

The cost-effectiveness of conventional discectomy compared to other surgical techniques for lumbar disk herniation. A systematic review

Thorsen MTH^{1*}, Ødegaard-Olsen Ø¹, Yde CL^{2,3}, Andersen MO^{2,3}, Draborg E^{1,4} and O'Neill S^{2,3}

¹Faculty of Health Sciences, University of Southern Denmark, Campusvej 55, 5000 Odense M, Denmark

²Spine Center of Southern Denmark, Lillebælt Hospital, Østre Hougvej 55, 5500 Middelfart, Denmark

³Institute of Regional Health Research, University of Southern Denmark, Campusvej 55, 5000 Odense M, Denmark

⁴COHERE, Centre for Health Economics Research, University of Southern Denmark, Odense, Denmark

Abstract

Background: The current study reviews the literature on the cost-effectiveness of conventional discectomy compared to other surgical techniques, by assessing studies with economical evaluation and studies using proxy measures of cost-effectiveness.

Methods: In April 2016, a comprehensive search was conducted in Medline, Embase and the Cochrane Database. Reference lists of retrieved articles were perused for further relevant publications. Randomized controlled trials and comparison studies, comparing conventional discectomy to other surgical interventions for patients with lumbar disk herniation, were included and reviewed by the authors. Data were gathered on the methodology of the studies, including study design, randomization, follow-up period, cost-estimation, etc. and the quality of the published studies was quantified using a modified version of the Drummond checklist.

Results: Twenty-four articles were included in the review, 9 retrieved from the original search, and an additional 15 from reference lists. Four studies included an economical evaluation and 20 reported proxy measures of cost-effectiveness. The quality of studies varied considerably and results were ambiguous; the four economic studies favored conventional discectomy, but none were randomized trials. Of the twenty proxy studies some favored the alternatives, and some reported no clear difference.

Conclusions: The available literature does not allow for strong conclusions due to the sparsity of high quality economic studies. The available evidence, however, suggests that any cost-effectiveness difference between conventional discectomy and the alternatives is unlikely to be great.

Introduction

Compared to many other spinal surgeries, discectomy is a relatively inexpensive procedure, but radiculopathy due to lumbar intervertebral disk herniation is one of the most common spinal disorder requiring surgical intervention. Thus, the relative cost effectiveness of different, competing surgical techniques is worthy of investigation, if limited resources are to be used rationally. Unfortunately, a reliable estimate of direct and indirect costs can be difficult to ascertain.

In Denmark, for instance, surgery for lumbar disk herniations may account for as much as one third of all lumbar spinal surgery [1] and while the direct costs can be estimated through the use of a national database [2] (approximately 35.000DKK / 5200 US\$ or 4600 Euro per operation), there is no simple way to estimate indirect costs related to sick-leave, lost production, etc. Between 2009 and 2013 more than 6000 surgeries for lumbar disk herniation were performed in Denmark alone³. The cost and frequency of disk surgery may differ between countries, but in general disk surgery is a relatively common intervention and although direct costs are obviously significant, indirect costs are likely to be far more important. Especially so, as disk herniations tends to affect individuals of working age [3].

Conventional open discectomy (CD) is considered an effective treatment for selected patients with lumbar disk herniation with

radicular pain⁴. In the last 30 years the success rates for sciatic pain has been reported in the range between 49% and 98%, depending on patient selection, duration of symptoms, success criteria, length of follow-up, etc [4,5].

A number of alternative surgical procedures have been and continue to be used in the treatment of lumbar disk herniation. For example, lumbar microdiscectomy (MD) has gained widespread acceptance⁶ and studies suggest that the procedure may be effective and associated with shorter hospital stay and earlier return to work compared to CD [5,7-9]. Conversely, the use of chemonucleolysis (CNL) which became popular in the 1970s and 1980s, has largely been replaced by other surgical techniques which do not expose patients to the allergic complications inherent to CNL [8].

Correspondence to: Thorsen MTH, Faculty of Health Sciences, University of Southern Denmark, Campusvej 55, 5000 Odense M, Denmark, Tel: +47 936 18 222; E-mail: Mayt101@yahoo.no

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Which surgical technique should be considered the standard or *reference technique* for lumbar disk herniation is a matter of debate and different surgeons have different preferences. Benz & Garfin [10], state that CD remains the *gold standard*, while Postacchini & Postacchini [8] claim that MD should be considered the gold standard. In 2012, CD was the most commonly used surgical procedure in the treatment of patients with lumbar disk herniation in Denmark (59%) [1] and thus CD was chosen as the standard (index treatment) in this literature review.

