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Outcomes, Expectations, and Complications Overview for the Surgical Treatment of Adult and Pediatric Spinal Deformity

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Abstract

The aim of this article was to summarize current literature on surgical treatment of pediatric and adult spinal deformity with regard to clinical outcomes and surgical complications. When surgery is considered for treatment of spinal deformity, it is important for both the physician and patient to appreciate the outcome objectives, have reasonable expectations, and understand the potential for adverse events. We conducted a comprehensive search of the English literature from the years 2000−2011 using Medline for articles related to the surgical treatment of spinal deformity, using selected terms. We reviewed abstracts and restricted them to those focused on surgical treatment of spinal deformity. We included clinical outcomes measures and overall complications rates, and reviewed corresponding manuscripts. For pediatric and adult spinal deformity, we identified 8 and 17 manuscripts, respectively, that included preoperative and postoperative assessments of outcomes measures. The vast majority of reported studies demonstrated that operative treatment has the potential to produce significant improvement of health-related quality of life. Surgical treatment of pediatric scoliosis, including idiopathic, neuromuscular, and congenital, had reported complication rates ranging from 4.4% to 15.4%, 17.9% to 48.1%, and 8.3% to 31%, respectively. Surgical treatment of adult scoliosis had reported overall complication rates ranging from 10.5% to 96%. The number of high-quality studies that provide assessment of the outcomes of surgery for pediatric and adult scoliosis remains limited; further study is needed. Available studies suggest that in selected patients, surgical treatment offers potential for improvement of health-related quality of life. The current literature also demonstrates the risks that accompany surgical procedures for the correction of spinal deformity. It is important that spinal deformity patients considering surgical treatment have appropriate expectations not only of the potential benefits it may offer, but also of the risks inherent to such procedures.

Keywords: Adult; Complication; Deformity; Outcomes; Pediatric; Spine; Surgery

Introduction

The earliest surgical techniques were developed to address injuries and traumas that were primarily threats to life without treatment. Major advances in solving the obstacles of bleeding, infection, and pain ushered in the modern era of surgical treatment. The resulting improvement in the safety of surgical procedures, coupled with the development of the academic structure of surgical training and study, vastly expanded the capabilities and indications for surgical treatment. Surgical procedures were no longer reserved primarily for life-threatening conditions, but soon found elective applications, including for conditions such as spinal deformity, that typically affect quality of life rather than being an immediate threat to life.

However, despite great advances in the safety and effectiveness of surgical care, all surgical procedures continue to have inherent risks of morbidity and mortality. Balancing these risks with the potential benefits of procedures can be a complex task for the surgeon, and as the role of patient autonomy and choice in health-care decisions continues to expand, so does the need to ensure the involvement of the patient in these decisions.

Spinal deformities are excellent examples of conditions for which surgical treatment may offer considerable improvement in measures of quality of life, such as pain, function, disability, and appearance. Nevertheless, the

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Table 1
List of peer-reviewed studies (2000−2011) that include both preoperative and postoperative measurement of outcomes measures in pediatric patients treated for spinal deformity.*

