Variations in cost calculations in spine surgery cost-effectiveness research

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Object. Cost-effectiveness research in spine surgery has been a prominent focus over the last decade. However, there has yet to be a standardized method developed for calculation of costs in such studies. This lack of a standardized costing methodology may lead to conflicting conclusions on the cost-effectiveness of an intervention for a specific diagnosis. The primary objective of this study was to systematically review all cost-effectiveness studies published on spine surgery and compare and contrast various costing methodologies used.

Methods. The authors performed a systematic review of the cost-effectiveness literature related to spine surgery. All cost-effectiveness analyses pertaining to spine surgery were identified using the cost-effectiveness analysis registry database of the Tufts Medical Center Institute for Clinical Research and Health Policy, and the MEDLINE database. Each article was reviewed to determine the study subject, methodology, and results. Data were collected from each study, including costs, interventions, cost calculation method, perspective of cost calculation, and definitions of direct and indirect costs if available.

Results. Thirty-seven cost-effectiveness studies on spine surgery were included in the present study. Twenty-seven (73%) of the studies involved the lumbar spine and the remaining 10 (27%) involved the cervical spine. Of the 37 studies, 13 (35%) used Medicare reimbursements, 12 (32%) used a case-costing database, 3 (8%) used cost-to-charge ratios (CCRs), 2 (5%) used a combination of Medicare reimbursements and CCRs, 3 (8%) used the United Kingdom National Health Service reimbursement system, 2 (5%) used a Dutch reimbursement system, 1 (3%) used the United Kingdom Department of Health data, and 1 (3%) used the Tricare Military Reimbursement system. Nineteen (51%) studies completed their cost analysis from the societal perspective, 11 (30%) from the hospital perspective, and 7 (19%) from the payer perspective. Of those studies with a societal perspective, 14 (38%) reported actual indirect costs.

Conclusions. Changes in cost have a direct impact on the value equation for concluding whether an intervention is cost-effective. It is essential to develop a standardized, accurate means of calculating costs. Comparability and transparency are essential, such that studies can be compared properly and policy makers can be appropriately informed when making decisions for our health care system based on the results of these studies.

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KEY WORDS • cost-effectiveness analysis • Medicare reimbursement • cost utility • cost-to-charge ratio • health care policy • direct cost

COSTS are an important aspect of clinical, insurance coverage, and payment decisions in health care. Specifically, cost containment has become a prominent issue in US health care policy. In 2012, US health care spending reached \$2.8 trillion, or approximately \$8915 per patient (including both inpatients and outpa-

tients), an increase of 175% from a decade ago (\$1.6 trillion), with projections of increased spending with the introduction of the Affordable Care Act in 2014.¹² With the continued elevation of health care expenditures, medical and surgical interventions are being increasingly scrutinized for their cost-effectiveness to both the patient and provider.

Given equal effectiveness between two procedures for the same medical or surgical indication, patients, providers, and payers will choose the less expensive procedure. It is the transparency of costs that may benefit both the public and private sectors.²² Cost-effectiveness research seeks

Abbreviations used in this paper: ACDF = anterior cervical discectomy and fusion; CCR = cost-to-charge ratio; CEA = cost-effectiveness analysis; CER = cost-effectiveness ratio; CUA = cost-utility analysis; ICER = incremental cost-effectiveness ratio; QALY = quality-adjusted life year.

to provide such transparency. Table 1 provides some important definitions when interpreting a cost-effectiveness analysis (CEA). Cost-utility analyses (CUAs), a type of cost-effectiveness analysis, produce a numerical ratio known as the incremental cost-effectiveness ratio (ICER) in dollars per quality-adjusted life year (QALY). This ratio is used to evaluate the cost-effectiveness between medical and surgical interventions. Defining a cutoff of what is cost-effective is a controversial issue in the literature, as it has been reported from \$20,000/QALY gained to \$100,000/QALY gained.^{22,39,40} The cost-effectiveness acceptability curve acknowledges that a single threshold value for cost-effectiveness does not exist and, instead, should be based on an individual's willingness to pay for a particular intervention. This curve illustrates the probability that one intervention is cost-effective compared with another intervention given a maximum acceptable cost-effectiveness ratio (CER) by the decision maker. Due to the uncertainty of what defines true cost-effectiveness, cost-effectiveness acceptability curves are commonly constructed by investigators.¹⁵

Systematic reviews of cost-effectiveness studies in spine care focus on the cost-utility ratio and measurements of the quality of a particular medical or surgical intervention.^{8,13,26} A major limitation of existing cost-effectiveness studies is the heterogeneous way in which costs are defined and calculated, as there has yet to be a standardized approach for conducting a cost-effectiveness study. This limitation leads to great difficulty interpreting the results of CUAs and the potential for biased results.^{6,26}

The purpose of this study was to systematically review all cost-effectiveness studies in the spine surgery literature, identify how costs were defined and calculated, and compare different cost methodologies among studies analyzing the same intervention. Understanding these differences will aid future investigators in performing more standardized CUAs.

