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DEFORMITY

Risk-Benefit Assessment of Surgery for Adult Scoliosis

An Analysis Based on Patient Age

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Study Design. Retrospective review of a prospective, multicenter database.

Objective. The purpose of this study was to assess whether elderly patients undergoing scoliosis surgery had an incidence of complications and improvement in outcome measures comparable with younger patients.

Summary of Background Data. Complications increase with age for adults undergoing scoliosis surgery, but whether this impacts the outcomes of older patients is largely unknown.

Methods. This is a retrospective review of a prospective, multicenter spinal deformity database. Patients complete the Oswestry Disability Index (ODI), SF-12, Scoliosis Research Society-22 (SRS-22), and numerical rating scale (NRS; 0–10) for back and leg pain. Inclusion criteria included age 25 to 85 years, scoliosis (Cobb ≥ 30°), plan for scoliosis surgery, and 2-year follow-up.

Results. Two hundred six of 453 patients (45%) completed 2-year follow-up, which is distributed among age groups as follows: 25 to 44 (n = 47), 45 to 64 (n = 121), and 65 to 85 (n = 38) years. The percentages of patients with 2-year follow-up by age group were as follows: 25 to 44 (45%), 45 to 64 (48%), and 65 to 85 (40%) years. These groups had perioperative complication rates of 17%, 42%, and 71%, respectively ($P < 0.001$). At baseline, elderly patients (65–85 years) had greater disability (ODI, $P = 0.001$), worse health status (SF-12 physical component score (PCS), $P < 0.001$), and more severe back and leg pain (NRS, $P = 0.04$ and $P = 0.01$, respectively) than younger patients. Mean SRS-22 did not differ significantly at baseline. Within each age group, at 2-year follow-up there were significant improvements in ODI ($P \leq 0.004$), SRS-22 ($P \leq 0.001$), back pain ($P < 0.001$), and leg pain ($P \leq 0.04$). SF-12 PCS did not improve significantly for patients aged 25 to 44 years but did among those aged 45 to 64 ($P < 0.001$) and 65 to 85 years ($P = 0.001$). Improvement in ODI and leg pain NRS were significantly greater among elderly patients ($P = 0.003$, $P = 0.02$, respectively), and there were trends for greater improvements in SF-12 PCS ($P = 0.07$), SRS-22 ($P = 0.048$), and back pain NRS ($P = 0.06$) among elderly patients, when compared with younger patients.

Conclusion. Collectively, these data demonstrate the potential benefits of surgical treatment for adult scoliosis and suggest that the elderly, despite facing the greatest risk of complications, may stand to gain a disproportionately greater improvement in disability and pain with surgery.

Key words: adult scoliosis, complications, outcomes, surgery, disability, surgery, age, elderly. **Spine 2010;36:817–824**

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The prevalence of adult scoliosis in the general population ranges from 2% to 32%,[1–5] and a recent study focusing on elderly volunteers reported a prevalence as high as 68%.[6] Because medical advances continue to gradually extend life expectancy and the demographics of the population expand the numbers of elderly to unprecedented levels, the impact of adult scoliosis will continue to increase.

The finding of scoliosis in many adults is simply incidental and requires only education and follow-up, but for others it can produce substantial pain and disability.[7–11] Initial management of symptomatic adult scoliosis, without progressive neurologic deficit, typically involves nonoperative treatments, in an effort to avoid the potential morbidity of an extensive

surgical intervention.[12] Nonoperative measures may temporize, but for a subset of patients, pain and disability may progress to a point warranting consideration of surgical treatment.[7,9–11,13]

Although it is typically for the relief of pain and disability that patients seek and surgeons offer surgical treatment for adult scoliosis, there is a remarkable paucity of literature to support the premise that surgery offers such benefits.[10,11,14–16] In addition, the complications associated with these procedures are not insignificant, with rates typically ranging from 10% to 40%.[14,17–19] Notably, most of these studies have focused on middle-aged adults, and presumably the complication rates would be even higher in the elderly. Consistent with this presumption, a report by Carreon *et al*[20] focused on perioperative complications of posterior lumbar decompression and arthrodesis in an elderly population that included patients with scoliosis and reported a complication rate of 80%.

Thus, elderly patients with symptomatic scoliosis who are considering surgical treatment must balance the expected improvement from surgery, which has not been well defined especially for the elderly, with the inherent risks of the procedure that are likely substantially increased because of their age.

The objectives of this study were 2-fold. First, we sought to assess the short-term complication rates associated with surgical treatment of adult scoliosis, stratified by age groups that include elderly patients. Second, we assessed 2-year outcome measures of disability, health status, and pain compared with baseline measures and stratified these results based on patient age to address whether elderly patients would experience similar benefits of surgery despite what we presumed would be greater complication rates.

