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REVIEW ARTICLE

Economic comparisons of endoscopic spine surgery: a systematic review

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Abstract

Purpose Full-endoscopic techniques are minimally invasive surgery alternatives to traditional spinal surgery. We performed a systematic review of the literature to assess the costs of these techniques compared to traditional approaches.

Methods A systematic review of the literature was performed for economic evaluations that compare endoscopic decompressions of the lumbar spine for stenosis or disc herniation to open or microsurgical decompressions. The search was performed in the following databases: Medline, Embase Classic, Embase, and Central Cochrane library, from January 1, 2005, to October 22, 2022. The included studies were each evaluated according to a formal assessment checklist to evaluate the quality of economic evaluations based on 35 criteria.

Result A total of 1153 studies were identified, with 9 articles included in the final analysis. In evaluating the quality of economic evaluations, the study with the fewest met criteria scored 9/35 and the study with the most met criteria scored 28/35. Only 3 studies completed cost-effectiveness analyses. Surgical procedure duration varied between studies, but hospital length of stays were consistently shorter with endoscopy. While endoscopy was more frequently associated with higher operating costs, studies that measured healthcare and societal costs found endoscopy to be advantageous.

Conclusion Endoscopic spine surgery was found to be cost-effective in treating patients with lumbar stenosis and disc herniation when compared to standard microscopic approaches from a societal perspective. More well-designed economic evaluations investigating the cost-effectiveness of endoscopic spine procedures are needed to further support these findings.

Keywords Endoscopic · Spine surgery · MIS · Cost-effectiveness

Introduction

Lumbar stenosis (LS) and lumbar disc herniations (LDH) are among the most common spine pathologies treated surgically [1, 2]. Historically, open laminectomy and discectomy were the main surgical procedures for LS and LDH. Over the past decades, technological advancements in spine surgery have allowed for minimally invasive (MIS) surgical alternatives [3]. Two popular MIS approaches to the lumbar spine include microscopic tubular techniques and endoscopic spine surgery, which offer several advantages over traditional approaches. Both techniques use muscle and bone sparing approaches, smaller drills, and offer greater magnification, and illumination [4, 5]. Microscopic techniques require retractors, tubes, and a microscope; comparatively, endoscopic surgery tends to offer small incisions, utilizes continuous saline irrigation, and offers several technical approach advantages (i.e., approaching the neural foramina)[6].

Full-endoscopic spine surgery has recently increased in popularity. Endoscopic procedures offer several advantages compared to traditional approaches, including decreased tissue dissection and muscle compromise[7], less blood loss, improved scarring, smaller incision size, reduced length of hospital stay (LOS), and earlier functional recovery [8, 9]. A 2016 systematic review and meta-analysis comparing endoscopic versus open discectomy for symptomatic LDH evaluated 9 randomized control trials (RCTs) and 1092 patients; the analyses showed slightly better clinical outcomes,

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greater patient satisfaction, lower intraoperative blood loss, and shorter length of stay in the endoscopic group[10]. A more recent 2018 study by Lee and colleagues evaluated five studies including 156 patients undergoing endoscopic decompression via interlaminar approach for central or lateral recess spinal stenosis, showing significant improvements in ODI and VAS scores for leg and back pain [11].

While several studies comparing the clinical effectiveness of endoscopic spine surgery exist [12–15], less have sought to evaluate the economic implications of endoscopic techniques compared with traditional approaches. These considerations are especially important in the current spine surgery landscape, where medical stakeholders increasingly emphasize the need for value-based healthcare [15, 16]. In spine surgery, providers are encouraged to offer cost-effective services that minimize the cost of intervention and hospitalization [17]. Given the previously mentioned advantages of endoscopic spine surgery, several authors have hypothesized greater cost savings when compared with traditional approaches [3, 18]. However, there are currently no systematic reviews analyzing cost measures and comparisons on endoscopic spine surgery in the literature. To address this knowledge gap, we performed a systematic review that compares the costs and cost-effectiveness between endoscopic spine surgery and microsurgery or open surgery to treat lumbar stenosis and lumbar disc herniations, while also evaluating the quality of the published literature on the topic.

Methods

We performed a systematic review of the literature of articles that compare costs from endoscopic decompressions of the lumbar spine for stenosis or disc herniation to other types of decompressions (open or tubular, with microscope or magnifying loupes). This systematic review adhered to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)[19]. Only studies including adult patients who underwent lumbar spine decompression (discectomy, laminectomy, foraminotomy), degenerative stenosis, or disc herniation were included. Only articles directly comparing an endoscopic group and an open or tubular decompression group were included. All inclusion and exclusion criteria are presented in detail in Table 1. Patients who underwent endoscopically assisted tubular decompression were excluded to avoid confounding variables and debate regarding the advantages of the full-endoscopic technique. Biportal endoscopic procedures were included.

The search was performed in the following databases: Medline, Embase Classic, Embase, and Central Cochrane library, from January 1, 2005, to October 22, 2022. The search was performed on October 22, 2022. A librarian experienced in performing systematic review searches (Genevieve Gore) was consulted to help develop the search strategy we used. We did not include articles published prior to 2005, given the evolution of surgical techniques over the past two decades. In short, three concepts were used to build our search strategy. The first concept was related to the pathology of disc herniation or spinal stenosis (central stenosis, lateral recess stenosis, foraminal stenosis) in the lumbar spine. The second concept included procedures to address these pathologies, including discectomy, decompression, laminectomy, laminotomy, or foraminotomy. The third concept focused on economic evaluations, including cost, cost-effectiveness, and cost–benefit analyses. Each concept included MeSH terms, keywords, and subject subheadings from the databases searched. The complete search strategy can be found in Appendix.

