- 1 NON-MEDICAL FACTORS SIGNIFICANTLY INFLUENCE THE LENGTH OF
- 2 HOSPITAL STAY AFTER SURGERY FOR DEGENERATIVE SPINE DISORDERS.

3

- 4 Background. Unnecessarily long hospital stays are costly and inefficient. Studies have
- 5 shown that the length of hospital stay (LOS) for spine surgical procedures is influenced
- 6 by various disease-related or medical factors but few have examined the role of
- 7 sociodemographic/socioeconomic (SDE) factors.
- 8 **Methods**. This was a retrospective analysis of data from 10,770 patients (5,056 men,
- 9 5,714 women; 62±15y) with degenerative spinal disorders, collected prospectively in an
- in-house database within the framework of EUROSPINE's Spine Tango Registry.
- 11 Surgeons completed the Tango surgery form (clinical history, demographics, surgical
- measures, complications), and patients, a baseline Core Outcome Measures Index.
- Stepwise linear regression analyses examined SDE predictors of LOS, controlling for potential medical/biological factors.
- 15 **Results**. The mean LOS was 7.9 ± 5.2 days. The final model accounted for 42% of
- variance in LOS, with SDE variables explaining 13% variance and medical/surgical
- 17 predictors, 29%. In the final model, the SDE factors age and being female were
- 18 significant independent predictors of LOS, whereas others were either non-significant
- 19 (insurance status, being of Swiss nationality, being a smoker) or reached only
- borderline significance (p<0.1) (BMI). Controlling for all other SDE and medical/surgical
- confounders, being female was associated with 1.11-day longer LOS (95%CI,0.96-
- 22 1.27;p<0.0001).
- Conclusions. Patients of advanced age and female gender are at increased risk of
 longer hospital stay after surgery for degenerative spinal disorders. Further studies
 should seek to understand the reasoning behind the gender disparity, in order to
 minimize potentially unnecessary costs of prolonged LOS. Targeted pre-operative
 discharge planning may improve the utilisation of hospital resources.
- 28 Keywords: length of stay; spine surgery; degenerative disorders of the cervical and
- 29 thoracic/lumbar spine; non-medical predictors
- 30

31 Introduction

Inpatient stays after orthopaedic surgery can be very costly. The use of hospital 32 33 resources such as equipment, staffing and bed capacity are all related to the length of stay (LOS). The LOS is a metric that is commonly used to plan resource utilisation and 34 to monitor the quality of care. Generally, LOSs have decreased steadily over the years 35 as a result of surgical innovations and improvements in perioperative management 36 [1][2]. Shorter LOSs are also being promoted in systematic developments such as the 37 introduction of prospective payment systems and diagnosis-related groups for hospital 38 reimbursements [3], which ensure payment of a given amount for a procedure 39 regardless of the hospitalisation episode. However, hospitals are constantly under 40 clinical and financial pressure to become more cost efficient and LOS is a common 41 target for cost-containing initiatives. Intuitively, the decision to discharge a patient after 42 surgery should be a medical one. The type and extent of surgery, as well as various 43 intraoperative variables, will play a role in how a patient feels after the operation and 44 how long their hospital stay will be. A longer, more complex surgery, with a greater level 45 of surgical invasiveness [4] can be expected to result in a longer stay than would a 46 shorter, more straightforward surgery. However, surgical variables are likely not the only 47 factors governing the LOS; for any given procedure, with its given degree of complexity, 48 various non-surgical and even non-medical factors can also be expected to play a role 49 50 and partially account for inter-individual differences in LOS.

