The Spine Journal 18 (2018) 1552–1557

Clinical Study

Cost-utility analysis of cervical deformity surgeries using 1-year outcome

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Received 30 August 2017; revised 5 January 2018; accepted 19 January 2018

Abstract

BACKGROUND CONTEXT: Cost-utility analysis, a special case of cost-effectiveness analysis, estimates the ratio between the cost of an intervention to the benefit it produces in number of quality-adjusted life years. Cervical deformity correction has not been evaluated in terms of cost-utility and

FDA device/drug status: Not applicable.

Author disclosures: ***GWP:*** Nothing to disclose. ***PGP:*** Grant: DePuy Synthes (F); Consulting: Medicrea (E), SpineWave (D); Speaking and/orTeaching Arrangements: Zimmer Biomet (C); Research Support (Investigator Salary,Staff/Materials): CSRS (E, pertaining to the submitted work). ***RQ:*** Nothing to disclose. ***HH:*** Consulting: NuVasive (C, Paid directly to institution/employer); Research Support (Investigator Salary, Staff/Materials): Pfizer (F, Paid directly to institution/employer); Grants: Orthofix (B, Paid directly to institution/employer, outside the submitted work). ***SH:*** Nothing to disclose. ***CB:*** Nothing to disclose. ***FS:*** Nothing to disclose. ***AJ:*** Nothing to disclose. ***MK:*** Grants: Cervical Spine Research Society (C, Paid directly to institution/employer), Barnes Jewish Foundation (C, Paid directly to institution/employer), Orthopedic Research and Education Foundation (C, Paid directly to institution/employer), CeraPedics (B, Paid directly to institution/employer), PCORI (E, Paid directly to institution/employer), AOSpine (PEEDS) (B, Paid directly to institution/employer); Fellowship Support: AOSpine (F, Paid directly to institution/employer), OREF (D, Paid directly to institution/employer), Omega (D, Paid directly to institution/employer, outside the submitted work). ***RH:*** Grant: Nuvasive, Inc (F, Paid directly to institution/employer), DePuy Spine (F, Paid directly to institution/employer), K2M (C, Paid directly to institution/employer); Support for travel to meetings for the study or other purposes: DePuy Spine (A); Consulting: DePuy Spine (D). ***CA:*** Royalties: Stryker (F), Zimmer Biomet (F), DePuy (F); Consulting: DePuy Synthes (C), Medtronic (C), Stryker (C), outside the submitted work. ***JS:*** Zimmer Biomet: consulting (F), royalties (D), Nuvasive: consulting (D), K2M: consulting (C), NREF: grants for fellowship support (E), AOSpine: grants for fellowship support (E), DePuy Synthes: research grants (D), Cerapedics: consultant (C), outside the submitted work. ***VL:*** Grant: DePuy Synthes (F, pertaining to the submitted work); Stock Ownership: Nemaris (nonfinancial); Speaking and/or Teaching Arrangements: DePuy Synthes (B), NuVasive (B), K2M (B), Medtronic (B); Board of Directors: Nemaris (nonfinancial), outside the submitted work. ***DB:*** Grant: DePuy Synthes (H, Paid directly to institution/employer), pertaining to the submitted work; Royalties: DePuy Synthes (C, Paid directly to institution/employer); Consulting: DePuy Synthes (B); Board of Directors: University of Kansas Physicians, Inc (0), International Spine Study Group (ISSG) (0); Research Support (Investigator Salary, Staff/Materials): DePuy Synthes (B, Paid directly to institution/employer). ***SB:*** Grant: DePuy Synthes, (F, pertaining to the submitted work); Royalties: K2 (B), Pioneer (B), Innovasis (nonfinancial), NuVasive (B); Consulting: K2, Allosource; Research Support (Investigator Salary, Staff/Materials): K2, Innovasis (F), NuVasive (D), DePuy Synthes (F), Stryker (E), outside the submitted work. ***CS:*** Grant: DePuy Synthes, pertaining to the submitted work (F); Royalties: Biomet (F), Medtronic (F); Nuvasive (F) Stock Ownership: NuVasive (G); Consulting: Biomet (B), Medtronic (C), NuVasive (B), Globus (C), Stryker (B); Board of Directors: ABNS (B), CSRF (nonfinancial); Grants: NIH (E), Department of Defense (E), AO (E), NREF (E), NACTIN (E) Fellowship Support: NREF (E), AO (E), University of Virginia (nonfinancial) ***FS:*** Grant: DePuy Synthes (F, pertaining to the submitted work); Royalties: K2M (E), MSD(C); Stock Ownership: Nemaris; Speaking and/or Teaching Arrangements: Zimmer Biomet (D), NuVasive (D), K2M (C), MSD (D), Medicrea (C); Board of Directors: Nemaris (nonfinancial); Grants: SRS (E, outside the submitted work). ***MG:*** Royalties: DePuy (G); Stock Ownership: Johnson & Johnson (100 shares), Proctor and Gamble (100 shares); Consulting: DePuy (D), Orthofix (D); Speaking and/or Teaching Arrangements: DePuy (B); Trips/Travel: DePuy (D), Orthofix (B, outside the submitted work).

