Back pain outcomes after minimally invasive anterior lumbar interbody fusion: a systematic review

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OBJECTIVE Minimally invasive anterior lumbar interbody fusion surgery (MIS ALIF) is a technique that restores disc height and lumbar lordosis through a smaller exposure and less soft-tissue trauma compared to open approaches. The mini-open and laparoscopic assistance techniques are two main forms of MIS ALIF. The authors conducted a systematic review that sought to critically summarize the literature on back pain following MIS ALIF.

METHODS In March 2020, the authors searched the PubMed, Web of Science, and Cochrane Library databases for studies describing back pain visual analog scale (VAS) outcomes after MIS ALIF. The following exclusion criteria were applied to studies evaluated in full text: 1) the study included fewer than 20 patients, 2) the mean follow-up duration was shorter than 12 months, 3) the study did not report back pain VAS score as an outcome measure, and 4) MIS ALIF was not studied specifically. The methodology for the included studies were evaluated for potential biases and assigned a level of evidence.

RESULTS There were a total of 552 patients included from 13 studies. The most common biases were selection and interviewer bias. The majority of studies were retrospective. The mean sample size was 42.3 patients. The mean follow-up duration was approximately 41.8 months. The mean postoperative VAS reduction was 5.1 points. The mean VAS reduction for standalone grafts was 5.9 points, and 5.0 points for those augmented with posterior fixation. The most common complications included bladder or urinary dysfunction, infection, and hardware-related complications.

CONCLUSIONS This was a systematic review of back pain outcomes following MIS ALIF. Back pain VAS score was reduced postoperatively across all studies. The complication rates were low overall. MIS ALIF is safe and effective at reducing back pain in appropriate patient populations.

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KEYWORDS laparoscopic; mini-open; visual analog scale; anterior lumbar interbody fusion; minimally invasive surgery

ANTERIOR lumbar interbody fusion (ALIF) is effective for managing degenerative or traumatic instability by fusing the spine via an anterior approach. ALIF allows restoration of both anterior disc height and lumbar lordosis, especially compared to other approaches.^{1,2} A retrospective study of 57 total patients comparing ALIF and transforaminal lumbar interbody fusion concluded that ALIF was superior for restoring foraminal height, the disc angle, and physiological lumbar lordosis.³ ALIF eliminates the need to dissect paraspinal muscles from the vertebrae associated with lateral approaches, thus decreasing the trauma and maintaining the vascular sup-

ply to these muscles.⁴ Multilevel ALIF is likely also better for deformity correction and restoration of lumbar lordosis than larger posterior-based osteotomies.⁵ There are complications associated with opening the abdomen during ALIF, which include vascular injury, sexual dysfunction, pancreatitis, bowel injury, and ileus.⁶ Therefore, minimizing exposure is preferred to limit complications.

Minimally invasive spine surgery (MISS) has become an attractive alternative to open approaches, allowing for decreased infection rates and shorter recovery periods.⁷ MISS has reduced soft-tissue damage compared to open surgery,⁸ and with reliance on fluoroscopy or laparoscopic

ABBREVIATIONS ALIF = anterior lumbar interbody fusion; DDD = degenerative disc disease; MIS = minimally invasive surgery; MISS = minimally invasive spine surgery; PRISMA = Preferred Reporting Items for Systematic Reviews and Meta-Analyses; VAS = visual analog scale.

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FIG. 1. PRISMA diagram. Process of exclusion and inclusion of studies.

py allows adequate visibility through smaller exposures.⁷ ALIF can be performed minimally invasively, and studies describing the mini-open, video-assisted, or image-guided ALIF have shown favorable outcomes.^{9–11} A study of 98 patients who underwent ALIF via either a mini-open exposure or laparoscopy concluded that one technique did not have a definitive benefit over the other.¹² Furthermore, a prospective study of 54 patients that compared laparoscopic minimally invasive surgery (MIS) with an open approach showed there was no difference in outcomes or fusion rates.¹³

Despite this, there have been no systematic reviews conducted on MIS ALIF. To address this gap, we performed a review of available demographic, clinical information, and pre- and postoperative measures with attention to back pain using the visual analog scale (VAS). Our study aimed to provide a concise representation of the current literature of MIS ALIF while identifying advantages and limitations.