Only few data are available on non-medical or sociodemographic/socioeconomic (SDE) 51 predictors of LOS in relation to spine surgery. In addition, some of the existing data are 52 inconsistent. Previous studies retrospectively reviewing factors related to prolonged 53 LOS have identified increased age as an important factor, explained by the fact that 54 aged tissue takes physiologically longer to heal and older patients may be less able to 55 function independently at home upon discharge. Other non-medical factors such as 56 insurance status, race/ethnicity or geographic location were found to be significant 57 predictors of prolonged LOS in anterior cervical spine procedures [5]. Female gender 58 has been found to be a significant predictor of LOS in some studies [6, 7] while other 59 reports have found no relationship between gender and LOS [8]. Often, the identification 60 of a given variable as a risk factor (or not) is influenced by the inclusion, in the model, of 61

- other closely related or "proxy" measures of that variable. Furthermore, some of the
- 63 prior LOS studies in the spine literature have substantial limitations such as small
- 64 sample sizes with inadequate statistical power, examination of just one specific
- 65 pathology, or a study design in which important medical confounders of LOS were not
- 66 included in the predictor models [7, 9].
- Against this background, the present study sought to determine the influence of non-
- 68 medical factors on LOS after surgery for degenerative spine disorders. It involved the
- data from a large consecutive series of patients, collected over 13 years, and made use
- of multivariable regression models to account for a high quality set of potential
- confounders such as the invasiveness of surgery, surgical complications and other
- 72 intraoperative factors.

73 Patients and methods

- The study was a retrospective analysis of data that had been collected prospectively
- 75 from consecutive patients operated in our Spine Centre, part of a tertiary care
- orthopaedic hospital in Switzerland. The data were collected in our local spine
- outcomes database between 2005 and 2017 using the framework of the EUROSPINE
- 78 Spine Tango Registry (https://www.eurospine.org/spine-tango.htm) and were
- 79 supplemented with additional data (insurance status, nationality, etc.) systematically
- 80 imported into the database from the clinic information system. The use of this routinely
- collected data, given with the patients' informed consent, was approved by the Ethics
- 82 Committee (KEK-ZH-Nr 2014-0418).
- 83

We identified 13,368 consecutive patients who were documented as having undergone spine surgery for degenerative diseases of the spine, with either a primary intervention or revision surgery. The cervical interventions primarily included anterior or posterior fusion (± instrumentation) procedures. Thoracic/lumbar interventions included posterior decompression and/or spondylodesis with rigid stabilization either with posterior and/or interbody fusion (open or mini-open/MISS), as well as complex deformity corrections. Overall, 10,770 of 13,368 patients were retained in complete case analyses (19% lost

due to missing data; i.e. "listwise deletion"; Fig 1). Their characteristics are described inTable 1.

93 Of the variables documented in the local database, predictors of LOS (i.e. number of days from surgery to discharge) were chosen based on the available literature, and 94 were categorised into blocks representing particular stages of the clinical pathway: 95 1) Non-medical patient characteristics; 2) Preoperative medical patient characteristics; 96 3) Surgical details; 4) Perioperative outcomes. The patient demographics and variables 97 considered in the analysis are illustrated in Table 1. Non-medical patient characteristics 98 comprised age, sex, BMI, smoking status, nationality and insurance status. 99 Preoperative medical characteristics included the Core Outcome Measures Index 100 (COMI)[10] pre-operative score (measure of symptoms/disease burden/reduced quality 101 of life before surgery), region operated (cervical vs thoracic/lumbar spine), morbidity 102 state (American Society of Anesthesiologists (ASA) class [11]), number of affected 103 segments, and previous surgery involving the same spine level. It must be noted that 104 there was an unknown degree of uncertainty around the spinal level of the repeat 105 106 surgical procedures included in the analysis because this item is not specifically measured in Spine Tango for each recorded instance of repeat surgery (only "number of 107 previous surgeries" and whether "any previous surgery done on the same level"). An 108 assumption was therefore made that cases of multiple repeat procedures were likely to 109 110 involve the same level repeatedly and the predictor was constructed accordingly. It is shown in the models with the caveat "at least one previous surgery involving same 111 level". As the predictor derived this way exhibited gualities suggesting a degree of 112 ordinality in the initial statistical models, it was retained despite the limitation. Surgical 113 114 procedures were characterised by whether instrumented fusion was used or not and whether the surgery was conventional or minimally/less invasive (MISS/LISS). In a 115 subset of data collected using a later iteration of the Spine Tango form, introduced in 116 2012 (Fig 1), more detailed surgical information was available, allowing calculation of a 117 surgical invasiveness index score for each case (based on the formulae of Mirza et al. 118 [4]). This represented a composite score, given by the number of levels operated and 119 whether anterior and/or posterior decompression, fusion and/or stabilisation procedures 120 had been carried out. The rich set of potential predictors was completed by the 121

- 122 perioperative outcome variables blood loss, duration of surgery, general medical
- 123 complications and surgical complications arising during surgery and before discharge,
- as documented on the Spine Tango form.