The database used to conduct this study was created with financial support from DePuy Synthes.

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https://doi.org/10.1016/j.spinee.2018.01.016
1529-9430/

in the context of value-based health care. Our objective, therefore, was to determine the cost-utility ratio of cervical deformity correction.

STUDY DESIGN: This is a retrospective review of a prospective, multicenter cervical deformity database. Patients with 1-year follow-up after surgical correction for cervical deformity were included. Cervical deformity was defined as the presence of at least one of the following: kyphosis (C2–C7 Cobb angle >10°), cervical scoliosis (coronal Cobb angle >10°), positive cervical sagittal malalignment (C2–C7 sagittal vertical axis >4 cm or T1–C6 >10°), or horizontal gaze impairment (chin-brow vertical angle >25°). Quality-adjusted life years were calculated by both EuroQol 5D (EQ5D) quality of life and Neck Disability Index (NDI) mapped to short form six dimensions (SF6D) index. Costs were assigned using Medicare 1-year average reimbursement for: 9+ level posterior fusions (PF), 4–8 level PF, 4–8 level PF with anterior fusion (AF), 2–3 level PF with AF, 4–8 level AF, and 4–8 level posterior refusion. Reoperations and deaths were added to cost and subtracted from utility, respectively. Quality-adjusted life year per dollar spent was calculated using standardized methodology at 1-year time point and subsequent time points relying on maintenance of 1-year utility.

RESULTS: Eighty-four patients (average age: 61.2 years, 60% female, body mass index [BMI]: 30.1) were analyzed after cervical deformity correction (average levels fused: 7.2, osteotomy used: 50%). Costs associated with index procedures were 9+ level PF ($76,617), 4–8 level PF ($40,596), 4–8 level PF with AF ($67,098), 4–8 level AF ($31,392), and 4–8 level posterior refusion ($35,371). Average 1-year reimbursement of surgery was $55,097 at 1 year with eight revisions and three deaths accounted for. Cost per quality-adjusted life year (QALY) gained to 1-year follow-up was $646,958 by EQ5D and $477,316 by NDI SF6D. If 1-year benefit is sustained, upper threshold of cost-effectiveness is reached 3–4.5 years after intervention.

CONCLUSIONS: Medicare 1-year average reimbursement compared with 1-year QALYdescribed $646,958 by EQ5D and $477,316 by NDI SF6D. Cervical deformity surgeries reach accepted cost-effectiveness thresholds when benefit is sustained 3–4.5 years. Longer follow-up is needed for a more definitive cost-analysis, but these data are an important first step in justifying cost-utility ratio for cervical deformity correction.

Keywords: Cervical deformity; Cervical surgery; Cost; Cost utility; Economic burden; Spinal alignment; Surgical correction

Introduction

With advances in understanding of sagittal alignment, osteotomy techniques, and improved patient safety, realignment procedures for correction of cervical spinal deformity has become more common [1]. The current health-care climate of diminishing resources increasingly demands justification of services [2]. Complex correction of cervical deformity employs a large amount of resources, requiring personnel for many hours, and includes high cost, with many implants, devices, and medications used for a single patient. Given the important recent advances in surgical intervention for cervical deformity, it is necessary to measure its benefit in terms of resources used.