Cost-effectiveness analysis is useful for identifying the most efficient use of health-care resources for a specific health condition, i.e. which of a number of alternative interventions offers most value for money. Cost-effectiveness studies can help clinicians and administrators make necessary decisions about choice of treatment on a rational basis [11]. To our knowledge there are no literature reviews reporting the cost-effectiveness of CD compared to other surgical techniques used for treating lumbar disk herniation.

The current study was conducted to determine whether the literature supports CD as being more cost-effective than other surgical techniques for lumbar disk herniation, by reviewing studies using a cost-effective analysis and studies that report proxy measures of costs. In this context, proxy measures of cost are defined as length of hospitalization, number of sick-leave days, disability requiring treatment, and cost of intervention.

Materials and methods

A literature review was conducted in accordance with the Prisma statement [12]. The review team consisted of two reviewers, ØO and MT. Any disagreement in manuscript review was solved by conferring with a health economy expert (Eva Draborg – ED) at the Center of Health Economic Research (COHERE), University of Southern Denmark in Odense, Denmark.

Eligibility criteria

Participants: Studies in which participating patients had a radiologically verified lumbar disk herniation.

Study design: Randomized controlled trials, non-randomized clinical trials and comparison studies.

Intervention: Conventional discectomy compared to other surgical interventions.

Area: Europe and North-America.

Language: English or Scandinavian languages.

Economic evaluation: Cost-effectiveness analysis or proxy-measures of cost.

Information sources

The following databases formed the basis for a systematic literature search: Medline (Pubmed format), Embase and Cochrane, which also contain the NHS economic evaluation database. In addition, the reference lists of all relevant articles, found by the original search strategy, was examined manually.

The date of last search was the 13th of April 2016.

To ensure that the search strategy and method was optimal, a senior librarian with particular experience and expertise in systematic reviews was consulted (Berit Elisabeth Alving, University of Southern Denmark).

Search

The search strategy was composed of the following PICO elements (patients, intervention, control, outcome): P: Patients with lumbar disk herniation radiologically verified, I: Conventional discectomy, C: Other surgical techniques and O: Cost-effectiveness or cost-benefit. The exact search string is shown in Appendix 1-3.

Study selection

Figure 1 illustrates the literature identification and review process as performed by both reviewers. The reviews were performed in parallel, but independently and blinded by each reviewer.

All articles were screened for inclusion criteria, first by title, then by abstract, and then in entirety. Articles fulfilling the inclusion criteria were included in the review.

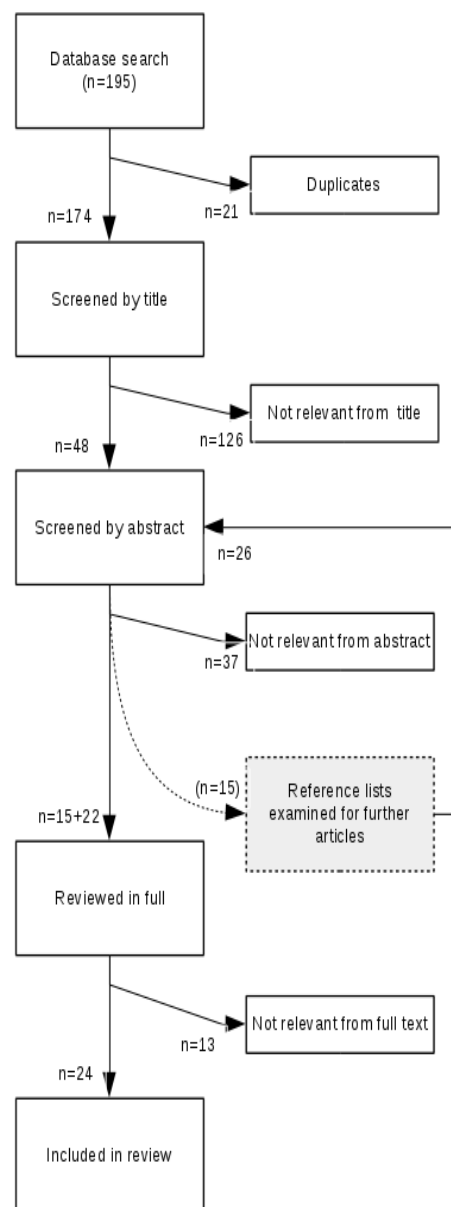


Figure 1. Literature search and review flow. The grey box indicates additional articles (n=15) identified by perusal of reference lists of articles from the original database search which made it through to abstract screening (n=48).

