

Comparison of the Minimally Invasive and Conventional Open Surgery Approach in the Treatment of Lumbar Stenosis: A Systematic Review and a Meta-Analysis

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Abstract

Introduction: Minimally invasive surgery (MIS) is increasingly used in the treatment of lumbar stenosis. However, it is still not clear if the employment of minimally invasive surgical techniques can achieve superior clinical outcomes compared to standard open laminectomy. **Materials and Methods:** An extensive literature review regarding the clinical outcome, safety, and efficiency of MIS and standard open surgery (OS) in the treatment of lumbar stenosis was conducted on Medline, Cochrane, EMBASE, and Google Scholar databases up to 19 August 2016. **Results:** Sixteen studies that enrolled a total of 1580 patients with surgically-indicated lumbar stenosis were identified; 793 patients underwent MIS and 787 patients underwent conventional OS. No significant difference was found in the improvement of Oswestry Disability Index (ODI) ($P = 0.718$) and operation time ($P = 0.322$) between patients from different treatment groups. MIS was associated with better visual analogue scale (VAS) for back pain ($P = 0.01$), shorter length of hospital stay ($P < 0.001$), and lower blood loss ($P < 0.001$). **Conclusion:** Our findings indicate that both MIS and standard OS can effectively manage patients with lumbar stenosis and lead to comparable clinical outcomes. Further studies are necessary to evaluate MIS with different types of conventional surgery for lumbar stenosis.

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Key words: Back pain, Laminectomy

Introduction

Spinal stenosis is a narrowing of the spinal canal with encroachment on the neural structures by surrounding osseous, discal, capsular, or ligamentous structures. Clinical symptoms include radicular leg pain and neurogenic claudication. The prevalence of this condition is growing as the population continues to age. Indications for surgery vary widely across geographic areas.¹ Although significant controversy exists regarding the management of lumbar spinal stenosis, it is still the most common reason for lumbar spine surgery in adults over the age of 65 years.^{2,3} However, the optimal surgical procedure for the treatment of lumbar spinal stenosis is still to be determined. The current standard approach are open laminectomy, medial facetectomy, and foraminotomy, with extensive removal of posterior spinal structures.⁴ The obvious advantage of the open approach is an excellent visualisation and access to damaged tissues; however, a substantial rate of postoperative complications

has been reported to be associated with this procedure.^{5,6} Also, extensive disruption of spine and supporting muscle structures may lead to adverse consequences, such as flexion instability, muscle weakness, and failed back surgery syndrome.⁷⁻⁹

As an alternative to standard open surgery (OS), endoscopic and minimally invasive surgical techniques have been developed. Minimally invasive surgery (MIS) procedures use muscle-splitting to access the spine, and leave the midline structures that support muscles and ligaments intact, resulting in less tissue trauma, reduced blood loss, faster recovery times and shorter hospital stays compared to standard OS.¹⁰ In addition, the possibility that the patient can be discharged on the same day as surgery can significantly reduce healthcare costs. Potential issues with MIS is that mastering the techniques requires additional training times,^{7,11} and it is not clear if employment of MIS techniques can lead to superior clinical outcomes compared

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to OS. The objective of our study was to compare standard open laminectomy with the MIS approach in regard to clinical outcome, safety, and efficiency.

Materials and Methods

Search Strategy

We followed the PRISMA guidance for systematic reviews of observational and diagnostic studies,¹² and searched the published literature using Medline, Cochrane, EMBASE, and Google Scholar up to 19 August 2016, with various combinations of the following key words: lumbar stenosis, minimally invasive surgery (MIS), conventional OS, laminectomy, fusion. In addition, we manually searched references in relevant publications to identify additional eligible trials. Inclusion criteria for the meta-analysis were randomised controlled trials (RCTs), prospective studies, and cohort studies that recruited patients with surgically-indicated lumbar stenosis who underwent surgical decompression with minimally invasive or conventional OS. Letters, comments, editorials, case reports, proceedings, personal communications, as well as studies that did not provide quantitative outcome were excluded.

Study Selection and Data Extraction

Data was extracted independently by 2 independent reviewers. A third reviewer was consulted in cases of disagreements. We extracted data on study population (number, age, and gender of subjects in each group), study design, and the major outcomes.

Quality Assessment

We assessed the RCT study quality using the Cochrane Risk of Bias Tool,¹³ and used Newcastle-Ottawa scale¹⁴ to assess the quality of non-RCTs. The quality assessment was performed by 2 independent reviewers, and a third reviewer to decide any disagreements.

Outcome Measures

The primary outcomes included the level of improvement of Oswestry Disability Index (ODI) and visual analogue scale (VAS) for back and leg pain. Secondary outcomes included operation time, length of hospital stay, blood loss, and complications.

Statistical Analysis

Peto odds ratios (POR) with 95% confidence intervals (CI) were calculated for dichotomous outcome variables (complications) between patients who underwent either minimally invasive or conventional surgery. For continuous

outcomes, the differences in means with 95% CI between the 2 groups were calculated for each individual study and for all studies combined.

Heterogeneity Assessment

We performed a χ^2 -based homogeneity test and determined the Q statistics and the inconsistency index (I^2). A random-effects model was used when the I^2 statistic was $>50\%$. The fixed-effect model was employed otherwise. Pooled effects were calculated and a two-sided P value <0.05 was used to indicate statistical significance. Sensitivity analysis was carried out using the leave one-out approach. Publication bias was assessed for the primary outcomes by constructing funnel plots by Egger's test. The absence of publication bias was indicated by the data points forming a symmetric funnel-shaped distribution and one-tailed significance level $P > 0.05$ (Egger's test). However, the publication bias analysis was not performed for the secondary outcomes due to the limited number of studies.¹⁵ In addition, subgroup analysis was performed per the type of conventional OS (transforaminal lumbar interbody fusion [TLIF] or laminectomy [decompression]). All analyses were performed using Comprehensive Meta-Analysis statistical software, version 2.0 (Biostat, Englewood, NJ, USA).

