



# The impact of deep surgical site infection on surgical outcomes after posterior adult spinal deformity surgery: a matched control study

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## Abstract

**Purpose** The impact of deep surgical site infection (SSI) on surgical outcomes after adult spinal deformity (ASD) surgery is still unclear. We aimed to study the morbidity of SSI in ASD and its impact on deformity correction and functional outcome.

**Methods** Prospective multicenter matched-cohort study including consecutively enrolled ASD patients. Patients developing SSI were matched to similar controls in terms of age, gender, ASA, primary or revision, extent of fusion, and use of tri-columnar osteotomies. Preoperative parameters, surgical variables, and complications were recorded. Deformity parameters and Health Related Quality of Life (HRQoL) scores were obtained preoperatively and at 6, 12, and 24 months. Independent *t* test and Fischer's exact test were used for comparisons.

**Results** 444 surgical ASD patients with more than 2 years of follow-up were identified. 20 sustained an acute SSI and 60 controls were accordingly matched. No differences were observed between groups in preoperative radiological and HRQoL variables confirming comparable groups. SSI patients had longer hospital stay and more mechanical complications including proximal junctional kyphosis. Infection was associated with more unrelated complications and revisions. Deformity correction was maintained equally at the different time intervals. One death was related to SSI. SSI patients had worse overall HRQoL status at 1 year and were less likely to experience improvement. However, no significant differences were recorded thereafter.

**Conclusion** SSI significantly affects the first postoperative year after posterior ASD surgery. It is associated with more complications, unrelated revisions, and worst quality of life. However its negative impact seems to be diluted by the second postoperative year as differences in HRQoL scores between the two groups decrease.

**Graphical abstract** These slides can be retrieved under Electronic Supplementary material.

### Key points

1. Matched Case Control Study to analyze the impact of early deep surgical site infection on radiological and functional outcomes after Adult Spinal Deformity Surgery
2. Data collection from prospective multicenter ASD database with more than 2 years follow-up
3. First study to specifically assess this in the ASD population

	6 months	12 months	24 months			
	Case	Control	Case	Control	Case	Control
Back Pain	3.81	0.94	4.07	0.84	3.38	0.92
Leg Pain	2.54	0.79	2.21	0.40	1.00	0.40
CSQI	6.17	0.89*	5.86	0.82*	5.78	0.92
ODI	45.47	0.84*	42.43	0.77	40.64	0.76
NI 36 Mental Component	38.47	0.39	41.41	0.80	39.93	0.49
NI 36 Physical Component	37.43	0.82*	36.99	0.81	36.64	0.76
NI32 Function	2.77	0.84*	3.17	0.74	3.29	0.77
NI32 Pain	3.15	0.39	3.39	0.26	3.19	0.46
NI32 Satisfaction	3.84	0.39	3.43	0.33	3.73	0.33
NI32 Body Image	3.29	0.39	3.33	0.33	3.42	0.33
NI32 Subtotal	3.19	0.39	3.39	0.33	3.37	0.33

### Take Home Messages

1. Surgical Site Infection significantly affects the first postoperative year after posterior Adult Spinal Deformity Surgery.
2. It is associated with more complications, unrelated revisions and worst quality of life.
3. However its negative impact seems to be diluted by the second postoperative year as differences in HRQoL scores between the two groups decrease.

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Extended author information available on the last page of the article

**Keywords** Adult spinal deformity · Scoliosis · Surgery · Deep surgical site infection · Complication · Clinical outcome

## Introduction

Adult spinal deformity (ASD) surgery is one of the most challenging surgical specialties. Significant deformities need tri-columnar osteotomies, or combined anterior and posterior approaches, increasing the technical complexity, and surgical morbidity [1–3] of these procedures. Despite this, its ability to improve the quality of life in these patients justifies its use [4, 5]. The short-term morbidity of ASD surgery has been extensively studied [1, 2, 6, 7], and so there is now an increasing interest in determining the impact of these complications on the final functional results of ASD [2, 7, 8].

Whilst most studies have focused on risk factors for, and the prevention of, surgical site infection (SSI), as well as on the economical and medical burden it has, no other study has investigated the impact of SSI on the final outcomes after ASD surgery [9–14]. The available knowledge in the literature is based on reported studies from the general spinal population, [9–11] and not on studies targeted specifically at SSI and its outcomes. Although no significant differences could be found in terms of functional outcomes, postoperative pain, or general health, these studies' conclusions were limited by their small and heterogeneous samples and did not specifically consider ASD or deep SSI in their results. They did not assess the impact of infection on non-union rates that can deleteriously affect the amount of deformity correction achieved, nor the functional outcomes after ASD surgery [9, 15, 16].

The primary objective of this study was to investigate the impact deep SSI has on ASD on Patient Reported Outcome Measures (PROMs) at different time intervals. The secondary objectives were to analyze the associated morbidity of SSI and its impact on deformity correction in this population.

Our hypothesis is that successfully treated deep SSI does not alter the functional outcome at 2 years even though it is likely to be associated with increased short-term morbidity.

## Methods

This is a matched control study using a prospective multi-centre database of patients with ASD.

We retrospectively analyzed prospectively collected data from ASD patients recruited in six European centres from four different countries sharing a common ASD comprehensive database.

All adult patients who had undergone posterior instrumented spinal fusion for ASD with a minimum 2-year follow-up were included. Institutional Review Board (IRB) approval was obtained from all participating centres, and informed consent was obtained from all the enrolled patients.

From this cohort, we then identified all patients who had been treated for deep SSI within the first 6 months of index surgery. The treating surgeon in each case made the diagnosis of infection clinically following the standard guidelines for deep SSI [17, 18]. Diagnosis was later confirmed by positive results on samples sent for microbiology. Treatment consisted of repetitive debridement as clinically needed, combined with targeted antibiotic therapy based on the growth sensibility. The choices of antibiotics as well as the duration of treatment were dependent on local protocols in each participating centre. As these were acute infections, original implants were maintained except in cases where infection was settled and poorly controlled.