Data collection process

Data was extracted on methodology and results using a modified version of the checklist by Drummond, *et al* [13] (Table 1 and Appendix 4).

Data items

The checklist by Drummond, *et al* [13] is specifically designed for studies with an element of economic evaluation and is used extensively in the literature as a gold standard for economical evaluations.

In the present study, the checklist was modified with a further 3 items being added:

1. **“Follow-up same for all?”** was added to assess comparable follow-up periods between study groups.
2. **“Was a method of randomization used or were the groups similar at baseline?”** was added to assess baseline comparability between study groups.
3. **“Was the withdrawal/dropout rate described?”** was added to assess drop-out bias.

Risk of bias in individual studies

The same checklist was used in all studies, with and without a specific economic evaluation, but checklist items that related specifically to an economic evaluation (questions 7 to 12) were omitted in studies which did not include such an analysis. This was done, to avoid excessive bias against otherwise methodologically sound studies, which had not been designed with such in-depth economic analysis in mind.

All items on the checklist were conferred with a health-economy expert (ED) prior to study assessment, to ensure that the reviewers had a common understanding of the assessment parameters.

Reviewers 1 and 2 assessed each study independently and subsequently compared their findings. All studies which included an economic evaluation as well as those studies where reviewer 1 and 2 were not in agreement, were conferred individually with the health economy expert until a consensus was reached.

Results

Search strategy

The literature search revealed a total of 195 articles (Medline 141, Embase 43 and the Cochrane database 11) – see appendix 1-3. After removal of duplicates 174 articles remained.

Onehundred-and-twenty-six were deemed not eligible for inclusion, based on the title alone and of the 48 remaining articles, 15 were deemed potentially relevant based on the abstracts [11,14-27]. Examination of the reference lists of these articles revealed another 26 articles of potential interest.

Based on the abstracts 37 studies were deemed potentially relevant and reviewed in full -- 15 from the database search and a further 22 from the references lists. On review of the full article texts, a further 13 were found not to fulfill the inclusion criteria (3 without intervention, 8 did not contain CD as an option, and 2 were written in French).

Ultimately 24 articles were included in the review, 9 retrieved from the original search, and 15 from manual reference list perusal. Five articles were conferred with the health-economist (ED) due to conflicting evaluations by reviewers 1 and 2.

The included manuscripts are summarized in Table 2 in descending order of quality, as assessed by the quality checklist. The quality assesment of each manuscript is detailed in table 3.

Description of results

The 24 relevant studies were published in the period between 1983 and 2016 (Table 1). Four of them included economical evaluations [28-31] and 20 used proxy measures [32-51]. Eight were randomized controlled trials (RCTs) and 16 were non-randomized comparison studies.

Eleven studies compared CD to CNL [29-32,36,37,41,42,49-51]. The outcome measures used were length of hospitalization in six studies [30-32,36,37,42], length of sick leave in four studies [43,48,50,51], disability in two studies^{37,48}, and cost of intervention in five studies [29-31,42,43].

Table 1. Quality criteria. Checklist used for quality assessment, based on the checklist by Drummond, *et al* [13].