MATERIALS AND METHODS

Patient Population

This study is a retrospective review of prospectively, consecutively collected patients from the Adult Deformity Outcomes (ADO) multi-institutional database for adult spinal deformity and was conducted by the ADO section of the Spinal Deformity Study Group. At the time of entry into the database, patients are classified into either operative or nonoperative treatment groups based on the initial management approach. The decision of whether to pursue operative or nonoperative treatment is made based on patient input and physician expertise. Within the confines of appropriate practice and in the absence of significant progressive neurologic deficits, the ultimate management decision is typically guided by patient choice. All patients at the time of database enrollment complete a battery of healthrelated quality of life (HRQOL) outcome tools including the Oswestry Disability Index (ODI), SF-12, and Scoliosis Research Society-22 (SRS-22) questionnaires and complete a standardized questionnaire that includes separate assessment of the numerical rating scale (NRS) score[21] for both back and leg pain, in which the extreme scores of 0 and 10 reflect states of no pain and "unbearable" pain, respectively. Patients are observed at regular intervals. This study was approved by the respective institutional review boards of the participating institutions.

The ODI is reported as a single score ranging from 0 to 100, with a higher score corresponding to a greater degree of disability.[22] The SF-12 is a general measure of overall health status and may be summarized using physical component score (PCS) and mental component score (MCS), with higher scores corresponding to better health status.[23] For the purposes of this study, focus will be placed on summarizing the SF-12 using the PCS. The SRS-22 was designed as a disease-specific (scoliosis) measure of health status with emphasis placed on pain, function, self-image, and mental health.[23,24] The SRS-22 can be summarized with a single score that ranges from 1 to 5, with 5 corresponding to the best status.

Inclusion criteria for this study were (1) patients with a primary diagnosis of adult idiopathic or degenerative scoliosis (Cobb angle $> 30°$) enrolled into the operative group of the ADO database between January 2002 and August 2006, (2) patient age of 25 to 85 years, (3) availability of baseline and 2-year HRQOL data. Patients with a history of spine surgery, which typically consisted of decompressions and/or shortsegment fusions, were not excluded from this study.

Clinical data extracted for this study included age, sex, and history of adolescent idiopathic scoliosis. Details of the operative treatment were extracted from forms completed by the surgeon and included surgical approach (anterior, posterior, or combined anterior and posterior), number of levels operated, operating room time, estimated blood loss, and whether the procedure included decompression, pelvic fixation, or osteotomy. Osteotomies were classified by the operating surgeon as anterior, pedicle subtraction, Smith-Peterson, vertebral column resection, or other. In addition, short-term (within the first month after surgery) complications were extracted and classified as minor or major.[20]

Imaging Parameters

Full-length scoliosis radiographs were obtained for all patients at the time of enrollment. Curves were classified based on the curve with the largest Cobb angle as thoracic, thoracolumbar/lumbar, or lumbosacral. Maximum Cobb angle, sagittal balance, and coronal balance were assessed using standard techniques.

Statistical Analyses

Frequency distributions and summary statistics were calculated for all clinical, operative, and radiographic variables. For categorical variables, crosstabulations were generated and Fisher exact or Pearson χ^2 tests were used to compare distributions. For continuous variables, *t* tests or analysis of variance tests were used to investigate differences in the distributions between subsets of patients classified by categorical data. For comparisons based on age, patients were grouped into 3 categories: 25 to 44, 45 to 64, and 65 to 85 years. Paired-samples *t* tests were used to compare baseline and 2-year HRQOL measures within each age group. Separate comparisons of baseline and 2-year HRQOL measures across age groups were performed using analysis of variance testing. Linear regression analyses were used to assess for independent associations of patient age and baseline outcome measure score with the change in the respective outcome measure from baseline to follow-up (*i.e.*, change in outcome measure = dependent variable and age and baseline outcome measure

= independent predictors). Statistical analyses were 2 sided, and $P < 0.05$ was considered statistically significant.

RESULTS

Patient Population and Imaging Parameters

During the approximately 5-year inclusion time of this study, 206 of 453 patients (45%) completed 2-year follow-up and are included in the present analyses. These patients are distributed among age groups as follows: 25 to 44 (n = 47), 45 to 64 (n = 121), and 65 to 85 (n = 38) years. The percentages of patients with 2-year follow-up by age group were as follows: 25 to 44 (45%), 45 to 64 (48%), and 65 to 85 (40%) years. Of the patients aged 25 to 44 years and 45 to 64 years, 15% in each group reported a history of back surgery, which was significantly less than the 41% of patients aged 65 to 85 years who reported a history of back surgery ($P = 0.002$). Demographic and radiographic parameters are summarized in Table 1. The overall mean age at presentation was 53 years (standard deviation = 12, range 25–82), and 91% of patients were women. The majority (86%) of patients had a history of untreated adolescent idiopathic scoliosis, whereas the remaining patients had degenerative scoliosis. Degenerative scoliosis and thoracolumbar scoliosis were significantly more common among older compared with younger patients ($P = 0.001$ and $P < 0.001$, respectively). The mean maximum Cobb angle and coronal balance did not differ significantly based on age group, but sagittal balance was significantly different among the age groups, with older patients having greater positive sagittal balance ($P < 0.001$).