Study (design and level of evidence)	N	Mean age (range)	Diagnosis and treatment	Length of follow-up	Outcomes measures and summary
Lubicky et al. [38] Prospective observational cohort from Prospective Pediatric Scoliosis Study, Level II	356	Mean not reported (13−18 y)	Diagnosis: AIS Treatment: surgery (3 groups: hooks only, pedicle screws only and hybrid construct)	Minimum 2 y	Measure: SRS-30 survey Summary: All patients showed significant improvement over 2 y of follow-up compared with baseline with regard to SRS total domain
Bohtz et al. [10] Retrospective review of single-surgeon case series, Level IV	50	15.1 y (8.8−33.2 y)†	Diagnosis: NMS(CP) Treatment: All were surgically treated.	Minimal follow-up of 24 mo	Measure: Modified version of CPCHILD questionnaire, assessed by caregivers of patients Summary: Quality of life improved after surgical scoliosis correction in patients, with high patient satisfaction rate of $>90\%$, assessed by caregivers
Watanabe et al. [11] Retrospective clinical outcome study, Level IV	84	15.8 y (9−26 y)†	Diagnosis: NMS(CP) Treatment: All were surgically treated (45 posterior spinal fusion and instrumentation alone and 39 had combined anterior and posterior surgery)	Mean 6.2 y (2−16)	Measure: Neuromuscular Questionnaire Summary: Surgical correction of NMS resulted in overall parent satisfaction rate of 92%, with 93% reporting improvement with sitting balance, 94% with cosmesis, and 71% in quality of life. Although functional improvement was limited, 8%−40% of patients perceived surgical results as improvement. Late complications, less major curve correction, greater residual major curve, and hyperlordosis of the lumbar spine after surgery resulted in decreased satisfaction
Upasani et al. [39] Retrospective review of prospective data, Level III	49	14 y (10.3−19.9 y)†	Diagnosis: AIS Treatment: All were surgically treated.	Minimum 5 y	Measures: SRS-24 Summary: SRS scores in pain, self-image, and function from back condition domains improved significantly from before surgery to 2-y follow-up visit ($p<.01$). However, there was a statistically significant increase in reported pain from 2 to 5 y after surgical treatment despite continued patient satisfaction
Howard et al. [9] Nonrandomized prospective comparative cohort, Level II	161	2 groups: Surgery: 14.2 y Medical/ interventional 15 y	Diagnosis: AIS Treatment: Surgery: 119 Medical/interventional 42	Minimum 2 y	Measure: 115-point Climent scale Summary: Surgery resulted in a small increase in spine-related quality of life at 2 y. Quality of life gains after posterior spinal fusions for AIS were small compared with observed controls
Newton et al. [40] Prospective, consecutive, single-surgeon case series, Level IV	50	14 y	Diagnosis: 44 AIS, 5 juvenile IS, 1 non-IS) Treatment: All were surgically treated	Mean 2.8 y (2−5 y)	Measures: SRS-22 or SRS-24 Summary: SRS Outcomes Questionnaire results suggested that patients were highly satisfied with outcomes 2 y after surgery
Merola et al. [41] Prospective observational multicenter study, Level IV	242	14 y (13−18 y)	Diagnosis: AIS Treatment: All were surgically treated	Minimum 2 y	Measure: SRS 24 Summary: Pain, general self-image, function from back condition, and level of activity domains of SRS-24 score demonstrated statistically significant improvement compared with preoperative status after correction of scoliosis at 2-y follow-up
Sweet et al. [42] Prospective observational clinical cases series from a single institution, Level IV	90	14 y (12−18 y)	Diagnosis: AIS Treatment: All were surgically treated with anterior spinal fusion	Minimum 2 y (2−6 y)	Measure: SRS outcome instrument Summary: Anterior instrumented fusions for AIS resulted in good radiographic and clinical outcomes with improvement in function, pain, and self-image domain of SRS outcome instrument and close to 90% satisfaction rate

Abbreviations: NMS, neuromuscular scoliosis; SRS, Scoliosis Research Society, CPCHILD, Caregiver Priorities and Child Health Index of Life with Disabilities.

* Includes studies in which both preoperative and follow-up standardized measures of clinical outcome are reported. Table does not include 20 studies that did not report both preoperative and postoperative assessment of outcomes measures [17−19,43−59].

† Study included predominantly pediatric population with few adults.

surgical procedures are typically substantial and include the risk of significant complications [1]. Spinal deformities can affect individuals of all ages, from congenital condition, to de novo onset in the elderly, and the underlying pathologies, natural histories, and treatment options for this broad spectrum of conditions vary greatly [2–4]. When surgery is considered for the treatment of spinal deformity, it is important for both the physician and patient to appreciate the outcome objectives, have reasonable expectations, and understand the potential for adverse events. The objectives of the present study were to review and summarize the current literature on the surgical treatment of pediatric and adult spinal deformity with regard to clinical outcomes and surgical complications. The results may prove useful in surgical planning and patient counseling, and in recognizing the limitations of the current literature.

Methods

We conducted a comprehensive search of the English literature using Medline for articles related to the surgical treatment of spinal deformity. For pediatric spinal deformity, we searched the literature with combinations of terms including 1) "pediatric," "congenital," "spine," "deformity," and "outcomes"; 2) "adolescent," "spine," "deformity," and "outcomes"; 3) "adolescent," "scoliosis," and "outcomes"; and 4) "neuromuscular," "scoliosis," "surgery," and "outcomes." For pediatric deformity surgery complications, we reviewed abstracts from the outcomes search, and searched the literature using the same combinations of terms, but substituting the term "complications" for "outcomes." Given the substantial number of etiologies for pediatric spinal deformity, for the purposes of the present review, we limited abstracts to those focused on adolescent idiopathic scoliosis (AIS), neuromuscular scoliosis, and congenital scoliosis.