Methods

Literature Search

In March 2020 we searched the PubMed, Web of Science, and Cochrane databases for articles containing clinical VAS outcomes after MIS ALIF that were published in the last 20 years. We used the following search terms (“minimally invasive” or “MIS” or “mini-open” or “mini open” or “laparoscopic” or “mini-ALIF” or “mini ALIF”) AND (“anterior lumbar interbody fusion” OR “anterior lumbar fusion” OR “anterior lumbar surgery” OR “ALIF”). Two authors (A.Y.C. and B.V.L.) independently reviewed the articles. Discrepancies were resolved by dis-

cussion and consensus. Data extraction was performed by B.V.L. and reassessed by A.Y.C. and E.H.C.

Study Criteria and Data Collection

The search returned 154 results from PubMed, 187 from Web of Science, and 7 from the Cochrane Library, totaling 227 unique citations after exclusion of duplicates. The following inclusion criteria were applied: 1) primary clinical study reporting VAS outcomes after MIS ALIF, 2) English language only; and 3) publication date within the last two decades. If the study in the title and abstract did not specify minimally invasive, the full text was reviewed (Fig. 1).

Overall, 93 potential studies met our inclusion criteria and were reviewed in full text. The following exclusion criteria were applied: 1) data from fewer than 20 patients, 2) the mean follow-up duration for the study was less than 12 months, 3) back pain VAS score was not included as an outcome measure, and 4) the article not investigating MIS ALIF specifically. ALIF included antepsoas approaches, and strictly lateral surgeries were excluded. Ultimately, 13 studies met the inclusion and exclusion criteria. This literature review was designed and performed using Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.¹⁴ Data from each study were collected for back pain VAS score, complications, and whether the patient had a standalone interbody fixation, as well as an additional posterior fixation.

We assessed the study methodology for each of the 13 selected studies for potential biases and assigned a level of evidence as previously described.¹⁴ Briefly, interviewer bias was defined as a systematic difference between how information was solicited, recorded, or interpreted (e.g., no

blinding). Recall bias was defined as bias due to outcomes of treatment affecting the patient's memory for previous events. Selection bias was defined as bias due to patient loss to follow-up or if the exposure and outcome occurred before patient selection. Response bias was defined as bias occurring with self-report and surveys.

Results

The initial search resulted in 348 articles. After the screening and assessment of full-text articles, 13 studies fulfilled the inclusion criteria.^{9,10,13,15–24} There were 552 patients included from these studies (Table 1). The level of evidence ranged from II to IV. The most common biases included selection bias (92.3%) and interviewer bias (84.6%). Approximately 38.5% (5/13) of studies were prospective and 69.2% (9/13) were retrospective. The patient demographics, study design, diagnosis, follow-up duration, location of surgeries, and surgical approach are summarized in Table 2. The mean collective sample size was 42.5 (range 20–142). The collective ratio of male to female study participants was 1 to 1.5. The mean collective follow-up duration was 41.8 months (range 3–120 months). Supplemental posterior screw fixation was performed in 43.5% (240/552) of patients, whereas ALIF was performed alone in 56.5% (312/552) of patients. The most common operated levels were L4–5 and L5–S1, with 9 studies reported for each.

The VAS score for back pain was collected preoperatively and postoperatively (Table 3). Two different scales for the VAS were used. Eleven studies used a scale ranging from 0–10,^{9,10,13,15,17–23} whereas 2 studies used a scale ranging from 0–100.^{16,24} The scale ranging from 0–100 was normalized to the scale ranging from 0–10 in this study. The mean postoperative VAS score reduction was 5.1 points. The mean VAS score reduction for standalone grafts was 5.9 points, and 5.0 points for posterior fixation.

The rate of complication and complication types are summarized in Table 4. The overall complication rate for standalone fixation (9.9%, 10/101) was lower than with posterior fixation (20.2%, 41/203). Complications that were relatively common included bladder or urinary dysfunction (2.5%, 14/552), infection (2.4%, 13/552), hardware-related complications (2.2%, 12/552), fracture (1.3%, 7/552), vascular injury (1.1%, 6/552), wound-related complications (1.1%, 6/552), and neurological complications (1.1%, 6/552). Rarer complications included gastrointestinal-related complications (0.9%, 5/552), deep vein thrombosis (0.7%, 4/552), and retrograde ejaculation (0.4%, 2/552). Hardware-related complications include malpositioned cages or pedicle screws causing symptoms. Wound-related complications included wound dehiscence, wound hematoma, or incision site pain. Neurological complications include L5 palsy, pain due to foraminal stenosis, and numbness. Gastrointestinal complications included bowel injury, paralytic ileus, or common bile duct lithiasis.

