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ORIGINAL ARTICLE

Morbidity and mortality in adult spinal deformity surgery: Norwich Spinal Unit experience

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Abstract
Purpose This study analyses the complications of spinal deformity surgery in adults to highlight pre-disposing factors.
Methods The clinical records and imaging were reviewed for 48 consecutive patients, 12 males and 36 females, with a mean age of 64 (31–86), who had surgery for spinal deformity. Mean follow-up time was 36 months (24–60). Patient data recorded were age, diagnosis and co-morbidities; deformity assessment: curve type, sagittal and coronal balance, Cobb angle. Operation details: number of instrumented levels, duration and intra-operative complications. Outcome: complications, re-operations, balance and Cobb angle.
Results 28 patients (58 %) had at least 1, 15 patients (27 %) had 2 and 5 patients (9.5 %) had more than 2 co-morbidities. Average time between 1st presentation and operation was 13 months (1–41). The mean number of levels fused was 10.8 (4–23). In addition to posterior pedicle screw instrumentation, 40 patients had chevron osteotomies and 8 had pedicle substraction osteotomies. Posterior interbody fusions were performed at one level in 17 of which 7 had 2 level fusion. Two patients had combined anterior and posterior approaches. Fusion to the pelvis was performed in 19 patients. There were a total of 27 major and minor complications in 19/48 (39.5 %) patients. Late complications included 5 patients who had revisions for proximal junctional kyphosis, 1 patient had revision for pseudoarthrosis and 4 patients had removal of mal-positioned screws.
Conclusions Factors associated with high complication rate in adult spinal deformity surgery are age, co-morbidities and severe sagittal imbalance at the time of presentation.

Keywords Adult degenerative deformity · Sagittal balance · Spino-pelvic balance · Co-morbidities · Complications

Abbreviations

C7-PS	C7 plumb line to posterior sacrum distance
PSO	Pedicle substraction osteotomy
VCR	Vertebral column resection
PJK	Proximal junctional kyphosis
PI	Pelvic incidence
LL	Lumbar lordosis

Introduction

Adult degenerative scoliotic deformities progress at a rate of 1–6° per year [1] and the decision has to be made by the treating surgeon whether to recommend surgery. Many factors have to be considered in making this recommendation and drawn to the patient's attention. These include age, co-morbidity, social circumstances and the patient's expectation of treatment. Lenke and Silva [2] proposed six distinct levels of surgical treatment. These start from decompression alone progressing to complex osteotomies with long fusions from pelvis to high thoracic spine.

Surgical treatment for adult spinal deformity has a high risk of complications. A recent systemic review of adult scoliosis surgery outcomes reported 13 % risk of pseudo-arthrosis and

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40 % risk of adverse peri-operative events [3]. Charosky et al. [4] reported overall complication rate of 39 % and re-operation rate of 26 %. The SRS register of morbidity and mortality of adult scoliosis surgery, however, reported only a 13.4 % complication rate [5].

Given that there has been significant inconsistency in the reported complication rate by various authors, we feel it is important for spinal units undertaking adult deformity surgery to accurately audit and publish their morbidity. Also we aimed to investigate the presumed relationship between complication rate with age and co-morbidities.

Methods

The clinical records and imaging of 48 consecutive patients who had surgery for adult scoliosis were reviewed. Inclusion criteria included the following:

1. Patients over the age of 30 with an established diagnosis of either adult de novo scoliosis or progression of adolescent idiopathic scoliosis.
2. Surgical intervention of one of the following types:
   (a) Fusion (with or without decompression) in situ for deformity at three levels or more.
   (b) Fusion with chevron osteotomy.
   (c) Fusion with pedicle subtraction osteotomy.
   (d) Fusion with vertebral column resection (VCR) and anterior reconstruction.
3. Minimum 2 years of post-operative clinical and radiological follow-up.

Exclusion criteria: single/double level decompression and short fusions for degenerative scoliosis and stenosis.

Patient demographics recorded were age at the time of presentation, interval between initial presentation and operation and co-morbidities.