TABLE 1. Demographic and Radiologic Parameters for 206 Operatively Treated Adults With Scoliosis Stratified Based on Patient Age

	Patient Age (Yrs)		
	25–44	45–64	65–85
n (%)	47 (23)	121 (59)	38 (18)
Female:male	39:8	110:11	39:9
Mean age (yrs) (SD, range)	36 (6, 25–44)	54 (6, 45–64)	70 (5, 65–82)
Scoliosis etiology (%)*			
Idiopathic	47 (100)	103 (85)	27 (71)
Degenerative	0 (0)	18 (15)	11 (29)
Curve type*			
Thoracic	27 (57)	34 (28)	5 (13)
Thoracolumbar	20 (43)	86 (71)	30 (79)
Lumbar/ lumbosacral	0 (0)	1 (1)	3 (8)
Mean maximum Cobb angle (SD, range)	57 (13, 35–89)	58 (17, 31–103)	51 (16, 30–81)
Mean sagittal balance (mm) (SD, range)*	15 (42, −128 to 124)	16 (45, −96 to 170)	58 (61, −41 to 252)
Mean coronal balance (mm) (SD, range)	18 (12, 3–54)	22 (19, 0–94)	23 (20, 1–92)

**P = 0.001 for scoliosis etiology.*
P < 0.001 for curve type. P < 0.001 for mean sagittal balance. P values are comparisons across all 3 age groups.
SD indicates standard deviation.

Operative Treatment and Perioperative Complications

Of the 206 patients assessed, details of surgical treatment were available for 200 (97%) (Table 2). The vast majority (n = 193, 97%) underwent a posterior procedure, and ~50% underwent an anterior procedure. Decompression, osteotomy, and pelvic fixation were more commonly performed in the surgical treatment of older patients ($P = 0.002$, $P = 0.03$, and $P = 0.001$, respectively). Operating room time, blood loss, and length of hospital stay were all significantly greater among older patients ($P < 0.001$, $P = 0.003$, and $P = 0.03$, respectively).

Minor and major complications were reported for patients in each of the age groups, 25 to 44 (Table 3), 45 to 64 (Table 4), and 65 to 85 years (Table 5). Minor, major, and overall complication rates were significantly higher among older patients ($P = 0.004$, $P = 0.02$, and $P < 0.001$, respectively; Figure 1). There were no deaths reported in this series.

Baseline and 2-Year Follow-up HRQOL Measures

At baseline, older patients had a greater degree of disability based on the ODI ($P = 0.001$; Figure 2), worse overall health status based on the SF-12 PCS ($P < 0.001$; Figure 3), greater severity of back pain based on the NRS back pain score ($P = 0.04$; Figure 4), and greater severity of leg pain based on the NRS leg pain score ($P = 0.01$; Figure 5). Health status as assessed by the SRS-22 total score did not differ significantly at baseline based on patient age ($P = 0.2$; Figure 6), which may reflect greater negative impact of appearance and lesser degree of pain among younger patients and *vice versa* for adult patients.

Although patients in each age group demonstrated a significant improvement in disability at 2-year follow-up compared with baseline, improvement in ODI was significantly greater among older patients, with mean changes of −7, −13, and −19 in the 25 to 44, 45 to 64, and 65 to 85-year-old age groups, respectively ($P = 0.004$) (Figure 2). Remarkably, at 2-year follow-up, ODI did not differ significantly based on age group ($P = 0.9$), and the mean ODI for those aged 65 to 85 years was equivalent to that of patients aged 25 to 44 years (Figure 2). Linear regression analysis of change in ODI from baseline to follow-up with both age and ODI at baseline as independent predictors suggested that ODI at baseline ($P < 0.001$) is a stronger predictor of the magnitude of ODI improvement compared with patient age ($P = 0.16$).

Health status, as assessed by the SF-12 PCS, improved significantly at 2-year follow-up compared with baseline for patients aged 45 to 64 years ($P < 0.001$) and for patients aged 65 to 85 years ($P = 0.001$) but did not change significantly for those 25 to 44 years old ($P = 0.1$; Figure 3).

TABLE 2. Operative Procedures and Parameters for 206 Surgically Treated Adults With Scoliosis Stratified Based on Patient Age

	Patient Age (Yrs)		
	25–44	45–64	65–85
n (%)	47 (23)	121 (59)	38 (18)
Operative data available (%)	44 (94)	119 (98)	37 (97)
Anterior procedure (%)	12 (27)	69 (57)	17 (46)
Mean levels (SD, range)	5 (2, 2–7)	4 (2, 1–8)	5 (2, 2–11)
Posterior procedure (%)	40 (91)	118 (98)	35 (95)
Mean levels (SD, range)	10 (3, 3–18)	11 (4, 2–18)	10 (5, 2–18)
Decompression (%)*	5 (11)	33 (28)	17 (46)
Osteotomy (%)†			
Anterior	1 (2)	0 (0)	1 (3)
Pedicle subtraction	1 (2)	5 (4)	1 (3)
Smith-Peterson‡	3 (6)	19 (16)	10 (26)
Vertebral column	0 (0)	2 (2)	0 (0)
Other	0 (0)	2 (2)	0 (0)
Pelvic fixation (%)§	7 (16)	58 (49)	16 (43)
Mean operating room time, h (SD, range)¶	7.0 (3.0, 2.0–17.5)	9.0 (2.9, 3.0–17.0)	8.3 (2.8, 3.0–14.3)
Mean estimated blood loss, mL (SD, range)	1016 (903, 75–4500)	1570 (1166, 16–5000)	1858 (1481, 50–6750)
Mean hospital stay, d (SD, range)**	8.2 (3.3, 3–16)	10.2 (5.1, 4–45)	11.1 (6.8, 2–36)

*$P = 0.002$.
†Inclusion of an osteotomy in the surgical treatment was significantly more common among patients aged 45–85 yr compared with those aged 25–44 yr ($P = 0.03$).
‡$P = 0.04$.
§$P = 0.001$.
¶$P < 0.001$.
‖$P = 0.003$.
**$P = 0.03$.
SD indicates standard deviation.