Question	Criteria for "yes"
1. Follow-up period same for all?	Was the timing of follow-up identical for both intervention groups?
2. Was a method of randomization used to allocate the patients? OR Are the groups similar at baseline?	Was a random (unpredictable) assignment sequence use to allocate the patients? OR Were the two groups similar on the given parameters e.g. sex, age distribution?
3. Was the withdrawal/dropout rate described?	The number of participants who were included in the study but did not complete the observation period or were not included in the analysis are described and reasons are given?
4. Was a well-defined question posed in an answerable form?	Is it clear what the authors were trying to do?
5. Was a comprehensive description of the competing alternatives given?	Was conventional discectomy and the control intervention explicitly described?
6. Was there evidence that the program's effectiveness had been established?	Was it clearly whether the criteria for treatment effectiveness had been met? If something is not worth doing, it's not worth doing well. Does the surgeon do more good than harm?
7. Were all the important and relevant outcomes and costs for each alternative identified?	Were all important cost and outcomes identified depending on what perspective(s) was/were taken (e.g. health provider, patient, society)?
8. Were outcomes and costs measured accurately in appropriate units prior to evaluation?	Was the cost quoted in appropriate units: the hours working time, number of visits, lost workdays, 'gained life years'
9. Were the outcomes and costs valued credibly?	Were cost and outcome measures valued correctly?
10. Were outcomes and costs adjusted for different times at which they occurred (discounting)?	Were all outcomes and costs adjusted to current values?
11. Was an incremental analysis of the outcomes and costs of alternatives performed?	Were the incremental costs analyzed in relation to the additional benefit it delivers?
12. Was a sensitivity analysis performed?	Were all the main areas of uncertainty considered and described by a sensitivity analysis?
13. Did the presentation and discussion of the results include all, or enough, of the issues that are of concern to users?	Have the authors of the article discussed weaknesses in the analysis and how they reached their results? Helping the reader to interpret the results.

Table 2. Article summaries

Study	Country	Design	Control	Sample	CD age	Control age	Follow up	Economic eval.
Alexander et al, 1989	USA	-	CN	100	18-65 (34)	18-54 (33)	Yes	No
Andrews et al, 1990	USA	-	MD	147	--- (38.7)	--- (43.4)	Yes	No
Barriose et al, 1990	Sweden	-	MD	150	n/a	n/a	Yes	No
Caspar et al, 1991	Germany	-	MD	418	19-68 (47.8)	17-71 (44)	Yes	No
Crawshaw et al, 1984	England	+	CN	52	n/a	n/a	Yes	No
Dullerud et al, 1999	Norway	-	APN	158	18-65 (41.8)	18-68 (38.8)	Yes	Yes
Ejeskär et al, 1983	Sweden	+	CN	29	19-73 (42.1)	21-51 (36.6)	Yes	No
Haines et al, 2002	USA	+	APN	34	--- (35.4)	--- (42.4)	Yes	No
Henriksen et al, 1996	Denmark	+	MD	79	36-48 (42.8)	30-46/39,7	Yes	No
Hermantin et al, 1999	USA	+	VMD	60	18-67 (40)	15-66 (39)	Yes	No
Javid, 1995	USA	-	CN	200	Men 19-81 (38.7) women 24-73 (44.5)	Men 19-72 (36) women 17-55 (39)	Yes	Yes
Kahanovitz et al, 1989	USA	-	MD	64	19-59 (38)	19-79 (44)	Yes	No
Launois et al, 1994	France	-	CN	146	n/a	n/a	Yes	Yes
Muralikuttan et al, 1992	N. Ireland	+	CN	92	19-60 (39)	20-53 (36)	Yes	No
Norton, 1986	USA	-	CN	105	24-64 (42/44)	20-67 (38/42)	n/a	No
Nyström, 1987	Sweden	-	MD	130	--- (43.9)	--- (39.7)	Yes	No
Ramirez et al, 1985	USA	-	CN	80	16-76 (42)	22-74 (41)	Yes	Yes
Silvers, 1988	Switzerland	-	MD	500	14-87 (49)	14-86 (54)	Yes	No
Schmid et al, 2016	USA	-	MD	540	--- (42)	--- (41)	Yes	No
Slotman et al, 1996	USA	-	LD	45	--- (40)	--- (34.5)	Yes	No
Tregonning et al, 1991	Canada	-	CN	268	22-62 (41.3)	20-65 (39.9)	Yes	No
Tullberg et al, 1993	Sweden	+	MD	60	18-64 (38)	17-59 (40)	Yes	No
van Alphen et al, 1989	Netherlands	+	CN	151	--- (33.5)	--- (34)	Yes	No
Weinstein, 1986	USA	-	CN	256	28-57 (40.5)	32-56 (41.9)	Yes	No

Description of the studies. Characteristics of the included studies ('Design' is +/- randomization) comparing lumbar discectomy to other surgical procedures (CD=Conventional discectomy, MD=Microdiscectomy, CN=Chemonucleolysis, APN=Automated Percutaneous Discectomy, VMD=Video assisted MD, LP=Laparoscopic discectomy.)