Results

Of the 815 articles initially identified, 765 were excluded for not being relevant after initial review of abstracts and titles (Fig. 1). Fifty studies were fully reviewed and 34

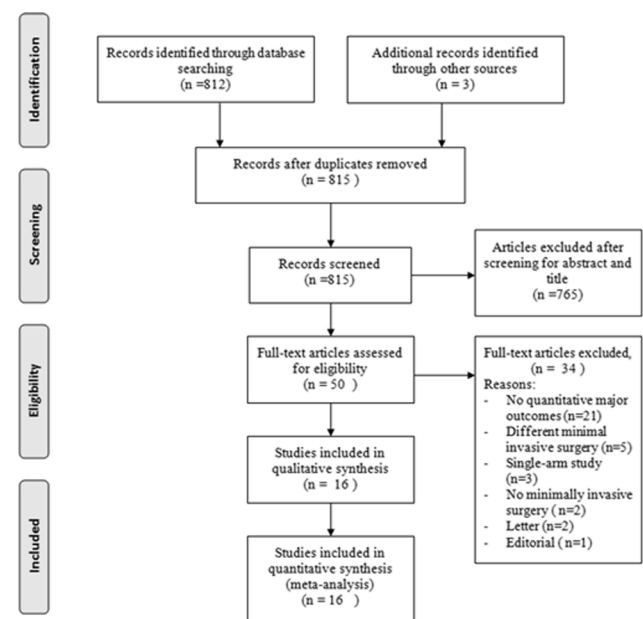


Fig. 1. PRISMA flow diagram.

Table 1. Summary of Basic Characteristics of Studies Selected for Meta-Analysis

First Author (Year)	Study Design	Comparison Group	Surgical Technique	No. of Patients	Age (Year)	Male (%)	Symptom Duration (Month)	Operated Level	Length of Follow-up (Month)	Newcastle-Ottawa Scale
Ang (2015)	NRCT	MIS	Minimally invasive lumbar laminotomy	83	58.1*	35%	NA		NA	8
		Conventional OS	Open lumbar laminotomy	30	54.7*	33%	NA	Single level	24	
Kim (2015)	NRCT	MIS	Microsurgical extraforaminal decompression	25	73	36%	13.67	L3 – L4/3; L4 – L5/13; L5 – S1/9	NA	9
		Conventional OS	Posterior lumbar interbody fusion	30	70	30%	14.42	L1 – L2/1; L3 – L4/1; L4 – L5/14; L5 – S1/14	NA	
Luo (2015)	RCT	MIS	MIS-TLIF using a tubular retraction system	42	64.4	55%	NA		26	NA
		Conventional OS	TLIF	54	66.5	59%	NA		27	
Nerland (2015)	NRCT	MIS	Microdecompression	246	68	58%	NA	L2/3: 13; L3/4: 126; L4/5: 203; L5/S1: 20	1y	9
		Conventional OS	Laminectomy	246	69	53%	NA	L2/3: 18; L3/4: 116; L4/5: 197; L5/S1: 26		
Hu (2014)	NRCT	MIS	Percutaneous intervertebral foramina endoscopic lumbar discectomy decompression	30	65	57%	5.3	L3/4: 12; L4/5: 15; L5/S1: 20	NA	9
		Conventional OS	Traditional surgery	30	67	50%	5.9	L3/4: 14; L4/5: 17; L5/S1: 21	NA	
Mobbs (2014)	RCT	MIS	Minimally invasive unilateral laminectomy for bilateral decompression	27	73	22%	NA	L2/3: 1; L3/4: 5; L4/5: 23; L5/S1: 0	36.9	NA
		Conventional OS	Conventional laminectomy	27	66	14%	NA	L2/3: 4; L3/4: 8; L4/5: 21; L5/S1: 3	44.3	
Singh (2014)	NRCT	MIS	MIS-TLIF	33	51.7	70%	NA	Single level	NA	7
		Conventional OS	Open-TLIF	33	49.9	64%	NA		NA	

MIS: Minimally invasive surgery; NA: Not applicable; OS: Open surgery; RCT: Randomised clinical trial; TLIF: Transforaminal lumbar interbody fusion

*Value presented as median.

Table 1. Summary of Basic Characteristics of Studies Selected for Meta-Analysis (Cont'd)

First Author (Year)	Study Design	Comparison Group	Surgical Technique	No. of Patients	Age (Year)	Male (%)	Symptom Duration (Month)	Operated Level	Length of Follow-up (Month)	Newcastle-Ottawa Scale
Wen (2014)	NRCT	MIS	Unilateral decompression via fenestration under quadrant retractor	32	56	41%	NA	One level: 23; two level: 9	32.8	9
Archavlis (2013)	NRCT	Conventional OS	Open decompression with fusion and internal fixation	50	57.8	36%	NA	One level: 38; two level: 12		
				24	67	42%	NA	L3–4: 2; L4–5: 16; L5–S1: 6	26	9
				25	68	32%	NA	L3–4: 1; L4–5: 17; L5–S1: 7	26	
Yang (2013)	NRCT	MIS	MIS-TLIF	43	55	35%	38		21	7
Eregeovic (2012)	NRCT	Conventional OS	Open-TLIF	104	52	36%	40		23	
				51	55.7	47%	33.5	One level, 82.4%; Multiple levels, 17.6%	NA	7
				22	55.8	59%	28.4	One level, 45.5%; Multiple levels, 54.5%	NA	
Harris (2011)	NRCT	MIS	Mini-open technique, with a small, central incision	30	66	33%	NA	Single level, L4/5	NA	9
				21	69.1	43%	NA		NA	

MIS: Minimally invasive surgery; NA: Not applicable; OS: Open surgery; RCT: Randomised clinical trial; TLIF: Transforaminal lumbar interbody fusion

*Value presented as median.

