Review Article

Patient-reported outcome measures in spine surgery: A systematic review

ABSTRACT

Background: Steadily increasing expenditure in the United States health-care system has led to a shift toward a value-based model that focuses on quality of care and cost-effectiveness. Operations involving the spine rank among some of the most common and expensive procedures performed in operating rooms nationwide. Patient-reported outcomes measures (PROMs) are a useful tool for reporting levels of outcome and analyzing patient recovery but are both under-utilized and nonstandardized in spine surgery.

Methods: We conducted a systematic review of the literature using the PubMed database, focusing on the most commonly utilized PROMs for spine disease as well as spinal deformity. The benefits and drawbacks of these PROMs were then summarized and compared.

Results: Spine-specific PROMs were based on the class of disease. The most frequently utilized PROMs were the Neck Disability Index and the modified Japanese Orthopaedic Association scale; the Oswestry Disability Index and the Roland-Morris Disability Questionnaire; and the Scoliosis Research Society 22-item questionnaire (SRS-22) for cervicothoracic spine disease, lumbar spine disease, and spinal deformity, respectively.

Conclusion: We found limited, though effective, use of PROMs targeting specific classes of disease within spine surgery. Therefore, we advocate for increased use of PROMs in spine surgery, in both the research and clinical settings. PROM usage can help physicians assess subjective outcomes in standard ways that can be compared across patients and institutions, more uniquely tailor treatment to individual patients, and engage patients in their own medical care.

Keywords: Health-care surveys, patient-reported outcome measures, quality of life, spinal deformity, spine pathology, spine surgery

INTRODUCTION

The United States (U.S.) national health expenditure accounted for 17.9% of total gross domestic product in 2017, and that value is projected to increase to 19.4% by 2027.[1] Among medical specialties, spine surgery arguably presents the highest potential for cost improvement. In the face of an aging U.S. population, where the percentage of people over 65 is projected to reach 20% by 2030, the field of spine surgery is under increasing scrutiny to evaluate cost-effectiveness.[2]

Patient-reported outcomes (PROs) and PRO measures (PROMs) are being evaluated as a tool for value-based care. PROs refer to any report that comes directly from a patient regarding his or her health.[3] PROs are particularly useful for outcomes that are subjective or require self-reporting, such as functional health status, health perceptions, and quality of life (QoL).[3] While the outcomes of medical interventions and procedures

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are hard to measure objectively, PROMs can provide patients' perspectives on the quality of care being received, as well as objective assessment of complex functional improvements. PROMs can be generic and applicable to a range of patients, or specific to a particular disease.[4] PROMs are being used today in a wide variety of clinical settings.[5,6]

Widespread use of PROMs by health systems began in Sweden before spreading internationally for a variety of pathologies.[7] National quality registers in Sweden are now required to incorporate PROs for certification to objectively compare outcomes based on patients' views of treatment effects.[8] Registers list many quality improvements resulting from PROM use, such as indications for surgery, monitoring complications after the patient leaves the hospital and enhancing shared decision-making with the patient.[8] These improvements contribute to the paradigm shift that is occurring throughout modern medicine, away from a paternalistic approach and toward patient-centered care.[9] PROMs represent an important part of this shift by increasing patients' involvement in their care as well as improving physician insight into patients' lives, wants, and desires.[10]

There is, notably, a lack of standardization in PROM usage for spinal disease. Guzman *et al*. found over 200 unique PROMs being used in spinal surgery from 2004 to 2013.[11] While we provide a comprehensive list of spine-specific PROMs used in spinal surgery, we aim to focus our review on those that are most widespread in the literature. The purpose of using PROMs is to standardize subjective experiences so that comparisons can be made between procedures and patient populations. These goals can only be attained if there is consensus as to which PROMs should be used. Therefore, this project does not aim to exhaustively review each PROM used in spinal surgery. Rather, we highlight the best, and most universally used, disease-specific PROMs for each area of spinal pathology. General PROMs are not discussed in detail in this review, and a discussion of each and every PROM is beyond the scope of this review. While no individual PROM can capture the vast array of human experiences, it is most pragmatic for the spine surgery community to come to a consensus on which PROMs are best and most widely used, and to begin using them routinely.

