# Comparing Utility Scores in Common Spinal Radiculopathies: Results of a Prospective Valuation Study

Nikhil R. Nayak[1] James H. Stephen[1] Kalil G. Abdullah[1] Sherman C. Stein[1] Neil R. Malhotra[1]

[1] Department of Neurosurgery, Hospital of the University of Pennsylvania, Philadelphia, Pennsylvania, United States

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**Address for correspondence** Neil R. Malhotra, MD, Department of Neurosurgery, Hospital of the University of Pennsylvania, 3400 Spruce Street, 3 Silverstein Pavilion, Philadelphia, PA 19104, United States (e-mail: neil.malhotra@uphs.upenn.edu).

## Abstract

**Study Design** Prospective observational study.

**Objective** To determine whether preference-based health utility scores for common spinal radiculopathies vary by specific spinal level.

**Methods** We employed a standard gamble study using the general public to calculate individual preference-based quality of life for four common radiculopathies: C6, C7, L5, and S1. We compared utility scores obtained for each level of radiculopathy with analysis of variance and *t* test. Multivariable regression was used to test the effects of the covariates age, sex, and years of education. We also reviewed the literature for publications reporting EuroQol-5 Dimensions (EQ-5D) scores for patients with radiculopathy.

**Results** Two hundred participants were included in the study. Average utility for the four spinal levels fell within a narrow range (0.748 to 0.796). There were no statistically significant differences between lumbar and cervical radiculopathies, nor were there significant differences among the different spinal levels ($F = 0.0850$, $p = 0.086$). Age and sex had no significant effect on utility scores. There was a significant correlation between years of education and utility values for S1 radiculopathy ($p = 0.037$). On review of the literature, no study separated utility values by specific spinal level. EQ-5D utilities for both cervical and lumbar radiculopathy were considerably lower than the results of our study.

**Conclusions** Utility values associated with the most common levels of cervical and lumbar radiculopathy do not significantly differ from each other, validating the current practice of grouping utility by spinal segment rather than by specific root levels. The discrepancy in average utility values between our study and the EQ-5D highlights the need to be mindful of the underlying instruments used when assessing outcomes studies from different sources.

**Keywords**
- radiculopathy
- standard gamble
- quality of life
- HRQoL
- EQ-5D



## Introduction

Spine-related ailments are a major cause of morbidity and lost productivity in the United States, affecting nearly 33 million people per year.[1] Although multiple spine-related symptoms often coexist, the individual symptomatic components can be broadly divided into those that cause axial pain, central neural dysfunction (myelopathy, neurogenic claudication), and nerve root dysfunction (radiculopathy). The term

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*radiculopathy* refers to the varying degrees of pain, sensory changes, and motor weakness associated with irritation of spinal nerves.

Etiologies of radiculopathy are numerous and include compression from herniated intervertebral disks, degenerative overgrowth, spinal instability, and certain autoimmune and metabolic disorders.[2–5] It is a common condition, affecting up to 5% of the population, with equal distribution among men and women.[6] The most common nerve roots affected in the cervical spine are C6 and C7, and extrapolating from the literature on herniated lumbar disks, the majority of lumbosacral radiculopathies are L5 and S1.[7,8] The treatment includes both nonoperative modalities (e.g., physical therapy, epidural steroid injections) and surgical intervention, depending on the causal pathophysiology, degree of debilitation, and duration of symptoms.

The most common surgical treatment for radiculopathy involves decompression of the affected nerve root by removing variable amounts of bone, ligament, and herniated disk material. This treatment constitutes the fifth most commonly performed surgery in U.S. hospitals with over 500,000 performed annually,[9] a figure that does not include the scores of patients with recalcitrant radiculopathy treated with spinal fusion surgery. Spinal fusion is the single most expensive surgical procedure in terms of aggregate costs, accounting for $12.8 billion spent on index hospitalization costs in the United States annually.[9] Therefore, it is no surprise that these procedures have been subject to numerous comparative and cost-effectiveness studies.