The local registry data represented a nearly complete record (99% coverage) of all relevant surgical procedures in the target period and the missing 1% were not expected to bias the results in either direction. The 19% cases excluded from the analysis by listwise deletion of those without a full complement of predictor variables appeared to be a random sub-sample of all potential participants, based on observable characteristics.

130 >>>>Insert Table 1 here<<<<

The dataset was analysed through a series of stepwise linear regression models. We 131 entered the aforementioned blocks of variables sequentially, retaining or dropping 132 variables after each step. Predictors were retained in models if they showed at least 133 134 borderline statistical significance (p<0.1) and if they proved generally robust in the context of a growing number of covariates. The distributional properties of the outcome 135 variable made it suitable for standard linear regression (Gaussian distributional 136 assumption / identity link function), resulting in model residuals following an 137 approximately normal distribution. Alternative GLM specifications were initially 138 considered but deemed unnecessary. Continuous predictors were entered as centred 139 variables where this was deemed useful in order to facilitate model interpretation. This 140 allowed interpretation of the constant as the predicted length of stay for an "average" 141 patient with reference values of the categorical predictors. All analyses were done in 142 Stata 15.1. 143

144 **Results**

The mean (\pm SD) LOS was 7.9 \pm 5.2 days. The main regression models are shown in Table 2. Model 1 includes the non-medical patient characteristics age, sex and BMI. The latter accounted for 13% of variance. We also tested for effects of smoking status, nationality (Swiss vs. other nationality) and type of health insurance, each of which was statistically insignificant. Preoperative medical patient characteristics were added in model 2, and showed that LOS was associated strongly and positively with previous

surgeries, COMI-score, morbidity and the number of affected spinal segments. The 151 model's predictive power improved to explain nearly 23% of variance. Key surgical 152 153 details were added in model 3. The number of cases in which MISS/LISS procedures were used was very small (see Table 1), but minimally invasive procedures were 154 nonetheless associated with reduced LOS (-1.5 days), while the use of rigid stabilisation 155 was associated with a pronounced increase of LOS (+3.8 days). The final model 156 157 included a set of perioperative outcomes: in addition to the amount of blood loss and the duration of surgery, we observed particularly strong effects for the presence of a 158 general medical complication (+2.2 days) and of a surgical complication (+4.3 days). 159 Predictive power peaked at nearly 43% of variance and the predictors included in 160 previous steps generally retained their effect directions, although they naturally revealed 161 gradually reducing effect sizes. Notably, female patients, even after controlling for a 162 large set of covariates that were strong determinants of LOS, had a systematically 163 longer LOS than male patients (+1.1 days). Further interaction analysis of model 4 164 (details not shown) revealed that the influence of sex on LOS varied somewhat by age 165 166 group. Table 2 shows the average effect over the entire age distribution, and, whilst an effect was present in all age groups, it was shown to increase with age: in the age group 167 under 45 y, women stayed 0.86 days longer than men; in the age group 45-64 y, 1.02 168 days longer; and in the age group 65+ y, 1.29 days longer. 169

The "average patient" in model 4 (a male recipient of back surgery of average age and BMI with a low risk profile, e.g. no complications or previous surgery, low blood loss and an uncomplicated standard surgical approach) was predicted to spend 4.8 days in hospital (model constant).

174 An alternative model specification relying on the more parsimonious invasiveness index

175 (replacing the individual variables MISS, rigid stabilisation, number of affected levels,

blood loss and duration of surgery)¹ showed the same significant predictors as the full

model, but previous surgery had a higher degree of stability in the model, the effect of

¹ Calculation of this score was only possible for the data collected since 2012 (see earlier) and therefore the model is based on a smaller, more recent subsample of patients (n=5,409) (Fig 1).

- 178 BMI achieved statistical significance, and gender still showed approximately the same
- effect size, with females having +1.2 days longer LOS than males (Table 3).