Discussion

This systematic review assesses the change in back pain VAS scores and the complications after MIS ALIF. We reviewed 552 cases from 13 studies for qualitative and quantitative analysis. Of the 13 studies, 11 were level IV

TABLE 1. Studies with sample size, level of evidence, and potential biases

Authors & Year	Sample Size	Evidence Level	Potential Biases
Aunoble et al., 2006 ¹⁰	20	IV	Interviewer, selection
Chung et al., 2003 ¹³	44	II	Interviewer, selection
Farah et al., 2018 ¹⁵	43	IV	Interviewer, selection
Flouzat-Lachaniette et al., 2015 ¹⁶	47	IV	Selection, responder
Hironaka et al., 2013 ¹⁷	142	IV	Interviewer, selection
Hosseini et al., 2017 ¹⁸	39	IV	Interviewer, selection
Kim et al., 2010 ¹⁹	63	IV	Interviewer, selection
Kleeman et al., 2001 ²⁰	22	II	Interviewer, selection
Lin et al., 2015 ²¹	22	IV	Interviewer, selection
Mamuti et al., 2016 ⁹	35	IV	Interviewer, selection
Park et al., 2009 ²²	29	IV	Interviewer, selection
Shim et al., 2005 ²³	20	IV	Selection, responder
Tobler & Ferrara, 2011 ²⁴	26	IV	Interviewer

evidence, and 2 studies were level II evidence. In these studies, the MIS ALIF indications including degenerative disc diseases (DDD), foraminal stenosis, spinal deformity, and failed posterior fusion were similar to the open ALIF indications. Associated symptoms include neurogenic claudication, radiculopathy, and leg or low-back pain.^{25–27} All studies reported a decrease in overall mean back pain VAS scores postoperatively. Although there was a wide range of complications after MIS ALIF, the complication rates were low overall. The most prevalent complications were bladder or urinary dysfunction (2.5%, 14/552), infection (2.4%, 13/552), and hardware-related complications (2.2%, 12/552).

Mini-Open and Laparoscopic

MIS ALIF can be performed via a mini-open exposure versus laparoscopic assistance. The mini-open approach is a variation on the original open approach that utilizes muscle-splitting techniques to minimize soft-tissue trauma.²⁸ Mini-open ALIF has been shown to be effective. A retrospective study of 684 patients concluded that the mini-open approach could be performed quickly with low rates of complications.²⁹ A laparoscopic approach was also developed after improvements in interbody fusion cage technologies. Regan et al. described a study of 240 total patients who underwent either laparoscopic or traditional approach ALIF and found that complication rates were similar between groups, but the laparoscopic group had shorter hospital length of stay and reduced intraoperative blood loss.³⁰ However, the authors conceded that the approach was technically difficult and that 10% of cases were converted to open approaches. In direct comparisons between mini-open and laparoscopic approaches, there appear to be no substantial differences. A prospective study of 50 consecutive total patients comparing the two approaches found there was no difference in surgical duration, blood loss, or length of stay, although the complication rate was higher among the laparoscopic group.³¹ There do not appear to be