The primary outcome instruments used in effectiveness studies quantify three major categories of patient-reported outcomes: global health-related quality of life (HRQoL), pain, and disease-specific disability. Although multiple disease-specific disability instruments exist for spinal conditions, such as the Oswestry Disability Index for low back pain and the Neck Disability Index for neck pain, there is no widely used radiculopathy-specific disability instrument. Pain is highly subjective and varies tremendously from patient to patient, thus the most reliable tools with which to compare patients with radiculopathy are global HRQoL instruments.

## Global HRQoL Instruments and Valuation Techniques

“Preference-based” instruments are a specific subtype of HRQoL measures used to derive utility scores, which generally range from 0 (death) to 1 (perfect health), although negative numbers may be reported and reflect health states deemed to be worse than death.[10] The utility scores obtained from these instruments are generated from studies of the general public employing valuation techniques such as the visual analog scale (VAS), time trade-off (TTO), and standard gamble (SG) methods.[11] Because the general public is surveyed, rather than only individuals afflicted with the specific disease state, such studies provide a “societal perspective” of utility.

The VAS is a line with two anchors usually being death (e.g., 0) and perfect health (e.g., 100) and asks responders to rate various health states as a single mark on the line. The TTO method presents the participant with a written description of a health state under evaluation and then presents the hypothetical choice of living for $X$ years in the described state, or a shorter amount of time, $Y$ years, in perfect health. The utility of the described health state is $Y/X$. For example, if the participant would rather live 5 years in perfect health than 10 years with severe low back pain, the utility for severe low back pain would be $5/10 = 0.5$.

Finally, the SG method presents participants with a choice of two alternatives: (1) a definite health state $A$ (e.g., severe low back pain) and (2) a hypothetical gamble, resulting in two possible health states (usually perfect health, $B$, or death, $C$). Participants are asked what probability of death they would accept for a chance at perfect health. For example, if the responder was indifferent between having severe low back pain ($A$) and a 30% probability of death, the utility of the severe low back pain state would be $1 - C = 0.7$.

“Direct measures” of utility involve surveying participants directly using the above valuation techniques, and “indirect measures” of utility take the form of standardized surveys not specific to any particular disease. The two most commonly used indirect utility instruments in the spine literature are the EuroQol-5 Dimensions (EQ-5D) and Short-Form (SF) surveys. The SF surveys have multiple iterations, the most common of which is the non-preference-based SF-36. The shorter, preference-based SF-6D was developed to directly generate utility scores, and because they involve the same questions, the SF-36 can be mapped to the SF-6D to derive utility scores. Utility values for these instruments depend on population-specific value sets used to derive the score. For the EQ-5D U.S. ($n = 4{,}048$) and United Kingdom ($n = 3{,}395$) value sets, scoring was performed using a TTO method.[12,13] The original SF-6D value set was developed using a SG study of 611 United Kingdom participants.[14] Studies on nonspinal diseases, such as coronary artery disease and osteoarthritis, have identified that utility values can vary widely between the two instruments and therefore they may not be interchangeable.[15,16]

Because of the disparate utility values generated from different instruments, researchers must specify which instrument was used to generate the data. In a similar vein, it may be useful for outcomes studies on radiculopathy to delineate the specific radiculopathies being treated and their associated utility values because different levels of radiculopathy present with different symptoms and disability. Although many studies present a breakdown of the affected spinal levels, they do not distinguish whether there are differences in utility by level, but rather group all patients as either having or not having radicular symptoms in a certain spinal segment (cervical, thoracic, lumbar). It is possible that different levels of radiculopathy (e.g., C6 versus C7) may be associated with different utility values, which would have implications for comparative outcomes research.

To clarify this void in knowledge, we conducted an SG study on the general public (a direct measure of utility) to assess the preference-based health utility between specific levels of spinal radiculopathy and compared our results to indirectly measured utility values identified in the literature.

## Materials and Methods

We employed the SG approach to calculate the individual preference-based HRQoL (utility values) for various radiculopathies.[17] Randomly chosen individuals on and around the campus of the University of Pennsylvania (community members) were interviewed and presented scenarios for each of four radiculopathies: C6, C7, L5, and S1. These scenarios (►**Supplementary Table 1** *[online only]*) were designed to explain typical clinical examples of the radiculopathy in question and were administered in random order. In the SG script (►**Supplementary Table 2** *[online only]*), subjects make hypothetical choices between taking a gamble with a variable risk of obtaining perfect health or immediate death versus spending a lifetime in the impaired health state. The utility for the health state is valued at 1 minus the risk of death at which the subject is indifferent between the two options. Individual responses were scored between 0 and 1. Age, sex, and years of education were also recorded for each subject. A waiver for the study was issued by the Hospital of the University of Pennsylvania Institutional Review Board.