METHODS

We performed a two-tiered systematic review per the Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines in order to detect the most commonly utilized PROMs for various categories of spine disease and deformity. We first searched the literature the most common instruments of common spinal pathology. For each spine-specific PROM encountered, a PubMed search was run to identify the number of associated articles. Titles and abstracts were systematically searched across the PubMed database. After identifying the most common PROMs for each area of spinal pathology, we conducted PubMed searches with free search terms including "Neck Disability Index," "Modified Japanese Orthopaedic Association," "Oswestry Disability Index," "Roland Morris Disability Questionnaire," and "Scoliosis Research Society Outcomes Questionnaire 22." We included all English language articles, case series, retrospective studies, review articles, and editorials concerning surgically amenable spinal pathology. Exclusion criteria included: (1) non-English language reports, (2) reports for which the full text was not available in a nonprint format, (3) reports focusing on nonspinal surgery, and (4) reports that did not present novel data or analysis regarding PROMs.

The main PROMs used in spinal surgery literature were assessed using the given articles. The benefits and drawbacks of these PROMs were then summarized and compared for each spinal condition. The level of evidence of the studies was also evaluated using the American College of Cardiology/American Heart Association clinical practice guideline recommendation classification system.

RESULTS

A total of 8599 articles were identified on our initial search. After exclusion, a total of 90 articles were included for systematic review [Figure 1]. The populations under review in these articles included patients with different categories of spine disease, including cervicothoracic spine disease, lumbar spine disease, and spinal deformity. The intervention in each study consisted of surgical treatment of the spinal pathology, with a comparison group being either a presurgical measure or conservative nonsurgical treatment. The primary outcome measure in the majority of these articles was a PROM, but additional outcome measures included radiological findings, postoperative complications, and mortality.

Seventeen articles were related to cervicothoracic disease, focusing on the Neck Disability Index (NDI) and the modified Japanese Orthopaedic Association scale (mJOA). Twenty articles were related to low back pain, focusing on the Oswestry Disability Index (ODI) and the Roland-Morris Disability Questionnaire (RMDQ). Twenty-two articles were cited related to spinal deformity, focusing on the Scoliosis Research Society 22-item questionnaire (SRS-22). Eleven articles were related to the future direction of PROMs in spinal surgery, with a focus on PROMIS. The findings of our study regarding the selected PROMs are summarized in Table 1,

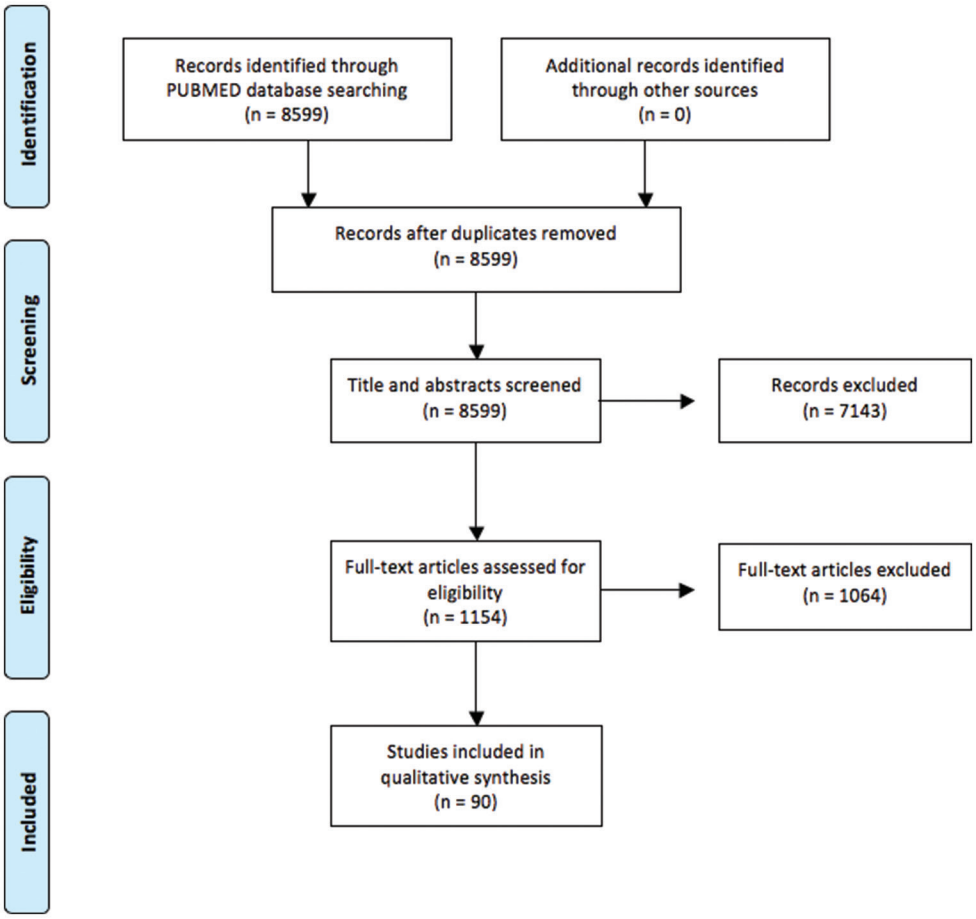

Figure 1: PRISMA systematic literature search flow-diagram. PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analysis