Table 1. Summary of Basic Characteristics of Studies Selected for Meta-Analysis (Cont'd)

First Author (Year)	Study Design	Comparison Group	Surgical Technique	No. of Patients	Age (Year)	Male (%)	Symptom Duration (Month)	Operated Level	Length of Follow-up (Month)	Newcastle-Ottawa Scale
Wang (2011)	NRCT	MIS	Minimally invasive transforaminal lumbar fusion	25	55	52%	NA	L3–L4; 2; L4–L5; 11; L5–S1: 9	27.5	9
		Conventional OS	Open transforaminal lumbar interbody fusion	27	56	56%		L3–L4; 2; L4–L5; 11; L5–S1: 10		
Yang (2011)	Non-RCT	MIS	Microendoscopic decompression via unilateral	42	54	57%	11.7*	L2/3: 2; L3/4: 4; L4/5: 18; L5/S1: 16; L4-S1: 2	16	9
		Conventional OS	Posterior lamina fenestration decompression	37	57	54%	14.2*	L2/3: 2; L3/4: 5; L4/5: 12; L5/S1: 15; L3–S1: 1; L4–S1: 2		
Yagi (2009)	RCT	MIS	Modified unilateral approach midline decompression microendoscopic laminectomy	20	73	40%	NA		17.8	NA
		Conventional OS	Conventional open laminectomy	21	71	29%	NA		18.6	
Cho (2007)	RCT	MIS	Split-spinous process laminotomy and discectomy	40	61	40%	NA	2.45 ± 0.68	15.1	NA
		Conventional OS	Conventional open laminectomy	30	59	50%	NA	2.56 ± 0.50	14.8	

MIS: Minimally invasive surgery; NA: Not applicable; OS: Open surgery; RCT: Randomised clinical trial; TLIF: Transforaminal lumbar interbody fusion

*Value presented as median.

Table 2. Summary of Outcomes in Studies Selected for Meta-Analysis (MIS Versus Conventional OS)

	Improvement (MIS Vs Conventional OS)			Operation Time (Min)	Length of Hospital Stay (Day)	Estimated Intraoperative Blood Loss (mL)
	ODI	VAS-Back	VAS-Leg			
Ang (2015)	26 vs 28	1.5 vs 4.0	6.0 vs 5.0	65 vs 65	1.1 vs 3.0	NA
Kim (2015)	21 vs 26	1.7 vs 3.2	4.8 vs 4.1	NA	NA	NA
Luo (2015)	56 vs 54	5.2 vs 4.9	NA	96 vs 83	NA	175 vs 296
Nerland (2015)	19 vs 17	NA	NA	One: 6.9; Two: -14.2	One: 1.6; Two: 2.0	NA
Hu (2014)	26 vs 27	NA	NA	60 vs 90	4.3 vs 9.5	13 vs 201
Mobbs (2014)	29 vs 18	NA	5.6 vs 3.9	NA	100.8 hour vs 55.1 hour	NA
Singh (2014)	NA	4 vs 4.8	NA	115.8 vs 186		124 vs 380
Wen (2014)	40 vs 41	4.7 vs 4.6	5.2 vs 5.1	52 vs 153	8.2 vs 8.6	25 vs 345
Archavlis (2013)	23 vs 24	4.4 vs 3.8	4 vs 3.8	220 vs 190	NA	185 vs 255
Yang (2013)	44 vs 43	6.6 vs 6.3	NA	175 vs 177	96 vs 170	362 vs 720
Ercegovic (2012)	NA	4.5 vs 2.7	NA	NA	NA	NA
Harris (2011)	32 vs 39	NA	5.5 vs 5.2	150 vs 156	2.5 vs 3.2	208 vs 335
Wang (2011)	27 vs 26	5.8 vs 5.4	NA	139 vs 143	NA	291 vs 652
Yang (2011)	41 vs 42	3.4 vs 2.4	NA	50 vs 75	9.4 vs 12.1	80 vs 140
Yagi (2009)	NA	NA	NA	71 vs 64	3.9 vs 12.5	37 vs 71
Cho (2007)	NA	4.1 vs 3.1	NA	259 vs 193	4 vs 7.2	154 vs 132

MIS: Minimally invasive surgery; NA: Not applicable; ODI: Oswestry Disability Index; OS: Open surgery; VAS: Visual analogue scale

were excluded for being a letter, being a single-arm study, reporting outcomes other than MIS, or not presenting outcomes quantitatively. Sixteen studies were included in the analysis.¹⁶⁻³¹

Study Characteristics

The 16 studies included 4 RCTs^{17,22,23,25} and the remaining were non-RCTs.^{18,20-24,27} All together, the studies included 1580 patients who had surgically-indicated lumbar stenosis. Of these, 793 patients underwent a MIS and 787 had conventional OS (n = 523 for laminectomy and n = 264 for TLIF). The basic characteristics of the studies are summarised in Table 1. The mean age ranged from 50 to 73 years and the percentages of male patients ranged from 14% to 70%. A summary of primary and secondary outcomes of selected studies are presented in Table 2.

Meta-Analysis

Oswestry Disability Index (ODI)

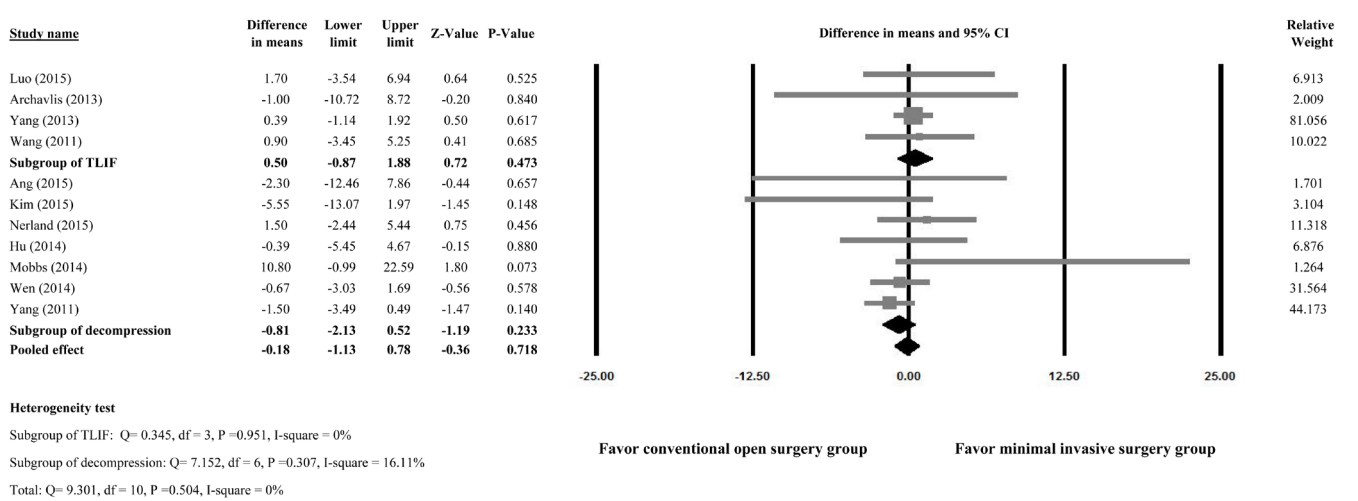
For ODI, 5 studies, (Singh [2014], Ercegovic [2012], Harris [2011], Yagi [2009] and Cho [2007]), were excluded due to lack of mean and standard deviation data. There was no evidence of heterogeneity across studies with regard to ODI ($Q = 9.301$, $I^2 = 0\%$), therefore, a fixed-effect model of analysis was used. The overall analysis revealed no