We calculated the means and standard deviations for the utility scores obtained for each of the four radiculopathy levels. The utility values of the different spinal levels were compared using analysis of variance with the Bonferroni correction for multiple comparisons. The adjacent levels within each spinal segment (cervical, lumbar) were compared using the Student *t* test. Multivariable linear regression was used to test the effects of the covariates age, sex, and years of education for each radiculopathy. All statistical analyses employed Stata v.12 (StataCorp, College Station, Texas, United States). Differences for which the probability was $<0.05$ were considered significant.

We also reviewed the literature for publications reporting EQ-5D utility scores for patients with cervical and lumbar radiculopathy. We limited our search to PubMed-indexed English-language articles published between 2000 and December 2014 that contained preoperative utility scores. We supplemented the search by using the "Related Articles" feature of PubMed and by manually searching the bibliographies of selected articles. If multiple studies were published from the same institution or utilizing the same database, only the largest study was included to avoid redundancy.

## Results

Two hundred community members were interviewed and included in the study; the demographics are summarized in ►**Table 1**. The average participant was 36.7 years with 16.2 years of education. The results of the SG for the four levels of radiculopathy are summarized in ►**Table 2**. The average utility values for the four spinal levels fell within a narrow range (0.748 to 0.796), with L5 radiculopathy resulting in the lowest utility and C7 radiculopathy resulting in the highest utility. There were no statistically significant differences in utility between lumbar and cervical radiculopathies, nor were there significant differences among the different spinal levels ($F = 0.0850$, $p = 0.086$). Correlations between the demographic factors and utility for each radiculopathy are summarized in ►**Table 3**. Sex and age had no significant effect on utility scores. There was a significant correlation between years of educations and the utility values for S1 radiculopathy ($p = 0.037$), as illustrated in ►**Fig. 1**.

**Table 1** Demographics of subjects

| Parameter | Mean | SD |
|---|---|---|
| Female sex (%) | 58.5 | |
| Age (y) | 36.7 | 18.2 |
| Education (y) | 16.2 | 2.5 |

Abbreviation: SD, standard deviation.

Multiple studies were identified with preoperative EQ-5D utility data for patients with radiculopathy and are detailed in ►**Table 4**. No study separated the utility values by specific spinal levels. For the EQ-5D, the median ages of subjects with lumbar and cervical radiculopathy were 44 and 49.3, respectively. The average preoperative utility ranged from 0.21 to 0.51 for lumbar radiculopathy and 0.55 to 0.59 for cervical radiculopathy. The postoperative utility values ranged from 0.58 to 0.87 for lumbar radiculopathy and 0.69 to 0.72 for cervical radiculopathy.

For reference, the EQ-5D utility scores range from $-0.594$ to 1, depending on the population-specific value set used.

## Discussion

The results of this study suggest that based on an SG survey of the general public, there are no significant differences in the utility values between the four most common levels of radiculopathy. Although functional disability varies by the affected nerve root, the contribution of pain may overshadow disability in terms of global HRQoL. On average, the participants were willing to undertake a 23% risk of death to be restored to perfect health from the described radiculopathy states. Additionally, age and sex did not play a role in how the participants valued each disease state. However, the utilities derived from our study were notably higher than those described in the literature based on the EQ-5D. Because of this finding, patients completing the EQ-5D have more potential for improvement than the theoretical maximum gain in utility of 0.23 among our study population. These differences would make the cost-utility ratios appear more favorable using the EQ-5D compared with our SG results.

**Table 2** Utility of radiculopathy

| Level | Mean utility | SD |
|---|---|---|
| C6 | 0.780 | 0.197 |
| C7 | 0.796 | 0.191 |
| L5 | 0.748 | 0.199 |
| S1 | 0.764 | 0.197 |

Abbreviation: SD, standard deviation.

