 (6.9)	14 (5.7)	0.69	3 (5.0)	17 (6.5)	0.66	5 (2.0)	11 (2.0)	0.96
<i>LOS</i>									
Mean (\pm SD) no. days	7.0 (\pm 3.4)	7.4 (\pm 23.4)	0.88	9.2 (\pm 3.9)	8.5 (\pm 4.3)	0.18	4.0 (\pm 2.2)	4.4 (\pm 3.1)	0.14

N number, % percentage within the group, *SD* standard deviation, *SLD* single-level decompression, *SLF* single-level fusion, *DH* disc hernia operation, *RES* patients operated on by residents as primary surgeons, *BCS* patients operated on by board-certified surgeons

⁺The data for estimated blood loss and duration of operation were exported from the clinic information system (by linking with the patient's operation ID code in the in-house database) to provide more exact values of blood loss (in ml) and operation duration (in minutes)

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

of cases and the numerical case load govern whether the learning curve is completed effectively [17]. Interestingly, considerable differences are observed between countries in relation to the active performance of residents in the operation theatre. One study investigating a total of 15 European countries reported that both Austria and Germany were below the international average in terms of the number of spine procedures per month performed by residents, while Switzerland was located in the middle of the range [18].

In teaching hospitals, training is an integral part of the overall patient care and patients are routinely referred to, examined by and operated on by residents. Patients might be

concerned about the quality and safety of the proposed treatment, especially in a surgical setting. Based on a survey of urologic patients, one study reported that 90% of the patients agreed that trainees needed to perform surgery under supervision to improve their skills; however, regarding their own particular procedure, only 77% were happy for a supervised trainee to do their operation [19]. Another study involving 200 patients admitted for gastrointestinal surgery reported similar findings, whereas the majority of patients felt comfortable with residents being involved in their overall care (86%), 32% of them did not want residents carrying out their operations [20].

The current study aimed to assess the influence of resident involvement in spine surgery, under the guidance of supervising experienced surgeons, on patient-related outcome and morbidity. Patient demographics were by and large comparable between the groups (RES and BCS) with the exception of BMI and age, which showed minor differences between RES and BCS groups. The direction of these differences would, if anything, have favoured the outcomes of the BCS patients (slightly fewer obese patients and slightly younger age), such that they are unlikely to have any influence on the conclusion that RES patients did not show worse outcomes than BCS patients. Baseline symptoms were also similar for the study groups, with the exception of preoperative leg pain, which was slightly but significantly higher for patients undergoing SLF operated by BCS rather than RES. The reasons why, in the fusion group, a higher proportion of BCS than RES patients had higher leg pain scores is currently unclear.

For all three types of procedure, blood loss, operation time and duration of hospitalization were comparable with those reported in the published literature [21–34]. In our series, blood loss was significantly higher in RES than BCS only for patients undergoing decompression for spinal stenosis. This might be explained by the less skilful use of the Kerrison rongeur in the spinal canal by the trainee, causing epidural venous bleeding, as well as less effective hemostasis strategies. Operation time was significantly higher in RES than BCS for patients undergoing surgery for either disc herniation or spinal stenosis. As procedures for single-level decompression are comparatively short and performed at a relatively high frequency, the expertise of BCSs is expected to result in significantly shorter operation times. The clinical relevance of differences in operation duration of 6–9 min is expected to be negligible as the complication rates were not any higher in the RES than the BCS. Typically, a longer duration of operation with increased blood loss is associated with a higher rate of complications [35–37]. Duration of hospitalization was found to be similar for both study groups. Hence, the time of discharge from hospital was not affected by the increased blood loss and longer operation times.

Surgical as well as general medical complications occurred at a rate commensurate with those reported in the literature [22, 23, 27, 32, 34, 38–44]. Our results revealed no difference in surgical complications between the groups. Interestingly, incidental dural lesions were slightly but not significantly lower in the RES groups for all three surgical procedures. The rates of incidental durotomy reported in the literature for lumbar spine surgery range from 0.5 to 18%, depending in part on the patients' age, previous surgery, gender and structural anatomic features such as juxtafacet cysts. [45–49]. In terms of surgeon experience, the evidence is mixed. Wiese et al. [50] reported a significant effect of

surgeon experience on the incidence of durotomy with 4.6% in the less experienced group (< 500 disc hernia procedures) and 1.6% in the more experienced group (> 500 disc hernia procedures). In contrast, according to McMahon, years of physician training or resident experience did not appear to be major determinants of the risk of dural tear [51].