For adult spinal deformity, we searched the literature with combinations of terms including 1) "adult," "spine," "deformity," and "outcomes"; 2) "degenerative," "spine," "deformity," and "outcomes"; 3) "adult," "scoliosis," and "outcomes"; and 4) "de novo," "scoliosis," "surgery," and "outcomes." For adult deformity surgery complications, we reviewed abstracts from the outcomes search, and searched the literature the same combinations of terms, but substituting the term "complications" for "outcomes."

Given the substantial advances that have been made with regard to instrumentation and techniques, we limited searches to cover the years 2000–2011, to determine the studies most relevant to current practice. We retrieved corresponding full-length manuscripts and reviewed them for all selected abstracts. We reviewed all abstracts retrieved from searches for pediatric and adult spinal deformity for relevance to surgical outcomes and surgical complications. With regard to outcomes studies, we focused on studies that included both preoperative and postoperative assessments of outcomes measures. We graded the articles according to the levels of evidence guidelines of Wright et al. [5], with levels from I though V as follows: Level I (well-done, randomized, controlled studies or systematic reviews of such studies), Level II (prospective cohort studies; poor-quality, randomized, controlled trials; or systematic reviews of such studies), Level III (case-control studies, retrospective cohort studies, or systematic reviews of such studies), Level IV (case series with no, or historical, control group), and Level V (expert opinion).

Results

Outcomes and expectations

Pediatric spinal deformity

Pediatric spinal deformity can result from congenital anomalies, neuromuscular disorders, genetic conditions, connective tissue disorders, skeletal dysplasia, and developmental (idiopathic) causes [2,6]. Among the most common types of pediatric spinal deformity are AIS, for which the etiology remains unclear; neuromuscular scoliosis; and congenital scoliosis. For these types of pediatric spinal deformity, we identified 8 manuscripts that included both preoperative and postoperative assessments of outcomes measures from the years 2000–2011 (Table 1). The graded levels of evidence for these studies were: Level II ($n = 2$), Level III ($n = 1$), and Level IV ($n = 5$). Six of the studies were of AIS, 2 were of neuromuscular scoliosis, specifically cerebral palsy, and none focused on congenital scoliosis.

For the studies that focused on AIS, 5 used the Scoliosis Research Society (SRS) outcomes measure and 1 used the Climent scale. The SRS is a disease-specific outcomes measure for spinal deformity that provides assessment of specific domains (pain, mental health, self-image, function, and satisfaction), as well as a total score [7]. The Climent scale includes a 21-item questionnaire with scoring on a Likert scale for each item that provides an overall assessment of spine-specific quality of life [8]. The reports of AIS that employed the SRS included a mixture of retrospective and prospective studies, and only included surgically treated patients. Each of these studies showed significant improvement of SRS scores at 2-year follow-up compared with preoperative assessment, and rates of satisfaction were as high as 90% (Table 1). One of the reports on AIS, the study that used the Climent scale, included patients treated with surgery and a cohort treated medically/interventionally [9]. This study demonstrated an improvement in spine-related quality of life at 2-year follow-up for patients treated with surgery; however, the magnitude of this improvement was small compared with improvements noted in the medical/interventional control group.

The reports of Bohtz et al. [10] and Watanabe et al. [11] addressed preoperative and postoperative outcomes measures for pediatric patients treated surgically for neuromuscular scoliosis (Table 1). Botz et al. used a modified version of the Caregiver Priorities and Child Health Index of Life with Disabilities questionnaire that was primarily completed by the caregivers of the patients. This questionnaire provides assessment of personal care, positioning, transferring and mobility, communications and social interaction, comfort and emotions, health, and overall quality of life [12]. Watanabe et al. used a modified version of the Neuromuscular Questionnaire, which provides assessment of expectations, cosmesis, function, patient care, quality of life, pulmonary, pain, comorbidities, self-image, and satisfaction [13–16]. Both of these studies reported significant improvement in quality of life at a minimum of 2-years' follow-up compared with preoperative assessment, and both had higher than 90% rates of satisfaction (Table 1).

In addition to the studies that included both preoperative and postoperative assessment of outcomes measures, 20 studies included only this assessment at follow-up (see footnote in Table 1). These studies were predominantly of AIS, but there were also 2 studies of neuromuscular scoliosis and 4 of congenital scoliosis. Although the conclusions that can be drawn from studies that do not include preoperative assessments of outcomes measures are limited, in general, these studies demonstrate high levels of satisfaction. Notably, a subset of the studies on AIS included both operative and bracing treatment, and outcomes assessments suggested beneficial effects of both treatment approaches [17–19].