The studies were initially screened through their titles and abstracts by two independent reviewers (LME and MG), and

Table 1 Inclusion and exclusion criteria for the systematic review

PICO	Inclusion criteria	Exclusion criteria
Population	Adult patients (18 years of age or older)	Stenosis of other etiology
	Degenerative stenosis or disc herniation of the lumbar spine	Stenosis affecting cervical or thoracic spine
Intervention	Full-endoscopic decompression compared to at least one open or tubular decompression method	Absent description of reference to methodological design of frailty or sarcopenia measure
		Fusion techniques
		Endoscopically assisted tubular decompression
Comparison	Comparison of the endoscopic decompression group to open or tubular decompressions group regarding any type of cost analysis, including cost-effectiveness	Absence of comparison concerning any type of cost analysis
Study Design	English language	Publications that are not original and comparative or do not include a full text (reviews, meta-analyses, editorials, case series, case studies, technical notes, or conference abstracts)
	Published after Jan. 1st, 2005	
	Full text articles	
	Randomized controlled trials, case series, cohort studies (retrospective, prospective)	

duplicates were identified and removed. Articles that either reviewer retained during initial screening were included for the full-text review. After that, reviewers with content expertise (LME, MG, QSA) performed a full-text review of these retained studies based on the inclusion and exclusion criteria. All accepted studies were included in the systematic review. Disagreements were resolved through discussion. Reference lists of included full-text articles were manually searched (by LME) to assess whether additional articles could be included in the study. Data collection was independently done by three reviewers (LME, MG, and QSA).

The following variables were collected: duration of surgery, hospital stay, cost of operation, direct hospital cost, secondary hospital cost, overall/direct hospital cost, indirect/societal cost, cumulative cost (sum of all costs), cost per quality-adjusted life years (QALY), incremental cost-effectiveness ratio (ICER). The principal measures used were the following: mean, the difference between values of endoscopy and comparison groups in percent (endoscopic—comparison divided by comparison × 100%), and reported p value of significance. The included studies were evaluated according to the quality assessment checklist in the "Guidelines for authors and peer reviewers of economic submissions to the BMJ" by Drummond and Jefferson [20] (by LME, MG, and QSA). This checklist is widely accepted as a comprehensive quality assessment tool for economic evaluations. Briefly, the checklist evaluates the quality of economic evaluations based on 35 criteria across three concepts: study design, data collection, analysis, and interpretation of results.

Results

Search results

A summary of the search strategy results is shown in Fig. 1. Overall, 9 articles were included in the final analysis [12–15, 21–25]. A meta-analysis was impossible as reporting outcomes across the 9 included studies was too heterogeneous. The data extracted from each of the 9 studies are presented in Tables 2 and 3. The details of the Oxford economic scores are available in Appendix, and the number of "yes" criteria that were obtained in each study (out of a score of 35) are summarized in Table 2. Only two studies performed a cost-effectiveness analysis (Choi, Gadjradj). A narrative summary of each included study is provided below.

Narrative summary of included articles

In a retrospective cost-effectiveness study published in 2019, Choi et al. evaluated 429 patients that underwent endoscopic discectomy (transforaminal endoscopic lumbar discectomy (TELD), interlaminar endoscopic lumbar discectomy (IELD), or unilateral biportal endoscopic discectomy (UBED)) and 136 open microdiscectomies [23]. Both duration of surgery and hospital stay were found to be significantly lower ($p < 0.01$) for the endoscopic group. The cost of surgery, direct hospital costs, and overall direct hospital costs of endoscopic discectomies were significantly reduced by 10%. In addition, endoscopy fared significantly better with lower indirect costs incurred by work loss and the total sum of all the above costs, with a decrease of 20.1% and 12.8%, respectively. Furthermore, a significant reduction of 23.1% to 26,776.9 USD was found regarding the cost per quality-adjusted life years (QALY) of endoscopic discectomies. This translated into an incremental cost-effectiveness ratio (ICER) of 36,016.6 USD in favor of endoscopy. However, the average secondary hospital costs of endoscopy, the costs associated with postoperative course management, and unexpected events 2 weeks after primary surgery were found to be higher but not statistically significant.

Kim et al. performed a cost-effectiveness analysis on a retrospective cohort of a nationwide database in South Korea [24]. In this study, 4749 patients underwent percutaneous endoscopic lumbar discectomy (PELD), while 45,004 underwent open discectomy (OD), 3265 had laminectomy, and 3243 had fusion as a surgical treatment of disc herniation. PELD was less costly than OD and had a lower reoperation probability. The ICER results showed that PELD was the cost-effective surgical method with respect to reducing reoperation probability.

Another retrospective study by Pan et al. compared PTED to OD [12]. It was not designed as a cost-effectiveness study, and the samples of the 2 groups were small. Nonetheless, the hospital stay and the cost of hospitalization of endoscopic discectomy were significantly ($p < 0.01$) lower than that of OD by 43.8% and 21.2%, respectively. The duration of endoscopic discectomy was also lower by approximately 7 min (mean: 64.8 min); however, this difference was neither statistically significant nor meaningful.

