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Review Article

Effect of fusion following decompression for lumbar spinal stenosis: a meta-analysis and systematic review

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Abstract: Purpose: The surgical methods of degenerative lumbar spinal stenosis include spinal decompression with or without instrumented or non-instrumented spinal fusion. Previous meta-analysis and systematic reviews have reported the contrast between surgical management and nonsurgical management for degenerative lumbar spinal stenosis, while no literature did among surgical managements. And it is evidenced that whether fusion should be added to spinal decompression in patients of lumbar spinal stenosis is still divisive. So our purpose is to identify whether spinal fusion with or without decompression has a better effect than decompression alone for patients with degenerative lumbar spinal stenosis. Methods: We searched the Cochrane Central Register of Controlled Trials (CENTRAL) for reports before November 2014 and PubMed, EMBASE, GOOGLE SCHOLAR for those before December 2014. We also searched the reference lists included in studies and previous reviews. Randomized Controlled Trials and prospective or retrospective cohort studies of patients with degenerative lumbar spinal stenosis after spinal decompression with or without fusion were eligible. Abstracted outcomes from retrieved articles included clinical outcome and reoperation rate of two aspects. Both random-effects and fixed-effects models were used to calculate the end-points. Results: We identified 23 studies with data collected from 61576 patients. The combined relative risk (RR) of clinical outcome for the spinal fusion compared with the spinal decompression was 0.91 (95% confidence interval [CI]: 0.85 to 0.98), and little evidence of heterogeneity was observed. Namely, a satisfactory clinical outcome was significantly more likely with fusion than with decompression alone. But there was a trend toward a higher reoperation rate with fusion compared with decompression alone (RR: 0.93; 95% CI: 0.88 to 0.97). Conclusion: This meta-analysis provides robust evidence of a better clinical outcome but a higher reoperation rate for spinal fusion compared with decompression alone.

Keywords: Decompression, spinal fusion, degenerative lumbar spinal stenosis, meta-analysis

Introduction

Acquired lumbar spinal stenosis is a degenerative spine disease defined as a narrowing of the spinal canal that produces compression of the neural elements before their exit from the neural foramen [1]. And lumbar spinal stenosis is a common condition in the old, which decreases function and quality of life. Stromqvist et al published a report that lumbar spinal stenosis is the most common diagnosis in patients requiring spinal surgery in Sweden [2]. The cause of lumbar spinal stenosis is multifaceted and definite, whereas the surgical management is still not clear.

Currently, the surgical management for degenerative lumbar spinal stenosis includes single or multilevel decompressive laminectomy with or without lumbar fusion [3]. Decompression surgery without fusion has been proved to be beneficial to patients with lumbar spinal stenosis, which has reported in many articles [4-8]. However, some other studies have shown that the addition of fusion is desirable for patients, since this procedure had acceptable surgical results [9, 10]. The method of spinal fusion begins to be prevalent, and Martin et al reported that fusion surgery increased by 220% from 1990 to 2001 for lumbar spinal stenosis [11].

So, the goal of our meta-analysis was to evaluate which is the fittest surgical management for patients with lumbar spinal stenosis, decompression alone or decompression with fusion.