TABLE 3. Complications in Surgically Treated Adults Aged 25 to 44 Years With Scoliosis (n = 47)

Minor Complications	Major Complications
Transient peroneal nerve neuropraxia from pneumatic compression tubing	Hemothorax
Airway edema, prolonged intubation	Deep wound infection (X2)
Mild pleural effusion	
New postoperative radiculopathy	
Mild atelectasis	Total = 3 (6%)
Total = 5 (11%)	
Overall total = 8 (17%)	

At 2-year follow-up, the SF-12 PCS remained significantly better for younger patients ($P = 0.03$), but the gap between younger and older patients narrowed substantially (Figure 3). Health status based on the SRS-22 improved significantly at 2-year follow-up compared with baseline within each age group (Figure 6), but similar to baseline assessment, the SRS-22 was not significantly different across age groups at 2-year follow-up ($P = 0.8$).

Both back and leg pain improved significantly at 2-year follow-up compared with baseline in each of the age groups assessed (Figures 4 and 5). Notably, despite older patients having started with significantly greater back and leg pain, at 2-year follow-up, back and leg pain scores did not differ significantly among the 3 age groups ($P = 0.9$ and $P = 0.7$, respectively). At 2-year follow-up, older patients (65 years and older) had significantly greater improvement of leg pain ($P = 0.02$) and a trend toward significantly greater improvement of back pain ($P = 0.06$), compared with younger patients (25–44 and 45–64-year-old age groups). Linear regression analysis of change in leg pain score from baseline to follow-up with both age and leg pain score at baseline as independent predictors suggested that leg pain score at baseline ($P < 0.001$) is a stronger predictor of the magnitude of leg pain score improvement compared with patient age ($P = 0.83$).

Assessment of Patients Lost to Follow-up

To assess for potential confounding effects, the characteristics of the 247 patients lacking 2-year follow-up data were compared with the 206 patients who did have this followup. At baseline, these 2 groups did not differ with respect to age ($P = 0.5$), ODI ($P = 0.3$), SF-12 PCS ($P = 0.9$), SRS-22 ($P = 0.3$), back pain NRS score ($P = 0.1$), or leg pain NRS score ($P = 0.6$). In addition, there was no evidence that complications were more frequent or severe among patients without 2-year follow-up. There were no operative or perioperative deaths among those lacking 2-year follow-up. For patients lacking 2-year follow-up, the minor and major complication rates were 6% and 13% for patients aged 25 to 44 years, respectively; 24% and 8% for those aged 45 to 64 years, respectively; and 21% and 18% for those aged 65 to 85 years, respectively.

DISCUSSION

This article provides an age-stratified assessment of the risks and benefits associated with surgical treatment of adult

TABLE 4. Complications in Surgically Treated Adults Aged 45 to 64 Years With Scoliosis (n = 121)

Minor Complications	Major Complications
Cerebrospinal fluid leak (X4)	Vascular injury (blood loss = 3.4 L)
Symptomatic pulmonary effusion (X4)	Vascular injury (blood loss = 3.0 L)
Superficial infection (X2)	Excessive blood loss (X4)
Calf deep venous thrombosis (X2)	Nerve root injury, quad weakness (X3)
Thrombophlebitis	New foot drop
Reintubation beyond immediate postoperative period, no negative sequelae	Radiculopathy, L3 screw removed
Postoperative coagulopathy (X2)	Deep wound infection (X4)
Central line sepsis, outpatient antiobiotics	Deep wound infection requiring instrumentation removal
Pneumonia	Pulmonary embolism
Postoperative delirium (X2)	Sepsis
New postoperative radiculopathy, no revision	
Intraoperative mucous plug requiring closure and delay of surgery	
Prolonged ileus (X3)	
Hypotensive episode/surgery aborted until later date	
Hyponatremia (X2)	
Urinary tract infection (X2)	
Significant skin blistering (related to positioning during surgery)	
Significant lower extremity swelling	
Pedicle infraction	
Total = 33 (27%)	Total = 18 (15%)
Overall total = 51 (42%)	

TABLE 5. Complications in Surgically Treated Adults Aged 65 to 85 Years With Scoliosis (n = 38)

