The number of surgical treatment options for skeletally mature patients with spine deformities has expanded over the past several decades. Advances in operative techniques, along with an understanding of biomechanics and advances in instrumentation, has allowed for the development of many surgical approaches to adult scoliosis. To determine the “best” approach to treat patients with adult deformity, clinicians must be familiar with risks and benefits of surgical intervention. Unfortunately, randomized controlled trials comparing operative with nonoperative management are lacking. Outcomes for adult deformity surgery are largely reported in reference to a specific surgical technique or in relation to a particular surgeon or surgical group. Investigators have used varying classifications of clinical outcomes and procedure-related complications, making analysis of the literature difficult.

The purpose of this systematic review was to synthesize existing data on the outcomes of surgical intervention for adult spine deformity. Four specific questions regarding outcome were proposed as follows: 1) What is the benefit of surgery for adult scoliosis in terms of correction of curve at a minimum 2-year follow-up? 2) What is the benefit of surgery for adult scoliosis based on standard clinical outcomes measures at a minimum 2-year follow-up? 3) What is the rate of complication with adult scoliosis surgery? 4) What is the rate of pseudarthrosis with adult scoliosis surgery?

Methods

A query of the PubMed and MEDLINE databases was performed to identify articles published from 1950 to the present using the following key words: “adult scoliosis surgery,” “adult spine deformity surgery,” “outcomes,” and “complications.” Exclusion criteria included follow-up shorter than 2 years and mean patient age younger than 18 years. Data on major curve (coronal scoliosis or lumbar lordosis Cobb angle as reported), major curve correction, Oswestry Disability Index (ODI) scores, Scoliosis Research Society (SRS) instrument scores, complications, and pseudarthroses were recorded.

Results. Forty-nine articles were obtained and included in this review; 3299 patient data points were analyzed. The mean age was 47.7 years, and the mean follow-up period was 3.6 years. The average major curve correction was 26.6° (for 2188 patients); for 2129 patients, it was possible to calculate average curve reduction as a percentage (40.7%). The mean total ODI was 41.2 (for 1289 patients), and the mean postoperative reduction in ODI was 15.7 (for 911 patients). The mean SRS-30 equivalent score was 97.1 (for 1700 patients) with a mean postoperative decrease of 23.1 (for 999 patients). There were 897 reported complications for 2175 patients (41.2%) and 319 pseudarthroses for 2469 patients (12.9%).

Conclusions. Surgery for adult scoliosis is associated with improvement in radiographic and clinical outcomes at a minimum 2-year follow-up. Perioperative morbidity includes an approximately 13% risk of pseudarthrosis and a greater than 40% incidence of perioperative adverse events. Incidence of perioperative complications is substantial and must be considered when deciding optimal disease management. Although the quality of published studies in this area has improved, particularly in the last few years, the current review highlights the lack of routine use of standardized outcomes measures and assessment in the adult scoliosis literature. (DOI: 10.3171/2009.12.FOCUS09254)
performed and returned 361 articles. The query was further limited to the English-language literature (341 articles) and a patient age of 19 years or older (334 articles). Abstracts from these articles were reviewed, and those that reported a minimum 2-year follow-up, average patient age older than 18 years, or did not specify either parameter in the abstract were retained for more detailed review. This yielded 44 articles for detailed review. A minimum 2-year follow-up was specified to include chronic or subacute complications (for example, pseudarthrosis) and to account for any loss of curve correction.

Next, a search of MEDLINE was performed to identify any pertinent articles published between 1950 and 2009 that were not identified in the previous PubMed search. A search for the key words “adult scoliosis and outcomes” (29 articles), “adult spine deformity and outcomes” (31 articles), and “adult scoliosis and complications” (59 articles) was performed. Abstracts from these searches yielded 14 additional articles for detailed review that were not identified previously in the PubMed search. Thus, 58 articles were identified by abstract for detailed review of methods and results. Nine of these articles were excluded from analysis due to failure to meet the minimum follow-up, patient age criteria, or report postoperative outcomes. Forty-nine articles were ultimately included in the analysis (Table 1).

The quality of evidence in the selected articles was classified using the USPSTF system for ranking evidence. Articles were reviewed for data on methodology (retrospective vs prospective), number of patients, mean patient age, and mean follow-up. Data regarding change in major curve at last follow-up in degrees and as a percentage of the original curve were recorded if available. A major curve was defined as the coronal scoliosis Cobb angle or lumbar lordosis Cobb angle as reported in the study. Clinical outcomes data based on postoperative ODI scores, change in ODI scores from preoperative, postoperative SRS instrument scores, and change in SRS scores from preoperative was also recorded when available. Finally, the number of complications and pseudarthroses were tallied.