180 Finally, given the long observation period (2005-2017), additional tests were carried out

- 181 for possible effects of time. However, whilst mean LOS varied from year to year there
- 182 was no clear trend towards either lower or higher LOS and no effect could be detected
- in the statistical models (controlling for individual years or pooled time periods).
- 184
- 185 >>>>insert Table 2 here<<<<
- 186 >>>>insert Table 3 here<<<<
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188 **Discussion**

This study was designed to determine the influence of non-medical factors on LOS after surgery for degenerative spinal disorders, whilst controlling for known medical and surgical determinants of LOS. Female gender and age, in particular, and (depending on the model in question) BMI were each found to be significantly and independently associated with a longer LOS, whilst insurance status, being of Swiss nationality, and being a smoker were non-significant. The non-medical factors accounted for almost one-third of the total variance in LOS explained by the model.

We intentionally included all relevant medical/surgical factors in our predictor models in 196 order to ascertain the unique influence of the sociodemographic/economic factors. The 197 effect of age was not simply a reflection of greater comorbidity or a higher incidence of 198 complications, since these factors were controlled for in the models by inclusion of the 199 ASA grade [12] and the presence of medical/surgical complications as documented on 200 the Spine Tango form. Instead, it is likely that the finding is explained by older people 201 202 recovering more slowly from surgery and anaesthesia (as well as from any associated complications), with older tissue taking longer to heal. The effect of age may also reflect 203 204 a sociological component, in that older patients may be considered less able to function

independently at home upon discharge. Our findings regarding age as a predictor of
LOS are in line with almost all previous studies [7, 8, 13–15]. Age, of course, is not a
modifiable risk factor and hence there are few practical implications that can emerge
from this finding; nonetheless, a knowledge of the independent influence of age on LOS
could allow for better discharge planning and the consideration of less costly
alternatives for postoperative care.

211 A significant finding from our study was that gender seemed to play a relevant role in governing LOS. The effect was consistent across different age groups, although more 212 marked in older patients. All else being equal, LOS was just over one day longer for 213 women undergoing spine surgery than for men. A similar gender difference in LOS has 214 215 been reported before, in two small studies in the spine literature [7, 9] and also in studies of patients undergoing shoulder [16], knee or hip surgery [17], although it has 216 not been a consistent finding in all [5, 18] and few studies have demonstrated an effect 217 beyond that mediated by an increase in complications in women. A very recent analysis 218 219 of the NSQIP database by Heyer at al. 2019 [19], also reported that female patients stayed significantly longer in hospital. The authors hypothesised that this may have 220 221 been due to the greater need for blood transfusion, higher incidence of urinary tract infections (UTIs), or more dependent preoperative status of women necessitating 222 223 subsequent discharge to nursing or rehabilitation facilities; however, despite having measured these explanatory variables, they did not go on to include them in a 224 225 multivariable model to test their hypothesis with respect to LOS [19]. In our study, complications as well as preoperative status were included in the multivariable model in 226 227 which female gender still exerted an independent effect on LOS, and hence these factors are unlikely to account for our findings. We were unable to account for the 228 severity of complications, and, if women had suffered more severe complications than 229 men, this could possibly have explained their longer LOS; however, at least based on 230 the types of complications recorded, there was no evidence to suggest that this was the 231 case. Another possible explanation for why women stay longer in hospital after surgery 232 is that more elderly women than men tend to live alone, since men have a shorter life 233 expectancy. A lack of family support has been shown to be associated with a prolonged 234 LOS [20]. A further possible explanation is that women typically experience slightly 235