Demographic and surgical variables were collected prospectively for all patients. All surgical and medical complications were recorded and were available for analysis.

Patients were assessed at established time intervals (pre-operatively, 6, 12, and 24 months post-operatively) with validated Health Related Quality of Life (HRQoL) outcome tools, and sagittal and coronal deformity measurements on standard whole-spine radiographs.

HRQoL parameters included Numerical Rating Scale for back pain and leg pain, Oswestry Disability Index (ODI), 36-Item Short Form Health Survey (SF-36), Core Outcome Measures Index (COMI) and Scoliosis Research Society 22 Score (SRS-22 Score).

Patients who had undergone treatment for a deep SSI formed the case group. They were accordingly matched to controls based on demographic and surgical variables known to affect both exposure (infection) and outcomes (quality of life) [19, 20]. These were: gender, age, American Society of Anesthesiologists Score (by categories 0–1, 2, 3–4), revision vs. primary surgery, extent of fusion and the use of tri-columnar osteotomies (Schwab 3+). We excluded from the control group patients who had been diagnosed with other non-surgical infections. We aimed at the highest matching proportion to form the control group.

We were able to compare absolute HRQoL figures at the different time intervals between groups. We compared the changes relative to the preoperative value at these intervals.

Secondary outcome analysis included mortality, complications, unplanned re-admission or re-operation, and size and maintenance of deformity correction. Radiological measures included overall deformity measurements, as well

as sagittal and spino-pelvic alignment parameters: SVA, LL, PI, PT, PI-LL, GT, and Major Cobb.

We used SPSS (MAC Os version 24.1) for statistical analysis. Descriptive and bivariate comparisons of demographic variables were performed between cases and controls using independent *t* test for continuous variable, and Fischer's exact test for the categorical variables. The level of statistical significance was set at  $p < 0.05$ .

## Results

Between January 2010 and January 2016, we identified 689 patients with ASD undergoing posterior spinal instrumentation for deformity correction. 444 had more than 2 years of follow-up available. 23 Patients had been treated for a deep SSI (5.2%) and out of these 20 within the first 6 months of their index surgery. From the remaining 421 patients, 391 had not suffered from any postoperative infection and were available for matching. We could yield a 1:3 matching

proportion after applying the six matching criteria. As such we had a 20:60 case–control cohort available for analysis (Fig. 1, Flowchart).

The mean time for the diagnosis of SSI was 20.1 days (range 1–76; standard deviation 20.4) in our retained cohort and 13 were diagnosed during the same initial hospital admission. Six patients had a nosocomial infection during their hospital stay prior to developing infection. The most common nosocomial infection was urinary tract infection (UTI) (four patients). The most commonly isolated single microorganism was methicillin-sensitive *Staphylococcus aureus* (five cases) and the infection was due to multiple organisms in six patients. Patients needed an average of 1.7 wound debridements (range 1–3) and 3.5 months of antibiotics (range 2.5–6.5 months) to treat their SSI. Priority was to retain implants in all patients, especially that infection was acute (mean 20 days, range 1–76 days). 65% patients needed a single debridement. Two patients needed partial implant exchange and they had all been deemed to be clear of infection at their last review. Prior to implant exchange, both