Cost-utility analyses are increasingly popular with decision makers' increasing emphasis on patient-centric and value per dollar data [3]. Cost-utility studies compare subjective patient-defined description of utility, such as quality-adjusted life year (QALY), to cost. When compared with the alternative of "doing nothing," as advocated in the World Health Organization (WHO) Guide to Cost-Effectiveness Analysis, cost-utility analysis gives generalizable information on the spending necessary to achieve better health [4]. This cost-utility ratio grades interventions by what improvement can be achieved per unit cost.

Medicare reimbursements are the most commonly employed cost-proxy in spine, allowing researchers to pinpoint the value of the actual procedures as determined by national consensus [2]. The Medicare reimbursement rate can be compared across specialties, and represents the national willingness-to-pay rate. This is suitable for health policy decisions regarding general resource allocation.

The goal of this study is to define cost-utility of surgical cervical deformity correction in terms of reimbursement per QALY. This ratio will be an important step in evaluating cervical deformity surgeries, and it is the hope of the authors that others may compare these data with alternative interventions.

Methods

Data source

This study was a retrospective review of a prospectively collected database of patients with cervical deformity consecutively enrolled from 14 sites around the United States. Internal Review Board approval was obtained at each participating site before study initiation. Inclusion criteria for the database were patients aged ≥18 years, and radiographic evidence of cervical deformity at baseline assessment, defined as the presence of at least one of the following: cervical kyphosis (C2–C7 Cobb

EVIDENCE & METHODS

Context
The authors assessed cervical deformity surgery via cost-utility analysis.

Contribution
Using a high-quality prospective database, they found that—at one year—reconstructive surgeries for cervical deformity do not meet cost-effectiveness thresholds but, if surgeries are 'durable' out to 3.5 years+, they will.

Implications
A well-performed and well-written study. We await longer follow-up.

angle >10°), cervical scoliosis (C2–C7 coronal Cobb angle >10°), C2–C7 sagittal vertical axis (SVA) >4 cm, or chin-brow vertical angle >25° (Fig. 1). Patients with active tumors or infections were excluded from the study.

Inclusion criteria

Patients with surgical cervical deformity meeting inclusion criteria and reaching 1-year follow-up were included for analysis.

Calculation of cost

Costs were accounted using job order cost accounting ("charge analysis") on the PearlDiver database, which gives 1-year Medicare reimbursement. International Classification of Diseases, Ninth Revision (ICD-9) codes were retrospectively assigned to each procedure in the cervical deformity database (eg, posterior cervical fusion 9+level: 81.03, 81.64; Table 1 lists all procedures queried). Medicare 1-year reimbursements given on the PearlDiver database were then queried for those combinations of ICD-9 codes, and the average Medicare 1-year reimbursement was assigned to the corresponding cervical deformity procedure. One-year reimbursement represents how much was given by Medicare to cover all procedures to the hospital until day 30. This includes postoperative complications during that time, those managed in a follow-up clinic visit, readmissions, etc. Cervical procedures queried included posterior cervical fusion (2–3 level; 4–8 level; or 9+ level) and anterior cervical fusion (2–3 level, 4–8 level, or 9+ level), and combined with various modifiers for additional procedures performed. Modifiers queried included an additional fusion procedure, discectomy, or bone morphogenetic protein use. Reoperations all fell under the ICD-9 description "4–8 level fusion refusion."

Table 1
Summary of demographics (N=84)

Female	50 (60%)
Age	61.17 y
BMI	30.08 kg/m^2
CCI	0.80
Smoker	5 (6%)
Previous cervical surgery	35 (42%)
Diagnosis	
Congenital kyphosis	2 (2%)
Degenerative cervical kyphoscoliosis	3 (4%)
Degenerative cervical scoliosis	3 (4%)
Degenerative kyphosis	37 (44%)
Iatrogenic cervical kyphoscoliosis	1 (1%)
Iatrogenic kyphosis	13 (15%)
Traumatic kyphosis	3 (4%)
Other	17 (20%)
Missing	5 (6%)

BMI, body mass index; CCI, Charlson comorbidity index.