Methods

We identified all cost-effectiveness studies in spine surgery published from 1976 to January 2014 using the CEA registry database at Tufts Medical Center Institute for Clinical Research and Health Policy—which uses the MEDLINE search engine to collect and screen studies to determine if the study has an original cost-utility estimate—and the MEDLINE search engine itself. The former is a comprehensive database of all health-related cost-effectiveness studies published from 1976 to the present. Both the CEA registry database and MEDLINE search engine were queried with the following keywords: “cost effectiveness,” “spine surgery costs,” “Medicare reimbursement,” “cost utility analyses,” “cervical,” “lumbar,” and “cost to charge ratio.” Articles were excluded if they were biomechanical studies, radiographic studies, animal studies, case reports, reviews, editorials, or methodologies, or if they were not written in the English language. In addition, any article focusing on nonoperative management alone was excluded.

Each article was reviewed in detail by two authors (M.D.A. and J.A.M.) with respect to the study topic, methodology, results, and length of follow-up. Direct cost definitions were recorded from each article to specifically identify inclusion of the following costs: outpatient visits, medications, physical therapy, imaging, surgeon/professional services, anesthesia, laboratory tests, and inpatient hospitalization. Note as well that inpatient hospitalization costs (see Tables 4 and 5) generally include hospital stay, nursing, inpatient medications, laboratory tests, and imaging. However, the medication, laboratory, physical therapy, and imaging costs reported by most studies are follow-up outpatient costs rather than inpatient costs. In addition, the perspective (societal, hospital, or payer) of how costs were calculated was also recorded. The societal perspective includes both direct and indirect costs,

TABLE 1: Important definitions in cost analyses

Cost Analysis Term	Definition
cost-effective	a term designating an intervention that provides the highest quality at the lowest cost over a set time frame in comparison to other interventions
cost-effectiveness study	a comparison between 2 or more medical or surgical interventions for the same indication, undertaken to determine which is the more (most) cost-effective based on both costs calculated & value (“effectiveness”)
cost-utility study	a type of cost-effectiveness study involving measuring the utility gained by an intervention based on a numerical patient-reported outcome scale
direct cost	a cost related to either inpatient or outpatient medical care, including the intervention
indirect cost	a cost to the patient related to missed time from work or decreased productivity due to the intervention
cost perspective	a view on how costs were defined in a particular study, which is important for the interpretation of those costs
societal	includes direct and indirect costs that the patient (“society”) incurs due to the intervention
hospital	includes direct costs that the hospital incurs due to the intervention
payer	includes direct costs that the insurance company incurs (payments to the hospital) due to the intervention
discounting	an economic statistical method of accounting for the time value of money to adjust future costs to the present day
cost-effectiveness ratio (CER)	a value equation, defined as total costs (direct + indirect) of an intervention divided by the quality of life, or utility, gained from the intervention; this is the end point of all CUAs
incremental CER (ICER)	the difference between the CERs of 2 different interventions used to determine if one intervention is more cost-effective than the other; negative ICERs are not reported & indicate that one intervention costs more & provides less utility gained than the other intervention

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whereas the hospital and payer perspectives include only direct costs. The discount rate (such as 3%, 5%, and others) for cost calculations was recorded if used. This rate is used to account for the time value of money in studies measuring costs over a long follow-up period. The CEA registry database also includes a subjectively assigned rating score for each article based on a 7-point Likert scale, which is based on the US Panel of Cost-Effectiveness in Health and Medicine recommendations.^{9,53} This score was likewise recorded and was based on the reasonableness of study assumptions and quality of the data analysis. All costs were recorded and converted to 2014 US dollars using national inflation rates from the US National Labor Bureau for comparison purposes.