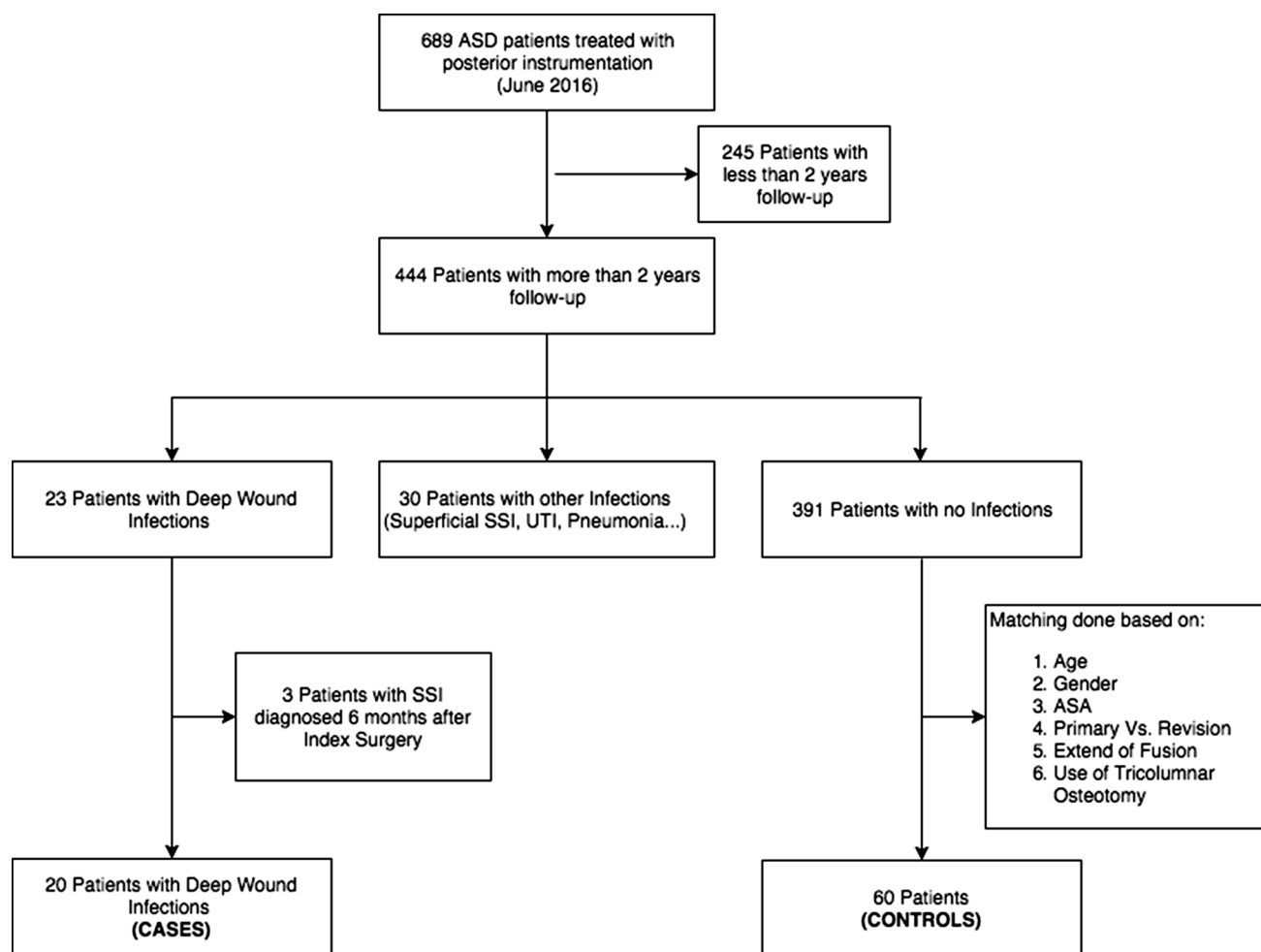


Fig. 1 Flowchart of patients participating in the study

patients had at least one failed debridement. One patient had *Staphylococcus epidermidis*, and the other patient, a multi-organism infection.

No significant differences were detected between cases and controls in matched or non-matched preoperative variables including radiological and HRQoL, confirming comparable samples (Table 1). Non-matched risk factors for infection were equally balanced between both groups; e.g. BMI ( $p=0.587$ ) diabetes ( $p=0.672$ ), smoking ( $p=0.696$ ), and blood loss ( $p=0.577$ ). Furthermore, both groups had similar proportion of patients from each participating centres ( $p=0.562$ ), limiting any site biases.

There was one death in the SSI group related to the infection itself, whereas no deaths were recorded at an average of 4.2 years after index surgery in the control group ( $p=0.250$ ) (Table 2). The patient in question was a 33-year-old lady with a background history of childhood poliomyelitis and lower-extremity motor paralysis. She had a lumbar osteotomy and T2 to pelvis fixation. She started complaining of fatigue and discomfort 2 days after index surgery and had a purulent discharge by the third day. She underwent surgical debridement and lavage that evidenced an extensive muscular necrosis. Intraoperative cultures grew *Acinetobacter bowmanii* and methicillin-resistant *S. aureus*. Despite extensive debridement and broad-spectrum antibiotics, her condition deteriorated and she went into sepsis in her immediate postoperative stay at the ICU. She soon developed a multi-organ failure and passed away on the eighth day after index surgery. We have accordingly removed this patient and its paired controls from the radiological and clinical outcomes analysis.

In terms of surgical complications and morbidity, the SSI group had a longer hospital stay (33.3 days vs. 12.8 days;  $p=0.004$ ). Patients with infection were also more likely to have other associated wound problems such as seromas or hematomas ( $p=0.021$ ). 52.6% of patients with an SSI had at least one associated major complication (vs. 42.1% in the control group,  $p=0.439$ ) and on average, they had more non-infectious major complications than the control group (2.32 vs. 1.46 complications/patient;  $p=0.049$ ). Both the groups had similar rates of mechanical/radiological complications (42.1 vs. 29.8%;  $p=0.400$ ). The SSI group had three times more proximal junctional kyphosis (PJKs) (31.6 vs. 10.5%;  $p=0.023$ ) (Table 2).

There were no differences in deformity correction between the groups at the different time intervals of the study. The primary sagittal deformity parameters improved significantly after surgery in both groups ( $p<0.05$ ) and this correction was maintained over time (Table 3).

When analyzing HRQoL scores, we could see that both groups benefitted from the surgery and this improvement was maintained throughout the follow-up period. All PROMs were significantly better at the 24-month mark

( $p<0.05$ ) except for the leg pain ( $p=0.123$ ), SF36 Mental Component Score (SF36 MCS) ( $p=0.271$ ), and SRS22 Mental Score ( $p=0.348$ ) (Table 4).

We did find that the results up to 1 year after surgery did vary between both groups in favour of the controls, mostly in the ODI (6 months), COMI (6 and 12 months), SF 36 Physical Component Score (SF36 MCS) (6 months), and SRS 22 Mental Score (6 months). Full results are reproduced in Table 5.

The non-infected group also experienced more pronounced improvement compared to baseline values during the first year. This was apparent when analysing the differences from baseline in each group and comparing both groups. The COMI and ODI scores were the best parameters that could reflect the differences from baseline values between both groups at 6 and 12 months. Differences from baseline value were initially noted in the ODI ( $-14.69$  vs.  $-1.5$ ,  $p=0.029$ ) and in SRS22-Mental component score ( $0.20$  vs.  $-0.34$ ,  $p=0.049$ ) at 6 months, but were later diluted at 1 year (Table 6).

We failed to demonstrate any other difference beyond 12 months between the groups in the different analysis conducted (Tables 4, 5, 6).