Table 3. Quality scores

Study	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Diff	Hosp	Sick	Disabil	Cost
Launois (1994)	+	?	-	+	-	+	-	+	+	-	+	+	+	+	CI	?	?	CI
Dullerud (1999)	+	+	-	+	+	+	-	-	-	-	+	-	+	+	?	?	?	CI
Ramirez (1985)	-	+	-	+	-	+	-	-	-	-	+	-	+	+	CI	?	?	CI
Javid (1995)	+	+	-	-	+	+	-	-	-	-	-	-	-	+	?	?	?	CI
Alexander (1989)	-	+	+	+	+	+							+		ND	?	?	?
Muralikuttan (1992)	+	+	+	-	+	+							+		ND	?	CD	CD
Ejeskär (1983)	+	+	+	-	-	+							+		CI	?	CD	?
Tregonning (1991)	-	+	+	-	-	+							+		?	ND	ND	?
Van Alphen (1989)	?	+	-	-	+	+							+		?	ND	CD	?
Weinstein (1986)	-	+	+	-	-	+							+		?	ND	?	?
Crawshaw (1984)	+	+	-	-	-	+							-		CI	?	CD	?
Norton (1986)	?	+	?	-	-	-							-		?	?	?	CD
Henriksen (1996)	+	+	+	+	+	+							+		ND	?	?	?
Tullberg (1993)	+	+	-	+	+	+							+		ND	ND	?	?
Andrews (1990)	-	-	+	-	+	+							+		CI	CI	?	?
Caspar (1991)	-	-	-	+	+	+							+		CI	CI	CI	?
Schmid (2016)	-	-	-	+	+	+							+		CI	?	?	?
Silvers (1988)	-	+	-	-	-	+							+		CI	CI	?	?
Kahanovitz (1989)	-	+	-	-	-	+							+		CI	ND	?	?
Nyström (1987)	-	-	-	-	-	+							+		CI	CI	?	?
Barrios (1990)	-	-	-	-	-	+							-		CI	CI	?	?
Haines (2002)	+	+	+	+	-	+							+		?	?	?	?
Slotman (1996)	-	-	-	-	-	+							+		CI	?	CI	CD
Hermantin (1999)	-	+	-	+	+	+							+		?	CD	?	?

Quality assessment (Q1-3: Patient selection/intervention, Q4-13: Economic evaluation, Diff-D.ii: Results). Columns Q1-13 refer to the applied quality criteria, as listed in table 1. Column 'Diff': Was there any difference reported in cost-effectiveness between the interventions? Columns 'Hosp', 'Sick', 'Disabil' and 'Cost' refer to 'Was there any difference in hospitalization days?', 'Was there any difference in days on sick leave?', 'Was there any difference in disability (prompting treatment)?' and 'Was there any difference in cost of intervention?', respectively. The cells list reported differences: 'CD' = a difference in favor of Conventional Discectomy, 'CI' = a difference in favor of the Control Intervention, 'ND' = no difference was reported, '?' = unknown, not reported or not applicable.

Nine studies compared CD to MD [33-35,39,41,44-46,49] and outcome measures used were length of hospitalization in all studies, length of sick leave in six studies [34-36,44,46,49], disability in one study³⁵, and cost of intervention in one study [46].

One study [47] compared CD to laproscopic discectomy (LD) using length of hospitalization, disability and cost of intervention as outcome measures.

One study [40] compared CD to video-assisted arthroscopic microdiscectomy (VAMD) and used length of sick leave as outcome measure.

Two studies [28,38] compared CD to automated percutaneous discectomy (APD), one [28] used cost of intervention as outcome measure, and the outcome measures of the other³⁸ were not applicable in the present review.

Eleven studies originated from the USA [29,30,32,33,38,39,41,43,46,47,51], twelve from Europe [28,31,34-37,39,42,44,45,49,50] and one from Canada [48].

Results of the cost-effectiveness studies

Of the four articles which included an economic evaluation, none were randomized.

Three studies compared CD to CNL, and 1 compared CD to ADP. The quality score of the studies varied considerably (see Table 2). However, all four studies favored the control intervention over CD. The results of the economic evaluations are described in the following section, listed in descending order of quality score: Launois, *et al* [31], Dullerud, *et al.* [28], Ramirez & Javid [30] and Javid [29].