Pre-operative radiological findings for coronal plane were curve characteristics, apex of the curve, degree of lateral listhesis and cobb angle. Sagittal plane evaluation included assessment of global sagittal balance (C7 plumb line) and spino-pelvic balance in the form of difference between both pelvic incidence and lumbar lordosis as described by Schwab et al. [6]. Post-operative radiological findings included assessment of curve correction in terms of Cobb angle improvement and improvement of sagittal balance looking at C7 plumb line as well as lumbar lordosis. Evidence of radiological failure or complications such as misplaced screws, pseudo-arthrosis and proximal junctional kyphosis (PJK) was recorded.

Six patients who had developed PJK and/or pseudoarthrosis post-operatively were analysed separately to determine if their deformities were more severe than in the rest of the group, but this was not analysed statistically because of the small numbers.

Operative details recorded were the surgical approach, single or dual stage operations, interbody fusions, extent of instrumentation and type of osteotomies undertaken.

Complications were recorded under the main categories of infection, neurological, general and mechanical complications. Further, sub-categories were defined as under:

Mortality, Infection: Superficial: No need for further surgery. Infection settled with antibiotics. Deep: Need for debridement or plastic surgery reconstruction.
Neurological: Major: Profound neurological deficit. Minor: Radicular pain or weakness in the distribution of a particular nerve root secondary to traction injury or misplaced pedicle screws.
General and peri-operative: DVT, PE, Anaesthetic, dural tears and wound haematoma.
Mechanical: Implant breakage, loosening, pseudoarthrosis, proximal junction kyphosis, Progression or loss of sagittal imbalance.

Results

Patient details

The average age at presentation was 64 years (31–86 years). The mean time from presentation to surgery was 13.2 months (1–41 months). During this period, patients underwent non-operative management through a multidisciplinary approach as deemed appropriate, and surgery was recommended on failure of this approach. Two patients who had surgery at 1 month from presentation had received non-operative treatment elsewhere.

Co-morbidities

28 (58 %) patients had one co-morbid condition and 20 patients (37.5 %) had two or more. These included hypertension, ischaemic heart disease, diabetes and previous history of stroke. It is clear from Table 1 that the patients over the age of 60 had a higher frequency of co-morbidity.

Table 1 Age and co-morbidities distribution

No. of co-morbidities	0	1	>1
Age (patient no.)			
<60 (15, 31.25 %)	13	2	0
>60 (33, 68.75 %)	7	14	12

Radiological findings

The mean Cobb angle was 38° (20–100) pre-operatively. Most common location with regards to the apex of the curve was L3–4 (20 patients, 37.5 %). Nine patients had apex located in either thoracic or thoraco-lumbar region. Lateral listhesis was noted in all patients most commonly at L2–3 level and averaged around 9.6 mm ranging from 4 to 22 mm.

27 patients were found to be in positive sagittal balance with an average of 7.7 cm distance between C7 plumb line and posterior sacrum. Spino-pelvic balance was evaluated by calculating difference between lumbar lordosis and pelvic incidence. Average pelvic incidence for those patients that did not develop PJK was measured to be 63 (40–95) and lumbar lordosis was 14.1 (2.5–65) pre-operatively with an average *PI–LL difference of 49*. Patients that went on to develop PJK needing revision had an average PI of 70.8 and LL of 18 and average *PI–LL difference of 52.2*.

Average Cobb angle correction for the entire group was 66 % down from pre-operative average Cobb angle of 38° (20–100) to 12° (1–50) post-operatively. Improvement in sagittal balance was reflected by C7PL–PS (C7 plumb line to posterior superior sacral end plate) distance, which was measured to an average of 50.2 mm (0–173) post-operatively from 71.26 mm (0–238) pre-operatively for patients without PJK and measured 78.8 mm (0–140) post-operatively from 117 mm (0–268) pre-operative for the group that developed PJK requiring revisions.

Surgical details

There were a total of 60 operative episodes with 46 primary and 14 re-operations. All primary operations were performed through a posterior approach and 2 re-operations included anterior–posterior combined approaches. All operations including re-operations were done as a single stage. Including all primary and revision operations an average of 10.8 (4–23) levels were fused. 40 patients had posterior release and chevron type of osteotomies, 8 patients underwent pedicle substraction osteotomies (PSO) and 2 patients had VCR. 17 patients had interbody fusion of which 7 had two level fusion, 19 patients had fusion extended down to sacrum of which 4 had additional fixation down to pelvis. Table 2 shows the extent of fusion.