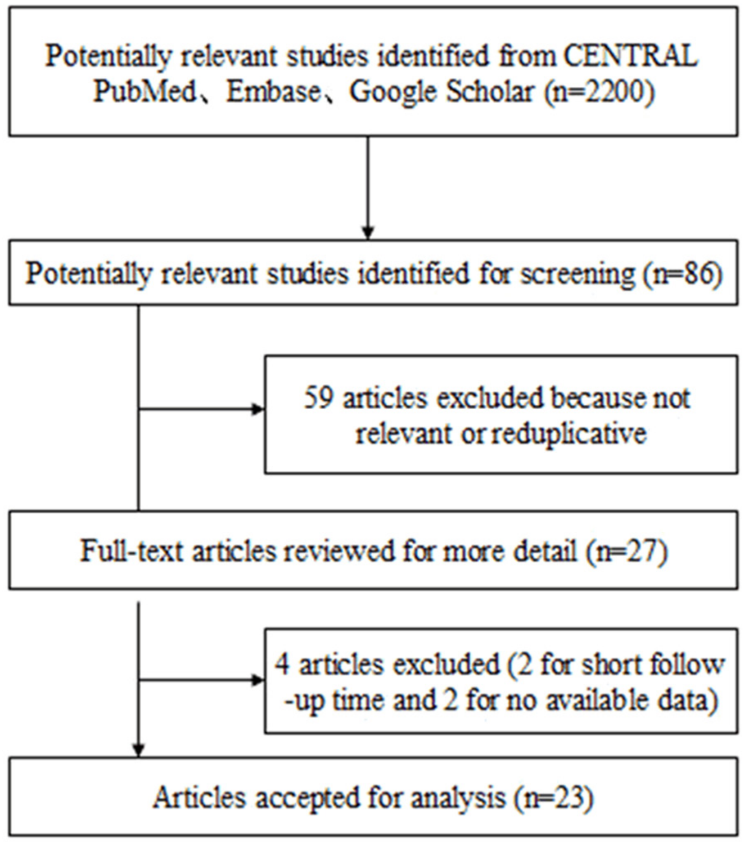

Figure 1. Flow diagram detailing study inclusion.

Methods

Search strategy

Relevant RCTs and cohort studies were identified [12]. We attempted to identify the cohort studies in according with the meta-analysis of observational studies in epidemiology guidelines [13]. Briefly, we searched the Cochrane Central Register of Controlled Trials (CENTRAL) for reports published before November 2014 and PUBMED, EMBASE, GOOGLE SCHOLAR for those published before December 2014 by using the following search terms: "decompression" and "spinal fusion" in combination with "lumbar spinal stenosis" without restrictions. All abstracts, studies and citations were reviewed irrespective language. Additionally, we reviewed the reference lists of retrieved articles.

Study selection

Studies are included in this meta-analysis if they met the following criteria: 1) the study is an RCT or comparative cohort study that investigated the surgical management of degenerative lumbar spinal stenosis comparing fusion to decompression with decompression alone; 2) the minimum follow-up was one-year; 3) the end-point interest was clinical outcome and reoperation rate. A study was excluded if it: 1) selected same patients in another included study; 2) was not a clearly a comparative study or did not use a comparative method. If one study reported more than one time-point of follow-up, we selected the data with the longest follow-up time. We used no language restrictions.

Data extraction

Data from the included studies were extracted by 2 independent reviews (L.L and H.W) using a standard data-collection form. Information was recorded as follows: last name of the first author, publication year, and study location, type of design, length of follow-up, number of participants, mean-age of patients, intervention and quality scores. The main abstracted outcomes were clinical outcome and reoperation rate. An attempt was made to compare other endpoint of interest such as complications. But because of high heterogeneity in reporting these outcomes in the primary studies, no pooled analysis could be performed on these outcomes. To group the clinical outcomes, we classified the ratings of "excellent", "good", "success", "significantly better", "satisfied" as a satisfactory clinical outcome whereas ratings of "fair", "poor", "same", "worse", "slightly satisfied", or "unsuccessful" were classified as an unsatisfactory clinical outcome.

Statistical analysis

The relative risk (RR) was used as a summary statistic for censored outcomes (clinical outcome and reoperation rate). The combined risk estimates were computed using either fixed-effects models or, in the presence of heteroge-