TABLE 2. Study characteristics and demographics

Study	Sample Size	Study Design	Mean Age (yrs)	Sex (M/F)	Mean FU (mos)	Indication for Surgery	Approach	Posterior Screw Fixation	Levels
Aunoble et al., 2006 ¹⁰	20	Pros	39	9/11	26	DDD	Laparo	1/20	L5-S1
Chung et al., 2003 ¹³ (laparoscopic)	22	Pros	49	5/17	24	DDD	Laparo	0/22	L5-S1
Chung et al., 2003 ¹³ (mini-open)	22	Pros	50	6/16	24	DDD	Mini-open	0/22	L5-S1
Farah et al., 2018 ¹⁵	43	Retro	43	19/24	18	DDD	Mini-open	43/43	L4-5 or L5-S1
Flouzat-Lachaniette et al., 2015 ¹⁶	47	Retro	64	9/38	36	DDD or scoliosis	Mini-open	2/47	L2-3, L3-4, or L4-5
Hironaka et al., 2013 ¹⁷	142	Retro	64	82/60	76	DDD	Mini-open	1/142	L4-5
Hosseini et al., 2017 ¹⁸	39	Retro	66	12/27	13	Adult spinal deformity	Mini-open	33/39	L4-5, L5-S1
Kim et al., 2010 ¹⁹	63	Retro	49	27/36	72	DDD	Mini-open	63/63	L4-5 or L5-S1
Kleeman et al., 2001 ²⁰	22	Pros	38	8/14	12	DDD	Laparo	0/22	L4-5 or L5-S1
Lin et al., 2015 ²¹	22	Retro	54	13/9	30	Lumbar pyogenic spondylodiscitis	Mini-open	22/22	L2-3, L3-4, or L4-5
Mamuti et al., 2016 ⁹	35	Retro	52	10/25	24	DDD	Mini-open	0/35	L4-5, L5-S1
Park et al., 2009 ²²	29	Retro	65	9/20	15	DDD	Mini-open	29/29	L4-5 level
Shim et al., 2005 ²³	20	Retro	54	1/19	20	DDD	Mini-open	20/20	Unspecified
Tobler & Ferrara, 2011 ²⁴	26	Pros	44 M, 40 W	15/11	24	DDD	Mini-open	26/26	L5-S1

FU = follow-up; Laparo = laparoscopic; Pros = prospective; Retro = retrospective.

TABLE 3. Summary of reduction in postoperative back pain VAS score

Authors & Year	Sample Size	VAS Score		
		Preop	Postop	Change
Aunoble et al., 2006 ¹⁰	20	6.5	2.7	3.8
Chung et al., 2003 ¹³	22	9.1	4.0	5.1
Chung et al., 2003 ¹³	22	9.4	3.7	5.7
Farah et al., 2018 ¹⁵	43	7	2	5
Flouzat-Lachaniette et al., 2015 ¹⁶	47	6.3	3.1	3.2
Hironaka et al., 2013 ¹⁷	142	8.7	3.0	5.7
Hosseini et al., 2017 ¹⁸	39	6.8	2.1	4.7
Kim et al., 2010 ¹⁹	63	6.2	1.7	4.5
Kleeman et al., 2001 ²⁰	22	7.7	1.9	5.8
Lin et al., 2015 ²¹	22	7.5	0.6	6.9
Mamuti et al., 2016 ⁹	35	7.9	1.4	6.5
Park et al., 2009 ²²	29	6.6	1.5	5.1
Shim et al., 2005 ²³	20	NA	NA	7.3
Tobler & Ferrara, 2011 ²⁴	26	6.7	3.7	3.0

NA = not available.

All VAS data are provided as means.

any clear advantages for either technique.^{12,30,31} Our review evaluated studies utilizing both techniques. The VAS score for back pain was significantly reduced postoperatively in all studies. The laparoscopic approach is more technically difficult. One consideration with any minimally invasive approach is that vascular injury can be difficult to control through small exposures.

VAS Outcomes

MIS ALIF has been shown to reduce back pain in appropriately selected patients with high-grade spondylolisthesis, DDD, central canal stenosis, and spinal deformity.^{27,32,33} All studies showed a significant reduction in VAS scores postoperatively (Table 2). For example, Hironaka et al. retrospectively reviewed 142 patients undergoing L4-5 mini-open ALIF for degenerative disease and found that VAS scores for back pain were significantly reduced postoperatively.¹⁷ The reason is likely that ALIF allows for anterior longitudinal ligament release and larger anterior interbody placement, restoring physiological lumbar lordosis.²⁷ MIS ALIF may prevent damage to paraspinal muscles and ligaments because anterior interbody placement may circumvent the requirement for posterior decompression in comparison to other approaches. However, there have been variable rates of fusion in the literature, which may be why standalone ALIF is less common and often augmented with posterior fixation.³⁴ MIS ALIF shows pain reduction comparable to open techniques.¹²

Complications

A summary of complications for each study is listed in Table 4. Complications from ALIF are rare but have the potential to be devastating. The risk is augmented when the exposure is smaller, as it is with MIS approaches. Although the rates were low, the various complications reported in