significant difference in the improvement of ODI between patients in the MIS and conventional OS groups (pooled difference in means = -0.18, 95% CI = -1.13 to 0.78, $P = 0.718$) (Fig. 2A). Four studies presented data for patients who received TLIF. Subgroup analysis comparing MIS and TLIF found no significant difference in ODI between the 2 groups (pooled difference in means = 0.50, 95% CI = -0.87 to 1.88, $P = 0.473$). Seven studies reported findings with respect to decompression surgery. Pooled analysis found ODI improvement was similar between patients who had MIS and those who had conventional decompression surgery (pooled difference in means = -0.81, 95% CI = -2.13 to 0.52, $P = 0.233$).

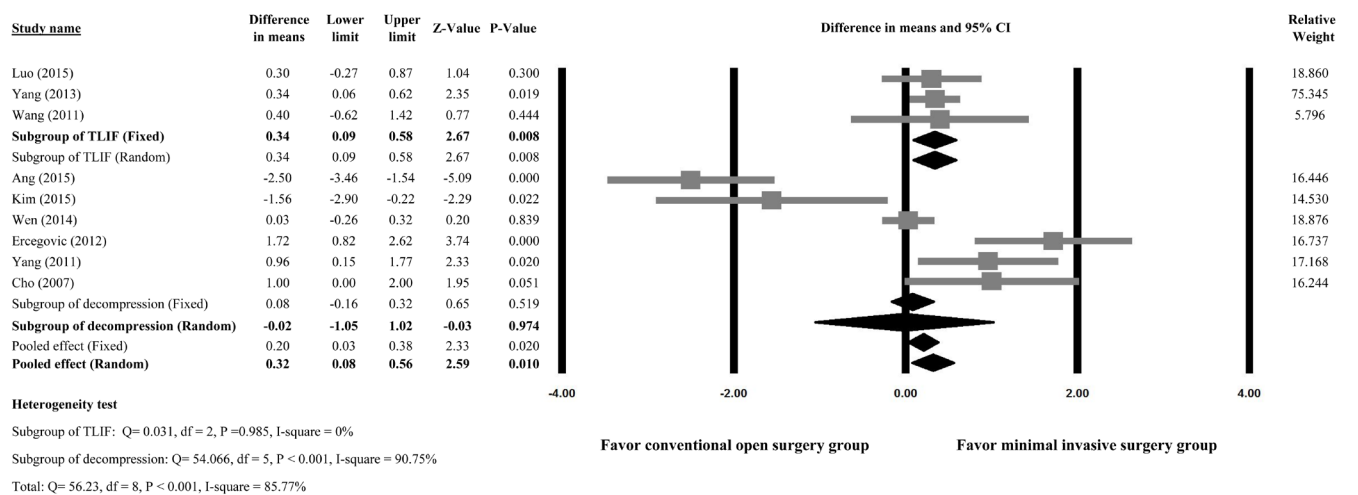
Visual Acuity Score

Significant heterogeneity in VAS for back and leg pain among the studies was observed (heterogeneity test: $I^2 = 85.77\%$ and 57.19% for back pain and leg pain, respectively); therefore, random effects models were used. The overall analysis revealed patients treated with MIS had significant better improvement of back pain than those who underwent conventional OS (pooled difference in means = 0.32, 95% CI = 0.08 to 0.56, $P = 0.010$) (Fig. 2B). Pooled data from studies that reported TLIF results (n = 3) found MIS showed greater improvement in back pain than conventional surgery (pooled difference in means = 0.34, 95% CI = 0.09 to