along with the level of evidence of the main cited articles. In addition, a comprehensive list of 37 spine-specific PROMs found on the PubMed database is included in Table 2, along with the number of associated articles. The most scientifically valid PROMs for each area of spinal pathology, as evidenced by the largest number of studies, were the subject of more focused analysis in this article. It is beyond the scope of this review to provide detailed analysis of any PROMs beyond the most widely used instruments as specified above.

DISCUSSION

Although spine disease is an infrequent cause of death, it is a common cause of pain and disability with severe effects on QoL.[37] Many subjective symptoms cannot be objectively measured but can be well reported by PROMs. Accordingly, PROMs are useful in the preoperative period both as a threshold value for improvement and for planning postoperative care, and they are also useful in the postoperative period to quantify the effects of treatment.[38,39]

Spine PROMs have been commonly used for research purposes of documenting outcomes from both conservative and surgical treatments.[40] Studies often use one disease-specific PROM and one general PROM. PROMs can also be compared to biophysical and clinical parameters to demonstrate multimodal efficacy.[40] For example, ODI scores have been shown to correlate with magnetic resonance imaging findings in patients with lumbar intervertebral disc degeneration.[40]

Spine-specific PROMs are ideal for clinical practice. They can be completed quickly and with minimal supervision in the waiting room and help frame the physician–patient discussion. They should be recorded both before and sequentially after any intervention to ascertain improvement.[41] Using preoperative PROMs to identify which patients are most likely to respond well to spine surgery could also improve cost savings, further and indirectly improving QoL.[42] Parai *et al*. recently concluded that a 1-year PROM follow-up for degenerative lumbar spine surgery is sufficient for clinical purposes and that no significant changes should be expected afterward.[43] Fekete *et al*. found similar results and noted that early postoperative results were a good predictor of long-term patient outcomes, concluding that a "wait and see" approach for poor initial outcomes at 3 months is ill-advised.[44] Instead, early intervention, rather than observation, is recommended

Table 1: The benefits, drawbacks, and final recommendations of selected patient-reported outcomes measures

Pathology	PROM	Benefits	Drawbacks	Conclusions and final recommendations
Cervicothoracic spine disease	NDI	Correlates with quality of life measurements and mental health measures[12]B, I Score correlates with patient's opinion of surgical outcome[13]B, I Improvement in myelopathy is a key factor for score improvement[14]B, I	Physical impairments and psychosocial factors cause variance in NDI scores[15]B, I	Both studies correlate with each other[16]B, I The authors recommend both the NDI and mJOA for use in cervical spine disease[C, I]
	mJOA	mJOA exhibits a positive correlation with JOA[17]B, I Good responsiveness to postoperative changes[18]B, I Improvement in myelopathy is a key factor for score improvement[14]B, I	mJOA must be administered by a physician, but p-mJOA does not[19] B, IIa	
Lumbar spine disease	ODI	Greater responsiveness to change than general health measures[20]B, I A better indicator of functional range of motion improvement versus Visual-Analog Scale[21]B, I Useful for predicting the extent of functional recovery postsurgery[22]B, I	Poor sensitivity to change for mild baseline symptoms[23]B, I Scoring possibly confounded by factors beyond low back pain (e.g., depression)[23]B, IIa Obscures improvement or regression in individual domains[24]B, IIa	No strong evidence to prefer ODI versus RMDQ[25]C, IIb The authors recommend ODI for severe disability and RMDQ for mild disability[26]C, I
	RMDQ	Greater responsiveness to change than general health measures[27]B, I Unidimensional measurement, specific for physical disability due to low back pain[28]B, I	Poor sensitivity to change for severe baseline symptoms[26]B, IIa Poor correlation to psychosocial disability[28]B, IIb	
Spinal deformity	SRS-22	Scores for minimum clinically important difference and substantial clinical benefit have been determined[29]B, IIa; [30]B, IIa Correlation with Cobb angle[30]B, I Correlation with cranial sagittal vertical axis[31]B, I Correlation with pelvic tilt[31]B, I; [32]B, I Responsive to changes in both pediatric and adult scoliosis patients[33]B, I; [34]B, I	Age, sex, and ethnicity all have a significant impact on score[35]B, IIa	SRS-22 is a valid and reliable tool[36]B, I The authors recommend the SRS-22 for use in spinal deformity[C, I]