Patient-reported outcomes were similar in the RES and BCS cases for all investigated types of surgery. Since the COMI's introduction, it has proven itself to be a valid instrument to assess the outcome of procedures such as those investigated in this present study [15]. The outcome scores reported in this study were in accordance with previously reported COMI scores up to 12 months postoperatively [52–55].

Appropriate and effective resident training is essential to produce skilled surgeons for the future. Nowadays, as in the past, surgeons obtain their surgical skills mainly by active participation in the operation room. The role of virtual reality simulation systems is still under evaluation [56]. Teaching hospitals need to ensure an optimal balance between the provision of education and patient safety. Further, the reconciling of both duties has to be cost effective. For legal and ethical reasons, surgical training is performed under strict supervision of a board-certified surgeons who can instruct the resident during the procedure and intervene if necessary.

Recent literature investigating the impact of resident participation in spine surgery generally suggests it is not associated with adverse perioperative outcome [6, 7, 57–59]. However, the amount of active involvement is not well defined in most studies. Some of the reports concern the mere presence of a resident at the operation table without specifying the kind or extent of their involvement as the primary surgeon. In contrast, Stienen et al. [10] executed a randomized controlled trial with a clear definition of resident participation, investigating the outcome of lumbar spine operations with a 4.5-year follow-up. Global outcome and reoperation rate were similar for the teaching and non-teaching cases, and our results corroborated this finding. However, instrumented procedures were not included in their study, and their data only reflected the education of residents for neurosurgery [10].

There are several limitations to this study. The first concerns its observational character and the potential risk of selection bias since patient assignment to study groups was not random. In most cases, patients were referred to surgery within the setting of the patient consultation. A staff surgeon allocated patients to the residents. It is not known whether there was any implicit selection bias regarding the underlying severity of the disease, although the comparable symptom severity and other baseline characteristics for the two groups would tend to suggest that any such bias was probably minimal. Patients presenting for a second opinion were usually seen by BCS, and if considered suitable for

surgery they were operated on by the respective BCS. These rather rare cases may have had an impact on comparability of the groups.

The study admission criteria were established in order to minimize selection bias. Patients with private health insurance were excluded because only BCS would operate such patients. Patients with previous surgery at the index level were excluded, because revision procedures are much more demanding/challenging and are therefore not commonly carried out by residents. Only single-level procedures were included to avoid heterogeneity that might have affected the assignment of patients to the treating surgeon. For herniated disc surgery, normally only one level is involved and the results of the present study are therefore of relevance to the typical herniated disc patient. However, spinal stenosis may involve multiple levels and it is not known whether the findings of the present study will also hold for multilevel decompression, or indeed for more complex surgery.

Second, though the database is robust, and residents performed the whole procedure on their own patients, the present study is unable to determine whether any intervention by the supervising BCS took place, or indeed whether he/she took over at any stage. In other words, we cannot ascertain whether every surgery was carried out entirely by the resident alone. This constitutes a weakness of the study, although the aim of the study was never to perform a comparative effectiveness study of the two surgeon groups, but rather to assess the everyday reality of the given teaching situation. In the present study, only cases where residents had been documented as the primary surgeon were included in the RES group. The residents had referred patients from their own outpatient clinic to surgery in agreement with their corresponding BCS, who also assisted with the procedure. Whenever appropriate, surgery was completed by the resident him/herself from incision to suture. However, the differing skills, experience and performance of the residents might have led to varying degrees of active involvement by the supervising surgeon. Hence, the roles of primary surgeon and assisting surgeon could have changed during each procedure. As such, the comparable outcomes reported cannot solely be attributed to the performance of the residents, since they were always accompanied by an experienced surgeon whose presence was required not only for educational but also legal and ethical reasons. Accordingly, the assisting supervisor could guide the operating resident, alert him/her in the case of an impending complication, or, in the worst case, intervene actively if warranted.

Our results are based on the given setting of our own teaching institution; possible institutional and national differences may limit their generalizability. Further research would be needed to support our findings and to assess whether they reflect the situation in the wider context of other institutions and countries.

The findings of the present study, carried out in the setting of a tertiary care orthopaedic hospital in Switzerland, suggest that single-level lumbar surgery including decompression for spinal stenosis or herniated disc, and spinal fusion, can be safely performed by supervised residents and yield similar patient-rated outcomes to those of more experienced specialists. Given it is necessary to continuously educate new spine surgeons, this is a reassuring message for prospective patients.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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