A. ODI



B. VAS-Back



C. VAS-Leg

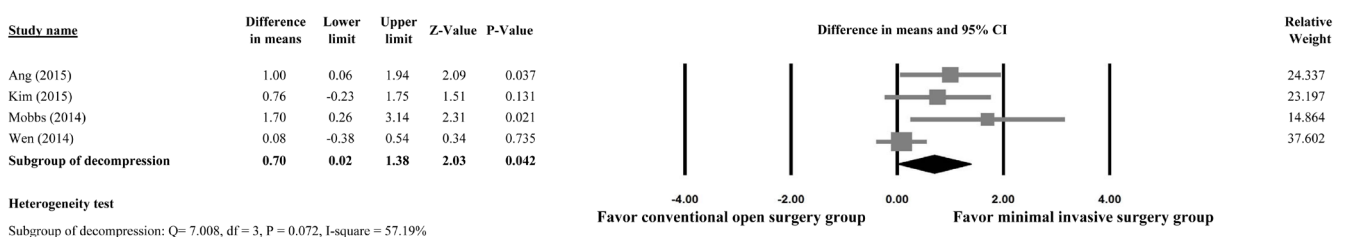


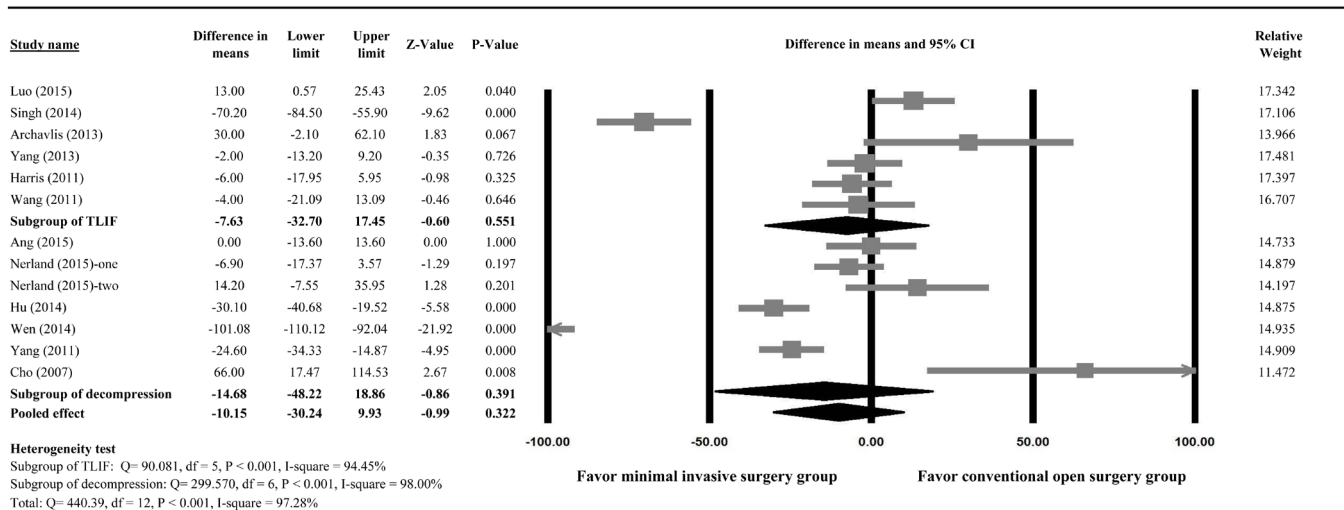
Fig. 2. Meta-analysis for primary outcomes. A) ODI; B) VAS-Back; C) VAS-Leg.

0.58, $P = 0.008$). In contrast, pooled analysis of data from the 6 studies that presented VAS for back pain following conventional decompression surgery found VAS results were similar between the 2 groups (pooled difference in means = -0.02, 95% CI = -1.05 to 1.02, $P = 0.974$).

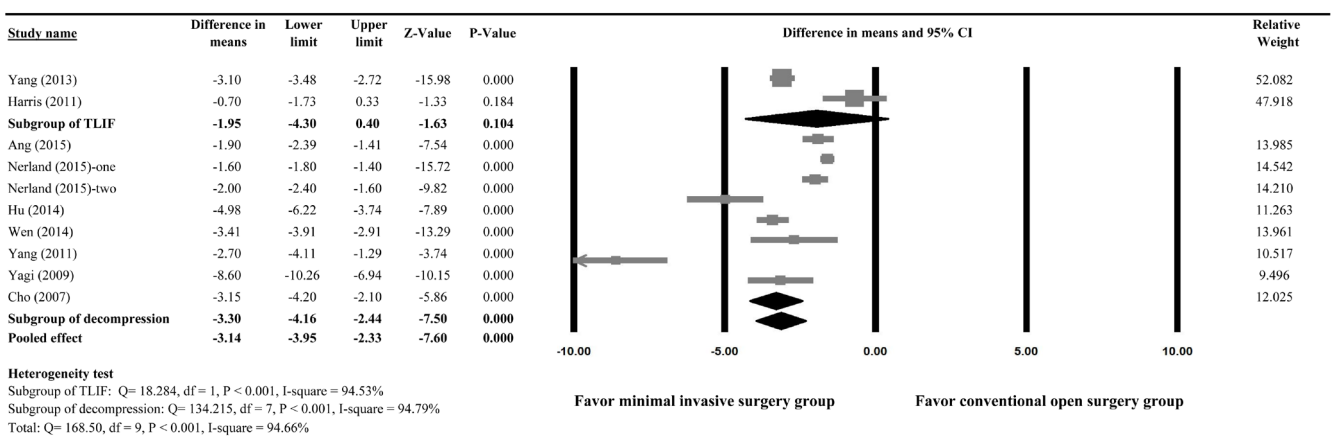
Four studies reported VAS for leg pain. The studies

evaluated MIS and conventional decompression surgery. Pooled analysis indicated patients treated with MIS had significant improvement in leg pain than those who underwent conventional decompression surgery (pooled difference in means = 0.70, 95% CI = 0.02 to 1.38, $P = 0.042$) (Fig. 2C).

A. Operation time



B. Length of hospital stay



C. Estimated intra-operative blood loss

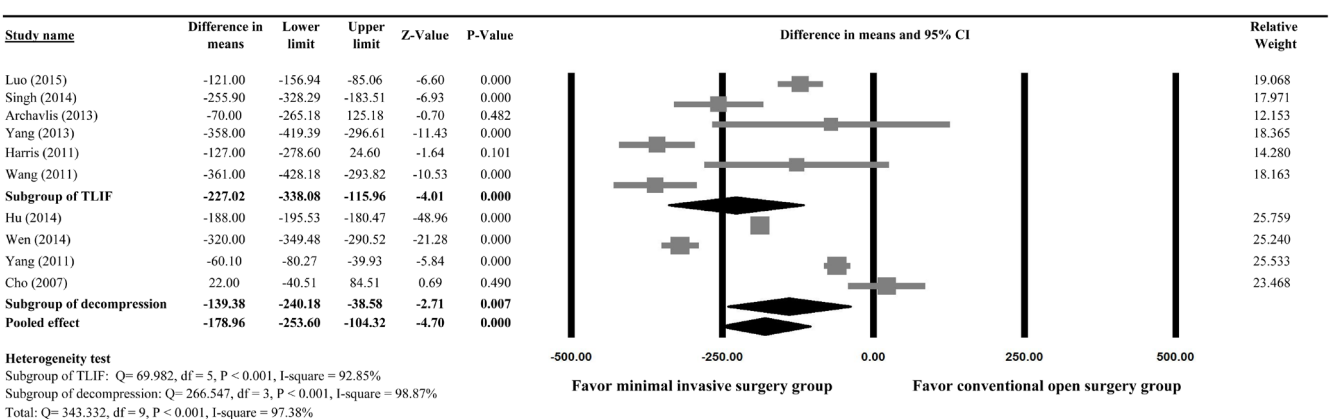


Fig. 3. Meta-analysis for secondary outcomes. A) Operation time; B) Length of hospital stay; C) Estimated intraoperative blood loss.