Unsal et al. conducted a retrospective study on 40 patients that underwent lumbar discectomy, comparing PELD and open microdiscectomy [25]. Patients that underwent endoscopy had a significantly shorter length of stay and shorter duration of surgery. Endoscopy was less expensive, with an overall cost of $1250 in the PLED with local anesthesia and 1742 $ in PLED with general anesthesia, as compared with the cost of open microdiscectomy, which was 2016 $ and $2349 for the spinal and general anesthesia, respectively.

Liu et al. retrospectively compared patients that underwent microscope-assisted tubular discectomy (MTD) with PTED (60 patients in each group) for lumbar disc herniation with 20-month follow-up [13]. The main objective of this study was to compare the clinical outcomes and quality of life measures, not cost-effectiveness measures. Overall, there was a higher cost in the endoscopic group

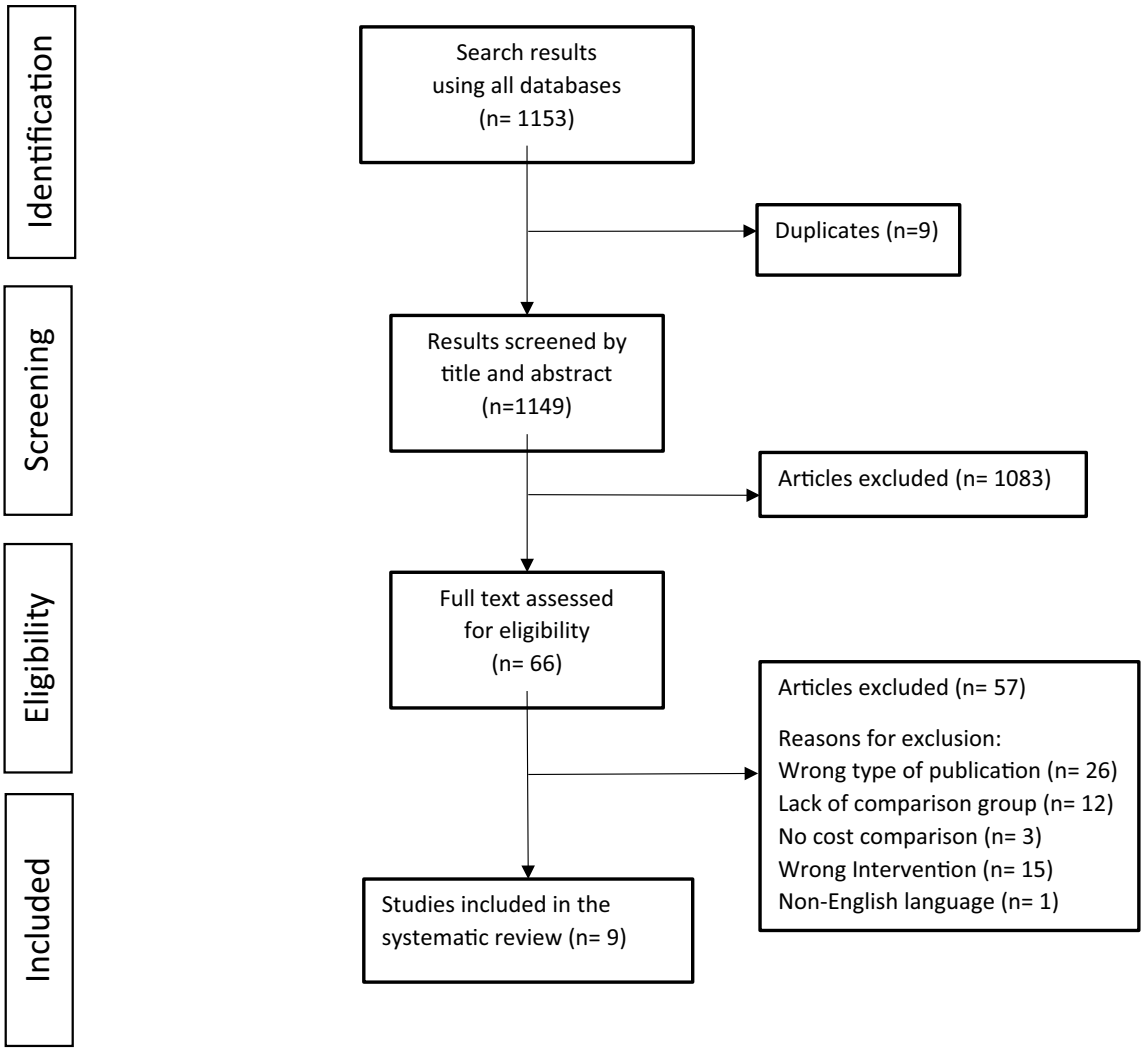

Fig. 1 PRISMA flowchart for included and excluded articles

(2972.3 USD) compared to the microscopic discectomy group (2359.8 USD). However, this article does not specify what was evaluated in the cost; thus, it is unclear whether the cost is related to the surgery itself or the entire hospitalization. Further, there are no measures made for societal costs. Patients in the endoscopy group had less intraoperative blood loss, smaller incision lengths, shorter hospital stays on average, but also a longer duration of surgery.