Descriptive statistics were calculated using the JMP statistical package (version 7.02, SAS Institute). Because of variability in the type of SRS instrument used by different investigators (SRS-22, SRS-24, SRS-29, or SRS-30), SRS scores were converted to SRS-30 score equivalents for purposes of statistical analysis. Weighted averages of age, length of follow-up, ODI, change in ODI, SRS-30 equivalent score, change in SRS-30 equivalent score, curve reduction in degrees, and curve reduction as a percentage of the original curve were calculated. Complications were not uniformly reported; classification (that is, minor vs major) was variable as was reporting of multiple complications in the same patient. Therefore, complication incidence was calculated by tallying the total number of complications reported divided by total number of patients in those studies that reported complications. The incidence of pseudarthrosis was calculated in a similar fashion: the number of pseudarthroses reported divided by total number of patients in those studies reporting pseudarthroses.

A total of 49 articles reporting data in 3299 patients were reviewed. Of the 49 articles reviewed, none were classified as Level I evidence according to USPSTF criteria. Four articles met criteria for Level II evidence as well-designed matched cohort studies or multiple time series with and without intervention. The remaining 45 articles were descriptive studies and therefore classified as Level III evidence. Eight studies were conducted in a prospective fashion, and the other 41 series were conducted in a retrospective manner. Only 4 articles reported on all specified outcome measures.

The average age of the patients included in this review was 47.7 years (Fig. 1). The average length of follow-up was 3.6 years (Fig. 2). Thirty-nine studies reported preoperative and postoperative major curve Cobb angles (for 2188 patients). At a minimum 2-year follow-up, the average reduction of the major curve was 26.6° (Fig. 3), or 40.7% as a percentage of the original curve (where this calculation was available; for 2129 patients).
Outcomes after adult scoliosis surgery

### TABLE 1: Literature review of postoperative radiographic and clinical outcomes for adult patients undergoing surgery for scoliosis with a minimum 2-year follow-up

<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>Level of Evidence</th>
<th>Study Design</th>
<th>Total No. of Patients</th>
<th>Mean Age (yrs)</th>
<th>Mean FU (yrs)</th>
<th>Mean ODI</th>
<th>SRS-30 Equivalent</th>
<th>Major Curve Reduction (°)</th>
<th>Major Curve Reduction (%)</th>
<th>No. of Complications</th>
<th>No. of Pseudarthroses</th>
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<td>52</td>
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<td>51</td>
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(continued)
Fifteen studies, including data from 1289 patients, used total ODI as a measure of clinical outcomes. The average ODI for patients in these studies was 41.2. Eleven studies including data from 911 patients reported both preoperative and postoperative ODIs. The average decrease in ODI from preoperative testing to latest follow-up in these studies was 15.7.

Twenty-six studies with data from 1700 patients used an SRS instrument to measure clinical outcomes at follow-up. Scores were converted to SRS-30 equivalent scores for purposes of comparison and analysis. The average SRS-30 score of patients in these series was 97.1. Ten studies, with data from 999 patients, reported both preoperative and postoperative SRS scores. The average decrease in SRS-30 scores in these patients was 23.1.

Forty-one articles reported on complications associated with surgery; 897 complications were reported in 2175 patients, giving a pooled incidence of 41.2% for patients in these series. Thirty-nine articles (2469 patients) reported on pseudarthroses. There were 319 pseudarthroses in these articles, giving a rate of 12.9%.

**Discussion**

An adult spine coronal deformity may develop de novo in the mature skeleton or progress from untreated adolescent scoliosis. Estimates of prevalence vary from 1 to 9% of the adult population. Adult patients present more often with pain or neurological symptoms than their adolescent counterparts, and surgery is generally indicated for patients with significant deformity-related pain or progressive curves. Several authors have reported high rates of patient satisfaction and functional improvement with operative treatment.

Historically, outcomes in the adult deformity literature have been reported in reference to specific procedures, pathology, or primary surgeon. This is reflected in the current review in that the majority of studies included were classified as Level III evidence (descriptive studies) according to USPSTF criteria. Although several prospective and matched cohort studies have been performed, definitive randomized controlled trials are lacking. There has been a trend toward increasing quality in evidence and methodology of publications in this area, particularly in the past few years. Three of 4 Level II studies included in the current review were published in 2009. In addition, 5 of 8 prospective studies in this review were published in 2007 or later; all 8 were published in 2002 or later.

The aim of the current study was to review different series to generate more powerful estimates of the effect of surgery for adult scoliosis. The current review focuses on the ODI and the SRS outcome instruments because these were the most consistently used measures. Complications and pseudarthroses, a significant cause of pain and reoperation in these patients, were included in the review rather than limiting it to only potential benefits of surgery. The inclusion criterion of a 2-year minimum follow-up was specified to increase the capture of subacute and chronic events (for example, pseudarthrosis or loss of curve correction).

**Correction of Curve**

Cobb angle correction varied from 9.1 to 53.9° (mean...
Outcomes after adult scoliosis surgery

Fig. 3. Bar graph illustrating distribution of average curve reduction of patients as reported in 39 reviewed series with data from 2188 patients at a minimum 2-year follow-up.