Minor Complications	Major Complications
Cerebrospinal fluid leak	Excessive blood loss (X4)
Deep venous thrombosis (X3)	Deep wound infection (X2)
Reintubation beyond immediate postoperative period, no negative sequelae (X2)	Myocardial infarction
Postoperative psychosis	Pulmonary embolism (X2)
Prolonged ileus (X3)	Hemothorax
Superficial infection (X4)	Nerve root injury
Bilateral pulmonary infiltrates	
Pneumothorax, no sequelae	
Total = 16 (42%)	Total = 11 (29%)
Overall total = 27 (71%)	

scoliosis. In each of the age groups assessed, outcome measures at 2 years after surgery improved significantly compared with baseline measures. However, compared with younger patients, older patients were shown to have significantly greater disability, greater severity of back and leg pain, and worse health status at baseline. In addition, older patients experienced significantly more complications with surgical treatment, with the oldest age group (65–85 years) having nearly 4 times the number of minor complications and nearly 5 times the number of major complications compared with the youngest age group (25–44 years). Nevertheless, despite their poorer status at baseline and their greater complication rates with surgery, at 2 year follow-up, the oldest patient group had outcome measures of disability, health status, and back and leg pain that were statistically indistinguishable from the other age groups, including those in the youngest age group. Collectively, these data demonstrate the potential benefits of surgical treatment for adult scoliosis and suggest that the elderly, despite facing the greatest risk of complications, may stand to gain a disproportionately greater improvement in disability and pain with surgery, compared with younger patients.

Although pain and disability are characteristically what ultimately draw patients with adult scoliosis to seek surgical treatment,[7,9–12,14,16,24–30] few reports have clearly addressed the surgical outcomes. A recent review assessed the literature published in *Spine* and *Journal of Bone & Joint Surgery* from 1996 to 2006 regarding primary surgical treatment of adult deformity and concluded that the 18 reports identified do not answer the question of whether surgical treatment benefits these patients.[15] A subsequent report by Bridwell *et al*[16] analyzed 56 adult scoliosis patients from 5 centers, administering validated measures before surgery and at both 1-year and

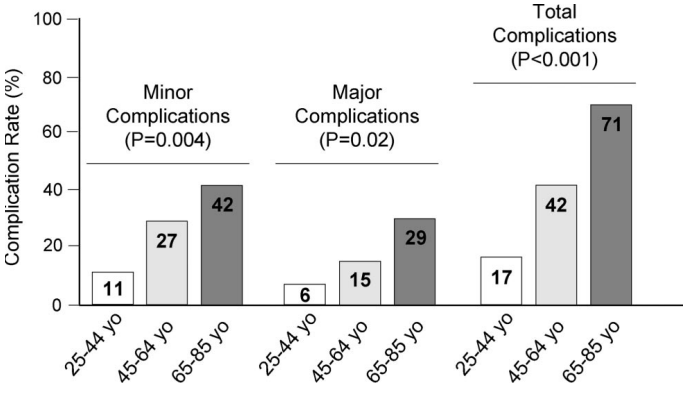

Figure 1. Complication rates in adults with scoliosis undergoing surgery stratified by age.

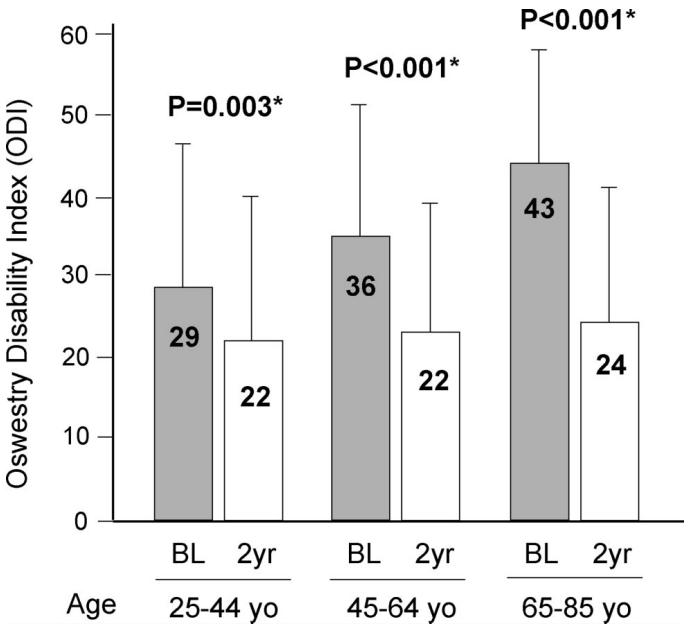

Figure 2. Relationship of patient age to improvement of disability in adults with scoliosis after surgical treatment. Bars indicate standard deviations. **P* values are from paired *t* tests.

2-year follow-up. They identified significant improvement in the SRS-22, ODI, and SF-12 physical health score. Although prospective, the number of patients was small and only included 7 patients older than 60 years.

Dickson *et al*[14] compared 81 adult patients with idiopathic scoliosis who had operative treatment with 30 patients who had been offered but declined operative treatment. Measures of pain, fatigue, and disability in the performance of specific activities of daily living demonstrated significant improvement among patients