Results

We identified 37 cost-effectiveness studies on spine surgery. Ten (27%) of the studies involved the cervical spine (Table 2) and the remaining 27 (73%) involved the lumbar spine (Table 3). Of the 37 studies, 10 were randomized control trials (27%), 8 were prospective cohorts (22%), 12 were retrospective cohort (32%), and 7 were decision-tree analyses (19%).

There was wide variation on cost calculation methods. Of the 37 studies, 13 (35%) used Medicare reimbursements, 12 (32%) used a case-costing database, 3 (8%) used cost-to-charge ratios (CCRs), 2 (5%) used a combination of Medicare reimbursements and CCRs, 3 (8%) used the United Kingdom National Health Service reimbursement system, 2 (5%) used a Dutch reimbursement system, 1 (3%) used the United Kingdom Department of Health data, and 1 (3%) used the Tricare Military Reimbursement system.

Nineteen (51%) studies completed their cost analysis from the societal perspective, 11 from the hospital perspective (30%), and 7 (19%) from the payer perspective. Of those studies with a societal perspective, 14 reported indirect costs while the other 5 studies did not specify what the indirect costs were.

Cervical Spine

All 10 cervical studies included anterior cervical discectomy and fusion (ACDF), 3 included cervical disc arthroplasty, 3 included posterior cervical fusion, and 1 included posterior cervical foraminotomy. Direct costs for ACDF ranged from \$5396 to \$29,898. Direct costs for cervical disc arthroplasty ranged from \$4499 to \$11,472 and for posterior cervical fusion ranged from \$17,740 to \$30,644. The broad range of costs is based on whether only index costs were calculated or if both index and follow-up costs were recorded, which is specified in Tables 4 and 5. Only 1 study reported indirect costs despite 3 studies (30%) taking the societal perspective. Only 3 studies (30%) reported using a discount rate.

Lumbar Spine

Surgical interventions in the lumbar spine studies included fusion (57%) and/or decompression via laminectomy or discectomy. Direct costs for fusion ranged from

\$13,892 to \$90,036. Thirteen (81%) of 16 studies analyzed from a societal perspective reported indirect costs. Thirteen studies (48%) reported using a discount rate.

Direct Cost Definitions

Tables 4 and 5 highlight the differences in how direct costs were defined by the included studies. Each of the following items was included in at least 1 study reviewed (% of 37 studies): outpatient visits (57%), medications (57%), laboratory studies (19%), physical therapy (57%), imaging (MRI, CT, radiography; 65%), surgeon (46%), anesthesia (8%), revisions/reoperations/complications (30%), and inpatient postoperative recovery costs (95%). All components were recorded from each study's methods section on cost calculations. Six studies (16%) did not include costs within the follow-up period analyzed.^{4,27,28,32,42,48}

Discussion

In 1996, the US Panel on Cost-Effectiveness in Health and Medicine published recommendations for investigators wishing to conduct high-quality CEAs that included using a 3% discount rate and including all costs from the societal perspective (both direct and indirect costs).⁵³ In 2012, Kepler et al.²⁶ published a systematic review on CUAs in spine care with a focus on what has been done and what needs to be done in the literature relative to cost-effectiveness in spine care. In their article, the investigators focused on how studies have measured the utility or effectiveness of an intervention. They proposed that the method of measuring cost is the single most complex issue facing researchers seeking to perform high-quality CEAs. The results of the present study confirm the marked heterogeneity in cost calculation methodology.

The first consideration when calculating costs is whether costs are being determined from the perspective of the hospital, the payer, or society. Costs from the hospital perspective include direct costs, costs of staff, supplies, utilities, and rent; however, the costs usually exclude those of the surgeon or anesthesiologist because those costs are covered by insurance companies.^{39,40} Costs from the payer perspective (for example, insurance companies) include payments to the hospital and physicians (direct costs). Costs from the societal perspective include indirect costs in addition to the same direct costs as the payer perspective. These indirect costs include the costs of productivity loss (time off work for the patient), as well as loss of work time for the caregiver.^{39,40} The societal perspective is the only one that incorporates both direct and indirect costs. In the present study, only about 50% of all articles included were performed from a societal perspective in line with the recommendations from the Panel on Cost-Effectiveness in Health and Medicine.⁵³ Despite the recommendation for a societal perspective, CEAs may be undertaken from a hospital or payer perspective depending on the intended use and user of the data. Hospitals care more about actual costs incurred, whereas the payer cares more about reimbursements.^{39,40} Therefore, it is critical that the perspective of the study be taken into account when interpreting costs, as these will vary based on the specified study objectives.