higher pain levels than men after surgery and for some degenerative disorders may be 236 less satisfied with the surgical result [21], leading the medical team to err on the side of 237 238 caution, delaying discharge to allow longer for recovery. In the past, women were considered to be the weaker sex and this idea might still prevail in the minds of either 239 patients or doctors, biasing their appraisal of readiness for discharge. Interestingly, a 240 previous study showed that spine surgeons tend to over-rate the 12-month outcome in 241 men more so than in women, in comparison to the patient's own ratings [22]. Whether or 242 not this is also the case in the early stages after surgery, remains to be known. A 243 previous study showed that a lack of paid employment was significantly associated with 244 a longer hospital stay after spine surgery [23]; although the findings were not specifically 245 related to gender, women are still less likely to be in paid employment than men. It is 246 also conceivable that the "working man" wishes to get back to his comfortable home 247 environment more readily than does the "home-maker" wife, for whom a return to home 248 effectively constitutes a return to work. Policy makers may wish to clarify the possible 249 explanations for the gender difference and evaluate whether less costly social (rather 250 251 than medical) care could be used to assist with earlier discharge in women. Discharge planning prior to admission with a focus on a clear endpoint in the patient's care could 252 ensure that all the support processes are in place to help the discharge happen in a 253 timely fashion [24]. 254

In the present study, BMI had a slight (but in most models statistically significant) 255 256 influence on LOS. The impact of a higher BMI or obesity on LOS is controversial, and may depend on the other variables included in the given predictor models. Obesity may 257 258 increase the risk of postoperative complications, exerting its effect through greater comorbidity or by simply making access to the surgical site more difficult. In the present 259 study, these covariates were controlled for in our model, perhaps minimising any effect 260 of BMI per se. Kalanithi et al showed that spinal fusion patients who were morbidly 261 obese were at significantly increased risk of a longer hospital stay, generating greater 262 hospital charges [25]. Possibly, in this respect, preoperative weight loss programmes or 263 lifestyle modification counselling may prove cost effective and at the same time allow 264 patients to benefit from improved postoperative outcomes. However, in the very obese, 265 the necessary weight loss may be difficult to achieve, and if it requires closely 266

supervised programmes and/or other medical interventions, then this may offset anypotential savings in terms of LOS.

Factors such as smoking status, nationality and health insurance were not significantly 269 270 associated with LOS in our study. The literature is inconsistent regarding the influence of smoking status on LOS. Using adjusted analysis, Seican et al. [26] reported that prior 271 smokers undergoing elective spine surgery were significantly more likely to have 272 prolonged hospitalisation and major complications compared with never smokers. It is 273 unclear why smoking showed no significant effect in the present study. We documented 274 current smoking habit rather than a history of smoking and it was based on self-275 declaration at the time of surgery; possibly, social desirability bias or the adoption of a 276 277 period of smoking cessation just prior to surgery may have influenced the accuracy of the responses. That nationality and health insurance had no significant effect on LOS 278 279 was encouraging, and suggested equitable hospital policy was in place with regard to 280 this aspect of care.

Despite including a large sample of data, collected systematically on a prospective 281 basis over many years, our study has certain limitations that require mention. First, it is 282 based on a secondary analysis of registry data supplemented with other routinely 283 collected clinical data and, as such, data items were not specifically provided and 284 designed to answer the research question. Additional important confounders may have 285 been omitted by virtue of the study design. Also, it involved the data from just one 286 orthopaedic hospital in Switzerland. The results should ideally be confirmed in a 287 multicentre study. This could be done using data collected with the same documentation 288 forms from other reliable centres in the EUROSPINE Spine Tango registry, and 289 employing the exact same approach to the statistical models. Whilst the extent of 290 surgery and predominant surgical technique (instrumented fusion or not; use of MISS) 291 were controlled for in the model, the degenerative disorders were only grouped as either 292 293 cervical or thoracic/lumbar, without further differentiation or comparison between diagnoses or specific operative procedures. This will be addressed in our future studies, 294 295 to create more detailed surgical models. Although standardised forms were used for data collection, there may have been inconsistencies in documentation between the 296

- different surgeons. And finally, a variable that was not included in the present study but
- that has been shown to be relevant in relation to LOS is the discharge destination [27].
- 299 In terms of achieving a more complete understanding of how non-medical factors affect
- LOS, the post-operative circumstances the patient has to face, such as going into a
- rehabilitation program or going home to live alone, should be known.