Calculation of utility

Quality of care was measured according to QALY [5].

$$\text{QALYs gained} = \left(Q^{i} - Q\right)\frac{1 - e^{-rL}}{r}$$

QALY is a generic measure of disease burden, evaluating the quality (Q) of life multiplied by quantity (life expectancy; L) of life to determine stotal health benefits, where *e* is Napier's mathematical constant and *r* is the discount rate. Change in Q (Qi-Q) can be tracked to determine the total utility gained by an intervention, and multiplied by life expectancy to determine QALY gained. A discount of 3% was implemented as recommended by the WHO [4]. Life expectancy was selected manually to model duration of treatment effectiveness, and was based on the US national averages for males (76.9 years) and females (81.6 years). Quality-adjusted life year was calculated using both a generic health-related quality of life score (HRQL), the EuroQol-5D (EQ5D), and a disease-specific HRQL, the Neck Disability Index (NDI), which was mapped to an SF6D index value for translation into QALY [6–8].

Statistical analysis

All data were statistically analyzed using SPSS Statistics 20.0 (IBM Corp, Armonk, NY, USA). Descriptive statistics were run on demographic and clinical variables. Utility changes were observed over time using EQ5D and NDI short form six dimensions (SF6D) adaptation. Finally, cost in dollars per QALY gained was calculated at the 1-year follow-up time point and using equation 1. Utility is assumed to be held constant after the 1-year time point. Cost per QALY is presented as cost per QALY with 1-year life expectancy, 5-year life expectancy, and 10-year life expectancy.

Results

Of 113 patients with surgical cervical deformity eligible for 1-year follow-up, 84 patients were analyzed. Demographic and clinical data are summarized in Table 2. Cervical

Table 2
Summary of baseline and 1-year postoperative improvements in health-related quality of life scores

HRQLs	Baseline	1Y	Δ1Y	p
NRS back pain	5.0	4.6	−0.5	.334
NRS neck pain	6.7	4.2	−2.5	<.001
NDI score	48.1	36.8	−11.3	<.001
mJOA score	13.4	14.1	0.7	.147
EQ5D VAS	70.2	76.7	6.6	<.001

HRQL, health-related quality of life score; NRS, numeric rating scale; NDI, Neck Disability Index; mJOA, modified Japanese Orthopedic Association; EQ5D VAS, EuroQol-5D visual analog scale.

Table 4
Summary of baseline and 1-year postoperative improvements in deformity measurements

Deformity measurements	Baseline	1Y	Δ1Y	p
C2–C7 SVA (mm)	48.7	40.9	−7.8	.025
Chin-brow vertical angle	5.4°	3.1°	−2.3°	.427
T1 Slope—C2–C7 angle	37.8°	26.6°	−11.1°	<.001
Lumbar lordosis	22.6°	22.6°	0.0°	.593
Thoracic kyphosis	15.0°	15.0°	0.0°	.970
C7–S1 SVA (mm)	5.7	25.9	+20.2	.081
Pelvic incidence-lumbar lordosis	−0.1°	0.9°	+1.0°	.718
Pelvic tilt	18.3°	17.8°	−0.5°	.758

SVA, sagittal vertical axis.

deformity corrections were most frequently performed for degenerative kyphosis (44%). Forty-two percent of patients had history of a previous cervical surgery. Table 2 describes changes in HRQL scores. Neck pain improved an average of 2.5 points and NDI score improved an average of 11.3 points.

Tables 3 and 4 describe the surgeries performed and deformity changes in these patients, respectively. Cervical deformity interventions were most frequently posterior (47.6%) or anterior then posterior (32.1%) approach. Posterior fusions spanned an average 8.7 levels. Anterior fusions spanned an average 3.6 levels. Operative time averaged more than 6 hours. Patients presented with severe baseline cervical deformity: average cervical SVA 48.7 mm, average chin-brow angle 5.4°, and average T1–CL 37.8°. Cervical SVA (Δ-7.8 mm, p=.025) and T1–CL (Δ26.6°, p<.001) improved significantly from pre- to postoperative evaluation.