Meta-Analysis for Secondary Outcomes

Random effects models were used for analysis of operation time, length of hospital stay, and intraoperative blood loss due to high heterogeneity among the studies (heterogeneity tests: $I^2 = 97.28\%$, 94.66% and 97.38% for operation time, length of hospital stay and intraoperative blood loss,

respectively). The overall analysis revealed that patients who received MIS had shorter operation time than those who underwent conventional OS; however, the findings did not reach statistical significance (pooled difference in mean = -10.15 , $95\% \text{ CI} = -3.24$ to 9.93 , $P = 0.322$) (Fig. 3A). Patients treated with MIS had shorter lengths

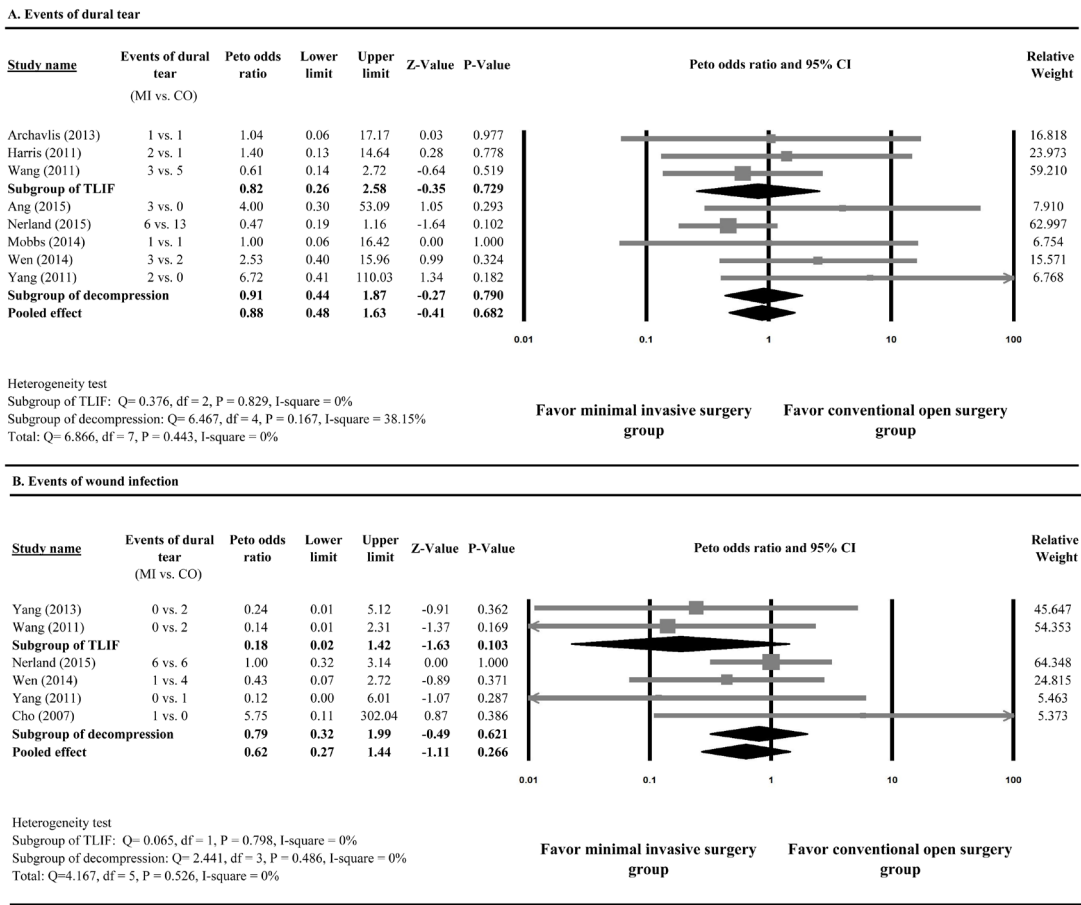


Fig. 4. Meta-analysis for safety outcomes. A) Dural tear; B) Wound infection.

of hospital stay (pooled difference in mean = -3.14, 95% CI = -3.95 to -2.33, $P < 0.001$) (Fig. 3B) and lower blood loss than those who underwent conventional OS (pooled difference in mean = -178.96, 95% CI = -253.60 to -104.32, $P < 0.001$) (Fig. 3C).

For patients in the TLIF subgroup, no significant difference in the operation time and length of hospital stay were observed compared with MIS ($P = 0.551$ and $P = 0.104$, respectively). In contrast, patients treated with MIS had shorter lengths of hospital stay (pooled difference in mean = -3.30, 95% CI = -4.16 to -2.44, $P < 0.001$) (Fig. 3B) and lower blood loss than those who underwent decompression surgery (pooled difference in mean = -139.38, 95% CI = -240.18 to -38.35, $P = 0.007$; Fig. 3C).

Meta-Analysis for Safety Outcomes

There was no significant heterogeneity in rates of dural tear and wound infection across studies (heterogeneity test: $Q = 6.866$, $I^2 = 0\%$ for dural tear and $Q = 4.167$, $I^2 = 0\%$ for wound infection); therefore, a fixed-effect model of analysis was used. Overall analysis revealed no significant

differences in the rates of dural tear and wound infection between the MIS and conventional OS groups (Fig. 4). No significant differences in the rates of dural tear and wound infection between the TLIF or conventional decompression groups compared with MIS were observed.

Sensitivity Analysis

With the exception of VAS for leg pain, the direction and magnitude of combined estimates did not vary markedly with the removal of the individual studies, indicating that the meta-analysis was robust and the data were not overly influenced by each study. Removal of Ang et al (2015), Kim et al (2015) and Mobbs et al (2014) studies in turn influenced the findings for VAS leg pain (Table 3).