Adult spinal deformity

The most common forms of adult scoliosis are those resulting from degenerative effects and those from untreated AIS. We identified 12 manuscripts that included both preoperative and postoperative assessments of outcomes measures for adult scoliosis from the years 2000–2011 (Table 2). The graded levels of evidence for these studies were: Level II ($n = 2$), Level III ($n = 6$), and Level IV ($n = 4$). Most of these studies included varying proportions of degenerative scoliosis and adult idiopathic scoliosis (untreated AIS). Outcomes measures included the Oswestry Disability Index (ODI), SRS, Short-Form-12, numeric rating scale scores for back and leg pain, and the Modems questionnaire. The mean length of follow-up in these studies ranged from 2 to 5 years, and patients in all but 1 study had a minimum of 2 years' follow-up. Each study reported favorable results for outcomes measures with surgical treatment, and all but 2 clearly demonstrated this with statistical analyses.

Smith et al. [1] provided assessment of outcomes based on age, and demonstrated that each age group assessed (25–44, 45–64, and 65–85 years) had significant improvement in outcomes measures. In addition, although they face the greatest risk of complications, the elderly had disproportionately greater improvement in disability and pain with surgery compared with younger patients. Smith et al. also reported that on average, at 2-year follow-up, back pain, leg pain, and disability (Oswestry Disability Index) can be expected to improve by approximately 60%, 60%, and 40%, respectively [20,21]. This is in contrast to patients treated medically/interventionally, who had on average no significant change of pain or disability at 2-year follow-up [20,21].

Bridwell et al. [22] prospectively assessed outcomes of operative versus medical/interventional treatment, and at 2-year follow-up demonstrated that operative treatment on average produced significant improvement in pain, disability, and other measures of health-related quality of life (HRQOL). In contrast, medically/interventionally treated patients on average had no significant change from baseline levels of pain and disability [22]. In a subsequent report, Bridwell et al. demonstrated that the improved outcomes experienced by surgically treated patients at 2 years after surgery were durable up to 5 years from surgery, except for a modest but statistically significant worsening of leg pain [23].

In addition to the studies that included both preoperative and postoperative assessment of outcomes measures, several included this assessment only at follow-up, including those recently summarized by Bridwell et al. [24] and 6 others not included in their review or that were subsequently published (see footnote in Table 2). Notably, a study by Li et al. [25] assessed operative versus medical/interventional treatment at a minimum of 2 years' follow-up, and focused on patients over 65 years of age. They demonstrated that the operatively treated patients had significantly less pain and better HRQOL, self-image, and mental health, and were more satisfied with the treatment compared with medically/interventionally treated patients.

Operative Complications

Pediatric spinal deformity

We identified 14 reports from the years 2000–2011 that included total complication rates associated with pediatric spinal deformity surgery (Table 3). Complication rates for AIS, neuromuscular scoliosis, and congenital scoliosis ranged from 4.4% to 15.4%, 17.9% to 48.1%, and 8.3% to 31%, respectively (Fig. 1). In general, the most common complications were wound infections (both superficial and deep), implant related (eg, instrumentation malposition and failure), pulmonary (eg, pneumonia and prolonged intubation), and durotomy. Reames et al. [26] reported rates of complications for 19,360 operative cases of pediatric spinal deformity based on the Scoliosis Research Society Morbidity and Mortality Database. The remarkably large number of cases permitted assessment of rates for uncommon complications, including new neurological deficit and mortality. For idiopathic, congenital, and neuromuscular scoliosis, the rates of new neurological deficit were 0.8%, 1.1%, and 2.0%, respectively, and the mortality rates were 0.02%, 0.3%, and 0.3%, respectively.

Table 2
List of peer-reviewed studies (2000–2011) that include both preoperative and postoperative measurement of outcomes measures in adult patients treated for spinal deformity.*