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Continuous	Mean (SD)	Median (Min-Max)
Age at OP	62.3 (14.5)	64 (6-94)
BMI score	26.4 (4.7)	26 (13-56)
COMI pre-score (0 (best) to 10 (worst) status) ¹	7.5 (1.9) [´]	7.9 (0-10) ²
Duration of surgery (hours)	2.7 (1.7)	2.5 (0.5-10)
Invasiveness Index based on using Spine Tango	7.9 (8.9)	6.0 (0-84)
formula (relevant data available from 2011; n=5,409)	1.0 (0.0)	
Categorical	n	%
outegorioui		70
Sex		
Male	5,056	47.0
Female	5,714	53.0
	0,711	00.0
Smoker ²		
No	7,540	74.7
Yes	2,550	25.3
165	2,330	20.0
Nationality ²		
Swiss	9,429	87.5
Other	1,341	12.5
Other	1,041	12.5
Insurance status ²		
Privately insured	3,184	29.6
Semi-privately insured	2,890	26.8
General public insurance scheme	4,696	43.6
General public insurance scheme	4,090	43.0
Previous surgery involving same level		
None	8,034	74.6
1 involving same level	1,495	13.9
	678	6.3
2 (at least one involving same level)		
3 or more (at least one involving same level)	563	5.2
Spine location		
Spine location	1 660	
Cervical	1,663	15.4
Thoracic or lumbar	9,107	84.6

Table 1. Predictor variables as used in the statistical models (n=10770)

¹ 0.19% of patients reported a baseline COMI score of 0, and 0.56% of <=1. These scores may seem unlikely, but we have no reason to assume that the responses are invalid. COMI is a self-report measure and thus contains subjective elements. Moreover, most of these patients had conditions that are not typically very symptomatic in terms of pain and disability but are at risk of serious progression if not treated e.g. early cervical myelopathy.

² These covariates were not retained in the final models due to statistical insignificance and instability likely caused by multi-collinearity (smoking status and insurance status correlate with age)

Morbidity state (ASA) No disturbance Mild/moderate Severe or worse	2,142 5,490 3,138	19.9 51.0 29.1
Type of surgery Conventional techniques MISS or LISS	10,515 255	97.6 2.4
Extent of lesion (number of affected levels) 1 segment 2-3 segments 4-5 segments 6 or more segments	5,202 4,705 640 223	48.3 43.7 5.9 2.1
Rigid stabilisation (anterior or posterior) No Yes	5,323 5,447	49.4 50.6
Blood loss <100ml 100-500ml 500-1000ml More than 1000ml	2,593 6,090 1,295 792	24.1 56.6 12.0 7.4
Any general medical complication ³ No Yes	9,956 814	92.4 7.6
Any surgical complication⁴ No Yes	9,885 885	91.8 8.2

³ General medical complications documented on the Spine Tango form included: anaesthesiological, cardiovascular,

pulmonary, cerebral, kidney/urinary, liver/GI, death, other. ⁴ Surgical complications included: wrong level, vascular, neurological, implant malposition, dural tear, wound infection, implant failure, other. An alternative statistical model in which we specifically included the detailed complication information (i.e. the different complication types) did not change the overall findings regarding the significant predictors.

Table 2. Main regression models (full dataset)