**Table 3** Correlations with utility (*p* value)

| Variable | Level | | | |
|---|---|---|---|---|
| | C6 | C7 | L5 | S1 |
| Sex | 0.584 | 0.465 | 0.713 | 0.921 |
| Age | 0.572 | 0.357 | 0.659 | 0.813 |
| Years of education | 0.196 | 0.453 | 0.084 | 0.037 |

There may be several reasons for the observed differences between our study and the literature. The most obvious source is that the patients in the literature experienced radiculopathy that warranted surgical intervention. Had we studied patients successfully treated with nonoperative measures, the results may have been different. Additionally, results from the SG method depend on the risk profile of the participants surveyed. If we assume that most individuals are risk averse, the utility scores will therefore be higher. The most commonly used EQ-5D value sets are based on TTO valuations, a method that does not present the participants with risk. Furthermore, the average age for our study population was ~37 years old, considerably younger than the median ages of 44 and 49.3 for lumbar and cervical radiculopathies, respectively, for the EQ-5D. Health values have been linked to age, sex, and current health state,[18] and although radiculopathy affects patients of all ages, the younger age of our cohort suggests they may have less overall disease burden than those profiled in the literature.

King et al performed SG and TTO utility studies in patients with diagnosed cervical myelopathy and found that a better current health state was associated with assigning higher utility values for theoretical disease states.[19] If the same holds true to our sample population, we would expect our cohort to rate the theoretical health states higher than those who actually have the disease, which is in line with our findings. On the other hand, patients with poorer health status have been found to provide higher valuations of their own disease state,[20] as evidenced by patients on renal dialysis,[18] which would be contradictory to our findings. In this scenario, we would expect that the patients profiled in the literature, who actually underwent surgical intervention for radiculopathy, to have rated their disease states higher than they actually did. Nevertheless, we do not have detailed knowledge of the health states and comorbidities of our sample population or the patients in the literature, although those variables may have had an effect in one direction or another.

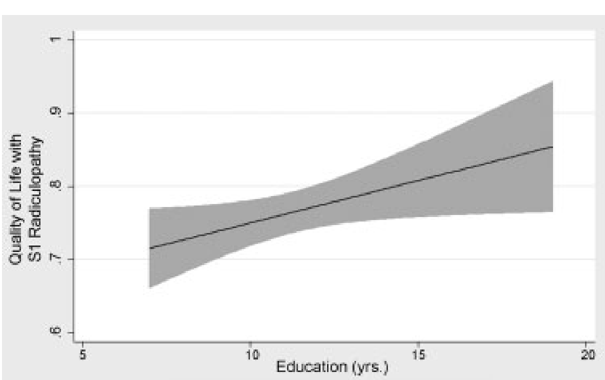


**Fig. 1** Linear regression of quality of life with S1 radiculopathy, plotted against years of education of interviewee. The line represents the fitted mean values, the gray area the 95% confidence intervals.

Another possible reason for the discrepancy is a fundamental difference between the valuation derived via indirect, generic assessment questions in the EQ-5D and the targeted scenarios presented in the SG, which focus directly on disease-specific pain and disability. Prior studies on spinal conditions such as cervical myelopathy and chronic low back pain have found that the utilities derived from primary SG and TTO surveys are higher than those obtained from the EQ-5D.[21,22] Carreon et al studied the relationship between the disease-specific disability instruments and the HRQoL instruments. In two studies of over 3,700 patients with degenerative cervical spine disorders and 14,500 patients with degenerative lumbar conditions undergoing surgical treatment, the authors could not accurately predict EQ-5D scores from Neck Disability Index, Oswestry Disability Index, or VAS scores.[23,24] For unclear reasons, however, when the same group performed similar studies using the SF-6D, they were able to develop models with a reasonable degree of accuracy.[25,26]