[A] Data derived from multiple randomized clinical trials or meta-analyses of such studies, [B]Data derived from a single randomized trial or nonrandomized trial or meta-analysis of such studies, [C]Observational studies with limitations in design or execution or consensus opinion of experts, Class of evidence (ACC/AHA Guidelines Classification Scheme), [I]Procedure/treatment should be performed/administered (benefit >>> risk), [IIa]It is reasonable to perform procedure/administer treatment (benefit>>risk), [IIb]Procedure/treatment may be considered (benefit≥risk). Key: Citation, level of evidence, class of evidence, Level of evidence (ACC/AHA Guidelines Classification Scheme). ACC/AHA - American College of Cardiology/American Heart Association; PROM - Patient-reported outcomes measures; NDI - Neck Disability Index; ODI - Oswestry Disability Index; RMDQ - Roland-Morris Disability Questionnaire; SRS-22 - Scoliosis Research Society 22; mJOA - modified Japanese Orthopedic Association Scale; p-mJOA - patient-derived mJOA

for postoperative thoracolumbar patients with poor PROM scores.

Although PROMs have shown to be effective clinical and research tools, they are still being underutilized in spine surgery. Guzman *et al*. analyzed 19,736 articles in five orthopedic journals on PubMed from 2004 to 2013 and found that only 1079 utilized PROMs (5.47%).[11] In addition, there were 206 unique PROMs, many of them improvised. This result demonstrates a lack of standardization in PROM use across various institutions. In 2017, Falavigna *et al*. found that 31.9% of spine surgeons do not routinely use PROMs.[45] These authors found that the main barriers to usage were a lack of time and staff to administer the PROM and additionally found that 28.3% of surveyed spine surgeons were not familiar with generic health-related QoL questionnaires.

Furthermore, certain communities and training pathways may be more conducive to adoption of PROMs: For instance, the majority of the articles about spine-specific PROMs analyzed during the creation of this systematic review were found in orthopedic journals, and relatively fewer were found in neurosurgical journals. This may be due to common QoL-related and functional outcome measures commonly employed in other orthopedic subspecialties, whereas prevailing neurosurgical outcomes are historically based on objective neurological signs and radiological findings.

Cervicothoracic Spine Disease-Neck Disability Index and modified Japanese Orthopedic Association

Cervicothoracic spine pathology is a common, complex, and heterogeneous global disease.[46] The lifetime incidence of neck-related pain has been reported in up to two-thirds of the population.[46] In addition, cervical spine disease is the most common cause of myelopathy in elderly patients.[47] The main PROMs being used to assess functional outcomes for cervicothoracic spine disease are the NDI and mJOA scores.[48] In our PubMed database search, the NDI was associated with 2026 articles and the mJOA was associated with 246 articles [Table 2]. All other disease-specific PROMs used for cervicothoracic spine pathology were associated with fewer than 100 articles.

The NDI originated in 1991 as an iteration of the Oswestry Low Back Pain Index modified for cervical pathology, and correlates

Table 2: A comprehensive list of spine-specific patient-reported outcomes measures