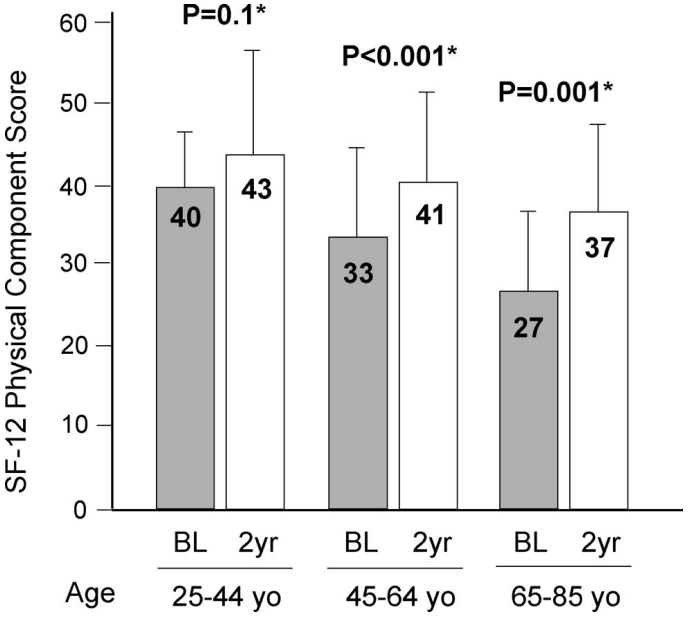

Figure 3. Relationship of patient age to improvement of health status based on the SF-12 PCS in adults with scoliosis after surgical treatment. Bars indicate standard deviations. **P* values are from paired *t* tests.

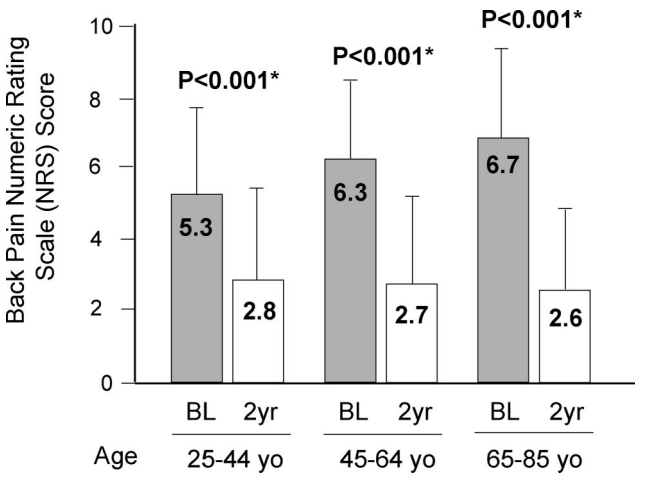

Figure 4. Relationship of patient age to improvement of back pain in adults with scoliosis after surgical treatment. Bars indicate standard deviations. **P* values are from paired *t* tests.

who elected for operative treatment, compared with those who pursued nonoperative treatment. However, this study had several limitations, including the use of questionnaires that were not validated and the use of now obsolete Harrington rod instrumentation.

In addition, Smith *et al*[10,11] recently reported on operative *versus* nonoperative treatment of pain and disability in adults with scoliosis. Despite having started with significantly greater disability and pain, surgically treated patients at 2-year follow-up had significantly less pain and disability than nonoperatively treated patients.

On the basis of a retrospective case-control series of adult deformity patients treated surgically, Glassman *et al*[31] compared standardized outcome measures of patients who did and did not have complications. At 1-year after surgery, the group of patients with major complications had a 2.1-point decrease in SF-12 general health score from preoperative to 1-year postoperative. In comparison, the group with minor complications had an improvement of 4.2 points, and the group of patients with no complications had an improvement

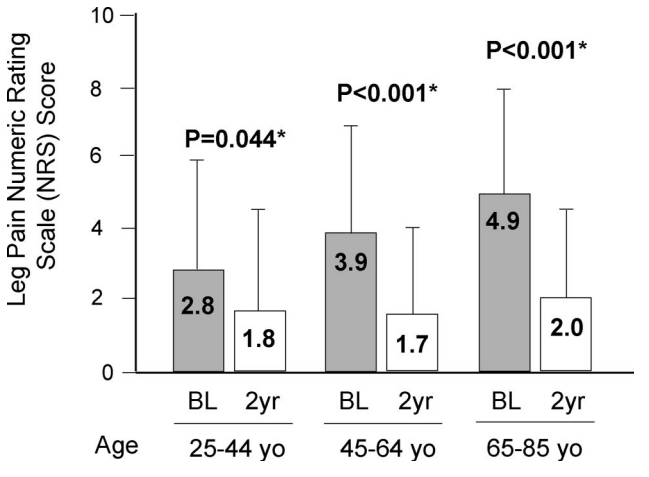

Figure 5. Relationship of patient age to improvement of leg pain in adults with scoliosis after surgical treatment. Bars indicate standard deviations. **P* values are from paired *t* tests.

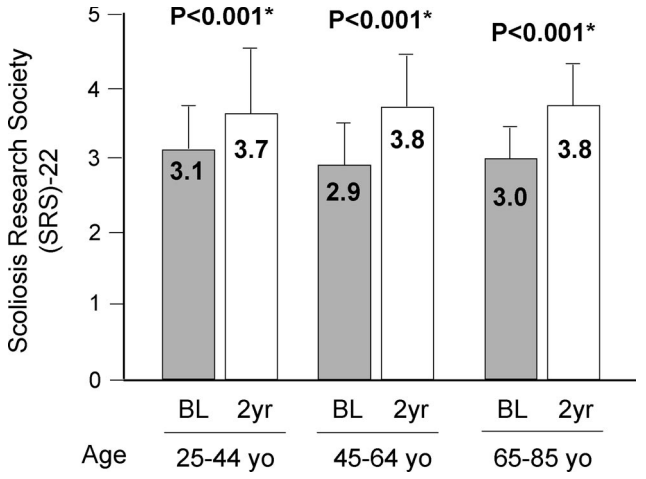

Figure 6. Relationship of patient age to improvement of health status based on the SRS-22 in adults with scoliosis after surgical treatment. Bars indicate standard deviations. **P* values are from paired *t* tests.

of 1.5 points. These data suggest that occurrence of major complications with adult deformity surgery does result in a modest impact on general health status.