## Discussion

SSI in spinal surgery is notorious to increase morbidity, mortality and costs [21, 22]. It is also associated with increased length of stay, more unplanned re-admissions and revisions, and more pseudoarthrosis [16]. The impact of a resolved infection on the final outcome is less clear. This is the first study specifically aimed at defining the impact of deep SSI on patient outcomes after ASD surgery. In the short-term, SSI was associated with a longer hospital stay ( $p=0.001$ ), and more wound complications ( $p=0.021$ ) in our study. The infected group had a higher number of major complications ( $p=0.049$ ). We also demonstrated that initial improvements in PROMs in the infected group were less sizeable than in the non-infected group. This negative impact of SSI seems to be diluted by the second year; however, as PROMs seem to catch-up.

The present study proves again that ASD surgery is a risky procedure with nearly 56% of our patients suffering any complication and 43% suffering a major complication. Unfortunately, we had one death directly related to infection. In the recent spinal literature, infection has been associated with increased mortality up to 5 years after infection. Risk factors for increased mortality included age and co-morbidities [22]. The impact that death has on the final outcome, even though real, could not be measured in our study. There was no reliable precedence in the literature on how to treat death in a PROM analysis when death is directly

**Table 1** Comparison of preoperative and surgical variables between groups

Preoperative variables	Cases ( <i>N</i> = 20)	Controls ( <i>N</i> = 60)	<i>p</i> value
Female <sup>a</sup>	14 (70.0%)	42 (70.0%)	1
Male <sup>a</sup>	6 (30.0%)	18 (30.0%)	
No co-morbidities	5 (28.3%)	17 (28.3%)	1
Cancer	3 (15.0%)	5 (8.3%)	0.405
Diabetes	1 (5.0%)	7 (11.7%)	0.672
Liver disease	2 (10.0%)	1 (1.7%)	0.153
Osteoporosis	0 (0%)	1 (1.7%)	1
Smoker	3 (15%)	7 (11.7%)	0.696
Tri-columnar osteotomies <sup>a</sup>	6 (30%)	18 (30%)	1
Revision surgery <sup>a</sup>	6 (30%)	18 (30%)	1
ASA 0–I <sup>a</sup>	7 (35%)	21 (35%)	1
ASA II <sup>a</sup>	7 (35%)	21 (35%)	
ASA III–IV <sup>a</sup>	6 (30%)	18 (30%)	
	Mean	Mean	<i>p</i> value
Demographic and surgical variables			
BMI	27.4	26.6	0.587
Age (years) <sup>a</sup>	57.9	53.8	0.377
Surgical duration (min)	375.5	338.4	0.343
Number of fused segments <sup>a</sup>	10.10	10.00	0.920
Number of osteotomies	1.60	1.63	0.947
Blood loss (ml)	1736.3	1911.6	0.577
ICU stay (h)	95.9	63.1	0.599
Hospital stay (days)	33.3	12.8	0.004
Preoperative radiological parameters			
SVA (mm)	75.53	53.05	0.239
PI	52.2	57.2	0.166
LL	−39.5	−43.4	0.620
PI-LL	12.7	13.8	0.864
SS	32.5	34.2	0.640
PT	19.6	23.0	0.273
Global tilt	31.2	28.9	0.640
Major Cobb coronal	34.2	38.2	0.556
Preoperative HRQoL parameters			
Back pain	7.2	6.8	0.567
Radicular pain	4.8	4.0	0.376
COMI	7.1	7.2	0.896
ODI	50.1	47.0	0.581
SF 36 MCS	38.8	39.5	0.828
SF 36 PCS	30.8	34.6	0.108
SRS22 function	2.6	2.9	0.254
SRS22 mental	3.0	3.1	0.779
SRS22 pain	2.2	2.4	0.310
SRS22 satisfaction	2.8	2.7	0.981
SRS22 self image	2.1	2.4	0.254
SRS22 subtotal	2.5	2.7	0.255

<sup>a</sup>Matched variable

**Table 2** Postoperative complications

Variables	Cases (N = 19)		Controls (N = 57)		p value
	N	%	N	%	
ICU needed	18	94.7	50	87.7	0.354
Intraoperative complications	6	31.6	13	22.8	0.543
Neurological complications	5	26.3	12	21.1	0.752
Intra-hospital complications	7	36.8	11	19.3	0.132
Wound complications (seroma, hematoma, dehiscencies)	5	26.3	3	5.3	0.021*
Implant complications (Pullout, loosening)	6	31.6	16	28.1	0.777
Radiological/mechanical complications (PJK, rod breakage, pseudoarthrosis)	8	42.1	17	29.8	0.400
Pseudoarthrosis	2	10.5	12	19.3	0.498
Proximal junctional kyphosis	6	31.6	5	10.5	0.023*
Any major complications other than infection	10	52.6	24	42.1	0.439
Any complication other than infection	15	78.9	39	68.4	0.560
Any revisions for reasons other than infection	8	42.1	13	22.8	0.139
Any re-admission for reason other than infection	6	31.6	13	22.8	0.543

Asterisk values indicate significance of *p* value (*p* < 0.05)

**Table 3** Overall radiological results at 24 months as compared to baseline (N = 76)

	Mean	Std. deviation	P value
SVA			
Pre-op	61.50	70.50	0.048*
24 months	38.15	53.58	
PI			
Pre-op	56.16	14.13	0.655
24 months	55.10	10.99	
LL			
Pre-op	−41.71	25.42	0.020*
24 months	−50.24	15.42	
PI-LL			
Pre-op	14.45	26.98	0.011*
24 months	4.84	14.85	
SS			
Pre-op	33.39	13.74	0.720
24 months	34.22	10.62	
PT			
Pre-op	22.72	12.08	0.230
24 months	20.74	9.53	
Global Tilt			
Pre-op	30.16	18.22	0.046*
24 months	24.54	14.03	
Major Cobb			
Pre-op	35.56	25.87	0.000*
24 months	19.16	17.29	

Asterisk values indicate significance of *p* value (*p* < 0.05)

related to the main variable. We omitted the dead patient along with her matched pairs from our result analysis. This decision was based on the fact that death, secondary to SSI, is extremely rare in the ASD population. Leaving the patient and keeping her PROMs at worst values would have severely distorted our analysis with the small sample. Detected differences would be harder to interpret. We, nevertheless, believe that death's impact cannot be obviated and a better way to account for it would be through a QALY (quality adjusted life year) analysis.