Quality Assessment

For the non-RCTs, the Newcastle-Ottawa scale score ranged from 7 to 9, out of 12 (Table 1) suggesting the studies were of good quality. Quality assessment of the RCTs indicated that 3 studies had random sequence generation and low risk for attrition and reporting bias (Fig. 5A). Half the

Table 3. Sensitivity Analysis

First Author (Year)	Statistics with Study Removed				
	Points	Lower Limit	Upper Limit	Z Value	P Value
ODI					
Ang (2015)	-0.16	-1.12	0.80	-0.32	0.748
Kim (2015)	-0.09	-1.05	0.87	-0.18	0.858
Luo (2015)	-0.24	-1.21	0.73	-0.49	0.627
Nerland (2015)	-0.28	-1.27	0.70	-0.56	0.576
Hu (2014)	-0.17	-1.14	0.80	-0.34	0.735
Mobbs (2014)	-0.25	-1.21	0.71	-0.51	0.611
Wen (2014)	-0.08	-1.12	0.97	-0.15	0.882
Archavlis (2013)	-0.17	-1.13	0.79	-0.34	0.731
Yang (2013)	-0.54	-1.76	0.68	-0.86	0.389
Wang (2011)	-0.23	-1.21	0.75	-0.46	0.644
Yang (2011)	0.22	-0.87	1.31	0.39	0.695
VAS-back					
Ang (2015)	0.43	0.03	0.84	2.10	0.036
Kim (2015)	0.28	-0.26	0.82	1.03	0.302
Luo (2015)	0.11	-0.51	0.73	0.35	0.725
Wen (2014)	0.14	-0.58	0.86	0.37	0.708
Yang (2013)	0.09	-0.64	0.82	0.24	0.808
Ercegovic (2012)	-0.03	-0.57	0.50	-0.12	0.903
Wang (2011)	0.11	-0.47	0.69	0.37	0.709
Yang (2011)	0.04	-0.54	0.62	0.13	0.898
Cho (2007)	0.05	-0.53	0.62	0.16	0.872
VAS-leg					
Ang (2015)	0.64	-0.22	1.50	1.47	0.143
Kim (2015)	0.75	-0.18	1.68	1.58	0.114
Mobbs (2014)	0.49	-0.12	1.10	1.56	0.118
Wen (2014)	1.03	0.42	1.65	3.29	0.001
Operation time					
Ang (2015)	-12.40	-36.00	11.20	-1.03	0.303
Luo (2015)	-13.62	-36.67	9.43	-1.16	0.247
Nerland (2015)-one	-11.72	-35.94	12.51	-0.95	0.343
Nerland (2015)-two	-13.60	-36.65	9.45	-1.16	0.248
Hu (2014)	-9.65	-34.23	14.93	-0.77	0.441
Singh (2014)	-6.50	-29.36	16.35	-0.56	0.577
Wen (2014)	-5.85	-19.65	7.94	-0.83	0.406
Archavlis (2013)	-14.62	-37.45	8.21	-1.26	0.209
Yang (2013)	-12.19	-36.09	11.71	-1.00	0.317
Harris (2011)	-11.83	-35.79	12.12	-0.97	0.333
Wang (2011)	-12.06	-35.54	11.41	-1.01	0.314
Yang (2011)	-10.09	-34.94	14.76	-0.80	0.426
Cho (2007)	-16.34	-38.89	6.21	-1.42	0.156

ODI: Oswestry Disability Index; VAS: Visual analogue scale

Table 3. Sensitivity Analysis (Cont'd)

First Author (Year)	Statistics with Study Removed				
	Points	Lower Limit	Upper Limit	Z Value	P Value
Length of hospital stay					
Ang (2015)	-3.18	-4.01	-2.34	-7.44	<0.001
Nerland (2015) - one	-3.22	-4.04	-2.39	-7.64	<0.001
Nerland (2015) - two	-3.18	-4.05	-2.31	-7.15	<0.001
Hu (2014)	-2.81	-3.55	-2.07	-7.49	<0.001
Wen (2014)	-2.96	-3.74	-2.19	-7.50	<0.001
Yang (2013)	-3.02	-3.83	-2.21	-7.29	<0.001
Harris (2011)	-3.26	-4.03	-2.49	-8.28	<0.001
Yang (2011)	-3.05	-3.82	-2.27	-7.70	<0.001
Yagi (2009)	-2.55	-3.19	-1.92	-7.91	<0.001
Cho (2007)	-3.00	-3.78	-2.22	-7.55	<0.001
Estimated intraoperative blood loss					
Luo (2015)	-198.65	-271.35	-125.94	-5.36	<0.001
Hu (2014)	-187.87	-287.84	-87.91	-3.68	<0.001
Singh (2014)	-182.86	-252.31	-113.41	-5.16	<0.001
Wen (2014)	-173.92	-240.37	-107.48	-5.13	<0.001
Archavlis (2013)	-197.61	-264.79	-130.44	-5.77	<0.001
Yang (2013)	-170.79	-238.07	-103.50	-4.97	<0.001
Harris (2011)	-195.21	-263.07	-127.35	-5.64	<0.001
Wang (2011)	-170.83	-238.25	-103.42	-4.97	<0.001
Yang (2011)	-207.61	-274.90	-140.33	-6.05	<0.001
Cho (2007)	-215.55	-281.97	-149.14	-6.36	<0.001
Events of dural tear					
Ang (2015)	0.80	0.43	1.51	-0.68	0.497
Nerland (2015)	1.48	0.65	3.39	0.93	0.354
Mobbs (2014)	0.87	0.47	1.64	-0.42	0.674
Wen (2014)	0.77	0.40	1.48	-0.78	0.433
Archavlis (2013)	0.87	0.46	1.64	-0.43	0.669
Harris (2011)	0.85	0.45	1.61	-0.50	0.616
Wang (2011)	0.95	0.48	1.86	-0.16	0.874
Yang (2011)	0.79	0.42	1.49	-0.72	0.471
Events of wound infection					
Nerland (2015)	0.36	0.10	1.23	-1.64	0.102
Wen (2014)	0.68	0.27	1.75	-0.79	0.428
Yang (2013)	0.67	0.28	1.60	-0.90	0.370
Wang (2011)	0.72	0.30	1.73	-0.74	0.462
Yang (2011)	0.67	0.28	1.59	-0.91	0.365
Cho (2007)	0.56	0.24	1.32	-1.33	0.185