In addition, Glassman *et al*[32] recently reported outcomes of single-level posterolateral lumbar arthodesis in elderly patients. Significant improvements in HRQOL measures were demonstrated. The occurrence of perioperative complications did not seem to adversely affect clinical and HRQOL outcomes at 2 years after surgery.

The short-term complication rates in this study are generally comparable with those reported previously, although this range is broad. Dickson *et al*[14] reported a 10% short-term complication rate after surgery for adult scoliosis in 81 patients with a mean age of 56 years. Grubb *et al*[27] reported 52 short-term complications in 53 adults (98%) with a mean age of 51 years who were surgically treated for scoliosis. Cho *et al*[18] reported a 30% short-term complication rate among 47 patients surgically treated for degenerative lumbar scoliosis. A short-term complication rate of 37% was reported by Daubs *et al* for 46 patients with a mean age of 67 years who underwent surgical treatment for scoliosis.

Although our data suggest that operative treatment has the potential to offer improvement of disability, health status, and pain in adults with scoliosis, we do not necessarily advocate surgical treatment for all adults with symptomatic scoliosis nor do we necessarily advocate selectively operating on elderly patients simply because they may be the most symptomatic. Nonoperative methods should typically be the first-line of treatment. When considering surgical treatment, several factors should be considered, including the severity of symptoms, impact of the symptoms on functionality and quality of life, overall health of the patient, and willingness of the patient to accept the risks of surgery.[11]

Adult scoliosis is a heterogeneous disease, with substantial ranges in radiographic parameters, such as location and magnitude of scoliotic curves, sagittal and coronal balance, and prevalence of foraminal and canal stenosis. In addition, surgical approaches to address adult scoliosis are not standardized and may include anterior, posterior, lateral, or a combination of approaches. Reflective of this heterogeneity, the radiographic (Table 1) and operative (Table 2) data in the present series demonstrate a range of pathologies and operative approaches both within and across age groups. For example, decompression for stenosis was significantly more common among older patients, suggesting that older patients may have been more likely to undergo operative treatment for symptoms related to neural compression, compared with younger patients. Because indications for surgery may differ based on patient age and spinal pathology, multiple standardized outcomes mea sures were used in the present analysis. The ODI reflects disability, the SF-12 PCS reflects health status, and the SRS-22 is a disease-specific measure that reflects a combined assessment of appearance, satisfaction, mental status, activity level, and pain.

In the present series, 2-year follow-up was not available for approximately one-half of the patients. This likely is due at least in part to patients who live prohibitively far from the treating center to enable routine follow-up beyond the perioperative period. We have demonstrated that the baseline measures of disability, health status, and pain were not significantly different from those for whom 2-year follow-up was available. In addition, there was no evidence that complications were more frequent or severe among patients without 2-year follow-up, and there were no apparent perioperative deaths among this group.

The strengths of this study include the prospective multicenter database from which data were extracted, the use of validated measures, and the relatively large patient population. In addition, patients were drawn from the practices of multiple surgeons at multiple institutions, offering representation of a broader range of patient populations and surgeon approaches. Although the data were prospectively collected, the primary limitation of this study remains the retrospective design.

CONCLUSION

Collectively, these data demonstrate the potential benefits of surgical treatment for adults with scoliosis and suggest that the elderly, despite facing the greatest risk of complications, may stand to gain a disproportionately greater improvement in disability and pain with surgery compared with younger patients.

➢ Key Points

- ❑ On average, elderly adults with scoliosis have significantly greater disability, greater severity of back and leg pain, and worse health status at baseline, compared with younger adults with scoliosis.
- ❑ Elderly adults with scoliosis had significantly more complications with surgical treatment, with the oldest age group (65–85 years) having nearly 4 times the number of minor complications and nearly 5 times the number of major complications compared with the youngest age group (25–44 years).

- Although outcome measures at 2 years after surgery improved significantly compared with baseline measures for all age groups assessed, elderly patients had the greatest degree of improvement, with outcome measures of disability, health status, and back and leg pain at 2-year follow-up that were statistically indistinguishable from the other age groups, including those in the youngest age group.
- Our data demonstrate the potential benefits of surgical treatment for adult scoliosis and suggest that the elderly, despite facing the greatest risk of complications, may stand to gain a disproportionately greater improvement in disability and pain with surgery compared with younger patients.