Despite this added morbidity and mortality, we have shown that both the infected and non-infected groups benefited equally from surgery in terms of deformity correction and quality of life at final review. At 24 months, and with the resolution of the infection, patients maintained good sagittal deformity correction combined with improvement in all their PROMs except SF36-MCS, SRS22-Mental Score, and leg pain. In the absence of a non-surgical control group, we cannot compare the benefit gained with surgery to non-operative management. When analysing the HRQoL parameters, the COMI score was the single most sensitive outcome measure to detect any difference between these two groups. This is in line with the recent literature and especially the recent work by Mannion et al. [23] who showed that despite its brevity, the COMI score was highly sensitive to any change in the patient's condition or disease itself.

Scheer et al. showed that psychological scores (SRS22 Mental Score and SF 36 MCS) improved less if patients had a complication needing a secondary intervention after ASD surgery [8]. In the present study, we could show that psychological scores (SF 36 MCS and SF22-Mental score) did not differ significantly from baseline at last follow-up (Table 5),



**Table 4** Overall HRQoL results at 24 months as compared to baseline ( $N=76$ )

	Mean	Std. deviation	<i>P</i> value
Back pain			
Pre-op	6.93	2.317	0.000*
24 months	4.32	3.179	
Leg pain			
Pre-op	4.33	3.640	0.123
24 months	3.34	3.374	
COMI			
Pre-op	7.4347	2.23807	0.000*
24 months	4.6918	2.56483	
ODI			
Pre-op	49.15	19.114	0.002*
24 months	37.76	19.974	
SF 36 MCS			
Pre-op	39.3110	12.28955	0.271
24 months	41.7120	11.30408	
SF 36 PCS			
Pre-op	33.2139	8.25521	0.004*
24 months	38.6356	11.05318	
SRS 22 function			
Pre-op	2.7294	0.89427	0.021*
24 months	3.1287	0.98324	
SRS22 mental			
Pre-op	3.040	0.9028	0.348
24 months	3.196	0.9223	
SRS22 pain			
Pre-op	2.3309	0.89230	0.000*
24 months	3.1954	1.06560	
SRS22 satisfaction			
Pre-op	2.744	1.2133	0.000*
24 months	3.721	1.0591	
SRS22 self image			
Pre-op	2.253	0.8222	0.000*
24 months	3.081	0.9122	
SRS22 subtotal			
Pre-op	2.5963	0.68574	0.000*
24 months	3.1444	0.83266	

Asterisk values indicate significance of *p* value ( $p < 0.05$ )

but that was across the whole sample. When we analyzed differences in absolute figures between both groups, there was an initial difference in SRS 22 Mental Score at 6 months that was lost thereafter ( $p 0.036$ ). We could also see that the SRS 22 Mental Score was less likely to improve at 6 months in the infected group ( $p 0.049$ ). There was no difference beyond 6 months in these parameters.

Four other studies tried to assess the impact of infection on clinical results after posterior spinal surgery [9–11] with differing conclusions. In the matched control analysis in 16

patients with posterior spinal fusion, Mok et al. detected no significant difference in the physical function, role physical, bodily pain, and general health domains between the infection group and control group at an average of 62 months [9]. However, in a similar study, Petilon did demonstrate a difference in back pain and Oswestry Disability Index in patients suffering from a deep infection after a lumbar fusion [13]. This was a matched-cohort study of 30 patients with SSI and 30 controls after a lumbar fusion. Patient population was heterogeneous in terms of diagnosis and they included anterior-only surgeries such as ALIFs, but did not include ASD patients.

Rhin et al. found no difference in the pain, function, self image, satisfaction, or total Scoliosis Research Society 22 scores after deep SSI in adolescent patients with idiopathic scoliosis after a minimum of 2 years [11]. Falavigna et al. [10] studied patients having lumbar fusion for degenerative disc disease, and found no significant difference in pain, functional disability, quality of life, or depression and anxiety. However, 53.8% of the patients with infection were not satisfied with the procedure at the final evaluation, compared with 15.4% of the patients without a deep wound infection ( $p=0.003$ ).

Even if infection does not seem to significantly alter the final functional outcome, these studies did not follow the recorded variables through time and they did not study the difference between infected and non-infected patients at defined time intervals. They also included heterogeneous groups of patients with respect to preoperative diagnosis and surgical procedure. They also did not stratify infections by timing. In addition, they had small samples and lacked detailed preoperative records.

Núñez-Pereira et al. analysed implant survival after SSI in Spinal surgery [24]. In their sample of 43 patients with posterior instrumented fusion, only 90% of the implants or patients survived the first debridement. At 2 years, 73% of patients were alive with implants. This survivorship rate was maintained thereafter. These results were reproduced in the literature [25, 26]. In ASD surgery, especially when associated to tri-columnar osteotomies, implants are essential during the first two postoperative years to ensure a stable environment for fusion. Fusion itself is a fundamental prerequisite to any surgical success. Risk factors for implant removal includes late infections, delayed surgery, delayed antibiotic treatment, greater number of past surgeries, high postoperative infection treatment score for the spine, and the presence of methicillin-resistant *S. aureus* [25–27]. Infection occurring in the first 90 days has higher chances to preserve original implants [28]. In our series, only two patients needed a partial exchange of instrumentation and we had one death. The survival rate with original implants was, therefore, 85% at 2 years. Two patients were re-instrumented with no further loss of sagittal correction, and all had their