Table 1. Characteristics of the included studies

First author	Publication year	Study location	Type	Mean duration	No. of patients	Mean age	Interventions	Outcomes
Athiviraham [23]	2007	Canada	Prospective	2 y	88	66.3	Group 1: decompression + fusion Group 2: decompression only	Clinical outcome/RMQS/reoperation rate
Bridwell [24]	1993	America	RCT	3 y	43	66	Group 1: decompression+ fusion Group 2: decompression	Clinical outcome/complications
Brodke [25]	2013	America	Retrospective	5 y	69	70	Group 1: laminectomy + fusion Group 2: laminectomy	VAS/clinical outcome/reoperation rate
Chen [26]	2010	China	Prospective	>3 y	145	60	Group 1: decompression + fusion Group 2: decompression	ODI/VAS/clinical outcome/reoperation rate/complications
Cornefjord [27]	2000	Sweden	Retrospective	7.1 y	96	64.4	Group 1: decompression + fusion Group 2: decompression	Clinical outcome/walking capacity/VAS/complication
Deyo [28]	2011	America	Retrospective	4-5 y	31543	76	Group 1: decompression + arthrodesis Group 2: decompression	Reoperation rate
Fokter [29]	2006	America	Retrospective	2 y	58	>60	Group 1: decompression + fusion Group 2: decompression	ZCQ/clinical outcome/
Forsth [30]	2013	Sweden	Retrospective	2 y	9744	>50	Group 1: decompression + fusion Group 2: decompression alone	ODI/EQ-5D/VAS/pain scores/reoperation rate
Fox [31]	1996	America	Retrospective	5.8 y	124	67.5	Group 1: decompression + arthrodesis Group 2: decompression	Clinical outcome/pain scores/ walking ability
Ghogawala [32]	2004	America	Prospective	1 y	34	69	Group 1: decompression + fusion Group 2: decompression alone	ODI/SF-36/PCS/reoperation rate/ complications
Grob [33]	1995	Sweden	RCT	28 m	45	67	Group 1: decompression + arthrodesis Group 1: laminotomy + facetectomy	Clinical outcome/Walking capacity/complications
Herkowitz [42]	1991	America	RCT	3 y	50	64	Group 1: laminectomy + arthrodesis Group 2: laminectomy	Clinical outcome/pain scores/vertebral motion
Katz [34]	1997	America	Prospective	2 y	272	>60	Group 1: laminectomy + arthrodesis Group 2: laminectomy alone	Clinical outcome/pain severity/ reoperation rate
Kin [11]	2013	South Korea	Retrospective	5 y	11027	NA	Group 1: decompression + fusion Group 2: decompression	Reoperation rate
Lee [35]	2013	South Korea	Retrospective	3.9 y	50	>75	Group 1: PLIF Group 2: DLF	VAS/ODI/reoperation rate
Matsudaira [36]	2005	Japan	Retrospective	2 y	37	67.4	Group 1: laminectomy + fusion Group 2: decompression	JOA/clinical outcome
Modhia [37]	2013	America	Retrospective	2 y	4793	NA	Group 1: decompression + fusion Group 2: decompression	Reoperation rate/pain scores
Rompe [38]	1999	German	Retrospective	8 y	72	>60	Group 1: laminectomy + fusion Group 2: laminectomy	VAS/clinical outcome/reoperation rate

Son [39]	2013	South Korea	Retrospective	5.5 y	60	71.1	Group 1: decompression + fusion Group 2: decompression alone	VAS/ODI/complications/reoperation rate/clinical outcome
Wu [40]	2008	China	Retrospective	51 m	181	58.3	Group 1: decompression + fusion Group 2: laminectomy/foraminotomy/ Fenestration/foraminotomy	Clinical outcome/complications
Yone [9]	1996	Japan	Retrospective	>2 y	17	>60	Group 1: decompression + fusion Group 2: decompression alone	JOA/clinical outcome
Yone [41]	1999	Japan	Retrospective	>2 y	33	60	Group 1: decompression + fusion Group 2: decompression alone	Clinical outcome JOA
Lad [43]	2014	America	Retrospective	>5 y	2995	>60	Group 1: decompression + fusion Group 2: decompression alone	Reoperation rate

RMQS: Roland-Morris Questionnaire Score; JOA: Japanese Orthopaedic Association; ODI: Oswestry Disability Index; SF-36: Short Form-36; PCS: Physical Component Summary; VAS: Visual Analogue Scale; EQ-5D: EuroQol Five Dimensions; ZCQ: Zurich Claudication Questionnaire.