Table 2 Surgical details of proximal and distal extent and number levels involved in fusion

Fusion levels	No.
Fusion to sacrum	19
Fusion to sacrum + pelvis	4
Fusion to L4 or L5	25
Fusion to PT spine, T3–5	27
Fusion to TL, T9–L1	21
10 or more levels fused	25

Complications and re-operations details

See Tables 3, 4 and 5.

Discussion

There is a considerable variation in the reported incidence of morbidity and mortality reported in the literature, and the rate of complication ranges from 0 to 53 % [3]. A systemic review by Yadla et al. [3], which included 49 articles and 3,299 patients, reported an overall complication rate of 41.2 %. The articles included were from 1981 to 2009 and the age of patients included was from 15 to 72.4. A recent SRS report on morbidity and mortality of adult scoliosis surgery indicated a 13.4 % overall complication rate from a database of 4,980 patients [5]. A recent multi-centre retrospective study from France reported 39 % overall complication rate [4].

As the severity of deformity increases so does the complexity of the surgery required. Lenke and Silva [2] proposed six levels of operative treatment ranging from: (1) decompression alone, (2) decompression and limited instrumented posterior spinal fusion, (3) decompression and lumbar curve instrumented fusion, (4) decompression with anterior and posterior spinal instrumented fusion, (5) thoracic instrumentation and fusion extension, and (6) inclusion of osteotomies for specific deformities. The current series includes only those patients offered surgery from level 3 upwards.

The time interval between first presentation and surgical intervention reflects patient optimisation process. Patients who failed non-surgical management were brought to an adult scoliosis clinic and were reviewed jointly by three consultant spinal surgeons.

The incidence of complications is higher in this series than in the SRS report [5], though similar to the meta-analysis reported by Yadla et al. [3]. This may be related to the age range and number of co-morbidities, both of which are higher in the current series than that of the SRS report.

PJK accounted for 7 re-operations. The reported incidence of PJK varies from 26 to 46 % in the literature [7–9]. The etiology is multi-factorial. Loss of posterior tension band due to excessive soft tissue dissection and facet joint damage at the top end of the construct, incorrect end vertebrae selection, proximal disc degeneration, stress fracture of proximal vertebrae and top end instrumentation failure are possible causes. Glassman et al. [10] reported positive sagittal balance to be the most reliable predictor of clinical

Table 3 Complications

Complications type		Age > 60 ($n = 33$)	Age < 60 ($n = 15$)
Wound infection	3 (6.2 %)	2 (4.16 %)	1 (2.1 %)
Superficial	1	0	1
Deep	2	2	0
Neurological	6 (12.5 %)	4 (8.32 %)	2 (4.16 %)
Major	1	1	0
Minor	5 (4-Revised pedicle screws)	3	2
Mechanical	6 (12.5 %)	6 (12.5 %)	0
Pseudoarthrosis	1 (2.1 %)	1	0
PJK	5 (8.3 %)	5	0
General		8 (16.6 %)	3 (6.25 %)
Dural tear	4 (8.33 %)	1	3
Wound haematoma	1 (2.1 %)	1	0
Pulmonary embolism	3 (6.25 %)	3	0
DVT	3 (6.25 %)	3	0
Mortality	1 (2.08 %), (PE)	1 (2.08 %)	0
Number of patients with complication	19 (39.5 %)	15 (31.25 %)	4 (8.3 %)

Table 4 Reasons for re-operations

Revised patients and re-operations	12/48 (25 %) patients, 14 re-operations
Reasons for reoperation	
Proximal junctional kyphosis (PJK)	5 (10.41 %) patients, 6 re-operations
Metal work	5 (10.4 %) patients, 5 re-operations
Impingement on nerve roots	4 (8.3 %)
Pseudoarthrosis and failure	1 (2.1 %)
Infection	2 (4.2 %) patients, 3 re-operations