Launois, *et al*

A comparison study, examining the economic costs and quality of life following CNL versus CD.

Launois, *et al* did not randomize the groups or describe the dropout rate, and it is difficult to determine whether the groups were comparable at baseline, yet this study had the highest quality checklist score. Launois, *et al* [31] considered all the *direct* costs of each alternative intervention using decision modeling to estimate quality of life and calculate the amount of saved QALYs. Furthermore, the authors calculated the costs of each probable outcome and the 7-year follow-up strengthens the quality further.

The authors reported fewer hospitalization days in the CNL group, and about half the monetary costs of those associated with CD. However, CD produced slightly better clinical results compared to CNL.

Dullerud, *et al*

Dullerud, *et al* [28] compared the costs of APD to that of CD and scored well in the quality assessment of the intervention, but the economic evaluation was lacking.

They included the direct costs of the procedure but did not specify other costs. The direct costs were based on the Norwegian DRG *internal reimbursement system* rather than actual costs and were therefore based on a pre-defined, standard estimate cost for that procedure.

The authors concluded that nucleotomy is a minimally invasive procedure with low complication rates, which potentially has a short recovery period and, arguably, therefore could be more cost-effective than traditional surgical treatment for lumbar disk herniation.

Ramirez and Javid

Ramirez and Javid [30] studied the cost-effectiveness of CNL versus CD.

The study had shortcomings both in the quality assessment of the intervention and the economic evaluation. The authors reported costs based on claims from insurance companies and not actual costs. In addition, all patients included were selected and recruited from the same hospital and all cost parameters were extracted from hospital charges.

The conclusions were somewhat ambiguous due to the shortcoming of the study, but the authors speculate that there is a difference in favor of CNL with regards to fewer hospitalization days and cheaper intervention.

Javid

The study by Javid [29] is a comparison study of the effectiveness and economic burden of CNL compared to CD.

Assessment of this study revealed that the intervention was adequately described but the quality of the economic evaluation was substantially lacking. Only overall direct costs were reported, specified as hospital charge and professional charge, but did not describe basis of the calculations. Any additional costs were not reported.

The total costs for both interventions were reported, with and without additional costs of re-operations. The basis for a cost-effectiveness analysis was in fact present, but as the authors presented no further analyses, it is debatable whether the study includes an actual cost-effectiveness analysis.

In any case, Javid [29] concluded that with adherence to strict criteria for selection and performance, CNL was less expensive than CD, and resulted in fewer hospitalization days.

Results of the studies reporting proxy measures for cost-effectiveness

The twenty studies which did not include an economic evaluation lend support to the following conclusions: In general the quality of the studies is not very impressive (see Table 2), but the better the quality of the studies, the less difference concerning the outcome of the compared interventions was reported.

CD compared to CNL: Overall the studies found either no difference, or fewer hospitalization days and less disability in favor of CD. Seven studies [32,36,37,42,43,48,50] recommended CD as the method of choice for lumbar disk herniation compared to CNL.

CD compared to MD: The majority of the studies found fewer hospitalization days [33-35,41,44-46] and fewer sick leave days [33-35,44,46] in favor of MD. None of the studies reported the cost of the intervention.

The study by Haines, *et al* [38] using APD was of good quality but did not include a sufficient number of patients to reach definitive conclusions.

The study by Slotman, *et al* [47] using LD reported fewer hospitalization days, less disability and lower costs in favor of the LD intervention.

The study by Hermantin, *et al* [40] using VAMD demonstrated fewer sick leave days in favor of VAMD compared to CD.

Discussion

To our knowledge, this is the first literature review examining the cost-effectiveness of CD compared to other surgical techniques used for lumbar disk herniation.

The review demonstrates that the volume and quality of research is insufficient to draw firm conclusions. However, studies which include an economic evaluation favor the alternative interventions over CD. Studies using proxy measures of economic costs reported mixed results.

Cost-effectiveness studies

Generally, the four cost-effectiveness studies present a rather narrow perspective on cost-effectiveness, with a clear focus on direct costs of surgery. Detailed descriptions of indirect costs, costs associated with post-surgical care, rehabilitation, lost productivity, etc are lacking. As indirect costs are known to be significantly greater than direct costs in relation to low-back pain management [52], the economic evaluation in these four studies, is of limited value.