**Table 5** HRQoL analysis—difference between groups at interval points ( $N=76$ )

	6 months		12 months		24 months	
		<i>p</i> value		<i>p</i> value		<i>p</i> value
Back pain						
Cases	3.81	0.944	4.07	0.854	3.36	0.923
Controls	3.87		4.24		4.57	
Leg pain						
Cases	2.94	0.798	2.21	0.404	3.00	0.467
Controls	2.72		2.96		3.43	
COMI						
Cases	6.17	<b>0.049</b>	5.86	<b>0.047</b>	5.74	0.092
Controls	4.86		4.15		4.46	
ODI						
Cases	45.87	<b>0.049</b>	42.43	0.075	40.64	0.701
Controls	34.22		34.33		37.02	
SF 36 mental component						
Cases	38.97	0.398	41.41	0.806	39.93	0.493
Controls	42.03		42.34		42.17	
SF 36 physical component						
Cases	31.48	<b>0.027</b>	34.99	0.051	36.64	0.707
Controls	37.24		40.22		39.15	
SRS22 function						
Cases	2.69	0.101	3.18	0.722	2.73	0.573
Controls	3.12		3.28		3.23	
SRS22 mental						
Cases	2.77	<b>0.036</b>	3.17	0.745	3.29	0.177
Controls	3.24		3.25		3.17	
SRS22 pain						
Cases	3.09	0.830	2.90	0.226	3.18	0.846
Controls	3.15		3.30		3.20	
SRS22 satisfaction						
Cases	3.62	0.318	3.50	0.326	3.68	0.813
Controls	3.94		3.83		3.73	
SRS22 body image						
Cases	3.11	0.629	3.06	0.285	2.95	0.311
Controls	3.29		3.33		3.12	
SRS22 subtotal						
Cases	2.92	0.212	3.09	0.402	3.03	0.201
Controls	3.19		3.29		3.17	

Bold values indicate significance of *p* value ( $p < 0.05$ )

infection controlled by 6 months from diagnosis. The fact that all infections in our sample were successfully treated and that there were no infection relapses explains in part our good overall results.

Even when implants are maintained, SSI patients seem to suffer from more pseudoarthrosis with rates varying between 38 and 44% [15, 16]. Risk factors for non-fusion with SSI seem to be female gender, extension to sacrum, use of allografts, and not using cages [15, 16]. In our series, we did not find any significant difference between both groups (10.5 vs. 19.3%). When we analysed mechanical complications as

a whole (PJK, rod breakage and non-unions), we saw that there was a higher prevalence in the infected group (42.1 vs. 29.8%,  $p$  0.400). This did not reach statistical significance. When analysed alone, PJK was much more prevalent in the context of infection (31.6 vs. 10.5%;  $p$  0.023) than in patients without SSI. No other study has investigated the rate of PJK in the context of SSI. We hypothesise that this higher rate of PJK in infected patients is due to a weakened posterior tension band or muscles due to the infection itself, the decreased activity of patients with infection or repeated surgical injury during revision.



**Table 6** HRQoL analysis—  
difference with baseline value

	6 months		12 months		24 months	
	<i>p</i> value		<i>p</i> value		<i>p</i> value	
Back pain						
Cases	− 3.19	0.749	− 2.93	0.667	− 4.27	<b>0.045</b>
Controls	− 2.86		− 2.53		− 2.21	
Leg pain						
Cases	− 1.31	0.870	− 1.64	0.651	− 2.18	0.264
Controls	− 1.48		− 1.21		− 0.95	
COMI						
Cases	0.14	<b>0.001</b>	− 1.27	<b>0.049</b>	− 1.68	0.303
Controls	− 2.66		− 3.13		− 2.91	
ODI						
Cases	− 1.50	<b>0.029</b>	− 4.69	0.052	− 6.40	0.424
Controls	− 14.69		− 14.53		− 11.03	
SF 36 mental component						
Cases	− 1.42	0.425	2.33	0.916	1.83	0.893
Controls	1.69		1.87		1.33	
SF 36 physical component						
Cases	0.09	0.220	2.66	0.211	4.61	0.795
Controls	3.32		6.36		5.42	
SRS22 function						
Cases	− 0.04	0.137	0.38	0.735	− 0.11	<b>0.034</b>
Controls	0.31		0.46		0.41	
SRS22 mental						
Cases	− 0.34	<b>0.049</b>	0.09	0.452	0.32	0.349
Controls	0.20		0.29		0.05	
SRS22 pain						
Cases	0.84	0.869	0.63	0.410	0.91	0.633
Controls	0.79		0.89		0.77	
SRS22 satisfaction						
Cases	0.61	0.457	0.44	0.304	0.38	0.214
Controls	1.04		1.00		1.02	
SRS22 body image						
Cases	0.94	0.831	0.99	0.832	0.76	0.794
Controls	1.03		1.05		0.85	
SRS22 subtotal						
Cases	0.35	0.281	0.54	0.521	0.47	0.873
Controls	0.56		0.66		0.50	

Bold values indicate significance of *p* value (*p* < 0.05)

The present study is the largest cohort study specifically studying the effect of SSI on surgical outcomes in spinal surgery. It also aims at studying this negative impact in long-term follow-up. The study contained a homogenous diagnostic and surgical population that was further matched using demographic and surgical variables known to affect both infection and outcome scores. In addition, the matched cohorts included in this analysis showed no differences in other non-matched known risk factors such as diabetes, liver disease, smoking, length of surgery, and blood loss. The size of the deformity and the baseline HRQoL parameters were

also comparable between both groups. This further increases the validity of our conclusions.