Pathology	PROM	Number of PubMed articles
Cervicothoracic spine disease	NDI*	2026
	The Modified Japanese Orthopaedic Association*	246
	Neck Pain Disability Scale*	114
	Nurick Scale	78
	Northwick Park Neck Pain Questionnaire	70
	Neck Bournemouth Questionnaire	27
	Copenhagen Neck Functional Disability Scale	16
	Whiplash Disability Questionnaire	15
	Myelopathy Disability Index*	14
	Cervical Spine Outcomes Questionnaire	12
Lumbar spine disease	ODI*	5490
	RMDQ*	964
	Quebec Back Scale	323
	PainDETECT	278
	Neuropathic pain symptom inventory	124
	Zurich Claudication Questionnaire	114
	Core Outcome Measures Index	110
	Swiss Spinal Stenosis Questionnaire	37
	Orebro Musculoskeletal Pain Questionnaire	32
	Pain Quality Assessment Scale	25
	NASS Questionnaire	12
	Low Back Pain Bothersomeness Scale	5
	Low Back Pain Impact Questionnaire	2
	Brief Pain Inventory and Brief Pain Inventory Short Form	2
	Japanese Orthopaedic Association Back Pain questionnaire	2
	West Haven-Yale Multidimensional Pain Inventory Interference Scale	1
Spinal deformity	Scoliosis Research Society Outcomes Questionnaire 22*	308
	Pediatric Outcomes Data Collection Instrument	186
	Quality of Life Instrument for Adolescent Idiopathic scoliosis	149
	Spinal Appearance Questionnaire	41
	Brace Questionnaire	17
	Early-Onset Scoliosis Questionnaire	17
	Bad Sobernheim Stress Questionnaire	16
	Walter Reed Visual Assessment Scale	7
	Scoliosis Quality of Life Index	4
	Spina Bifida pediatric questionnaire	1

*Most commonly used and covered in our review. NDI - Neck Disability Index; PROM - Patient-reported outcomes measures; ODI - Oswestry Disability Index; RMDQ - Roland-Morris Disability Questionnaire; NASS: North American Spine Society

with QoL measurements such as the 36-item short-form health survey (SF-36) and measurements of mental health symptoms such as depression and anxiety outside of major psychiatric disorders among patients with cervicothoracic spondylosis and associated radiculopathy.[12,49] The NDI form consists of 10 different sections: pain intensity, personal care, lifting, reading, headaches, concentration, work, driving, sleeping, and recreation.[13] Each section is scored 0–5 points, with a higher score associated with a more significant disease burden.[13] When NDI scores were compared to patients' opinions about the surgical outcome for single-level degenerative disc herniation, a score of 7 or less corresponded to a good outcome.[13] Certain variables, such as physical impairments and psychosocial factors, are independently associated with neck disability in patients with cervical spondylotic radiculopathy, and explain 73% of the variance in NDI scores.[15] It has, therefore, been recommended that evaluation for treatment effectiveness should be done by basing it only on the changes in the NDI items that are related to each patient's activity limitations and participation restrictions.[50] Patients should be screened for major depressive disorder, which can have a confounding effect.[15]

The mJOA has demonstrated good responsiveness to postoperative changes in the context of cervicothoracic spondylotic myelopathy and myelopathy secondary to deformity.[51] The original JOA score was developed by the JOA in 1975 but used region-specific markers such as

the ability to use chopsticks to score the participant.[17] The mJOA was modified off and demonstrated a positive correlation with the original JOA scale and assesses four distinct components of cervicothoracic myelopathy: upper and lower limb dysfunction, sensation, and micturition, and is groups scores with 15–17 points, 12–14 points, and 0–11 points indicating mild, moderate, and severe myelopathy, respectively.[17,51] Reports discuss an overall improvement of 9.81–13.8 in patients treated at an 1-year follow-up.[18] A limitation of the mJOA is that it must be administered by a physician, necessitating additional time and resources during ambulatory consultations. Rhee *et al*. evaluated and validated a patient-derived version of the mJOA (p-mJOA) which provide an identical mean scores to the mJOA in assessing myelopathy with low patient burden in completing the survey and added benefit of not requiring a physician to proctor the survey which minimize and remove any potential physician bias.[19]

The NDI and mJOA are both valid and reliable PROMs that we recommend for use in cervicothoracic spine disease. Both PROMs are used today in a variety of cervicothoracic spine disease surgeries, from cervical disc replacement to deformity correction.[52,53] Improvement in myelopathy is a key factor associated with NDI and mJOA score improvement.[14] Studies have also shown that the mJOA and NDI demonstrate a correlation with each other and PROMIS scores, although a significant difference remains between the outcome measures.[16] One study showed that at a 1-year follow-up after cervical deformity corrective surgery, 46% of patients improved in mJOA score, whereas 71.4% demonstrated improvement in NDI score.[54]

Low back pain: Oswestry Disability Index and Roland-Morris disability questionnaire

Low back pain is the leading cause of years lived with disability in both developed and developing countries and is ranked sixth in overall disease burden measured in disability-adjusted life years.[55] A multinational review in 2008, which encompassed 165 studies from 54 countries, found that the mean prevalence of low back pain at any given point in time was 18.3% and that the 1-month prevalence was 30.8%.[56] The two disease-specific PROMs most commonly used to assess functional outcomes are the ODI and the RMDQ. In our PubMed database search, the ODI was associated with 5490 articles and the RMDQ was associated with 964 articles [Table 2]. All other disease-specific PROMs for low back pain were associated with fewer than 400 articles.