Within the published spine literature, reporting HRQoL using the SF-36 is actually more common than with the EQ-5D, although most studies utilizing the SF-36 report individual domain subscores or component summary scores, which are not directly comparable to utility scores. However, the SF-36 can be mapped to the preference-based SF-6D to derive utility scores. We could only identify a single study with radiculopathy-specific SF-6D utility values. Mummaneni et al evaluated 148 patients undergoing lumbar diskectomy for radiculopathy who presented with a mean preoperative utility of 0.517.[27] We could not identify any studies providing SF-6D utility values specific to cervical radiculopathy. Two studies on cervical myelopathy and nonspecific cervical degenerative disk disease, which presumably would include many patients with coexisting radiculopathy, reported preoperative values of 0.575 and 0.55, respectively.[28,29]

There are multiple limitations in the current study. The participants in our survey were all recruited from a single city in the Northeastern United States. Additionally, our sample population was younger and had a high average level of

**Table 4** Recent studies reporting EQ-5D values for cervical and lumbar radiculopathy patients

| First author | Year | Country | Disease | Procedure | Instrument | *n* | Mean age (y) | Preoperative utility | Postoperative utility |
|---|---|---|---|---|---|---|---|---|---|
| Hansson[30] | 2007 | Sweden | Lumbar radiculopathy | Lumbar diskectomy | EQ-5D | 92 | 43 | 0.403 | 0.628 |
| Tosteson[31] | 2008 | USA | Lumbar radiculopathy | Lumbar diskectomy | EQ-5D | 775 | 40.7 | 0.49 ± 0.20 | 0.82 |
| Zweig[32] | 2012 | Switzerland | cLBP with radiculopathy | 1-level lumbar disk arthroplasty | EQ-5D | 313 | 42.5 | 0.29 | 0.706 |
| Parker[33] | 2013 | USA | Lumbar radiculopathy | Hemilaminectomy | EQ-5D | 54 | 57 | 0.51 ± 0.27 | 0.87 |
| Solberg[34] | 2013 | Norway | Lumbar radiculopathy | Lumbar diskectomy | EQ-5D | 692 | 46 | 0.26 ± 0.35 | – |
| Godil[35] | 2013 | USA | Neck pain with radiculopathy | ACDF | EQ-5D | 88 | 52.3 | 0.59 ± 0.22 | – |
| Fritzell[36] | 2014 | Sweden | Lumbar radiculopathy | Lumbar diskectomy | EQ-5D | 13,305 | 44 | 0.26 ± 0.34 | – |
| Fritzell[36] | 2014 | Sweden | Lumbar radiculopathy | Revision lumbar diskectomy | EQ-5D | 257 | 43 | 0.21 ± 0.32 | – |
| Lubelski[37] | 2014 | USA | Lumbar radiculopathy | Lumbar diskectomy | EQ-5D | 116 | 49 | 0.46 ± 0.20 | 0.71 |
| Lubelski[37] | 2014 | USA | Lumbar radiculopathy | Revision lumbar diskectomy | EQ-5D | 80 | 56.8 | 0.40 ± 0.20 | 0.58 |
| Alvin[38] | 2014 | USA | 1-level cervical radiculopathy | ACDF | EQ-5D | 45 | 49.3 | 0.55 | 0.69 |
| Alvin[38] | 2014 | USA | 1-level cervical radiculopathy | Posterior cervical foraminotomy | EQ-5D | 25 | 46.5 | 0.57 | 0.72 |

Abbreviations: ACDF, anterior cervical diskectomy and fusion; cLBP, chronic low back pain; EQ-5D, EuroQol-5 Dimensions.

education than the patients with radiculopathy identified in the literature. There is also potential selection bias because of their recruitment from the campus of a university and its surrounding neighborhoods. Finally, detailed information on survey participants' comorbidities had not been recorded, thus there is patient heterogeneity both among our study population and populations in the literature. These factors may limit the comparability of the two populations and the generalizability of the results.

Despite the limitations, the results of this study are nevertheless important because they demonstrate that from a societal perspective, the utility values associated with the most common levels of cervical and lumbar radiculopathy do not significantly differ from each other. These findings provide validation for the current practice of grouping the utility values for radiculopathy by spinal segment rather than by specific root levels. Additionally, the discrepancy between the average utility values elicited from our study and those derived from the EQ-5D highlights the need to be mindful of the instruments used when assessing comparative and cost-effective studies from different sources. The variations due to the disparate instruments may result in vastly different comparative outcomes results. Understanding the sources of variation and developing methods to better compare the different instruments will be increasingly important as patient-reported outcomes play a growing role in clinical research and health policy.