Three patients died within 1 year of the surgery and eight underwent 4–8 level revision fusion. At 1-year follow-up, EQ5D improved significantly (baseline: 0.52, 1 year: 0.66, p<.001), as did NDI SF6D (baseline: 0.30, 1 year: 0.42, p<.001). Including average life expectancy (average 18.7 years, range 1–46 years) and a 3% discount rate, average QALYs gained were 0.09 according to EQ5D and 0.12 according to NDI SF6D at 1 year, 0.40 according to EQ5D and 0.55 according to NDI SF6D if 1-year benefit is sustained to 5 years, and 0.75 according to EQ5D and 1.02 according to NDI SF6D if 1-year benefit is sustained to 10 years (Fig. 2).

Costs associated with each tabulated index procedure are presented in Table 5. Average 1-year reimbursement cost for all patients was $55,097. Mean cost per QALY sustained at 1 year was $646,958 by EQ5D and $477,316 by NDI SF6D. At 5 years, the mean cost per QALY sustained was $137,269 for EQ5D and $100,426 for NDI SF6D. At 10 years, the mean cost per QALY sustained was $73,772 for EQ5D and $53,972 for NDI SF6D. Mean QALYs gained upon reaching life expectancy was on average 1.23 by EQ5D and 1.74 by NDI. Therefore, mean cost per QALY with patients reaching life expectancy was $44,574 by EQ5D and $31,594 by NDI.

Table 3
Clinical summary

Surgeries performed (N=84)	
Avg. number anterior levels fused	3.6
Avg. number posterior levels fused	8.7
Approach	
Anterior	14 (16.7%)
Posterior	40 (47.6%)
Anterior then posterior	27 (32.1%)
Posterior then anterior then posterior	3 (3.6%)
Three-column osteotomy	13 (15.4%)
Op time (min)	364.3

Discussion

The amount spent on cervical spine surgeries in the United States continues to rise [9]. With an aging population and increasing incidence of cervical deformity disorders, the amount spent on cervical deformity may increase in the future [10]. Although substantial cost and effort goes into surgical correction of cervical deformity, there is a potential for dramatic improvement. Therefore, cost-utility analysis is an important step in defining value of surgical correction of cervical deformity in terms of dollars spent.

In 2004, Michael Porter defined value as health outcome yield per dollar spent [11]. Cost-utility analyses are one type of cost-analysis that describes value by placing cost in the numerator and patient-centric subjective utility in the denominator, most frequently QALY [3]. Cost analyses are most effective, as dictated by the WHO Guide to Cost-Effectiveness Analysis, evaluating an intervention against "doing nothing" [4]. This allows for evaluation of exclusive, possibly difficult-to-compare options in a hospital's budget, as they frame health services in the context of what improvement can be achieved. Particularly in a field with such paucity of cost-analyses such as cervical deformity, this is an important first step in value estimation.

The current protocol describes health outcome in terms of a generic health-related quality of life measure in addition to a disease-specific patient-reported outcome. EQ5D has large appeal because it can be applied across many disciplines, therefore allowing comparison with many different interventions. NDI mapping to the SF6D index, which allows for calculation of QALY, was first performed in 2011 by Carreon et al. and was recently validated [8,12]. In combination, the general and disease-specific outcomes describe

Table 5
Categorization of surgeries performed according to ICD-9 coding and respective average 1-year Medicare reimbursement rate