The ODI was initially published in 1980 by Fairbank to measure disability in daily living associated with low back pain.[57] The original questionnaire has 10 categories, each with six gradations scored 0–5, for a total possible score of 50. The score is then normalized as a percentage, which can fall under one out of five possible classifications of disability (minimal 0%–20%, moderate 21%–40%, severe 41%–60%, crippling 61%–80%, and 81%+ bedbound).[58] A drop in the ODI of 12.8 points was determined to be the minimum detectable change by Copay *et al*., and a score of 22 or less indicates an adequate treatment of symptoms.[59,60] As a disease-specific measurement, the ODI is more sensitive to change than more general health measures, such as the SF-36, when tracking the effectiveness of treatments.[20] It has also been shown to be a better indicator of improvement in the functional range of motion when compared to a visual analog scale.[21] In addition, the ODI may be useful in the process of determining surgical candidacy. One prospective study on surgical outcomes in upper lumbar disc herniations found that patients with a preoperative ODI in the moderate disability range did not show significant improvement postdiscectomy compared to those with a higher preoperative classification.[22]

There are a few precautions that should be taken when using the ODI in the context of lumbosacral disease. As a PROM, it exhibits a small ceiling effect and large floor effect; that is, ODI is more sensitive to change when following patients with more severe presenting symptoms. Furthermore, as aforementioned, because the ODI is considered a multidimensional measure, there may be confounding factors, such as underlying depression or anxiety, which affects the measure.[23] Besides, although its individual questions have been found to have perfect-to-moderate discriminatory capacity for their specific category, its nature as a composite score does not reveal which particular categories are responsible for a change in score, or if some domains have improved while others have regressed.[24,61] Finally, the ODI is not a comprehensive measure of outcomes pertinent to patients, failing to properly evaluate aspects such as the ability to exercise and participate in leisure activities.[62] Thus, the ODI should not be the sole outcome measure used in practice. Care should be taken to ascertain whether or not an intervention would significantly improve the domains most pertinent to a particular individual.[63] The latest recommended version of the ODI is 2.1b.

The RMDQ is also utilized in lumbosacral pain.[64] Derived from the Sickness Impact Profile, it contains 24 yes/no statements, with a score of 4 points or more indicating disability.[64] The RMDQ has been shown to have greater responsiveness to change when compared to more general health measures, such as the SF-36 and the SF-12.[27] Unlike the ODI, the RMDQ is unidimensional in construct where Its measurements only reflect aspects of physical disability and has poor correlations to psychosocial disabilities arising from back pain.[28,65] Its

measurements only reflect aspects of physical disability and has poor correlations to psychosocial disabilities arising from back pain.[28] Finally, the RMDQ has been found to have a small floor effect but a large ceiling effect, which is opposite to that of the ODI.[26] A recent meta-analysis found that there is no strong evidence to advocate for using either the ODI or the RMDQ over the other for low back pain.[25] However, the floor and ceiling effects of the ODI and RMDQ suggest that the former is more sensitive when tracking changes in patients with more severe disease at baseline, while the latter is more sensitive to changes in patients with milder disease. Clinically, this translates to the ODI being favored in tracking postoperative outcomes, whereas the RMDQ is more effective in monitoring outcomes of physical rehabilitation and conservative therapies. Furthermore, the strengths and weaknesses of these two lower back pain PROMs are complementary, and these tools may be used together for a synergistic effect.

Spinal deformity – Scoliosis Research Society 22-item questionnaire

Scoliosis and other forms of pediatric and adult spinal deformity (ASD) have major effects on QoL secondary to pain, neurological and physical deficits, and psychosocial and practical daily function.[66] ASD can impart extreme disability, with a mean SF-36 value comparable to patients with a multisystemic disease such as diabetes mellitus type 2, cardiovascular disease, and rheumatoid arthritis.[67] As with other spinal pathology, much of the burden of deformity is highly subjective.

Over the years, the SRS has developed tools to allow physicians to classify patients' diseases and provide additional insight into patients' lives and well-being.[68-71] The SRS-22 is used to assess QoL and surgical outcomes in an array of different spinal deformities.[72,73] It consists of 22 questions covering four domains: pain, functioning, self-image, and satisfaction with the surgery.[74] Participants answer either yes or no to a question or in accordance with a Likert scale (from strongly disagree to strongly agree). Each question is scored 1–5 points, with 5 representing the best possible outcome.[36] In our PubMed database search, the SRS-22 was associated with 308 articles [Table 2]. All other disease-specific PROMs for spinal deformity were associated with fewer than 200 articles.