TABLE 2: Cost analyses of cervical spine surgery (1976–2014)*

Authors & Year	Study Design	No. of Patients	Follow-Up	Indication	Intervention	Perspective	CCM	Discount Rate (%)	DC (\$)	IC (\$)	LR
Carreon et al., 2013	RC	352	60 mos	radiculopathy	ACDF	societal	Medicare	NR	15,714	NR	4
Qureshi et al., 2013	DT	NA	20 yrs	radiculopathy	ACDF CDA	payer	CCR Medicare	3	12,415 9999	NR	4
Fehlings et al., 2012	PC	70	24 mos	CSM	ACDF/PCFU	hospital	CCD	3	21,952	NR	4
Fernández-Fairen et al., 2012	RC	61	24 mos	CSM	ACDF + implant ACDF + autograft	hospital	CCD	NR	9471 13,788	NR	2
Whitmore et al., 2012	RC	72	12 mos	CSM	ACDF PCFU	payer	CCR (ACDF) Medicare CCR (PCFU) Medicare	NR	23,072 18,766 29,898 17,740	NR	4
Ghogawala et al., 2011	PC	50	12 mos	CSM	ventral fusion dorsal fusion	payer	CCR	NR	20,014 30,644	NR	4
Tumialán et al., 2010	RC	38	NR	radiculopathy	ACDF PCFO	societal	Tricare Military	NR	10,783	14,537	4
Menzin et al., 2010	RC	541	24 mos	DDD	ACDF CDA	societal	CCR	NR	11,903 11,472	NR	4
Bhadra et al., 2009	RC	60	31 mos	radiculopathy	ACDF CDA	payer	UK Dept of Health	NR	5396 4499	NR	3
Angevine et al., 2005	DT	78	NR	CS	ACDF	hospital	CCD	3	15,755	NR	3.5

* CCM = case-costing database; CCM = cost calculation method; CDA = cervical disc arthroplasty; CS/CSM = cervical spondylosis/myelopathy; DC = direct costs (inflation adjusted); DDD = degenerative disc disease; DT = decision tree analysis; IC = indirect costs (inflation adjusted); LR = CEA Registry Likert rating; NA = not applicable; NR = not reported; PC = prospective cohort; PCFO = posterior cervical foraminotomy; PCFU = posterior cervical fusion; RC = retrospective cohort; UK = United Kingdom.

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TABLE 3: Cost analyses of lumbar spine surgery (1976–2014)*