Study (design and level of evidence)	*N*	Mean age (range)	Diagnosis and treatment	Length of follow-up	Outcomes measures and summary
Smith et al. [20] Prospective observational cohort study from the SDSG, Level III	206	3 age groups: 36 y (25–44 y), 54 y (45–64 y), 70 y (65–82 y)	Diagnosis: Adult-IS (*n*=177), de novo (*n*=29) Treatment: All were operatively treated	Mean 2 y (min 2 y)	Measures: ODI, SRS-22, SF-12 PCS, NRS BP, NRS LP Summary: Patients in all age groups improved significantly but older patients had greater pain and disability at baseline and the greatest magnitudes of improvement with surgery
Bridwell et al. [23] Prospective observational cohort study with matched and unmatched comparisons from the SDSG, Level II	113	No overall mean age provided 18–39 y (*n*=27) 40–60 y (*n*=58) >60 y (*n*=28)	Diagnosis: All patients had adult symptomatic lumbar scoliosis Treatment: All were operatively treated	3–5 y (min 3 y)	Measures: ODI, SRS-22 (total), SRS-22 (satisfaction), NRS BP, NRS LP Summary: Patients improved significantly with surgery at 2-y follow-up. Improvement did not deteriorate at follow-up of 3–5 y, except for a modest increase in leg pain
Good et al. [60] Retrospective matched cohort, single-institution study, Level III	48	2 treatment groups: before/after: 45 y (18–62 y); after-only: 44 y (18–68 y)	Diagnosis: Adult-IS (*n*=42), kyphoscoliosis (*n*=29), congenital scoliosis (*n*=2) Treatment: All were operatively treated (24 posterior-only and 24 combined before/after)	Mean 4.9 y for before/after patients Mean 2.9 y for after-only patients (min 2 y)	Measures: ODI, SRS-30 Summary: Both treatment groups (after-only and before-after) had significant improvement in SRS-30 and ODI at last follow-up and there was no significant difference in scores between groups
Bridwell et al. [22] Prospective observational cohort study with matched and unmatched comparisons from the SDSG, Level II	160	All patients 40–80 y of age 2 treatment groups: Operative: mean age not specified; Medical/interventional: 60 y	Diagnosis: All patients had adult symptomatic lumbar scoliosis Diagnosis not otherwise specified Treatment: Operative (*n*=85), medical/interventional (*n*=75)	Mean 2 y (min 2 y)	Measures: ODI, SRS-QOL subscore, NRS BP, NRS LP Summary: Patients treated surgically improved significantly; medical/ interventional treatment produced no significant change in outcomes measures
Glassman et al. [30] Prospective observational cohort study from the SDSG, Level III	283	50 y (17–78 y)	Diagnosis: scoliosis (50%), kyphosis (22%), other (23%) Treatment: All were operatively treated	Mean 2 y (min 2 y)	Measures: ODI, SRS-22, SF-12, NRS BP, NRS LP Summary: Patients had significant improvement in ODI and SRS total score and a trend toward improvement in Short Form-12 at 1 and 2 y after surgery. Comparison of 1- versus 2-y scores revealed no significant differences
Smith et al. [61] Prospective observational cohort study from the SDSG, Level III	317	2 treatment groups: Operative: 51 y (21–77 y); medical/interventional: 53 y (21–81 y)	Diagnosis: Adult-IS (*n*=279), de novo (n=38) Treatment: Operative (*n*=147), medical/interventional (*n*=170)	Mean 2 y (min 2 y)	Measures: ODI, SRS-22, NRS BP Summary: Patients treated surgically had significant improvement of back pain, disability, and SRS-22. Medical/interventional treatment produced no significant change in outcomes measures. (Same conclusions when patients with de novo scoliosis analyzed separately.)

(*continued on next page*)

Table 2 (*continued*)

Study (design and level of evidence)	N	Mean age (range)	Diagnosis and treatment	Length of follow-up	Outcomes measures and summary
Smith et al. [62] Prospective observational cohort study from the SDSG, Level III	208	2 treatment groups: Operative: 55 y (23–77 y); medical/interventional: 55 y (21–81 y)	Diagnosis: Adult-IS (n=178), de novo (n=30) Treatment: Operative (n=96), medical/interventional (n=112)	Mean 2 y (min 2 y)	Measures: ODI, NRS LP Summary: Patients treated surgically had significant improvement of leg pain and disability; medical/ interventional treatment produced no significant change in outcomes measures
Bridwell et al. [63] Prospective observational cohort study of consecutive cases from the SDSG, Level III	56	No overall mean age provided 21–40 y (n=16) 41–60 y (n=33) >60 y (n=7)	Diagnosis: All patients had adult symptomatic scoliosis. Diagnosis not otherwise specified. Treatment: All were operatively treated	Mean 2 y (min 2 y)	Measures: SRS-22, ODI, SF-12 Summary: Surgical treatment significantly improved pain, self-image, and function based on the SRS, ODI, and SF-12 PCS measurements
Cho et al. [64] Retrospective observational cohort 2-center study, Level IV	47	67 y (48–83 y)	Diagnosis: All patients had degenerative lumbar scoliosis Treatment: All were operatively treated	Mean 3.8 y (min 2 y)	Measure: ODI Summary: Patients had substantial (no p values indicated) improvement in ODI after surgery. Improvement in ODI was significantly less in patients with late complications
Daubs et al. [65] Retrospective observational cohort single-center study, Level IV	46	67 y (60–85 y)	Diagnosis: de novo (n=17), FSI (n=15), "adult scoliosis" (n=11), AS (n=2), NF (n=1) Treatment: All were operatively treated	Mean 4.2 y (0.7–11 y)	Measure: ODI Summary: Patients treated surgically had significant improvement of disability at last follow-up. Presence of comorbidity did not affect ODI at last follow up
Shapiro et al. [66] Retrospective single-surgeon case series, Level IV	16	66 y (50–80 y)	Diagnosis: All patients had adult-IS, low back pain, and spinal stenosis Treatment: All were operatively treated	Mean 3.4 y (min 2 y)	Measures: SRS, ODI Summary: Patients had significant improvement in SRS total and subscores and in disability at last follow-up, compared with preoperative assessment
Eck et al. [67] Retrospective, consecutive case, observational cohort single-center study, Level IV	58	43 y (21–60 y)	Diagnosis: All patients had adult-IS Treatment: All were operatively treated	Mean 5 y (min 2 y)	Measures: Selected questions from SRS and Modems questionnaires Summary: Patients had substantial (no p values indicated) improvement in function and pain and high satisfaction scores after surgery. Patients fused short of the sacrum (L4 or L5) were more likely to have degeneration distal to the fusion and to have less clinical improvement