Foocharoen et al. retrospectively compared UBED (43 patients) and OD (37 patients) [14]. The authors found that endoscopy resulted in significantly less postoperative pain, lower opioid consumption, and shorter length of stay, with an equal rate of postoperative complications. However, endoscopy had a longer surgical duration and higher hospital cost (1256 USD compared with 911 USD).

Cheung et al. compared 161 patients undergoing conventional microscope-assisted lumbar decompression (CD) with 160 patients undergoing full-endoscopic interlaminar decompression [22]. A decision analysis model comparing these patients over a 1-year time horizon was conducted. Relevant unit costs associated with each surgical procedure and each possible complication treatment were estimated. The average total costs for endoscopy and CD were found to be HKD$54,863 and HKD$52,748, respectively. Both procedures carried similar costs in terms of hospitalization, radiology, and routine follow-up visits. A 3.9% (HKD$2,115) difference in total cost was largely due to the differences in the cost of surgery and complications. There were no societal costs in this manuscript.

An et al. retrospectively compared 47 patients undergoing PELD to 46 patients undergoing open lumbar discectomy [15]. The objective of this study was not a formal economic evaluation but aimed to evaluate the safety and efficacy of PETD. There is little cost comparison in a table showing that the cost of PETD was 3.55 [3.30, 3.80] RMB, compared with 6.18 [5.78, 6.50] RMB. This represents a 74% decrease

Table 2 A summary of baseline characteristics of included studies

Study (year, country)	Oxford Quality Assessment Criteria that were appropriate (n/35)	Study design	Endoscopy				Other Technique			
			Procedure	n	age	Follow up (months)	Procedure	n	age	Follow up (months)
Pan Zhimin [12]	9	retrospective	TELD	48	39.5 avg	16.7 avg	OD	58	42.8 avg	OD 17.3 avg
Kim Chi Heon [24]	22	retrospective	PELD	4749	NR	NR	OD, OL, Fusion	51,512	NR	NR
Choi Kyung-Chul [23]	20	retrospective	TELD IELD UBED	429	45.5 49.0 49.1 mean	NR	OMD	136	47.9 mean	NR
Cheung [22]	14	Retrospective	ULBD	160	63 mean	NR	Bilateral microscopic laminotomy	161	63 mean	NR
Foocharoen Thanit [14]	10	Retrospective	UBED	43	39.1 mean	5 median	OD	37	36.2 mean	6 median
Lantao Liu [13]	10	Retrospective	PTED	69	50.7	> 20	OMD	60	53.4	> 20
Unsal Ülkün Ünlü [25]	14	Retrospective	IELD	20	47.6 LA 44.5 GA mean	NR	OMD	20	48.2 (SA) 46.9 (GA) mean	NR
An [22]	10	Retrospective	PETD	49	52.98 mean	15.98 mean	OD	46	52.98 mean	16.11 mean
Gadjradj [21]	28	RCT	PTED	304	45.3 mean	12	OD	309	45.7 mean	12

PELD percutaneous endoscopic lumbar discectomy, *TESSYS* percutaneous Transforaminal Endoscopic Surgical System, *RCT* randomized control trial, *OD* open discectomy, *OL* open laminectomy, *UBED* unilateral biportal endoscopic discectomy, *OMD* open microdiscectomy, *ULBD* unilateral laminotomy for bilateral decompression, *LA* local anesthesia, *GA* general anesthesia, *SA* spinal anesthesia

Table 3 Hospital LOS, surgery duration, and costs associated with endoscopic procedures among included studies

	Hospital Length of stay (days)		Surgery duration (min)		Healthcare cost (USD $)		Operating cost (USD $)		Societal cost (USD $)	
Study	Endo	Other	Endo	Other	Endo	Other	Endo	Other	Endo	Other
Pan Zhimin	7.2	12.8	64.8	72	NR	NR	1263.8	1602.8	NR	NR
Kim Chi Heon	NR	NR	NR	NR	1600	Discectomy 2204 Laminectomy 2459	NR	NR	NR	NR
Choi Kyung-Chul	5	8.7	62.4	70.8	3806	4302	1799.6	1988.8	607.2	759.8
Cheung	NR	NR	NR	NR	NR	NR	4329.52	3979.82	NR	NR
Foocharoen Thanit	4.8	7.4	100.4	67.9	NR	NR	NR	NR	NR	NR
Liu	5.4	10.6	76.2	51.1	NR	NR	2972.3	2359.8	NR	NR
Unsal Ülkün Ünlü	0.4 (LA) 1.1(GA)	1.3 (SA) 1.4 (GA)	35 (LA) 33(GA)	48 (SA) 45 (GA)	1,249.5 (LA) 1,741.5 (GA)	2,015.6 (SA) 2,348.7 (LA)	871	1,170	NR	NR
An	3	7.1	65.3	127.7	NR	NR	3.5	6.18	NR	NR
Gadjradj	NR	NR	NR	NR	5865	6112	4500	4095	15,090	17,633

in cost. However, the authors do not specify what this cost represents. It is unclear if this decrease represents operative costs, hospitalization costs, or a combination thereof.