Table 5 Patients with proximal junctional kyphosis and subsequent management

Case No.	PI	Pre-op LL	Post-op LL	Levels fused at index operation	Management of PJK
1	67	20	35	T12–L4	T4–L4, Proximal extension
2	73	25	35	L2–L5,	1st re-operation: Proximal extension to T9; T9–L5
					2nd re-operation: Distal extension to pelvis; T9–Ilium, 3 level PLIF,
3	69	−22	31	T8–L5 with PSO at L2	VCR at L2, Proximal extension to T4; T4–S1, combined single stage
					Anterior and posterior approach
4	65	5	40	T7–L5	T3–L5 with PLIF 2 levels
5	75	25	25	L2–L5	T3–L5

symptoms and emphasised on restoration of sagittal balance. Besides the above factors, restoration of spino-pelvic balance has gained increasing attention recently. The patients in our series that developed PJK (Table 5) presented with a high PI-LL mismatch, which reflects the fact that they required large amount of correction, which could not be achieved at the index operation. Schwab et al. suggested a simplistic formula of achieving a lumbar lordosis within 9° of pelvic incidence. However, when PJK develops post-operatively, the options available are simply extension of fusion above and below, removal of previous hardware and osteotomies/VCR followed by extension of fusion. 4 patients had further extensions and 1 patient underwent VCR in our series for the management of their PJK.

One patient had major neurological deficit following operation and developed paraplegia secondary to possible spinal cord ischaemia. Post-operative MR failed to reveal any compression or mal-positioned hardware. This episode stresses the importance of multi-modality (SSEP, MEP and EMG) monitoring (this patient did not have formal neuro-monitoring) and avoidance of hypotension in the

post-operative period. Minor neurological deficits were in the form of radicular pain due to impingement of nerve roots secondary to mal-positioned screws and that necessitated change in 4 patients. Minor neurological deficits are, however, not uncommon in adult deformity surgery [11].

A patient died secondary to acute PE on the eighth post-operative day. There is no consensus regarding post-operative VTE prophylaxis following major adult deformity surgery, although it is recognised that there is a relative contra indication to intra-operative thromobo-prophylaxis in spinal surgery due to the potential for neurological compression from post-operative haematoma formation. In our practice, post-operative prophylaxis is started if the clotting studies are normal and the patient's mobilisation is slow [12, 13].

The rate of pseudoarthrosis reported in the literature varies from 4 to 24 % [14]. Aebi [15] reported lumbosacral pseudoarthrosis and sagittal imbalance to be the commonest complications. In the present series, one patient developed pseudoarthrosis and presented with pain and rod breakage, requiring exchange of the rod and further bone grafting. Overall, no pseudoarthrosis was observed at lumbosacral junction. We recommend either interbody fusion or extension of instrumentation to ilium or both, where the posterior construct is likely to span multiple segments into upper thoracic spine.

The definition and reporting of complications have been inconsistent throughout the literature. Some authors have reported on specific complications like surgical site infection rate in adult deformity approaching 5.5 % with deep infection being 3.5 % [16]. Schwab et al. [17] reported major peri-operative complication rate in the order of 8.4 %. Cho et al. [18] reported major complications in 34.3 % of the patients undergoing revision deformity surgery. While most of the literature reports an average complication rate of about 40 %, the overall surgeon reported complication rate in the SRS registry remains around 13.4 % [5]. This raises the question of whether complications are fully reported in registries, as much of the information is entered immediately after surgery and the mechanisms for ensuring complication at a later stage may not be sufficiently robust.

Conclusion

Adult spinal deformity surgery remains challenging and is associated with a high complication rate. Many patients have co-morbid conditions and this appears to be related to age as would be expected. While good medical management is clearly essential, most complications are of a mechanical and surgical nature and reflect sub-optimal technical results.

We recommend a detailed analysis of the kyphotic deformity and spino-pelvic balance, the use of intra-operative spinal cord monitoring, post-operative high-dependency care and regular audit arrangements. Pre-operative patient counselling should include an estimation of the risk of an adverse outcome from surgery based on the severity of the deformity, age and co-morbidities.

Conflict of interest None.

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