Authors & Year	Study Design	No. of Patients	Follow-Up (mos)	Indication	Intervention	Perspective	CCM	Discount Rate (%)	DC (\$)	IC (\$)	LR
Adogwa et al., 2012 ³	RC	50	24	ASD	revision fusion	societal	Medicare	NR	30,216	20,979	2
Adogwa et al., 2012 ²	RC	42	24	spinal stenosis	revision fusion	societal	Medicare	NR	32,965	19,927	2
Glassman et al., 2012	PC	80	60	DDD	posterolateral fusion	societal	Medicare	NR	15,720	NR	4
Kim et al., 2012	RC	150	120	spondylolisthesis	decompression fusion	hospital	CCD	3	5330	NR	6.5
									18,461		
Parker et al., 2012	PC	30	24	spondylolisthesis	MIS-TLIF	societal	Medicare	NR	26,379	12,857	5
					open TLIF				28,647	20,105	
Parker & McGirt, 2012	PC	45	24	spondylolisthesis	TLIF	societal	Medicare	NR	27,019	12,395	4.5
Sanborn et al., 2012	DT	448	NA	DDD	PSF	payer	Medicare	NR	18,159	NR	3
Tosteson et al., 2011	PC	2347	48	spinal stenosis	fusion	societal	Medicare	3	64,083	NR	5
				spondylolisthesis	fusion				90,036		
Tso et al., 2012	RC	220	24	spinal stenosis	decompression fusion	hospital	CCD	3	3550	NR	4.5
									13,892		
Adogwa et al., 2011	RC	45	24	spondylolisthesis	TLIF	societal	Medicare	NR	27,524	12,627	2
Parker et al., 2011	PC	54	24	spinal stenosis	hemilaminectomy	societal	Medicare	NR	15,055	11,393	2.5
Parker et al., 2013	RC	54	24	spinal stenosis	MIS laminectomy	societal	Medicare	NR	14,892	10,297	3.5
					open laminectomy				15,576	12,132	
van den Akker et al., 2011	RCT	325	12	sciatica	tubular discectomy	societal	Dutch	NR	5971	18,207	3
					microdiscectomy				5476	15,596	
Fritzell et al., 2011	RCT	152	24	low back pain	disc arthroplasty	hospital	CCD	NR	23,224	68,992	3.5
					PLIF				26,838	78,353	
Carreon et al., 2009	RCT	106	24	radiculopathy	fusion (rhBMP-2)	hospital	CCD	3	40,914	NR	3
Tosteson et al., 2008 ⁴⁵	RCT	634	24	stenosis/spondylolisthesis	fusion	societal	Medicare	3	21,756	8679	6.5
Tosteson et al., 2008 ⁴⁶	RCT	775	24	disc herniation	open discectomy	societal	Medicare	3	24,892	8719	5
van den Hout et al., 2008	RCT	283	12	disc herniation	early surgery	societal	Dutch	NR	9023	20,636	5
Freeman et al., 2007	RCT	83	24	low back pain	fusion	payer	NHS	3.5	19,585	15,277	6
Hansson & Hansson, 2007	PC	1146	24	disc herniation	surgery	societal	CCD	5	16,188	NR	3.5
North et al., 2007	RCT	42	37	failed back surgery	reoperation	hospital	CCD	NR	58,509	NR	4
Soegaard et al., 2007	RCT	146	24	spondylolisthesis	posterolateral fusion	societal	NHS	3	80,201	4136	6
Räsänen et al., 2006	PC	270	3	radiculopathy	decompression	hospital	CCD	5	4251	NR	2
Rivero-Arias et al., 2005	RCT	38	24	low back pain	fusion	societal	NHS	3.5	14,922	217	4.5
Kuntz et al., 2000	DT	NA	NA	stenosis/spondylolisthesis	laminectomy fusion	payer	CCR	NR	21,315	NR	6
									31,175		
Malter et al., 1996	DT	126	NA	disc herniation	discectomy	hospital	CCD	5	27,402	NR	4.5
Launois et al., 1994	DT	NA	NA	sciatica	discectomy	hospital	CCD	5	4759	NR	3

* ASD = adjacent-segment disease; DDD = degenerative disc disease; MIS = minimally invasive surgery; NHS = United Kingdom National Health Service; PLIF = posterior lumbar interbody fusion; PSF = pedicle screw fixation; RCT = randomized control trial; rhBMP-2 = recombinant human bone morphogenetic protein-2; TLIF = transforaminal lumbar interbody fusion.

TABLE 4: Direct cost distribution in the 10 cervical studies*

Authors & Year	Intervention	DC Total (\$)	Includes Follow-Up	OVs	Meds	Labs	PT	Imaging	Surgeon	Anesthesia	RRCs	IPCs
Carreon et al., 2013	ACDF	15,714	yes	—	—	—	—	—	—	—	—	+
Qureshi et al., 2013	ACDF	12,415	yes	—	—	—	—	—	+	—	—	+
	CDA	9999										
Fehlings et al., 2012	ACDF/PCFU	21,952	yes	+	+	+		+	+	+	+	+
Fernández-Fairen et al., 2012	ACDF + implant	9471	yes	+	+	—	+	+	—	—	—	+
	ACDF + autograft	13,788										
Whitmore et al., 2012	ACDF (CCR)	23,072	yes	—	+	+	+	+	+	—	—	+
	PCFU (CCR)	29,898										
	ACDF (Medicare)	18,766										
	PCFU (Medicare)	17,740										
Ghogawala et al., 2011	ventral fusion	20,014	yes	—	—	—	—	—	—	—	—	+
	dorsal fusion	30,644										
Tumialán et al., 2010	ACDF	12,415	yes	—	—	—	—	—	—	—	—	+
	PCFO											
Menzin et al., 2010	ACDF	11,903	yes	—	—	—	—	+	+	—	+	+
	CDA	11,472										
Bhadra et al., 2009	ACDF	5396	yes	—	—	—	—	—	—	—	—	+
	CDA	4499										
Angevine et al., 2005	ACDF	15,755	no	—	—	—	—	—	—	—	—	+

* DC = direct costs; IPCs = inpatient costs; Meds = medications; OV = outpatient visits; PT = physical therapy; RRCs = revisions, readmissions, or complications; + = included in direct cost definitions; — = not included in direct cost definitions.