Disclosures
Nikhil R. Nayak, none
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Neil R. Malhotra, none

## References

1 Martin BI, Deyo RA, Mirza SK, et al. Expenditures and health status among adults with back and neck problems. JAMA 2008;299(6): 656–664
2 Bush K, Cowan N, Katz DE, Gishen P. The natural history of sciatica associated with disc pathology. A prospective study with clinical and independent radiologic follow-up. Spine (Phila Pa 1976) 1992; 17(10):1205–1212
3 Denard PJ, Holton KF, Miller J, et al; Osteoporotic Fractures in Men (MrOS) Study Group. Back pain, neurogenic symptoms, and physical function in relation to spondylolisthesis among elderly men. Spine J 2010;10(10):865–873
4 Komori H, Shinomiya K, Nakai O, Yamaura I, Takeda S, Furuya K. The natural history of herniated nucleus pulposus with radiculopathy. Spine (Phila Pa 1976) 1996;21(2):225–229
5 Polston DW. Cervical radiculopathy. Neurol Clin 2007;25(2):373–385
6 Tarulli AW, Raynor EM. Lumbosacral radiculopathy. Neurol Clin 2007;25(2):387–405
7 Deyo RA, Rainville J, Kent DL. What can the history and physical examination tell us about low back pain? JAMA 1992;268(6): 760–765
8 Radhakrishnan K, Litchy WJ, O'Fallon WM, Kurland LT. Epidemiology of cervical radiculopathy. A population-based study from Rochester, Minnesota, 1976 through 1990. Brain 1994;117; (Pt 2):325–335
9 Weiss AJ, Elixhauser A, Andrews RM. Characteristics of Operating Room Procedures in U.S. Hospitals, 2011. HCUP Statistical Brief #170. Rockville, MD: Agency for Healthcare Research and Quality; February 2014. Available at: https://www.hcup-us.ahrq.gov/reports/statbriefs/sb170-Operating-Room-Procedures-United-States-2011.pdf
10 Walters SJ, Brazier JE. Comparison of the minimally important difference for two health state utility measures: EQ-5D and SF-6D. Qual Life Res 2005;14(6):1523–1532
11 Green C, Brazier J, Deverill M. Valuing health-related quality of life. A review of health state valuation techniques. Pharmacoeconomics 2000;17(2):151–165
12 Johnson JA, Luo N, Shaw JW, Kind P, Coons SJ. Valuations of EQ-5D health states: are the United States and United Kingdom different? Med Care 2005;43(3):221–228
13 Kind P, Hardman G, Macran S. UK Population Norms for EQ-5D. Vol. 172;York, UK: Centre for Health Economics, University of York; 1999
14 Ware JE Jr, Sherbourne CD. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. Med Care 1992;30(6):473–483
15 Sach TH, Barton GR, Jenkinson C, Doherty M, Avery AJ, Muir KR. Comparing cost-utility estimates: does the choice of EQ-5D or SF-6D matter? Med Care 2009;47(8):889–894
16 van Stel HF, Buskens E. Comparison of the SF-6D and the EQ-5D in patients with coronary heart disease. Health Qual Life Outcomes 2006;4:20
17 Morgenstern O, Von Neumann J. Theory of Games and Economic Behavior. Princeton, NJ: Princeton University Press; 1953
18 Sackett DL, Torrance GW. The utility of different health states as perceived by the general public. J Chronic Dis 1978;31(11): 697–704
19 King JT Jr, Tsevat J, Roberts MS. Positive association between current health and health values for hypothetical disease states. Med Decis Making 2004;24(4):367–378
20 Dolan P. The effect of experience of illness on health state valuations. J Clin Epidemiol 1996;49(5):551–564
21 King JT Jr, Tsevat J, Moossy JJ, Roberts MS. Preference-based quality of life measurement in patients with cervical spondylotic myelopathy. Spine (Phila Pa 1976) 2004;29(11):1271–1280
22 Wetherington S, Delong L, Kini S, et al. Pain quality of life as measured by utilities. Pain Med 2014;15(5):865–870
23 Carreon LY, Bratcher KR, Das N, Nienhuis JB, Glassman SD. Estimating EQ-5D values from the Neck Disability Index and numeric rating scales for neck and arm pain. J Neurosurg Spine 2014;21(3): 394–399
24 Carreon LY, Bratcher KR, Das N, Nienhuis JB, Glassman SD. Estimating EQ-5D values from the Oswestry Disability Index and numeric rating scales for back and leg pain. Spine (Phila Pa 1976) 2014;39(8):678–682
25 Carreon LY, Anderson PA, McDonough CM, Djurasovic M, Glassman SD. Predicting SF-6D utility scores from the neck disability index and numeric rating scales for neck and arm pain. Spine (Phila Pa 1976) 2011;36(6):490–494
26 Carreon LY, Glassman SD, McDonough CM, Rampersaud R, Berven S, Shainline M. Predicting SF-6D utility scores from the Oswestry disability index and numeric rating scales for back and leg pain. Spine (Phila Pa 1976) 2009;34(19):2085–2089
27 Mummaneni PV, Whitmore RG, Curran JN, et al. Cost-effectiveness of lumbar discectomy and single-level fusion for spondylolisthesis: experience with the NeuroPoint-SD registry. Neurosurg Focus 2014;36(6):E3
28 Fehlings MG, Jha NK, Hewson SM, Massicotte EM, Kopjar B, Kalsi-Ryan S. Is surgery for cervical spondylotic myelopathy cost-effective? A cost-utility analysis based on data from the AOSpine North