The SRS-22 is a valid and reliable tool that has been extensively studied and compared to biological markers of ASD.[36] The SRS-22 scores for the minimum clinically important difference and substantial clinical benefit have been determined for patients after surgery, and demonstrate a moderate association with clinical and radiographic measurements such as the Cobb angle.[29,30,75] Specifically, the SRS-22 shows a decreased trend at Cobb angles >43°–48°.[30] Markers of sagittal balance, such as the sagittal vertical axis, have a significant correlation with all SRS domains, and pelvic tilt, which describes the orientation of the pelvis in relation to the body, has demonstrated correlation with SRS-22 in function and self-image domains.[31,32]

As with all PROMs, the SRS-22 is based on subjective symptoms and can be impacted by patient characteristics. Age, sex, and ethnicity all have a significant impact on the SRS-22 score secondary to psychosocial and cultural norms and must be considered during evaluation.[35] On average, Caucasians tend to score higher, and Hispanics tend to score lower.[76] Although there has been some concern that taking the questionnaire has negative impacts on the patient's body image, evidence against this was provided by Villamor *et al*. in 2018.[76]

The SRS-22 is responsive to changes in both pediatric and adult scoliosis patients, and is also being used to compare the effects of treatment on patients of different ages.[33,34,77,78] Durand *et al*. examined the relationship between age, lumbar stiffness after fusion surgery and SRS-22 satisfaction score among patients who underwent deformity surgery and he found that the patient satisfaction and SRS-22 score were markedly more associated with lumbar stiffness among younger (<60-years-old) versus older patients (> 60-years-old). Additionally, he reported an inverse relationship between lumbar stiffness and satisfaction rate particularly pronounced among younger patients with low baseline comorbidity burden compare to old patients with multiple comorbidities.[78] Another study compared SRS-22 improvements after scoliosis surgery in older patients versus younger patients and found that older patients trended for greater improvements than younger patients.[79]

Patient-reported outcomes measures *information system*

The PROMIS was recently developed by the National Institutes of Health in an attempt to set a standard for outcome measures.[80] Thus, much of the recent research in PROMs has been focused on comparing PROMIS scores with legacy PROMs.[80] The majority of current literature demonstrates that PROMIS is comparable to existing measures when used in the measurement of pathologies such as cervicothoracic spondylotic radiculopathy and/or myelopathy, lumbosacral spondylosis, and both primary and metastatic spine neoplasms.[80-87] These studies demonstrate moderate-to-strong correlations between PROMIS and legacy PROM domains, with PROMIS offering comparable or improved floor and ceiling effects, similar responsiveness to change, and shorter times required to complete.[80-87] On the other hand, several studies indicate that PROMIS continues

to have room for improvement.[88,89] Bernstein *et al*. found that for ASD, PROMIS and SRS-22 did not have a strong correlation in the domains of Satisfaction and Self-Image/Appearance.[88] In a separate study, Bernstein *et al*. also found that PROMIS demonstrated a markedly increased floor effect compared to the ODI and NDI when evaluating patient depression in the setting of spine neoplasms.[90] However, this result may be partially attributed to "hasty completion" of PROMIS depression questions by patients.[89] In any case, as PROMIS is further developed and refined, future studies utilizing PROMs may see a shift toward utilizing PROMIS, either in conjunction with legacy measures or as the sole device, when capturing outcomes. Nevertheless, legacy PROMs currently have an advantage over PROMIS in that they already have a strong body of research that supports their use.[80-87]

Cost-effectiveness and quality of care

In an age where hospitals and physicians are moving toward a system of value-based care, numerous PROMs have been proposed to measure the quality of the care being received. Whereas measures such as NDI, mJOA, and RMDQ have proven to be accurate measures of functional outcomes of patients after surgical intervention, other measures such as patient satisfaction surveys, the Euro-Qol-5D (EQ-5D), and the SF-12for physical and mental components (SF-12 PCS and SF-12 MCS, respectively) have been proposed to highlight the treatment effectiveness and general quality of care over time.