The second consideration of cost calculation is the time frame in which costs are measured to provide for an accurate CEA.^{9,39,40} In spine care, long-term effectiveness is emphasized more than short-term gains.^{9,39,40} High up-front costs associated with surgery may allow researchers to conclude that surgery may not be cost-effective in a 2- to 3-month, or even 12-month time frame. However, by extending the time horizon analyzed for a given intervention and assuming that minimal costs are realized after the index surgery, the value equation calculated at 2 years may allow one to conclude that that same intervention is cost-effective. For example, Tosteson et al.⁴⁵ published 2 articles (one with 2-year follow-up, the other with 4-year follow-up) following the same patient cohort and saw substantial improvements (more cost-effective) in the value equation with the additional 2 years of follow-up data. In extending the time frame, the total direct costs reported may likely be higher and thus should be taken into consideration when comparing direct costs between studies of different time frames. However, this is not always the case. For example, Räsänen et al.³⁸ reported a direct cost for spinal decompression of \$4251 at the 3-month follow-up, Kim et al.²⁷ reported a direct cost of \$5330 with 120 months of follow-up, and Tso et al.⁴⁸ reported a direct cost of \$3550 after 24 months of follow-up. The difference in these costs, despite the time frame, lies in how direct costs were defined and from where they were acquired.

The third consideration of cost calculation is how to define and where to acquire the costs.^{9,39,40} Payments, charges, costs, and expected reimbursement are four separate entities and should not be used synonymously. Direct costs are generally defined as costs attributed to

patient care, including the index surgery and postoperative hospital care, diagnostic testing, outpatient visits, medications, surgeon and anesthesia costs, physical therapy, staff, and utilities.^{9,39,40} However, definitions used by studies varied considerably (Tables 4 and 5), which likely explains the wide variation in total costs reported. While most studies included inpatient costs, less than two-thirds of all studies included outpatient visits or medications, and less than half included costs of the surgeon. However, it is important to note that these percentages are based on the definitions reported in the methods.

Direct costs can be calculated using hospital costs (case-costing databases specific to each hospital), but usually those cost data are not available to the public. Thus, investigators commonly use Medicare national payment data, private payer payment data, or CCRs as estimates of actual costs.^{24,49} Medicare data do not yield absolute cost-effectiveness calculations because the federally funded program only collects proxy measurements of hospital costs. However, a recent review of how to obtain and analyze Medicare cost data argued for their place as the best estimate for actual costs among the options available.^{9,49} Cost-to-charge ratios are coefficients used to convert hospital charges into cost estimates. They vary by hospital, but are publicly available from the Healthcare Cost and Utilization Project.²⁴ The Healthcare Cost and Utilization Project is not comprehensive of every hospital, however, as some states are excluded for various reasons on an annual basis. A major limitation of CCRs is that they estimate costs based on a specific selection of resources (hospital-wide charges/costs), which may not be the same when CCRs are applied to individual patient treatments.

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TABLE 5: Direct cost distribution in the 27 lumbar studies*