Procedure	ICD-9 codes	Cost	N
Posterior cervical fusion (9+ level)	81.03, 81.64	$76,617	17
+ BMP	81.03, 81.64, 84.52	$52,592	0
Posterior cervical fusion (4–8 level)	81.03, 81.63	$40,596	25
+ Anterior cervical fusion (2–3 level)	81.03, 81.63, 81.02, 81.62	$40,925	6
+ Anterior cervical fusion (4–8 level)	81.03, 81.63, 81.02, 81.63	$67,098	22
+ Discectomy	81.03, 81.63, 80.99	$58,755	0
Anterior cervical discectomy and fusion (2–3 level)	81.02, 81.62, 80.99	$29,364	0
Anterior cervical discectomy and fusion (4–8 level)	81.02, 81.63, 80.99	$31,392	14
Posterior cervical refusion (4–8 level)	81.03, 81.64, 81.33	$35,371	8

BMP, bone morphogenetic protein; ICD-9, International Classification of Diseases, Ninth Revision.

functional status, quality of life, and overall perspective, allowing for a full account of health outcome.

Medicare allowable rates are the most commonly employed method for estimated cost in spine care [2]. One-year reimbursement rates, averaged for all such surgeries on PearlDiver database, represent the amount that society is willing to pay for a given intervention. This is extremely useful for a macro-analysis of cost-utility, but can also treat two very different surgeries the same, most frequently with varying use of off-label biologics, bone graft substitutes, and instrumentation. Recent work in the field of lumbar spinal deformity describes Medicare reimbursement rates as 17% (range: 12%–21%) lower than direct costs [13]. This highlights the need for more precise cost analyses for local resource allocation.

In defining an acceptable way to define a procedure as "cost-effective," the WHO recommends a lower threshold of one multiplied by gross domestic product per capita, and an upper threshold three times as high, which for the United States in 2016 are ~$52,000 and $156,000, respectively [14,15]. The current study found 1-year cost-utility measured at $646,958 by EQ5D and $477,316 by NDI SF6D. This value is significantly higher than the acceptable threshold owing to shorter follow-up. Extending utility past 1 year, although overlooking possible complications and deterioration exceeding the discount rate after 1 year, describes reaching an acceptable cost-utility threshold according to the disease-specific NDI SF6D measure by 3 years, and according to the more general EQ5D by ~4.5 years. These outcome goals are contingent on maintenance of the benefit realized 1 year post operation to the longer follow-up time points. There are few long-term studies on patients with cervical deformity; however, lumbar spinal deformity literature indicates durable long-term benefit [16].

To the author's knowledge, there are no comparable studies describing cost-utility of surgical intervention for cervical deformity. In thoracolumbar spinal deformity, Terran et al. reported that 40.7% of patients met a threshold of <$100,000/QALY at 5-year follow-up [16]. The current study's more favorable estimate of cervical procedures may be owing to an optimistic model of revision and quality-of-life changes. A review on cost-utility analyses in spine by Kepler et al. in 2012 describe Cost or QALY conclusions ranging from $2,200 to $9,900,000 [17].

There are several limitations to the study. Cost analysis used a Medicare patient population, which are inherently older and more comorbid, which may have resulted in a higher complication rate, increasing the reimbursement rate. Medicare reimbursement rates do not account for direct hospital costs, and has been shown to be lower than direct costs in a lumbar deformity cohort. Medicare reimbursement rates ignore certain expenses incurred in the care that are non-billable. Finally, concerns have been raised that the EQ5D may have ceiling effects, which would limit its sensitivity in cases demonstrating large improvement from baseline.

Conclusions

The current study analyzes complex fusions spanning over four levels and frequently including combined approach and osteotomy. Medicare 1-year average reimbursement compared with 1-year QALY described $646,958 by EQ5D and $477,316 by NDI SF6D. If 1-year benefit is sustained, upper threshold of cost-effectiveness is reached 3–4.5 years after intervention. Medicare costs and QALY analysis is comparable across fields and interventions. As such, this is an important first step in defining the cost-utility ratio of cervical deformity surgeries. Further randomized controlled trials with a nonoperative comparison group are needed.

Fig. 1 Utilities according to US EuroQol 5D, and the Neck Disability Index mapped to the SF6D according to Glassman et al. SF6D, Short Form 6D.

Fig. 2 QALY according to years of sustained benefit with utility held constant from 1-year time point. QALY, quality-adjusted life year.

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