ODI: Oswestry Disability Index; VAS: Visual analogue scale

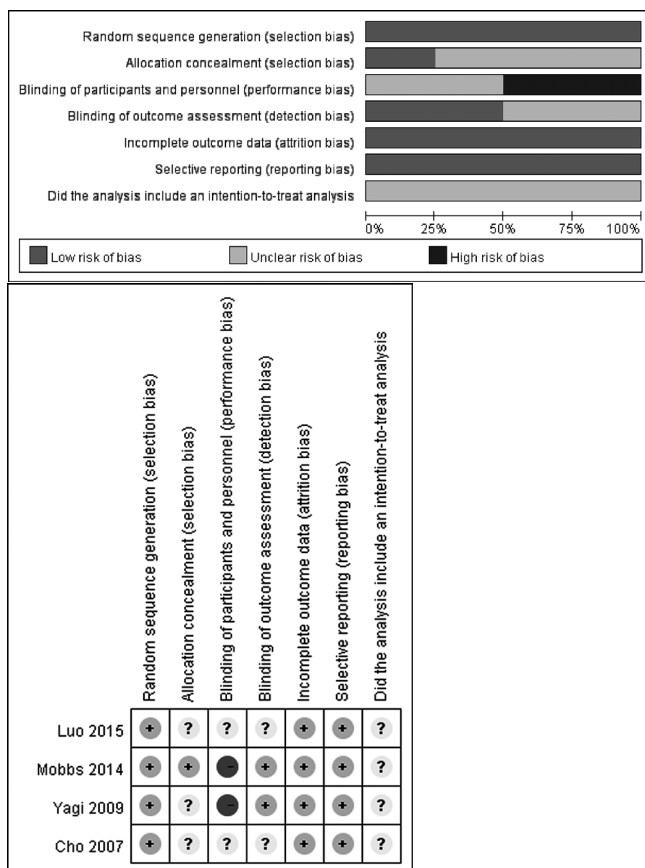


Fig. 5. Quality assessment.

studies showed blinding bias. This was expected as double blinding was difficult to perform due to the necessity of different surgical interventions. The risk of intention-to-treat analysis was unclear. Overall, the included studies had low risk for attrition and reporting bias, but high risk of performance bias (Fig. 5B).

Discussion

Although open laminectomy is the standard of care for treatment of lumbar stenosis, it may lead to adverse consequences, such as flexion instability, muscle weakness, and failed back surgery syndrome due to profound disruption of spine and surrounding muscle structures.⁷⁻¹¹ In recent years, there has been rapid development of the minimal access techniques for decompression and stabilisation of the lumbar spine. A number of potential benefits of this approach include smaller scars, decreased blood loss, reduced wound pain, and shorter hospital stays. These benefits, however, have to be carefully considered against possible shortcomings, such as a steep learning curve for doctors as well as high cost of equipment for implementation of MIS. The purpose of our meta-analysis study was to

assess the clinical outcome, safety, and efficiency of MIS compared with open laminectomy in the treatment of lumbar stenosis. To our knowledge, this is the first meta-analysis on this topic.

Our results found no significant difference in ODI and operation time between MIS and conventional OS. However, MIS was associated with significantly better VAS for back pain, shorter length of hospital stay, and lower blood loss than conventional OS. Overall, subgroup analysis which compared MIS with TLIF or conventional decompression surgery showed similar results to the overall analysis. Exceptions included the findings that VAS for back pain was similar between MIS and conventional decompression surgery, and no difference in length of hospital stay was seen between groups who received MIS or TLIF. Additionally, rates of complications, such as dural tear and wound infection were similar between MIS and conventional surgery.

The findings are consistent with previous studies. Recent systematic review concluded that, based on the available literature, minimally invasive lumbar surgery for posterior lumbar decompression or fusion has similar rate of complications compared with OS.³² The authors also noted the reduction of blood loss was less with MIS, while the length of hospital stay was not dependent on choice of surgical intervention.³² Payer et al analysed 9 studies comparing the MIS and standard OS in the treatment of degenerative lumbar stenosis and found that both procedures produced similar outcomes for lumbar disc herniation, or transforaminal or posterior lumbar interbody fusions.³³ In addition, a number of studies demonstrated a significantly shorter hospital stay for the patients who underwent minimally invasive lumbar laminotomy.^{30,34-36}

It was previously shown that MIS techniques may lead to higher rates of complications, such as dural tears, inadequate decompression,^{10,37} and longer operation times.³⁸ However, our study showed no significant differences in the rates of dural tear, wound infection, and operation times between conventionally or MIS-treated patients. It is possible that minimal exposure of the spine during MIS can result in incomplete treatment and lead to higher recurrence of symptoms at later follow-up times.^{39,40} Assessment of the outcomes at later time points will help to address this possibility and to more accurately estimate the cost-effectiveness of MIS, which depends on sustained clinical benefits over time.⁴¹

The major limitations of our study are the small number of included publications, varied sample sizes, and the design heterogeneity in the analysed trials. Only 4 studies were RCTs. The sample size in the Nerland et al study was significantly larger compared to other included studies, which may have potentially influenced the treatment effect estimates. Moreover, details of surgical interventions

differed between the studies. Of the 16 included studies, only 2 (Archavlis et al, 2013 and Hu et al, 2014) reported results of postoperative VAS within 5 days of surgery. In Archavlis et al, no difference between treatment groups at day 3 postsurgery was observed. However, Hu et al observed that the MIS group had significantly better VAS compared with OS group. Due to only 2 studies reporting postoperative VAS findings, we did not perform a meta-analysis for this outcome. Additional controlled studies with larger patients groups and longer follow-up times are warranted to confirm our conclusions.

Conclusion

Our results highlight that employment of MIS techniques can lead to clinical outcomes that are comparable to those of conventional OS. Additionally, MIS is associated with lower blood loss and shorter hospital stay, and therefore could reduce the overall cost of care for lumbar stenosis patients. Hence, MIS techniques should be considered as a primary treatment for qualifying patients with lumbar stenosis.

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