This study suffers from inherent limitations applicable to all multicentre studies. One of these might be the non-standardised approach and management of infection in the different participating centres. Another major limitation is the small sample size and the lack of statistical power to detect differences between groups. We also did not stratify infections according to their virulence nor to their course. We are conscious that infection cannot be considered as a homogeneous entity, and patients might fare differently and

their results vary accordingly. We only included acute infections that were diagnosed and treated very early on, and all of our patients cleared the infection with the exception of the patient that died. With a bigger sample, possible differences might be better delimited and/or patients could be stratified according to infection characteristics. Finally, the present study as mentioned, could not account for death when comparing both groups due to intrinsic limitations in methodology. A better way to measure the impact of infection and associated mortality would be to analyse QALY differences between both groups.

## Conclusion

ASD patients have a high rate of SSI. When occurring, deep SSI significantly affects recovery in the first postoperative year. It increases the length of hospital stay and is associated with more complications, unrelated revisions, and a worse quality of life during the first year. SSI can even be deadly in extreme of cases. However, when successfully treated, its negative impact seems to wear-off by the second year, as differences in outcome scores become less pronounced. Despite early SSI, patients seem to benefit from posterior ASD surgery just as much as their non-infected counterparts. Also, at the 2-year follow-up, resolved SSI does not seem to have a significant bearing on the size of deformity correction, provided that the implants are maintained. These findings increase our understanding of the impact of early SSI on final outcome. It also provides surgeons with more insight when counselling potential surgical patients on the risks and benefits of surgery, and likely outcomes.

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## Compliance with ethical standards

**Conflict of interest** None of the authors has any potential conflict of interest.

## References

1. Sciubba DM, Yurter A, Smith JS, Kelly MP, Scheer JK, Goodwin CR, Lafage V, Hart RA, Bess S, Kebaish K, Schwab F, Shaffrey CI, Ames CP, International Spine Study G (2015) A comprehensive review of complication rates after surgery for adult deformity: a reference for informed consent. *Spine Deform* 3(6):575–594. <https://doi.org/10.1016/j.jspd.2015.04.005>
2. Ayhan S, Aykac B, Yuksel S, Guler UO, Pellise F, Alanay A, Perez-Grueso FJ, Acaroglu E, Group EESS (2016) Safety and efficacy of osteotomies in adult spinal deformity: what happens in the first year? *Eur Spine J* 25(8):2471–2479. <https://doi.org/10.1007/s00586-015-3981-3>
3. Bianco K, Norton R, Schwab F, Smith JS, Klineberg E, Obeid I, Mundis G Jr, Shaffrey CI, Kebaish K, Hostin R, Hart R, Gupta MC, Burton D, Ames C, Boachie-Adjei O, Protopsaltis TS, Lafage V, International Spine Study G (2014) Complications and intercenter variability of three-column osteotomies for spinal deformity surgery: a retrospective review of 423 patients. *Neurosurg Focus* 36(5):E18. <https://doi.org/10.3171/2014.2.focus1422>
4. McCormick JD, Werner BC, Shimer AL (2013) Patient-reported outcome measures in spine surgery. *J Am Acad Orthop Surg* 21(2):99–107. <https://doi.org/10.5435/JAAOS-21-02-99>
5. Ames CP, Scheer JK, Lafage V, Smith JS, Bess S, Berven SH, Mundis GM, Sethi RK, Delele DA, Coe JD, Hey LA, Daubs MD (2016) Adult spinal deformity: epidemiology, health impact, evaluation, and management. *Spine Deform* 4(4):310–322. <https://doi.org/10.1016/j.jspd.2015.12.009>
6. Smith JS, Klineberg E, Lafage V, Shaffrey CI, Schwab F, Lafage R, Hostin R, Mundis GM Jr, Errico TJ, Kim HJ, Protopsaltis TS, Hamilton DK, Scheer JK, Soroceanu A, Kelly MP, Line B, Gupta M, Deviren V, Hart R, Burton DC, Bess S, Ames CP, International Spine Study G (2016) Prospective multicenter assessment of perioperative and minimum 2-year postoperative complication rates associated with adult spinal deformity surgery. *J Neurosurg Spine* 25(1):1–14. <https://doi.org/10.3171/2015.11.spine151036>
7. Soroceanu A, Burton DC, Oren JH, Smith JS, Hostin R, Shaffrey CI, Akbarnia BA, Ames CP, Errico TJ, Bess S, Gupta MC, Deviren V, Schwab FJ, Lafage V, International Spine Study G (2016) Medical complications after adult spinal deformity surgery: incidence, risk factors, and clinical impact. *Spine* 41(22):1718–1723. <https://doi.org/10.1097/brs.0000000000001636>
8. Scheer JK, Mundis GM, Klineberg E, Hart RA, Deviren V, Burton DC, Protopsaltis TS, Gupta M, Rolston JD, Bess S, Shaffrey CI, Schwab F, Lafage V, Smith JS, Ames CP, International Spine Study G (2016) Recovery following adult spinal deformity surgery: the effect of complications and reoperation in 149 patients with 2-year follow-up. *Eur Spine J* 25(8):2612–2621. <https://doi.org/10.1007/s00586-015-3787-3>
9. Mok JM, Guillaume TJ, Talu U, Berven SH, Deviren V, Kroeber M, Bradford DS, Hu SS (2009) Clinical outcome of deep wound infection after instrumented posterior spinal fusion: a matched cohort analysis. *Spine* 34(6):578–583. <https://doi.org/10.1097/BRS.0b013e31819a827c>
10. Falavigna A, Righesso O, Traynelis VC, Teles AR, da Silva PG (2011) Effect of deep wound infection following lumbar arthrodesis for degenerative disc disease on long-term outcome: a prospective study: clinical article. *J Neurosurg Spine* 15(4):399–403. <https://doi.org/10.3171/2011.5.SPINE10825>
11. Rihn JA, Lee JY, Ward WT (2008) Infection after the surgical treatment of adolescent idiopathic scoliosis: evaluation of the diagnosis, treatment, and impact on clinical outcomes. *Spine* 33(3):289–294. <https://doi.org/10.1097/BRS.0b013e318162016e>
12. Glassman SD, Hamill CL, Bridwell KH, Schwab FJ, Dimar JR, Lowe TG (2007) The impact of perioperative complications on clinical outcome in adult deformity surgery. *Spine* 32(24):2764–2770. <https://doi.org/10.1097/BRS.0b013e31815a7644>
13. Pilon JM, Glassman SD, Dimar JR, Carreon LY (2012) Clinical outcomes after lumbar fusion complicated by deep wound infection: a case-control study. *Spine* 37(16):1370–1374. <https://doi.org/10.1097/BRS.0b013e31824a4d93>
14. Albert TJ, Purtill J, Mesa J, McIntosh T, Balderston RA (1995) Health outcome assessment before and after adult deformity surgery. A prospective study. *Spine* 20(18):2002–2004 (discussion p2005)
15. Weiss LE, Vaccaro AR, Scuderi G, McGuire M, Garfin SR (1997) Pseudarthrosis after postoperative wound infection in the lumbar spine. *J Spinal Disord* 10(6):482–487