Abbreviations: min, minimum; SDSG, Spinal Deformity Study Group; Adult-IS, adult idiopathic scoliosis; AS, ankylosing spondylitis; BP, back pain; Degen, degenerative (de novo) scoliosis; FSI, fixed sagittal imbalance; HRQOL, health-related quality of life; LP, leg pain; MCS, mental component score; NF, neurofibromatosis; NRS, numeric rating scale score; ODI, Oswestry Disability Index; PCS, physical component score; QOL, quality of life; SRS, Scoliosis Research Society.

* Includes studies in which both preoperative and follow-up standardized measures of clinical outcome are reported. Table does not include studies [24,25,55,68–71] that did not report both preoperative and postoperative assessment of outcomes measures.

Table 3
Overall complication rates associated with surgery for pediatric spinal deformity based on literature from years 2000–2011.

No.	Reference	Diagnosis	Mean age (y)	No. patients	Overall complications (%)
1	Lehman et al. [72]	AIS	14.9	114	4.4
2	Coe et al. [73]	AIS	10–17*	6,332	5.7
3	Reames et al. [26]	AIS	≤18*	11,227	6.3
4	Patil et al. [74]	AIS	≤18*	35,600	14.9
5	Carreon et al. [75]	AIS	14.3	702	15.4
6	Reames et al. [26]	NMS	≤18*	4,657	17.9
7	Tsirikos et al. [56]	NMS	13.9	287	22.6
8	Tsirikos et al. [57]	NMS	13.4	45	26.6
9	Modi et al. 2009 [76]	NMS	22†	52	32.7
10	Mohamad et al. [77]	NMS	14	175	33.1
11	Edwards et al. [78]	NMS	13.5	62	40
12	Modi et al. [77]	NMS	14.7	27	48.1
13	Wang et al. [79]	CS	12.9	60	8.3
14	Reames et al. [26]	CS	≤18*	2,012	10.6
15	Jalanco et al. [50]	CS	4	21	22.7
16	Ayvaz et al. [44]	CS	12	29	31

Abbreviations: NMS, neuromuscular scoliosis; CS, congenital scoliosis.
* Mean age not specified and could not be calculated based on data provided.
† Patient population was predominantly pediatric patients.

Adult spinal deformity

We identified 17 reports from the years 2000–2011 that included total complication rates associated with operative treatment of adult spinal deformity (Table 4). The reported overall complication rates range from 10.5% to 96%. The highest rate includes complications up to 5 years after surgery, and included a focused assessment of pseudarthrosis (24% rate) [27]. Based on a prospective multicenter study, Smith et al. [1] reported a strong relationship between the rates of complications and patient age. The total complication rates for the age groups 25–44, 45–64, and 65–85 years were 17%, 42%, and 71%, respectively, including major complication rates of 6%, 15%, and 29%, respectively. In general, the most common complications reported in adults were wound infection (both superficial and deep), excessive intraoperative blood loss, deep venous thrombosis, durotomy, and pulmonary effusion. Although Smith et al. did not specifically investigate the relationship between comorbidities and complications, others have reported a significant association between the occurrence of complications and preexisting health problems [28].

Discussion

This article provides an overview of outcomes, expectations, and complications for the surgical treatment of adult and pediatric spinal deformity based on the literature from 2000 to 2011.