The four cost-effectiveness studies all supported the alternative surgical procedures over CD. None of the studies were designed as randomized trials however and their conclusions should thus be tempered by the risk of selection bias.

Furthermore, the identification, measurement and estimation of costs in these studies were carried out in different settings, over different time periods, using different data sources and thus the external validity can be questioned.

Three of the four cost-effectiveness studies compared CD to CNL which, in Denmark at least is no longer in common use due to potential problems with allergic reactions. The fourth cost-effectiveness study compared CD to APD which is also an uncommon procedure.

Studies reporting proxy measures for costs

When compared to CNL [32,36,37,42] and MD [33-35,39,44,46,49] no clear picture emerges for or against CD, but it is noteworthy that the studies with the highest quality assessment [32,39,42,49] all report no difference between techniques. It thus remains unclear which, if any method is superior. The review and meta-analysis by Kamper, *et al* [17] reached similar conclusions.

The studies investigating VAMD [40] and LD [47] suggest that these techniques can serve as an alternative to CD, but underline that these are demanding techniques and therefore require a considerable amount of training. Arguably, this might suggest that the techniques are cost-effective in a longer prospective, but this is speculative and more research with longer follow-up periods would be needed to be able to support such a conclusions.

Methodological considerations

The present search strategy was developed in collaboration with an expert librarian with extensive experience in systematic literature reviews and search strategies. Nevertheless, of the included articles only 9 were retrieved from the original search strategy, while 15 were retrieved by manual perusal of reference lists. Arguably, this could be interpreted as an indication that the search strategy was insufficient – alternatively, that a majority of relevant manuscripts have been insufficiently indexed.

A well-established checklist for the economic evaluation¹³ was used, and both reviewers scored the articles by the checklist separately, before findings were compared and conferred with an experienced

health economy expert (ED) to ensure correct assessment. Using the checklist by Drummond, *et al* [13] could potentially have resulted in lower ratings of studies which did not include an economic evaluation. Thus items related to economic evaluation were omitted where appropriate, to counter such bias and economic studies and proxy measure studies have been dealt with separately.

In this review we evaluated the literature on different surgical techniques, but obviously it was not possible to determine how the surgical techniques were actually performed, beyond the descriptions reported in the methodology sections. In many cases, this was simply reported as ‘conventional discectomy’ and terms to that effect. The exact procedure of the surgical interventions may vary greatly and could therefore potentially influence the outcome. It is also likely that the surgical techniques have been substantially revised over the last 20 years. Considering the relatively old age of some studies included in this review, this may be of importance in the evaluation of outcomes.

Future directions

Further research: Arts, *et al* [53] published a study protocol with the aim of determining whether MD is more cost-effective than CD for patients with lumbar disk herniation. To our knowledge, the final results are not published, but the protocol is a good example of how future research in this field could be performed. Arts *et al*⁵³ intend to randomize the patients prospectively, and consider the outcome measures (function, pain, quality of life, recovery, re-operation), in relation to costs. The costs include the direct medical costs, indirect productivity cost, work-efficiency, re-operation, complications, as well as other medical costs (physiotherapy, visits to general practitioners and medical specialists, nursing care and medication). Arguably, their suggested two-year follow-up may be insufficient, but in cost-effectiveness studies, indirect costs and societal costs ought to be included if possible.

Conclusions

On the basis of the available literature, there is little ground on which to make strong recommendations for one surgical procedure over another, at least in terms of cost-effectiveness. Generally speaking, studies were not of high quality and surgical techniques were only superficially described.

Nevertheless, on the basis of the literature at hand, the findings can be summarized as follows:

- The literature on CNL is conflicting, with economic evaluations suggesting that CNL has lower costs compared to CD, but conversely non-economic studies suggest better clinical outcomes of CD.
- No economic evaluation of MD compared to CD was found, but most (low quality) non-economic studies report fewer days in hospital or sick leave with MD, which arguably could translate to lower costs.
- Only very few studies report on LD, VAMP and APD and none provide a reliable basis for estimating their cost-effectiveness.

Conflicts of interest

No external financial or material support has been sought or received. The authors have no financial interests in the study outcome. The submitted manuscript is entirely the work of the listed authors -- no external parties have influenced the protocol, data collection, analysis or reporting of the current work.

We declare no conflicts of interest.

Ethics

No institutional ethics approval is required for literature reviews.

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