Authors & Year	Intervention	DC Total (\$)	Includes Follow-Up	OVs	Meds	Labs	PT	Imaging	Surgeon	Anesthesia	RRCs	IPCs
Adogwa et al., 2012 ³	revision fusion	30,216	yes	+	+	—	+	+	+	—	—	+
Adogwa et al., 2012 ²	revision fusion	32,965	yes	+	+	—	+	+	+	—	—	+
Glassman et al., 2012	PLF fusion	17,092	yes	+	—	—	+	+	—	—	+	+
Kim et al., 2012	decompression fusion	5330 18,461	no	—	—	+	—	+	—	—	—	+
Parker et al., 2012	MIS-TLIF open TLIF	26,379 28,647	yes	+	+	—	+	+	+	—	—	+
Parker & McGirt, 2012	TLIF	27,019	yes	+	+	—	+	+	+	—	—	+
Sanborn et al., 2012	PSF	18,159	no	—	—	—	—	+	+	—	+	+
Tosteson et al., 2011	fusion fusion	64,083 90,036	yes	+	+	—	+	+	+	—	—	+
Tso et al., 2012	decompression fusion	3550 13,892	no	—	+	+	+	+	—	+	+	+
Adogwa et al., 2011	TLIF	27,524	yes	+	+	—	+	+	+	—	—	+
Parker et al., 2011	hemilaminectomy	15,055	yes	+	+	—	+	+	+	—	—	+
Parker et al., 2013	MIS laminectomy open laminectomy	14,892 15,576	yes	+	+	—	+	+	+	—	—	+
van den Akker et al., 2011	tubular discectomy microdiscectomy	5971 5476	yes	+	+	—	+	—	+	—	+	+
Fritzell et al., 2011	disc arthroplasty PLIF	23,224 26,838	yes	+	—	—	+	+	—	—	+	+
Carreon et al., 2009	fusion (rhBMP-2)	40,914	yes	+	+	+	+	+	+	—	+	+
Tosteson et al., 2008 ⁴⁵	fusion	21,756	yes	+	+	—	+	+	+	—	—	+
Tosteson et al., 2008 ⁴⁶	open discectomy	24,892	yes	+	+	—	+	+	+	—	—	+
van den Hout et al., 2008	early surgery	9023	yes	+	+	—	—	—	—	—	—	—
Freeman et al., 2007	fusion	19,585	yes	—	—	—	—	—	—	—	+	+
Hansson & Hansson, 2007	surgery	16,188	yes	—	—	—	—	—	—	—	—	+
North et al., 2007	reoperation	58,509	no	—	+	+	+	+	—	+	—	+
Soegaard et al., 2007	PLF fusion	80,201	yes	+	+	—	+	—	—	—	+	+
Räsänen et al., 2006	decompression	4251	yes	—	—	—	—	—	—	—	—	—
Rivero-Arias et al., 2005	fusion	14,922	yes	+	+	—	+	+	—	—	+	+
Kuntz et al., 2000	laminectomy fusion	21,315 31,175	no	—	—	—	—	—	—	—	—	+
Malter et al., 1996	discectomy	27,402	yes	+	—	—	+	+	—	—	—	+
Launois et al., 1994	discectomy	4759	yes	+	+	+	—	+	—	—	—	+

* PLF = posterolateral fusion; PSF = pedicle screw fixation; + = included in direct cost definitions; — = not included in direct cost definitions.

Microcosting is another method investigators use to estimate costs, but is rarely used due to a lack of generalizability and difficulty obtaining data.^{9,39,40}

Indirect costs are those costs not directly related to patient care. Usually, they represent missed time from work or homemaking for the patient and caregivers, or decreased productivity of the patient who returns to work after recovering from surgery. Indirect costs can contribute substantially to total costs and are typically estimated using the human capital method, whereby a patient or caregiver's time off work in hours is multiplied by his or her wage rate (indirect costs are defined here from an economics perspective; standard accounting usually treats indirect

costs as synonymous with overhead costs, which would be considered a direct cost from an economics perspective). The problem associated with this method is that the wage rates must be known in a retrospective study or acquired in a prospective manner.^{9,39,40} Therefore, some studies use the average national wage index to estimate the wage rate of all patients without inquiring to each patient directly. In the present review, only 43% of studies reported indirect costs and most used the human capital method or did not specify how these costs were calculated. Other than direct and indirect costs, intangible costs (improvement in productivity conferred by an intervention) and opportunity costs (investments in health care that could have been used

for an alternative investment) must be considered, but generally are difficult to incorporate in a CEA. Discounting, or accounting for the time value of money, is also important in calculating accurate present-day costs, especially when cost-effectiveness studies follow costs over a 1- or 2-year postoperative time frame. Multiple complex methods exist for how to adjust for the time value of money beyond discounting that some investigators may use. Based on the Panel on Cost-Effectiveness in Health and Medicine,⁵³ analysts should use a standard annual discount rate of 3%. Inflation and currency fluctuations must also be considered when interpreting cost-effectiveness studies from different years and different countries.^{9,39,40} Finally, many CEA studies conduct power analyses to confirm their sample size is sufficient for detecting differences in cost, or studies may conduct sensitivity analyses to account for the uncertainty of assumptions made in performing the CEA, which provides a 95% confidence interval of costs or effectiveness.^{45–47}