America prospective CSM study. J Neurosurg Spine 2012;17(1, Suppl):89–93
29 Skolasky RL, Carreon LY, Anderson PA, Albert TJ, Riley LH III. Predicting health-utility scores from the Cervical Spine Outcomes Questionnaire in a multicenter nationwide study of anterior cervical spine surgery. Spine (Phila Pa 1976) 2011;36(25):2211–2216
30 Hansson E, Hansson T. The cost-utility of lumbar disc herniation surgery. Eur Spine J 2007;16(3):329–337
31 Tosteson AN, Skinner JS, Tosteson TD, et al. The cost effectiveness of surgical versus nonoperative treatment for lumbar disc herniation over two years: evidence from the Spine Patient Outcomes Research Trial (SPORT). Spine (Phila Pa 1976) 2008;33(19):2108–2115
32 Zweig T, Aghayev E, Melloh M, Dietrich D, Röder C; SWISSspine Registry Group. Influence of preoperative leg pain and radiculopathy on outcomes in mono-segmental lumbar total disc replacement: results from a nationwide registry. Eur Spine J 2012;21(6, Suppl 6):S729–S736
33 Parker SL, Adogwa O, Davis BJ, et al. Cost-utility analysis of minimally invasive versus open multilevel hemilaminectomy for lumbar stenosis. J Spinal Disord Tech 2013;26(1):42–47
34 Solberg T, Johnsen LG, Nygaard ØP, Grotle M. Can we define success criteria for lumbar disc surgery? Estimates for a substantial amount of improvement in core outcome measures. Acta Orthop 2013;84(2):196–201
35 Godil SS, Parker SL, Zuckerman SL, Mendenhall SK, McGirt MJ. Accurately measuring the quality and effectiveness of cervical spine surgery in registry efforts: determining the most valid and responsive instruments. Spine J 2015;15(6):1203–1209
36 Fritzell P, Knutsson B, Sanden B, Strömqvist B, Hägg O. Recurrent versus primary lumbar disc herniation surgery: patient-reported outcomes in the Swedish Spine Register Swespine. Clin Orthop Relat Res 2015;473(6):1978–1984
37 Lubelski D, Senol N, Silverstein MP, et al. Quality of life outcomes after revision lumbar discectomy. J Neurosurg Spine 2015;22(2):173–178
38 Alvin MD, Lubelski D, Abdullah KG, Whitmore RG, Benzel EC, Mroz TE. Cost-utility analysis of anterior cervical discectomy and fusion with plating (ACDFP) versus posterior cervical foraminotomy (PCF) for patients with single-level cervical radiculopathy at 1-year follow-up. J Spinal Disord Tech 2014