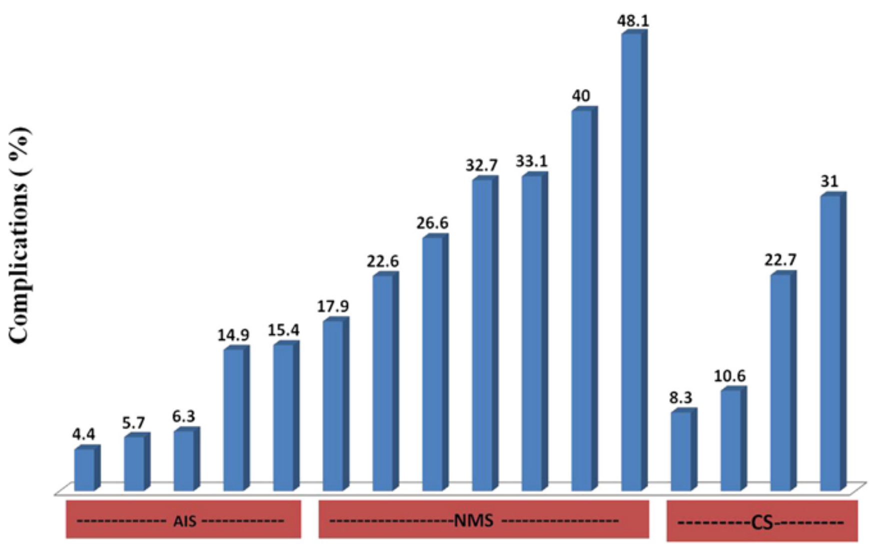

Fig. 1. Overall complication rates reported for the surgical treatment of spinal deformity in pediatric patients (2000–2011). Each bar represents a reported study. AIS, adolescent idiopathic scoliosis; NMS, neuromuscular scoliosis; CS, congenital scoliosis.

Table 4
Overall complication rates associated with surgery for adult spinal deformity based on literature from years 2000–2011.

No.	Reference	Mean age (y)	No. patients	Overall complications (%)	Comments
1	Sansur et al. [80]	54	4,980	10.5	
2	Ali et al. [81]	49	28	14	
3	Patil et al. [74]	18–44*	8,460	16.7	Only complications before hospital discharge
4	Smith et al. [20]	36	47	17	
5	Li et al. [25]	75	34	17	Only includes major complications
6	Smith et al. [20]	56	578	23	Only patients with fixed sagittal deformity
7	Patil, et al. [74]	45–64*	5,196	23.2	Only complications before hospital discharge
8	Patil et al. [74]	>65*	2,635	26.3	Only complications before hospital discharge
9	Bridwell et al. [23]	50	113	33	Complications up to 5 y after surgery
10	Suk et al. [82]	27	70	34	All patients had VCR
11	Glassman et al. [83]	50	434	36	
12	Bridwell et al. [22]	58	85	36	
13	Daubs et al. [65]	67	46	37	
14	Smith et al. [20]	54	121	42	
15	Cho et al. [84]	51	250	52	
16	Lapp et al. [85]	43	44	55	All had combined before and after procedures
17	Cho et al. [64]	67	47	68	
18	Mummaneni et al. [86]	56	10	70	All patients had PSO
19	Smith et al. [20]	70	38	71	
20	Emami et al. [68]	55	54	71	
21	Shapiro et al. [66]	66	16	75	
22	Weistroffer et al. [27]	54	50	96	Complications up to 5 y after surgery, including 24% pseudarthrosis rate

Abbreviations: VCR, vertebral column resection; PSO, pedicle subtraction osteotomy.
* Mean age was not specified and could not be calculated based on data provided.

Despite the significant risk of complications that is inherent to these procedures, the vast majority of reported studies demonstrate that operative treatment has the potential to produce significant improvement in HRQOL. The factors that motivate patients with spinal deformity to seek surgical treatment are complex and highly dependent on age, type of deformity, and impact of the deformity on the individual patient.

Reported studies of surgery for adult spinal deformity include a remarkably broad range of complication rates. These rates likely depend on many factors, including what is defined as a complication, how meticulously the complications were collected and recorded, length of patient follow-up, complexity of the cases reported, experience level of the operating surgeon, and whether the studies were conducted prospectively or retrospectively.