In this review, we found that there were substantial differences between studies in cost calculation methods and the associated results reported. For example, at 2 years postoperatively, Tosteson et al.⁴⁵ reported a direct cost of lumbar fusion for spinal stenosis to be \$21,756, whereas Tso et al.⁴⁸ reported a direct cost of \$13,892 for the same procedure, same indication, and same follow-up. The key difference is that the former study included 2-year follow-up costs and used Medicare reimbursements, whereas the latter did not include follow-up costs and used a case-costing database for cost calculation. For ACDF, Whitmore et al.⁵⁴ reported a Medicare-based cost of \$23,072 with 1-year follow-up, whereas Carreon et al.¹⁰ reported a direct cost of \$15,714 with 5-year follow-up. Both studies included follow-up costs. The former used the CCR method, while the latter used Medicare payments for cost calculations. However, the approximately \$8000 difference in costs can be understood by examining how the respective investigators defined direct costs. The former study included outpatient pharmacy, laboratory, physical therapy, imaging, and surgeon costs, which were not specifically accounted for by the latter study. A final important example to consider is shown by Launois et al.,²⁹ who reported a direct cost of discectomy for lumbar disc herniation to be 15,400 francs (\$4759 US 2014 dollars). For the same procedure, Malter et al.³⁰ reported a direct cost of \$27,402 and Tosteson et al.⁴⁶ reported \$24,892. This difference is likely both a function of differences in health care costs when compared between countries, as well as differences in methods of cost calculation.

We did not include studies on nonoperative treatment in spine care to keep our analysis concise and homogenous and to allow for more direct comparisons. However, it is worth noting what has been done relative to costs and cost-effectiveness in the nonoperative literature. Indrakanti et al.²⁵ conducted a systematic review that included 27 studies of both nonoperative and operative interventions for treating low-back pain. The authors reported ICERs comparing nonoperative interventions (physiotherapy, acupuncture, community exercise, spinal manipulation) but did not compare costs alone. Bell et al.⁵ conducted a CEA of spinal cord stimulation for failed back surgery, showing its benefit

in reducing overall health care costs compared with operative management and providing recommendations for improving the effectiveness of spinal cord stimulation, but did not actually measure effectiveness. Fritzell et al.¹⁹ investigated fusion versus nonoperative treatment for chronic low-back pain and found significantly higher costs for fusion despite higher gains in quality of life associated with fusion. The authors concluded that lumbar fusion would be more cost-effective than nonoperative treatment due to the higher gains in quality of life. Similarly, the Spine Outcomes Research Trial (SPORT) found that surgery for lumbar disc herniation was associated with greater costs but also greater QALY improvements.⁴⁷ Similar to Fritzell et al.,¹⁹ the authors proposed that the cost/QALY showed surgery to be the more cost-effective option. In contrast, Shvartzman et al.⁴³ found that 5 years postoperatively, surgery and nonoperative interventions for herniated lumbar disc disease were not significantly different with respect to either quality of life outcomes or costs. There is substantial variability in the conclusions of the cost-effectiveness of nonoperative management of spinal pathologies because of the differences in the methods of collecting cost data. Some of the aforementioned studies were purely costing studies without any associated quality of life outcomes data, which further complicates comparisons between these studies. Further research will be necessary to compare the costs among nonoperative interventions in addition to comparing operative versus nonoperative costs.

Investigators wishing to conduct a CEA should ensure that their analysis is both transparent and comparable to other studies. Based on the Panel on Cost-Effectiveness in Health and Medicine, a societal perspective (inclusion of indirect costs), 3% discount rate, and explicit definition of direct costs should be used in future cost-effectiveness studies. Many studies conducted since these recommendations were made in 1996 have not followed them and it is critical that future studies do adhere to the recommendations. However, as mentioned above, there are justifications for the use of a hospital or payer perspective based on the audience/readership and objectives of the study. Thus, authors should identify the perspective of their cost analysis early on for proper interpretation. In addition, given the importance of long-term follow-up in spine care, studies should also try to obtain long-term cost data.^{9,39,40} The question remains as to which cost calculation method (Medicare, CCR, case-costing database, and others) should be the gold standard; the literature appears to favor the Medicare method. Given the potential importance of the results of cost-effectiveness studies to our health care system, it is vital that a standardized cost methodology be adhered to for proper interpretation by policy makers and the public.

Conclusions

Differences in cost have a direct effect on the value equation of whether an intervention is cost effective. As such, investigators must be specific and detailed in their methods on how costs were calculated and from what sources. Comparability and transparency are essential for future clinical and policy decisions in an evolving health care landscape.

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Disclosure

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

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