	MODEL (1)	MODEL (2) MODEL (3)		MODEL (3)	MODEL (4)	
VARIABLES	Coefficient [95% CI]	Coefficient [95%		ficient [95% CI]		cient [95% CI]
Age at OP (centred)	0.10*** [0.098 - 0.11]	0.058*** [0.050 - 0	.065] 0.064***	[0.057 - 0.071]	0.060***	[0.053 - 0.066]
Sex: female	1.91*** [1.73 - 2.10]	1.70*** [1.52 - 1	.88] 1.12***	[0.95 - 1.28]	1.11***	[0.96 - 1.27]
BMI score (centred)	0.096*** [0.077 - 0.12]	0.036*** [0.017 - 0	.055] 0.038***	[0.020 - 0.056]	0.015*	[-0.0011 - 0.032]
Previous surgery involving same level None = reference 1 involving same level		0.67*** [0.41 - 0	.92] -0.017	[-0.26 - 0.22]	-0.28**	[-0.510.061]
2 (at least one involving same		1.68*** [1.32 - 2	.05] 0.55***	[0.21 - 0.89]	0.17	[-0.15 - 0.49]
level) 3 or more (at least one involving same level)		1.96*** [1.56 - 2	.35] 0.83***	[0.46 - 1.21]	0.46***	[0.12 - 0.81]
COMI pre-score (centred)		0.18*** [0.13 - 0	.22] 0.15***	[0.11 - 0.20]	0.12***	[0.075 - 0.16]
Spine location: Thoracic/lumbar = reference Spine location: cervical		-1.49*** [-1.74	1.24] -3.01***	[-3.262.77]	-2.19***	[-2.431.95]
Morbidity state (ASA): no disturbance = reference Morbidity state (ASA): mild/moderate		0.78*** [0.52 - 1	-	[-0.23 - 0.26]	-0.11	[-0.34 - 0.12]
Morbidity state (ASA): severe or worse		2.24*** [1.92 - 2	.57] 1.41***	[1.11 - 1.72]	0.89***	[0.61 - 1.18]
Extent of lesion: 1 segment = reference Extent of lesion: 2-3 segments Extent of lesion: 4-5 segments Extent of lesion: 6 or more segments		1.19*** [1.00 - 1 2.71*** [2.33 - 3 4.53*** [3.90 - 5	.09] 2.36***	[0.70 - 1.05] [2.01 - 2.72] [2.91 - 4.07]	0.39*** 0.93*** 1.55***	[0.22 - 0.56] [0.58 - 1.27] [0.99 - 2.11]

Adjusted R-squared		0.131		0.226		0.333		0.424
Observations		10,770		10,770		10,770		10,770
Constant	6.81***	[6.67 - 6.94]	5.03***	[4.77 - 5.29]	4.72***	[4.48 - 4.97]	4.83***	[4.54 - 5.12]
Any surgical complication ¹							4.25***	[3.97 - 4.53]
Any general medical complication ¹							2.23***	[1.94 - 2.52]
Duration of surgery (centred)							0.42***	[0.34 - 0.50]
Blood loss: 500-1000ml Blood loss: more than 1000ml							1.49*** 1.61***	[1.16 - 1.83] [1.19 - 2.03]
Blood loss: <100ml = reference Blood loss: 100-500ml							0.57***	[0.36 - 0.77]
Rigid stabilisation (anterior or posterior)					3.79***	[3.61 - 3.97]	2.34***	[2.11 - 2.56]
Type of surgery: conventional technologies = reference Type of surgery: MISS or LISS					-1.46***	[-1.990.93]	-1.17***	[-1.670.67]

** p<0.01, ** p<0.05, * p<0.1

¹An alternative statistical model in which we specifically included the more detailed complication information (i.e. the different complication types) did not change the overall findings regarding the significance of the other variables explaining LOS.

VARIABLES	Coefficient [95% CI]		
Age at OP (centred)	0.055***	[0.044 - 0.065]	
Sex: female	1.15***	[0.91 - 1.40]	
BMI score (centred)	0.059***	[0.034 - 0.085]	
Previous surgery involving same level None = reference			
1 involving same level 2 (at least one involving same level) 3 or more (at least one involving same level)	-0.0064 0.86*** 0.86***	[-0.35 - 0.34] [0.38 - 1.35] [0.34 - 1.39]	
COMI pre-score (centred)	0.12***	[0.052 - 0.18]	
Spine location: thoracic/lumbar = reference Spine location: cervical	-1.34***	[-1.681.01]	
Morbidity state (ASA): no disturbance = reference Morbidity state (ASA): mild/moderate Morbidity state (ASA): severe or worse	0.34 1.18***	[-0.072 - 0.75] [0.69 - 1.67]	
Any general medical complication	2.46***	[1.96 - 2.95]	
Any surgical complication	5.83***	[5.42 - 6.25]	
Invasiveness index ¹	0.22***	[0.21 - 0.24]	
Constant	4.27***	[3.87 - 4.66]	
Observations Adjusted R-squared	5,409 0.393		

Table 3. Alternative regression model using invasiveness index (calculable in data collected after 2012)

*** p<0.01, ** p<0.05, * p<0.1

¹ based on the formulae of Mirza et al [4] but calculated on the basis of the fields completed on the Spine Tango Surgery form

Figure 1 Data flow diagram