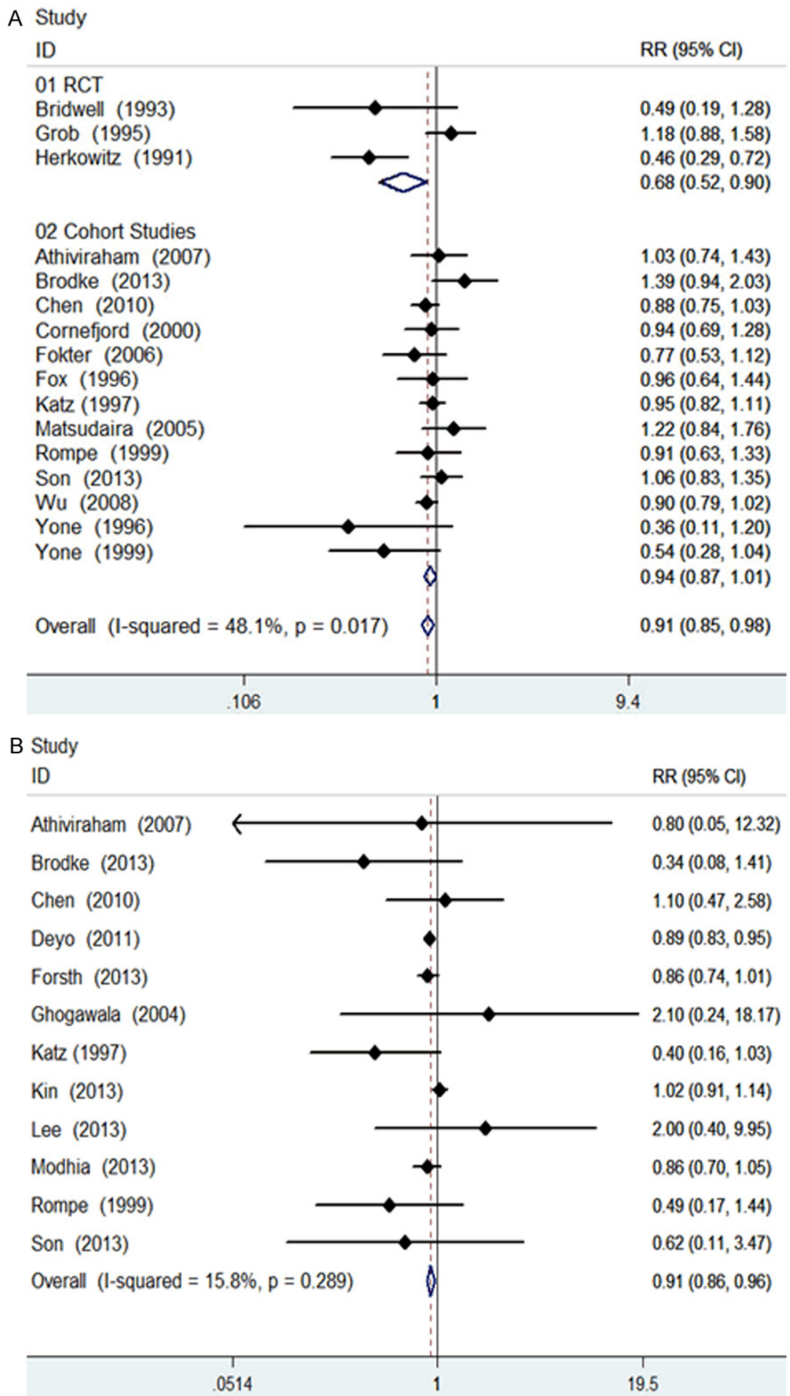

Figure 2. Forest plot. In (A: For clinical outcome) and (B: For reoperation rate), each study is shown by the point estimate of the relative risk and 95% CI for the RR (extending lines).

neity, random-effect models in this meta-analysis [14]. Heterogeneity of effect size across studies was assessed by the X^2 and I^2 statistic (I^2>50% was regarded as substantial heterogeneity) [15]. The quality of all observational studies was assessed with the use of the Newcastle-Ottawa Scale (NOS). This was assessed by examining three components: method of patient selection, comparability of the study groups, and number of outcomes reported. A star rating of 0-9 was allocated to each study based on these parameters. The one randomized trial was considered to be of higher quality for the purpose of this study. In the current study, we considered a study awarded seven or more stars as a high-quality study, because standard validated criteria for important end points have not been established [16]. Two reviewers (L. L and H. W) assessed the quality of the studies. Any disagreement was resolved by discussion. Potential publication bias was assessed by Begg's funnel plots and Egger's regression test [17, 18]. All analyses were performed by using STATE version 11.0 (StataCorp LP, College Station, Texas). A *P* value <0.05 was considered significant, except where otherwise specified.