The study by Gadjradj et al. was a well-designed economic evaluation study that was conducted alongside a 12-month multicenter RCT, in which patients were randomized to PTED or open microdiscectomy [21]. A total of 613 patients with sciatica were included. Effect measures included leg pain and QALYs, as derived using EQ-5D-5L. Direct and indirect costs were measured from a societal perspective. Statistically significant differences in leg pain and QALYs were found in favor of PTED at 12-month follow-up. Surgery costs were higher for PTED than for open microdiscectomy, but all other disaggregate costs and total societal costs were lower for PTED than for open microdiscectomy. Cost-effectiveness acceptability curves indicated that the probability of PTED being less costly and more effective (i.e., dominant) compared with open microdiscectomy was 99.4% for leg pain and 99.2% for QALYs. An incremental cost-effectiveness ratio (ICER) of −€70,235, favoring PTED over open microdiscectomy, was noted.

Discussion

Full-endoscopic and microscopic techniques are MIS alternatives to traditional spinal surgery with established clinical efficacy and favorable complication profiles [26]. The cost of performing advanced techniques is an important consideration in appreciating the total benefit to the patient, and society, and when comparing potential advantages of one technique over another. The main costs associated with treating sciatica and back pain are related to hospital costs and sick leave from work [27]. The actual cost of intervention is therefore multifactorial and depends on operating room time, use of operating room equipment, surgical comorbidities, hospital length of stay, time to return to work, and secondary surgical interventions. These elements are commonly grouped in terms of operating costs, healthcare costs, and societal costs and often expressed in economic evaluation studies in terms of quality-adjusted life years (QALYs) [28].

Incremental cost-effectiveness ratios (ICERs) are an important economic metric and are dependent on the ratio between incremental costs over incremental effects when comparing two interventions [29]. Decision makers rely on such cost-effectiveness evaluation to determine whether investing in an intervention is justified. Only 3 studies in our review completed cost-effectiveness analyses. Choi et al. reported an ICER of $36,016.60 per QALY gained when compared endoscopic discectomy versus microdiscectomy [23]. Kim et al. also found their ICER to be in favor of endoscopy (465$/% reoperation) when considering the rate of reoperation between PELD and open discectomy [24]. Gadjradj et al. published a recent and well-designed economic evaluation study that was conducted alongside a 12-month multicenter RCT, in which patients with sciatica were randomized to PTED or open microdiscectomy [21]. Direct and indirect costs were measured from a societal perspective. Surgery costs were higher, but all other costs as well as total societal costs were lower for PTED. They reported an ICER of €70,235.00 per QALY gained favoring endoscopic discectomy over open microdiscectomy. This article is also unique as the only large Western study that is most likely representative of common practices in North American and European healthcare systems. Although there was significant heterogeneity in the cost-effectiveness measures reported across the 3 studies, there is evidence that supports that endoscopic discectomy is more cost-effective

than microdiscectomy. Furthermore, the cost per QALY gained reported by Choi et al. for endoscopic discectomy was $26,776.90 versus $34,840.40 for microdiscectomy, which are both within the limits of what is widely accepted as a cost-effective intervention [30].

Of the 9 articles identified, surgical times varied between studies, but hospital length of stays were consistently shorter with endoscopy. While endoscopy was more frequently associated with higher operating costs, all studies that measured healthcare and societal costs found endoscopy to be advantageous.

The studies included in this systematic review had several methodological limitations that were apparent in our quality assessment. Using the Drummond and Thomson quality assessment for economic health studies, all studies had flaws that were identified. The criteria regarding study design were well executed across all studies, but the analysis and interpretation of results generally performed poorly in the quality assessment tool. For example, sensitivity analyses were only completed in the Gadjradj et al. study, which allowed readers to appreciate the robustness of their results even when different analysis assumptions were altered. As such, the conclusions of the other studies are not as strong as they could otherwise have been. In addition, 5 of the 9 studies did not clearly state the primary outcome measure for the economic evaluation. Overall, the study with the fewest met criteria on the quality assessment tool was 9/35 and the study with the most met criteria was 28/35. To improve the quality of the literature, further studies on the topic should be based on studies that have a clear primary outcome defined, with health states that are measured using standardized metrics, and with cost estimates that are measured from a societal perspective, if possible. Also, these studies should focus on more cost-effectiveness or cost–benefit analyses so that a comparison in costs between two interventions can be appropriately evaluated. In fact, only 3 studies provided ICER estimates, which limits how decision-makers can interpret the value of an endoscopic approach over the alternative microscopy approaches. With these improvements in the literature, it would be possible to better understand the value of using endoscopic approaches for lumbar decompression or discectomy surgery.

Our study has limitations we must acknowledge. First, the exclusion of non-English studies may cause some bias to our results and interpreting the current state of the literature on the topic. Second, we only included studies published as of 2005. While some studies may have been omitted, we decided to concentrate on more recent articles that offer fair comparisons incorporating advances in modern endoscopic and microscopic techniques. Third, we chose to limit comparisons to decompression procedures of the lumbar spine and exclude cervical and thoracic levels, as well as endoscopic fusion procedures as these do not reflect common practice patterns of most MIS endoscopic spine surgeons. Fourth, additional limitations are inherent to the quality of published articles and the heterogeneity in their published data that renders meta-analyses impossible. It is also difficult to compare costs across different studies as they are often based on varied patient populations representing different healthcare practice patterns. Results related to hospital stays, for example, are not representative of North American practices where nearly all endoscopy or MIS surgery for sciatica is performed in the outpatient setting [31–33].