Adult spinal deformity

Although the prevalence of adult scoliosis has been reported to be as high as 68% in elderly volunteers [29], most of those affected are asymptomatic. Others, who may develop pain, functional limitations, neurological dysfunction, and disability, can present for clinical management. In the absence of progressive neurological deficits, the first-line therapies should typically be medical/interventional, and may include physical therapy, steroid injections, nonsteroidal anti-inflammatory medications, and, in some cases, narcotics. Surgical treatment may become an option for patients who fail to respond satisfactorily to medical/interventional treatments. The factors that govern the transition from medical/interventional to operative treatment are not fully understood. Smith et al. [3] reported that factors associated with operative management include severe radiculopathy, positive sagittal malalignment, and weakness. Glassman et al. [30] reported that surgical patients had more frequent leg pain and greater back pain.

Although the current literature suggests that surgical treatment has the potential to improve disability, HRQOL, and pain in adults with scoliosis, the decision to pursue surgical treatment remains complex. Several factors should be considered when contemplating surgical treatment, including the severity of symptoms, the impact of the symptoms on functionality and quality of life, the overall health of the patient, and the willingness of the patient to accept the risks of the surgery [1]. Conversations between surgeons and patients with regard to possible surgical treatment should include clear discussions about what benefits the surgical treatment may or may not offer, the expectations of the patient, and the potentials risks that are inherent in the procedures.

It is also important to recognize that although most studies suggest that operative treatment of symptomatic adult scoliosis can offer improvement, these assessments are based on averages across large groups of patients. Not all surgically treated patients will achieve average or above-average outcomes; instead, changes in outcomes measures from baseline to follow-up have been reported to span a continuum from remarkable improvement to unchanged or worsened symptoms, in some cases [31].

Pediatric spinal deformity

There are distinct differences between pediatric and adult patients with spinal deformity with regard to factors that motivate surgical treatment and outcomes expectations. Furthermore, pediatric spinal deformities include a heterogeneous collection of conditions, with differing symptoms, natural histories, treatment approaches, and outcomes expectations. Among the most common types of pediatric spinal deformity are AIS, neuromuscular scoliosis, and congenital scoliosis.

The goals of surgery for AIS may include prevention of worsened physical appearance in the future, improvement of present physical appearance, improvement of present emotional wellbeing and prevention of future emotional problems, prevention of future pain, and prevention of future lung and heart problems [32]. For many of these goals, it is difficult to provide objective assessment with standardized outcomes tools. The SRS questionnaire was developed to incorporate measures including appearance, pain, disability, function, and satisfaction in an attempt to quantify the multifaceted impact of AIS. The current literature suggests that surgery for AIS can result in measureable and significant improvement, based on the SRS questionnaire.

In contemplating surgical treatment for AIS, it is important to weigh its natural history and the potential impact of surgical treatment on the patient in later life. In general, curves that are less than 30° at skeletal maturity should not progress or have pulmonary problems. Surgery is often recommended once curves reach 45° to 50°, owing to concern that such curve magnitude may progress even beyond skeletal maturity [2]. Although the existing literature on long-term surgical results has many limitations that make definitive statements impossible, some surgically treated AIS patients require additional surgery later in life. These cases may result from disease progression and degenerative changes that may be compounded by rigid instrumentation.

The most common causes of neuromuscular scoliosis are cerebral palsy and muscular dystrophy. The prevalence of scoliosis with cerebral palsy has been reported to be as high as 72% [33–36]. This deformity usually progresses even after skeletal maturity. The progression is typically accompanied by a substantial impact on functional abilities, which may include cardiopulmonary function and sitting balance [11]. Thus, the objectives and expectations of surgical treatment may not only include improvement of pain and cosmesis, but also improvement of sitting, personal care, transferring and mobility, pulmonary issues, and patient care. We identified 2 studies that provide assessment of preoperative and postoperative outcomes measures for neuromuscular scoliosis, specifically cerebral palsy. Both of these studies indicated an overwhelmingly high satisfaction rate after surgery [10,11], even though this form of pediatric scoliosis has the highest rate of operative complications.

Congenital spinal deformity is generally categorized based on failures of segmentation, failures of formation, and mixed anomalies [2,37]. These anomalies can disrupt the balanced growth of the spine and produce substantial and progressive spinal deformity. Medical/interventional therapies such as bracing often have limited indications, because many of these deformities require surgical therapy. Expectations of surgery often relate to stopping deformity progression and improving lung and cardiac function.

Conclusions

The number of high-quality studies that provide assessment of the outcomes of surgery for pediatric and adult scoliosis remains relatively limited, and further study is needed. Available studies suggest that in selected patients, surgical treatment offers the potential for improvement of HRQOL. The current literature also demonstrates the risks that accompany surgical procedures for the correction of spinal deformity. It is important that spinal deformity patients considering surgical treatment have not only appropriate expectations of the potential benefits it may offer, but also a sufficient appreciation of the risks inherent in such procedures.

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