Results

Literature search

A total of 2200 studies were identified on the computer using the predefined search strategy (**Figure 1**). Most of these studies were excluded because some of which were reduplicative and others were not relevant to our analysis after title and abstract were reviewed. In the first selection, 86 were classified as possible for inclusion. After full-text review of 27 papers, 2 studies [19, 20] were excluded because their length of follow-up was too short (<1 year). Two more studies [21, 22] were excluded because the data didn't existed or was not available. Therefore, only 23 limited studies comparing

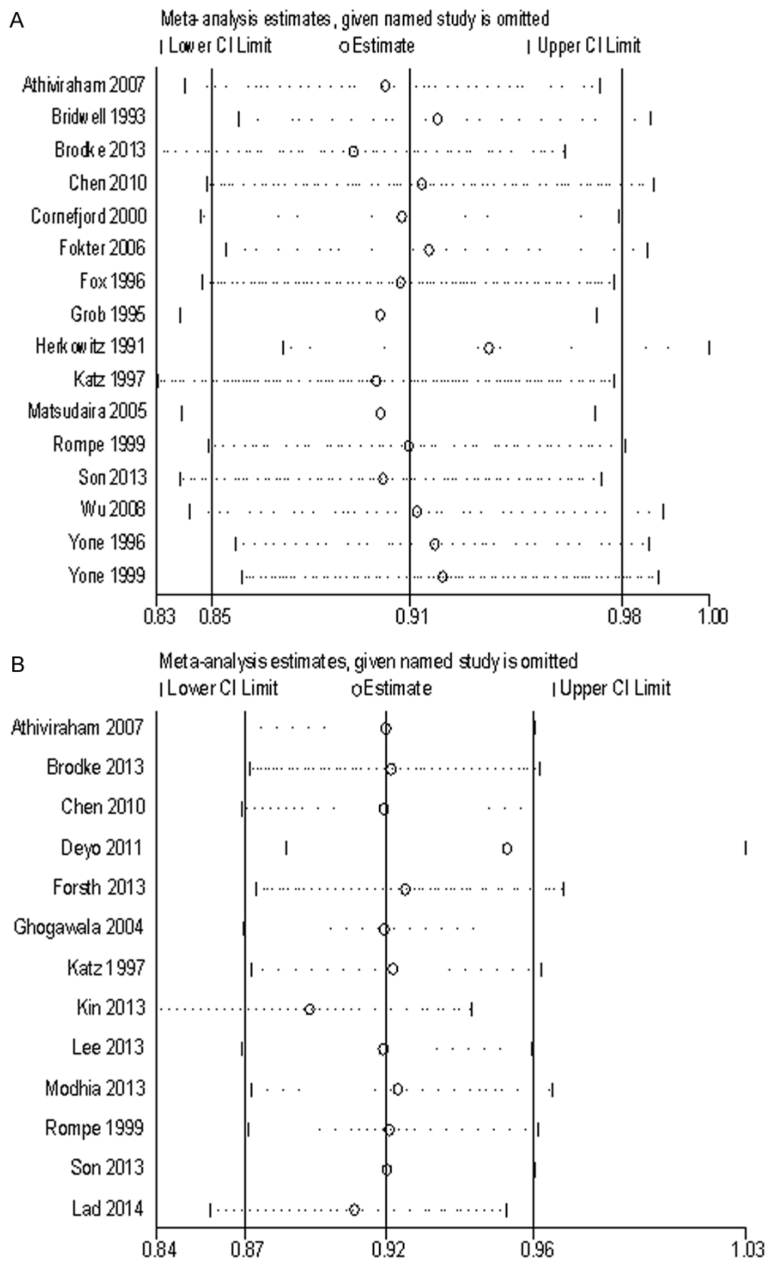

Figure 3. Influence analysis of meta-analysis. A and B: Show the influence of individual studies on the summary RR. The vertical axis indicates the overall RR and the two vertical axes indicate its 95% CI. Every hollow round indicates the pooled RR when the left study is omitted in this meta-analysis. The two ends of every broken line represent the respective 95% CIs.

61576 patients with degenerative lumbar stenosis that fulfilled the selection criteria were included in this meta-analysis [9, 11, 23-42].

Study details

The detailed characteristics of the 23 included studies are illustrated in the table (**Table 1**). These studies were published before December 2014, including 3 RCTs and 20 observational studies. Of these 11 studies were conducted in North American, 4 in Europe, and 8 in Asia. The length of the follow-up period ranged from 1 to 8 y. The number of patients involved in studies ranged from 17 to 31543, total with a median of 2677. Among the 23 studies included here, there were two study endpoints to be set for analysis: one was clinical outcome and the other was reoperation rate. 16 studies reported the clinical outcome and 13 reported the reoperation rate.