Conclusions

This systematic review suggests that endoscopic spine surgery to treat lumbar stenosis and disc herniation is a cost-effective approach to treating patients when compared to standard microscopic approaches. Further research that investigates the cost-effectiveness of these procedures, by addressing the main methodological limitations in the literature, is necessary to obtain stronger evidence that justifies its use.

Appendix X: search strategy used across the three databases used in the systematic review

Medline search

1 (intervertebral disk degeneration/ or intervertebral disk displacement/ or (dis?opath$ or spondylodiscitis or spondylochondrosis or chondrosis or hernia$ or perfora$ or ruptur$ or degenerat$ or degradat$ or displac$ or prolaps$ or protru$ or avuls$ or compress$ or extru$).tw,kf,ot.) and (intervertebral disk/ or intervertebral disk degeneration/ or intervertebral disk displacement/ or (disc? or disk? or intervertebral or intradiscal or intradiskal).tw,kf,ot.) 50,780
2 exp spinal stenosis/ or ((canal or central or foramin* or lateral or spin*) adj3 stenos?s).mp. or "neurogenic claudication".mp. or exp radiculopathy/ or (Radiculopath* or "radicular pain").mp. or ((lumb* adj5 spondyl*) or Spondylos*).mp. or exp spondylosis/34447.
3 1 or 276,221.
4 lumbar vertebrae/ or lumbosacral region/ or (low* back* or lumbar or lumbo* or l1 or l2 or l3 or l4 or l5 or sacrolumb* or thoracolumb*).tw,kf,ot.271585.
5 3 and 438,649.
6 ((herniation or spinal stenos?s) not ((cerebr* or cranial or cranio* or cervical or thoracic) not (lumbar or lumbo* or sacrolumb* or thoracolumb*))).ti.9309.
7 5 or 642,079.

8 exp Diskectomy/6764.
9 Laminectomy/10387.
10 Foraminotomy/229.
11 Decompression, Surgical/17565.
12 (dis?ectom* or laminectom* or laminotom* or foraminotom* or decompression*).mp.73979.
13 8 or 9 or 10 or 11 or 1,273,979.
14 7 and 1,310,848.
15 Economics/27467.
16 exp "Costs and Cost Analysis"/260775.
17 Economics, Nursing/4013.
18 Economics, Medical/9226.
19 Economics, Pharmaceutical/3083.
20 exp Economics, Hospital/25638.
21 exp "Fees and Charges"/31239.
22 exp Budgets/14050.
23 (budget* or economic* or cost or costs or costly or costing or price or prices or pricing or pharmacoeconomic* or expenditure* or expense or expenses or financial or finance or finances or financed or money or monetary or fee or fees or payee* or payer* or paying or payment* or pays or affordable or expensive or invest or invested or investing or invests or investment*).ti,ab,kf.1320374.
24 exp models, economic/16153.
25 markov chains/15827.
26 markov.ti,ab,kf.27497.
27 monte carlo method/31684.
28 monte carlo.ti,ab,kf.57507.
29 exp Decision Theory/12975.
30 (decision* adj2 (tree* or analy* or model*)).ti,ab,kf.33806.
31 or/15–301,541,530.
32 7 and 13 and 31,636.

Embase classic + embase

1 (intervertebral disk degeneration/ or intervertebral disk hernia/ or (dis?opath$ or spondylodiscitis or spondylochondrosis or chondrosis or hernia$ or perfora$ or ruptur$ or degenerat$ or degradat$ or displac$ or prolaps$ or protru$ or avuls$ or compress$ or extru$).tw,kf,ot.) and (intervertebral disk/ or intervertebral disk degeneration/ or intervertebral disk hernia/ or (disc? or disk? or intervertebral or intradiscal or intradiskal).tw,kf,ot.) 70,637
2 vertebral canal stenosis/ or ((canal or central or foramin* or lateral or spin*) adj3 stenos?s).mp. or "neurogenic claudication".mp. or exp radiculopathy/ or (Radiculopath* or "radicular pain").mp. or ((lumb* adj5 spondyl*) or Spondylos*).mp. or spondylosis/80384.
3 1 or 2,135,998.
4 exp lumbar vertebra/ or lumbosacral region/ or lumbosacral spine/ or (low* back* or lumbar or lumbo* or l1 or l2 or l3 or l4 or l5 or sacrolumb* or thoracolumb*).tw,kf,ot.383856.
5 3 and 452,724.
6 lumbar disc hernia/ or lumbar spinal stenosis/11949.
7 5 or 654,726.
8 ((herniation or spinal stenos?s) not ((cerebr* or cranial or cranio* or cervical or thoracic) not (lumbar or lumbo* or sacrolumb* or thoracolumb*))).ti.11569.
9 7 or 858,886.
10 exp discectomy/6865.
11 laminectomy/ or laminotomy/26578.
12 foraminotomy/1109.
13 spinal cord decompression/7585.
14 (dis?ectom* or laminectom* or laminotom* or foraminotom* or decompression*).mp.115084.
15 10 or 11 or 12 or 13 or 14,115,155.
16 9 and 1,515,871.
17 Economics/246771.
18 Cost/64841.
19 exp Health Economics/1000134.
20 Budget/32715.
21 budget*.ti,ab,kf.46260.
22 (economic* or cost or costs or costly or costing or price or prices or pricing or pharmacoeconomic* or pharmaco-economic* or expenditure or expenditures or expense or expenses or financial or finance or finances or financed or fee or fees or payee* or payer* or paying or payment* or pays or affordable or expensive or invest or invested or investing or invests or investment*).ti,kf.373479.
23 (economic* or cost or costs or costly or costing or price or prices or pricing or pharmacoeconomic* or pharmaco-economic* or expenditure or expenditures or expense or expenses or financial or finance or finances or financed or fee or fees or payee* or payer* or paying or payment* or pays or affordable or expensive or invest or invested or investing or invests or investment*).ab. / freq = 2,573,946.
24 (cost* adj2 (effective* or utilit* or benefit* or minimi* or analy* or outcome or outcomes)).ab,kf.275005.
25 (value adj2 (money or monetary)).ti,ab,kf.3923.
26 Statistical Model/172084.
27 economic model*.ab,kf.5898.
28 Probability/137230.
29 markov.ti,ab,kf.36042.
30 monte carlo method/47766.
31 monte carlo.ti,ab,kf.60085.
32 Decision Theory/1849.
33 Decision Tree/18723.
34 (decision* adj2 (tree* or analy* or model*)).ti,ab,kf.46572.
35 or/17–341,990,065.
36 16 and 35,818.