As a percentage of the original curve, correction ranged from 1 to 87% (mean 40.7%). The natural history of untreated spinal deformity is progression of the curve, and this has been illustrated by several comparative series.\(^5,44\) Unlike adolescent scoliosis in which bracing can prevent progression of the curve, no such utility has been found in the skeletally mature patient.\(^33\)

Clinical Outcome Measurements

There was no consensus in the reviewed literature on the measurement of clinical outcomes. At least 9 separate formal instruments were used in the reviewed series. The most commonly used instruments were the ODI (15 studies) and SRS outcomes instrument (26 studies). Several versions of the SRS instrument were used, including SRS-24, SRS-29, SRS-30, and the SRS-22 (the modified SRS instrument). However, only 21 studies (42.9%) reported both preoperative and postoperative scores.

The ODI is a widely used and validated instrument for outcomes measurement of a variety of pathological conditions.\(^28\) The average postoperative ODI in the 15 series that reported them was 41.2. This correlates with a clinical picture of moderate to severe disability. In their review of 947 adults with spinal deformity, Schwab et al.\(^30\) found a mean ODI score of 30 suggesting that the patients in the current review were more disabled by their disease than the general adult scoliosis population.

The difference in ODI scores that correlates with significant clinical improvement ranges from 4 to 15 points.\(^28\) Eleven studies in the current review reported both preoperative and postoperative ODI scores. For the 911 patients in these 11 studies, there was an average decrease of 15.7 points (range 3.1–32.3 points) after surgery, suggesting that significant clinical improvement did occur in patients in those series.

Several versions of the SRS are commonly used and have been previously validated in adults and children with scoliosis.\(^5,14\) Several variations of the SRS format were used by investigators to report outcomes; the difference in SRS versions is primarily inclusion or exclusion of certain groups of questions. For purposes of comparison, it was necessary to convert scores to the SRS-30 scale. To our knowledge, there has been no previous validation of such a conversion. Using this method, the average SRS-30 equivalent score of patients in the 26 studies using a version of the SRS instrument was 97.1. In the aforementioned study by Schwab et al., the average SRS-22 score was 67, which is equivalent to a score of 100.5 on the SRS-30 scale, suggesting minimal difference between patients in these series and the general adult scoliosis population.

Bago et al.\(^6\) recently reported that the minimal important difference, the difference in score correlating to a patient’s self-perceived improvement in outcome for raw SRS scores is approximately 13 points. The average decrease in SRS-30 equivalent score found in the 10 studies that reported both pre- and postoperative SRS scores was 23.1 points. This difference represents a significant improvement in patient-reported outcome at a minimum 2-year follow-up for patients who underwent surgery in those series.

Eight series reported use of both ODI and SRS score as measures of outcome, 14 reported ODI alone, 25 reported SRS score alone, and 13 reported neither. The ability to compare outcomes in the scoliosis literature is limited by the lack of consensus on which measurement instrument to use, a consistent method of pre- and postoperative assessment, and whether to include clinical outcomes data in such series at all. An agreement on these standards seems overdue as performance measures in surgery become increasingly important.

Complications and Pseudarthroses

The incidence of reported complications in the reviewed articles ranged from 0 to 53%. There was no consensus regarding the classification or categorization of complications. Several authors divided complications into major or minor categories while others reported early versus late complications.\(^5,15,16,52,63\) The method used in this systematic review may overestimate the true incidence of complications. Several series reported only the number of complications and did not specify whether multiple complications occurred in the same patient. For analysis, the incidence of complication was calculated as the total number of complications divided by the number of patients in those series reporting complications. This formula implicitly assumes that multiple complications did not occur in the same patient. Therefore, this approach may not accurately reflect overall incidence of perioperative adverse events in these series.

The rate of pseudarthroses in the reviewed series ranged from 0 to 41%.\(^20,45\) This range is slightly broader than other estimates, although the overall rate in the current review of 12.9% is similar to previously published rates.\(^15\)

Conclusions

The current review analyzes outcomes data for adult spine deformity surgery with a minimum 2-year follow-up. The average major curve correction in these series was 26.6°, or about 40.7% correction of the original curve. Based on the most commonly reported clinical outcomes.
measures, the ODI and SRS instrument, surgery for adult scoliosis appears to improve clinical outcomes at a minimum 2-year follow-up. Although the quality of studies in this area has improved, particularly in the past few years, this review highlights the lack of routine use of standardized outcome measures and methods for preoperative and postoperative assessment in the current literature. Such standardization should be expanded to include methods of complication classification and reporting.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: S Yadla, JK Ratliff, JS Harrop. Acquisition of data: S Yadla. Analysis and interpretation of data: S Yadla, MG Maltenfort, JK Ratliff, JS Harrop. Drafting the article: S Yadla, MG Maltenfort, JK Ratliff, JS Harrop. Critically revising the article: S Yadla, MG Maltenfort, JK Ratliff, JS Harrop. Reviewed final version of the manuscript and approved it for submission: S Yadla, MG Maltenfort, JK Ratliff, JS Harrop. Statistical analysis: MG Maltenfort.

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