Main analysis

Grouped analysis detected a slightly higher probability of achieving a satisfactory clinical outcome with spinal fusion than with decompression alone (RR, 0.91; 95% CI, 0.85 to 0.98) (**Figure 2A**). A test for heterogeneity indicated that a great few of the variability in end point was likely due to clinical or methodological diversity between studies rather than to chance (I^2=48.1%, P=0.01). The results yielded by the exclusion of one study every time were similar. The further influence analysis also showed the robustness of our results (**Figure 3A**). Visual inspection of the Begg funnel plot did not identify substantial asymmetry (**Figure 4A**). The Begg rank correlation test (P=0.137) and Egger liner regression test (P=0.353) also indicated no evidence of publication bias about clinical outcome between spinal fusion and decompression alone.

It also provided the information that there was a higher reoperation rate under the spinal fusion compared with the decompression alone (RR, 0.93; 95% CI, 0.88 to 0.97) (**Figure 2B**). And there was little heterogeneity among studies (I^2=3.7%, P=0.410). The influenced analysis

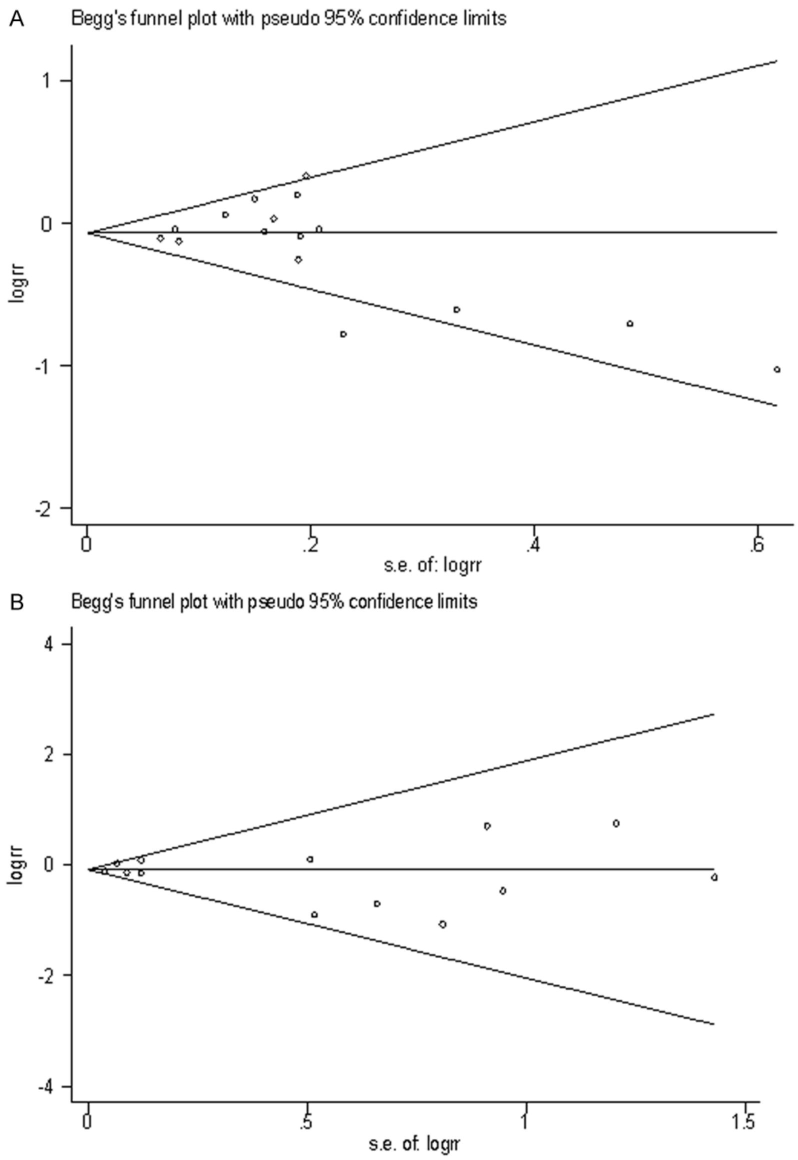

Figure 4. Publication bias plots. A and B: Show the Begg's funnel plots of studies included in the meta-analysis for clinical outcome and reoperation rate, respectively. The vertical axis represents log [RR] and the horizontal axis means the standard error of log [RR]. Horizontal line and sloping lines in funnel plot represent summary RR and expected 95% CIs for a given standard error, respectively. Area of each circle represents contribution of the study to the pooled RR.

showed that our result was robust (**Figure 3B**). Either graphical inspection for funnel plots or quantitative evaluation from Begg's test (P=0.631) and Egger's test (P=0.484) indicated the absence of publication bias in reoperation rate (**Figure 4B**).