Cochrane central register of controlled trials (cochrane library/wiley)

IDSearchHits.

#1(((((([mh ^"intervertebral disk degeneration"] OR [mh ^"intervertebral disk displacement"] OR (dis?opath?):ti,ab,kw) AND ([mh ^"intervertebral disk"] OR [mh ^"intervertebral disk degeneration"] OR [mh ^"intervertebral disk displacement"] OR (disc? OR disk? OR intervertebral OR intradiscal OR intradiskal):ti,ab,kw)) OR ([mh "spinal stenosis"] OR ((canal OR central OR foramin* OR lateral OR spin*) NEAR/3 stenos?s):ti,ab,kw OR "neurogenic claudication":ti,ab,kw OR [mh radiculopathy] OR (Radiculopath* OR "radicular pain"):ti,ab,kw OR ((lumb* NEAR/5 spondyl*) OR Spondylos*):ti,ab,kw OR [mh spondylosis])) AND ([mh ^"lumbar vertebrae"] OR [mh ^"lumbosacral region"] OR ((low* NEAR/2 back*) OR lumbar OR lumbo* OR l1 OR l2 OR l3 OR l4 OR l5 OR sacrolumb* OR thoracolumb*):ti,ab,kw)) OR (((herniation OR ("spinal" NEAR/2 stenos?s)) NOT ((cerebr* OR cranial OR cranio* OR cervical OR thoracic) NOT (lumbar OR lumbo* OR sacrolumb* OR thoracolumb*))):ti)) AND (([mh Diskectomy]) OR ([mh ^Laminectomy]) OR ([mh ^Foraminotomy]) OR ([mh ^"Decompression, Surgical"]) OR ((dis?ectom* OR laminectom* OR laminotom* OR foraminotom* OR decompression*):ti,ab,kw)) AND (([mh ^Economics]) OR ([mh "Costs and Cost Analysis"]) OR ([mh ^"Economics, Nursing"]) OR ([mh ^"Economics, Medical"]) OR ([mh ^"Economics, Pharmaceutical"]) OR ([mh "Economics, Hospital"]) OR ([mh "Fees and Charges"]) OR ([mh Budgets]) OR ((budget* OR economic* OR cost OR costs OR costly OR costing OR price OR prices OR pricing OR pharmacoeconomic* OR expenditure* OR expense OR expenses OR financial OR finance OR finances OR financed OR money OR monetary OR fee OR fees OR payee* OR payer* OR paying OR payment* OR pays OR affordable OR expensive OR invest OR invested OR investing OR invests OR investment*):ti,ab,kw) OR ([mh "models, economic"]) OR ([mh ^"markov chains"]) OR (markov:ti,ab,kw) OR ([mh ^"monte carlo method"]) OR ("monte carlo":ti,ab,kw) OR ([mh "Decision Theory"]) OR ((decision* NEAR/2 (tree* OR analy* OR model*)):ti,ab,kw)) in Trials162.