Patient satisfaction surveys are seen as less cumbersome ways to evaluate the quality of care and are often considered valuable indices of performance.[91] Reimbursements are often tied to such surveys, as these can provide evaluators with a quick "snap-shot" view of treatment effectiveness.[45,92] Health-care systems are often evaluated by the public and industry based on patient satisfaction surveys, with the implication that better patient surveys equate to a higher quality of care.[93-95] However, given the relative subjectivity of such surveys and the wide-ranging difference in how the public defines "satisfaction," patient satisfaction surveys have come under criticism from the medical establishment.[94,96] For instance, Godil *et al*. concluded that patient satisfaction surveys of physicians and treatment are not an accurate predictor of the quality, safety, and effectiveness of care but rather an evaluation of the service of care.[96]

Furthermore, Fenton *et al*. associated high patient satisfaction scores with increased utilization of hospital resources and increased mortality, suggesting that these surveys may be problematic in evaluating the quality of care.[94] However, patient satisfaction surveys are not PROMs and should not be used in lieu of them, such as ODI for functionality and EQ-5D for QoL measurements. Godil *et al*. contend that the functionality of such surveys must be clear to both patient and the provider.[96]

Besides, the nature of spine surgeries and low back pain produces numerous confounding factors that may skew patient surveys.[96] For example, patients may have developed a drug tolerance from chronic medical treatment of low back pain. Surgery, while improving functionality, may additionally cause withdrawal symptoms that may be very unpleasant for the patient during recovery and can be reflected in patient satisfaction surveys.[96] The wide ranging mental statuses of patients before and after a procedure can also skew patient satisfaction surveys.[53] Some studies have shown that anxious or depressed patients may have poorer outcomes after undergoing spine surgery.[97-99] To counteract this circumstance, Elsamadicy *et al*. have contended that pretreatment of depression and anxiety before cervical spine surgery is necessary for improving clinical outcomes and the patient's perception of postoperative health status.[100] Our overall viewpoint is that while patient satisfaction surveys are an important source of patient feedback, we must reiterate that they should not be used in place of PROMs in evaluating treatment outcomes or the quality of medical care.

As mentioned previously, different PROMs are used to evaluate the success of treatment on different aspects of a patient's life, from functional improvement to pain, to QoL improvements. It should be noted that improvements in one aspect may not signify a concurrent improvement in others. Therefore, despite the additional time and resource cost, it is advisable that more than one PROM be used to completely capture the patient's improvement following medical or surgical intervention. Besides, different QoL measures should be utilized for different parts of the spine. When evaluating cervical spine surgery, SF-12 PCS has been shown to be an accurate measurement of meaningful improvement with higher responsiveness compared with EQ-5D and SF-12 MCS.[97,101] Singh *et al*. have stated that both the SF-12 and the expanded 36-question SF-36 are sensitive to physical and mental health status changes in patients undergoing decompressive surgery.[102] In contrast, the EQ-5D was seen as a more accurate measure in lumbar spine surgery for postoperative improvement in QoL.[99,103,104]

Final recommendations

In light of the available literature, we recommend both the already widely used NDI and the mJOA as optimal PROMs to be used for cervicothoracic spine disease. We recommend the ODI and RMDQ for lumbar disease and lower back pain requiring surgical intervention: the ODI may be more suited for severe diseases and the RMDQ for mild-to-moderate

lumbar spine disease. Finally, we recommend the SRS-22 for spinal deformity. Each PROM has longstanding proven efficacy and validity as well as strong correlations with objective and biological outcomes.

PROMs are valid and reliable tools that provide a common language for clinicians and researchers to evaluate the effectiveness of specific treatments. They can be useful to measure outcomes of the greatest importance for patients, caregivers, and providers for disorders of the spine, and they provide objective means to compare the effectiveness of various treatments. While the PROMs discussed above have been considered standard of care, PROMIS is a standardized system of reporting health measures, which has recently been shown to be noninferior or superior to older counterparts in many spine pathologies. Further validation and improvement of this system may lead to more precise studies on the relative effectiveness of surgical interventions and on selecting proper surgical candidates.

CONCLUSION

PROMs help physicians assess subjective outcomes in standard ways, more uniquely tailor treatment to individual patients, and engage patients in their medical care. We provide a comprehensive overview of the most popular and efficient PROMs used at different levels of the spine via a systematic literature review. Available literature suggests limited yet effective use of PROMs targeting specific classes of surgically amenable spinal disease. We advocate for increased use of PROMs in spine surgery in both the research and clinical settings.

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Conflicts of interest
There are no conflicts of interest.

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