Discussion

This meta-analysis of 23 included studies involving 61576 participants supports a result that decompression with fusion is significantly beneficial with decompression alone from clinical outcome but have a higher chance of reoperation rate for patients with lumbar spinal stenosis. Sensitivity and influence analyses demonstrated the robustness of our result from the pooled meta-analysis.

Heterogeneity is often a constant concern in a meta-analysis. There is medium heterogeneity in the end-point of clinical outcome whereas little evidence of heterogeneity was observed in the reoperation rate. This was partially explained by the following facts: the design styles of the pooled studies were not same; the people from each study were different, therefore maybe they have different body function which produced different reaction to the same surgical managements; and the number ranges of included patients differ greatly a wide difference in several studies.

An attempt was made to compare morbidity, ODI, VAS, JOA and complications; but we will choose nothing but clinical outcome and reoperation rate because of heterogeneity in reporting these outcomes in the primary studies or too few studies related, no pooled analysis could be performed on these outcomes. In the result of clinical outcome which owned 3 RCTs and 13 cohort studies, the combined RR is 0.91 and 95% CI 0.85 to 0.98. Sensitivity analyses demonstrated that the RCTs actually reported a larger benefit to the use of adjunctive fusion than did the weaker nonrandomized studies. This might be attributable in part to the reservation, in cohort studies, of more aggressive management for the treatment of patients with more severe disease progression. From the result of reoperation rate, we could know the combined RR was 0.93 and 95% CI 0.88 to 0.97 with little heterogeneity. Because the 13 included studies shared the same study design. Obviously, the decompression alone had a lower reoperation rate than decompression with fusion which is in accordance with some previous studies. Grob et al reported a randomized trial which suggested no advantage of fusion over laminectomy alone in patients with spinal stenosis without instability [33]. Deyo et al showed that during 4 years postoperatively, patients who underwent fusion did not have a lower reoperation rate than in patients who had surgery without fusion [44]. Recently, the reoperation rate during 4 years did not differ when fusion surgery was added [28]. According to the population-based studies the reoperation rate was not reduced regardless of the recent increase of fusion surgery [45]. From the above mentioned articles, a fusion was performed in more than half of the readmission suggests that a potential major cause of readmission is the development of a new instability. The instability could be caused by excessive facet resection, excess stress on the remaining supporting structures, continued degenerative process, or the natural history of lumbar spinal stenosis disease [46-48].

Lumbar spinal stenosis can cause pain or discomfort in the lower back, buttocks or legs. These symptoms are predominantly due to lateral stenosis. Patients with persistent symptoms receiving despite non-surgical treatment should be referred to spinal surgeons. The goal of surgery is to decompress the spinal canal and neural foramina. Since many surgical options can be found, one may find it difficult to choose the optimal procedures. The traditional procedure is a decompressive laminectomy, consisting of removal of the spinous processes, lamina, ligament flava and media portions of the facet joints. Regarding fusion, there are no class I studies proving the fusion improve functional outcomes in patients without criteria of instability. However, there are many papers with class II and III evidence levels advocating concomitant spinal fusion and arthrodesis to improve outcomes and avoid late instabilities, even in patients without spondylolisthesis or spinal deformities [49].

This current meta-analysis was designed to address limitation. Incorporating comparative observational studies in addition to RCTs expanded the base of available evidence, and methods were used to address the limitations of including nonrandomized studies; the difference in sample size, patient age, the length of follow up, the evaluation of end-points, the methods of decompression, the numbers of fused levels and other factors among the studies might be responsible for the heterogeneity; not all studies provide the details of prevalence of clinical outcome and reoperation rate, which may cause bias; the skills of different surgeons may influence our final result; we need a standard to assess the surgery skill in order to avoid surgeon bias. These above may affect the veracity of this meta-analysis.

In conclusion, there is moderate evidence that fusion leads to a better clinical outcome than decompression alone in the treatment of lumbar spinal stenosis. Our results showed that fusion had a higher reoperation rate than decompression alone as the same with the previous clinical articles or systematic reviews. This is supported by the fact that most studies either statistically or non-statistically favored fusion and no study statistically favored decompression alone.

Disclosure of conflict of interest

None.

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