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Declarations

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References

1. Blamoutier A (2013) Surgical discectomy for lumbar disc herniation: surgical techniques. Orthop Traumatol Surg Res 99:S187–S196
2. Lurie J, Tomkins-Lane C (2016) Management of lumbar spinal stenosis. BMJ. https://doi.org/10.1136/bmj.h6234
3. McAfee PC, Phillips FM, Andersson G, Buvenenadran A, Kim CW, Lauryssen C et al (2010) Minimally invasive spine surgery. Spine 35:S271–S273
4. Choi G, Pophale CS, Patel B, Uniyal P (2017) Endoscopic spine surgery. J Korean Neurosurg Soc 60:485–497
5. Vaishnav AS, Othman YA, Virk SS, Gang CH, Qureshi SA (2019) Current state of minimally invasive spine surgery. J Spine Surg 5:S2-10
6. Yeung A, Yeung C (2003) Advances in endoscopic disc and spine surgery: foraminal approach. Surg Technol Int 11:255–263
7. Momin AA, Steinmetz MP (2020) Evolution of minimally invasive lumbar spine surgery. World Neurosurg 140:622–626
8. Basil GW, Wang MY (2019) Trends in outpatient minimally invasive spine surgery. J Spine Surg 5:S108–S114
9. Allen RT, Garfin SR (2010) The economics of minimally invasive spine surgery. Spine 35:S375–S382
10. Cong L, Zhu Y, Tu G (2016) A meta-analysis of endoscopic discectomy versus open discectomy for symptomatic lumbar disk herniation. Eur Spine J 25:134–143
11. Lee C-H, Choi M, Ryu DS, Choi I, Kim CH, Kim HS et al (2018) Efficacy and safety of full-endoscopic decompression via interlaminar approach for central or lateral recess spinal stenosis of the lumbar spine. Spine 43:1756–1764
12. Pan Z, Ha Y, Yi S, Cao K (2016) Efficacy of transforaminal endoscopic spine system (TESSYS) technique in treating lumbar disc herniation. Med Sci Monit: Int Sci Lit Inc. 22: 530–9
13. Liu L, Xue H, Jiang L, Chen H, Chen L, Xie S et al (2021) Comparison of percutaneous transforaminal endoscopic discectomy and microscope-assisted tubular discectomy for lumbar disc herniation. Orthop Surg 13:1587–1595
14. Foocharoen T (2021) Early outcomes: a comparison between biportal endoscopic spine surgery and open lumbar discectomy for single-level lumbar disc herniation. J Med Assoc Thai 104:123–128
15. An J, Zhang J, Yu T, Wu J, Nie X, He T et al (2022) A retrospective comparative study of modified percutaneous endoscopic transforaminal discectomy and open lumbar discectomy for gluteal pain caused by lumbar disc herniation. Front Surg. https://doi.org/10.3389/fsurg.2022.930036
16. Asher AL, Speroff T, Dittus RS, Parker SL, Davies JM, Selden N et al (2014) The national neurosurgery quality and outcomes database (N2QOD). Spine 39:S106–S116
17. McGirt MJ, Resnick D, Edwards N, Angevine P, Mroz T, Fehlings M (2014) Background to understanding value-based surgical spine care. Spine 39:S51–S52
18. Regan J, Guyer R (1997) Endoscopic techniques in spinal surgery. Clin Orthop Relat Res 335:122–139
19. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD et al (2021) The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. https://doi.org/10.1016/j.ijsu.2021.105906
20. Drummond MF, Jefferson TO (1996) Guidelines for authors and peer reviewers of economic submissions to the BMJ. BMJ 313:275–283
21. Gadjradj PS, Broulikova HM, van Dongen JM, Rubinstein SM, Depauw PR, Vleggeert C et al (2022) Cost-effectiveness of full endoscopic versus open discectomy for sciatica. Br J Sports Med BMJ 56:1018–1025

22. Cheung PWH, Wong CKH, Lau ST, Cheung JPY (2020) Cost analysis comparison between conventional microsurgical decompression and full-endoscopic interlaminar decompression for lumbar spinal stenosis surgery. J Spine Surg 6:721–728
23. Choi KC, Shim HK, Kim JS, Cha KH, Lee DC, Kim ER et al (2019) Cost-effectiveness of microdiscectomy versus endoscopic discectomy for lumbar disc herniation. Spine J 19:1162–1169
24. Kim CH, Chung CK, Kim MJ, Choi Y, Kim MJ, Hahn S et al (2018) Increased volume of lumbar surgeries for herniated intervertebral disc disease and cost-effectiveness analysis: a nationwide cohort study. Spine 43:585–593
25. Ünsal ÜÜ, Şentürk S (2021) Comparison of direct costs of percutaneous full-endoscopic interlaminar lumbar discectomy and microdiscectomy: results from turkey. Ideggyogy Sz 74:197–205
26. Li W-S, Yan Q, Cong L (2022) Comparison of endoscopic discectomy versus non-endoscopic discectomy for symptomatic lumbar disc herniation: a systematic review and meta-analysis. Glob Spine J 12:1012–1026
27. van Tulder MW, Koes BW, Bouter LM (1995) A cost-of-illness study of back pain in the Netherlands. Pain 62:233–240
28. Whitehead SJ, Ali S (2010) Health outcomes in economic evaluation: the QALY and utilities. Br Med Bull 96:5–21
29. Pearson SD (2018) The ICER value framework: integrating cost effectiveness and affordability in the assessment of health care value. Value Health 21:258–265
30. Ogden J (2017) QALYs and their role in the NICE decision-making process. Prescriber 28:41–43
31. Sivaganesan A, Hirsch B, Phillips FM, McGirt MJ (2018) Spine surgery in the ambulatory surgery center setting: value-based advancement or safety liability? Neurosurgery 83:159–165
32. Pendharkar AV, Shahin MN, Ho AL, Sussman ES, Purger DA, Veeravagu A et al (2018) Outpatient spine surgery: defining the outcomes, value, and barriers to implementation. Neurosurg Focus 44:E11
33. Linhares D, Fonseca JA, Ribeiro da Silva M, Conceição F, Sousa A, Sousa-Pinto B et al (2021) Cost effectiveness of outpatient lumbar discectomy. Cost Eff Resour Alloc 19:19