References

1. Carter OD, Haynes SG. Prevalence rates for scoliosis in US adults: results from the first National Health and Nutrition Examination Survey. *Int J Epidemiol* 1987;16:537–44.
2. Francis RS. Scoliosis screening of 3,000 college-aged women. The Utah Study: phase 2. *Phys Ther* 1988;68:1513–6.
3. Kostuik JP, Bentivoglio J. The incidence of low-back pain in adult scoliosis. *Spine* 1981;6:268–73.
4. Perennou D, Marcelli C, Herisson C, et al. Adult lumbar scoliosis. Epidemiologic aspects in a low-back pain population. *Spine* 1994;19:123–8.
5. Robin GC, Span Y, Steinberg R, et al. Scoliosis in the elderly: a follow-up study. *Spine* 1982;7:355–9.
6. Schwab F, Dubey A, Gamez L, et al. Adult scoliosis: prevalence, SF-36, and nutritional parameters in an elderly volunteer population. *Spine* 2005;30:1082–5.
7. Smith JS, Fu KG, Urban P, et al. Neurological findings in adults with scoliosis: incidences and correlations with operative *versus* conservative management. *J Neurosurg Spine* 2008;9:326–31.
8. Aebi M: The adult scoliosis. *Eur Spine J* 2005;14:925–48.
9. Glassman SD, Schwab FJ, Bridwell KH, et al. The selection of operative versus nonoperative treatment in patients with adult scoliosis. *Spine* 2007; 32:93–7.
10. Smith JS, Shaffrey CI, Berven S, et al. Operative *versus* nonoperative treatment of leg pain in adults with scoliosis: a retrospective review of a prospective multicenter database with two-year follow-up. *Spine* 2009;34:1693–8.
11. Smith JS, Shaffrey CI, Berven S, et al. Improvement of back pain with operative and nonoperative treatment in adults with scoliosis. *Neurosurgery* 2009;65:86–93.
12. Glassman SD, Berven S, Kostuik J, et al. Nonsurgical resource utilization in adult spinal deformity. *Spine* 2006;31:941–7.
13. Fu KG, Smith JS, Sansur CA, et al. Standardized measures of health status and disability and the decision to pursue operative treatment in elderly patients with degenerative scoliosis. *Neurosurgery* 2010;66:42–7.
14. Dickson JH, Mirkovic S, Noble PC, et al. Results of operative treatment of idiopathic scoliosis in adults. *J Bone Joint Surg Am* 1995;77:513–23.
15. Bridwell KH, Berven S, Edwards C II, et al. The problems and limitations of applying evidence-based medicine to primary surgical treatment of adult spinal deformity. *Spine* 2007;32:S135–9.
16. Bridwell KH, Berven S, Glassman S, et al. Is the SRS-22 instrument responsive to change in adult scoliosis patients having primary spinal deformity surgery? *Spine* 2007;32:2220–5.
17. Daubs MD, Lenke LG, Cheh G, et al. Adult spinal deformity surgery: complications and outcomes in patients over age 60. *Spine* 2007;32:2238–44.
18. Cho KJ, Suk SI, Park SR, et al. Complications in posterior fusion and instrumentation for degenerative lumbar scoliosis. *Spine* 2007;32:2232–7.
19. Tribus CB. Degenerative lumbar scoliosis: evaluation and management. *J Am Acad Orthop Surg* 2003;11:174–83.
20. Carreon LY, Puno RM, Dimar JR II, et al. Perioperative complications of posterior lumbar decompression and arthrodesis in older adults. *J Bone Joint Surg Am* 2003;85A:2089–92.
21. McDowell I, Newell C. *Measuring Health: A Guide to Rating Scales and Questionnaires*. 2nd ed. New York: Oxford University Press; 1996.
22. Fairbank JC, Pynsent PB. The Oswestry Disability Index. *Spine* 2000;25:2940–52; discussion 2952.
23. Bridwell KH, Cats-Baril W, Harrast J, et al. The validity of the SRS-22 instrument in an adult spinal deformity population compared with the Oswestry and SF-12: a study of response distribution, concurrent validity, internal consistency, and reliability. *Spine* 2005;30:455–61.
24. Berven S, Deviren V, Demir-Deviren S, et al. Studies in the modified Scoliosis Research Society Outcomes Instrument in adults: validation, reliability, and discriminatory capacity. *Spine* 2003;28:2164–9; discussion 2169.
25. Glassman SD, Berven S, Bridwell K, et al. Correlation of radiographic parameters and clinical symptoms in adult scoliosis. *Spine* 2005;30:682–8.
26. Kanter AS, Asthagiri AR, Shaffrey CI. Aging spine: challenges and emerging techniques. *Clin Neurosurg* 2007;54:10–8.
27. Grubb SA, Lipscomb HJ, Suh PB. Results of surgical treatment of painful adult scoliosis. *Spine* 1994;19:1619–27.
28. Glassman SD, Bridwell K, Dimar JR, et al. The impact of positive sagittal balance in adult spinal deformity. *Spine* 2005;30:2024–9.
29. Bradford DS, Tay BK, Hu SS. Adult scoliosis: surgical indications, operative management, complications, and outcomes. *Spine* 1999;24:2617–29.
30. Oskouian RJ Jr, Shaffrey CI. Degenerative lumbar scoliosis. *Neurosurg Clin N Am* 2006;17:299–315, vii.
31. Glassman SD, Hamill CL, Bridwell KH, et al. The impact of perioperative complications on clinical outcome in adult deformity surgery. *Spine (Phila Pa 1976)* 2007;32:2764–70.
32. Glassman SD, Polly DW, Bono CM, et al. Outcome of lumbar arthrodesis in patients sixty-five years of age or older. *J Bone Joint Surg Am* 2009;91:783–90.