16. Wang TY, Back AG, Hompe E, Wall K, Gottfried ON (2017) Impact of surgical site infection and surgical debridement on lumbar arthrodesis: a single-institution analysis of incidence and risk factors. *J Clin Neurosci*. <https://doi.org/10.1016/j.jocn.2017.01.020>
17. Mangram AJ, Horan TC, Pearson ML, Silver LC, Jarvis WR (1999) Guideline for prevention of surgical site infection, 1999. Centers for Disease Control and Prevention (CDC) Hospital Infection Control Practices Advisory Committee. *Am J Infect Control* 27(2):97–132 (**quiz 133–134; discussion 196**)
18. Horan TC, Gaynes RP, Martone WJ, Jarvis WR, Emori TG (1992) CDC definitions of nosocomial surgical site infections, 1992: a modification of CDC definitions of surgical wound infections. *Infect Control Hosp Epidemiol* 13(10):606–608
19. Xing D, Ma JX, Ma XL, Song DH, Wang J, Chen Y, Yang Y, Zhu SW, Ma BY, Feng R (2013) A methodological, systematic review of evidence-based independent risk factors for surgical site infections after spinal surgery. *Eur Spine J* 22(3):605–615. <https://doi.org/10.1007/s00586-012-2514-6>
20. Pull ter Gunne AF, Hosman AJ, Cohen DB, Schuetz M, Habil D, van Laarhoven CJ, van Middendorp JJ (2012) A methodological systematic review on surgical site infections following spinal surgery: part 1: risk factors. *Spine* 37(24):2017–2033. <https://doi.org/10.1097/BRS.0b013e31825bfca8>
21. Yeramaneni S, Robinson C, Hostin R (2016) Impact of spine surgery complications on costs associated with management of adult spinal deformity. *Curr Rev Musculoskelet Med* 9(3):327–332. <https://doi.org/10.1007/s12178-016-9352-9>
22. Casper DS, Zmistowski B, Hollern DA, Hilibrand AS, Vaccaro AR, Schroeder GD, Kepler CK (2018) The effect of postoperative spinal infections on patient mortality. *Spine* 43(3):223–227. <https://doi.org/10.1097/BRS.0000000000002277>
23. Mannion AF, Vila-Casademunt A, Domingo-Sabat M, Wunderlin S, Pellise F, Bago J, Acaroglu E, Alanay A, Perez-Grueso FS, Obeid I, Kleinstuck FS, European Spine Study G (2016) The core outcome measures index (COMI) is a responsive instrument for assessing the outcome of treatment for adult spinal deformity. *Eur Spine J* 25(8):2638–2648. <https://doi.org/10.1007/s00586-015-4292-4>
24. Nunez-Pereira S, Pellise F, Rodriguez-Pardo D, Pigrau C, Bago J, Villanueva C, Caceres E (2013) Implant survival after deep infection of an instrumented spinal fusion. *Bone Jt J* 95-B(8):1121–1126. <https://doi.org/10.1302/0301-620x.95b8.30784>
25. Tsubouchi N, Fujibayashi S, Otsuki B, Izeki M, Kimura H, Ota M, Sakamoto T, Uchikoshi A, Matsuda S (2017) Risk factors for implant removal after spinal surgical site infection. *Eur Spine J*. <https://doi.org/10.1007/s00586-017-5294-1>
26. Tominaga H, Setoguchi T, Kawamura H, Kawamura I, Nagano S, Abematsu M, Tanabe F, Ishidou Y, Yamamoto T, Komiya S (2016) Risk factors for unavoidable removal of instrumentation after surgical site infection of spine surgery: a retrospective case-control study. *Medicine (Baltimore)* 95(43):e5118. <https://doi.org/10.1097/MD.00000000000005118>
27. Dipaola CP, Saravanja DD, Boriani L, Zhang H, Boyd MC, Kwon BK, Paquette SJ, Dvorak MF, Fisher CG, Street JT (2012) Postoperative infection treatment score for the spine (PITSS): construction and validation of a predictive model to define need for single versus multiple irrigation and debridement for spinal surgical site infection. *Spine J* 12(3):218–230. <https://doi.org/10.1016/j.spine.2012.02.004>
28. Cahill PJ, Warnick DE, Lee MJ, Gaughan J, Vogel LE, Hammerberg KW, Sturm PF (2010) Infection after spinal fusion for pediatric spinal deformity: thirty years of experience at a single institution. *Spine* 35(12):1211–1217. <https://doi.org/10.1097/BRS.0b013e3181c212d1>

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