TABLE 4. Complication reported

Authors & Year	Complication Rate	Complications
Aunoble et al., 2006 ¹⁰	NA	1/20 vascular complication, 1/20 donor-site infection, 1/20 superficial wound dehiscence
Chung et al., 2003 ¹³ (laparoscopic)	13.64%	1/22 cage malposition, 1/22 retrograde ejaculation, 1/22 bladder dysfunction
Chung et al., 2003 ¹³ (mini-open)	9.09%	1/22 deep vein thrombosis, 1/22 bladder dysfunction
Farah et al., 2018 ¹⁵	4.60%	1/43 superficial wound infection, 1/43 urinary infection
Flouzat-Lachaniette et al., 2015 ¹⁶	12.70%	1/47 iliac vein laceration, 1/47 ureteral injury, 1/47 L3 corporeal fracture, 2/47 endplate fractures, 1/47 L5 palsy, 1/47 acute coronary syndrome, 1/47 cardiac arrest, 1/47 acute cardiac, 1/47 common bile duct lithiasis, 6/47 acute urinary retention, 4/47 urinary tract infection, 1/47 paralytic ileus
Hironaka et al., 2013 ¹⁷	2.82%	1/142 wound infection, 1/142 liquorrhea due to a dural tear injury, 1/142 vertebral body fractures needing a posterior pedicle screw fixation, 1/142 misplaced cage that required revision
Hosseini et al., 2017 ¹⁸	35.90%	2/39 urinary tract infection, 1/39 bilateral leg swelling, 1/39 wound dehiscence, 1/39 adult spinal deformity, 6/39 proximal junctional kyphosis, 1/39 deep vein thrombosis, 1/39 decreased postop L4–S1 sensation; 2/39 screw loosening, 1/39 hematoma, 1/39 vertebral body fracture, 1/39 encephalopathy, 2/39 ileus, 1/39 endplate fracture, 1/39 renal failure, 1/39 acute transaminitis, 1/39 respiratory tract infection, 2/39 deep surgical site infection
Kim et al., 2010 ¹⁹	8.20%	3/73 left iliac vein injuries, 2/73 wound hematomas, 1/73 deep vein thrombosis
Kleeman et al., 2001 ²⁰	9.00%	1/22 bowel injury, 1/22 vascular injury
Lin et al., 2015 ²¹	45.45%	5/22 urinary retention, 3/22 constipation, 2/22 numbness in thigh
Mamuti et al., 2016 ⁹	5.71%	1/35 deep vein thrombosis, 1/35 retrograde ejaculation and unilateral vasodilation of lower limb
Park et al., 2009 ²²	0%	None
Shim et al., 2005 ²³	5.00%	1/20 compressed L5 root and radicular pain
Tobler & Ferrara, 2011 ²⁴	NA	7/26 pedicle screw removal for pain, 2/26 foraminal stenosis radiculopathy, 1/26 incisional pain, 1/26 nerve impingement from pedicle screw

our studies were wide and included vascular injury, retrograde ejaculation, bladder dysfunction, wound complications, infection, proximal junctional kyphosis, screw loosening, ileus, and nerve impingement. Complications varied between studies. For example, Flouzat-Lachaniette et al. reported urinary symptoms as being most common, while Hosseini et al. reported more structural complications (e.g., proximal junction kyphosis, screw loosening, etc.).^{16,18} There were 4 studies that reported vascular injury, and the rates were low overall (1.1%). MIS approaches are often converted to open approaches to control hemorrhaging in these cases. Most vascular injuries associated with ALIF occur around L4–5. The vascular complication rates are comparable among MIS and open approaches, although evidence in the literature has been limited and of low quality.³⁵ Further higher quality research is required to evaluate the exact difference in complication risk between MIS and open approaches.

Study Limitations

There are limitations to our study that must be considered. First, the majority of studies were retrospective and of a low level of evidence, as summarized in Table 1. Although retrospective studies are typical of spine literature, they are vulnerable to recall or response biases. Second, the sample size was small for most of the studies included (e.g., fewer than 100 subjects), which confers vulnerability to potential biases such as publication bias. Third, there was heterogeneity among the studies in terms of indications for MIS ALIF (e.g., disc degeneration, spondylo-

listhesis, disc herniation, scoliosis, pseudoarthrosis, etc.). Fourth, there was heterogeneity in terms of technique (e.g., laparoscopic vs mini-open) that also made standardization of results challenging. These limitations should be considered when drawing conclusions from our study.

Conclusions

We presented a systematic review of back pain outcomes following MIS ALIF, which included mini-open and laparoscopic techniques. There was a reliable reduction in back pain postoperatively across all included studies. The complication rates were low, including vascular injury. Future studies should focus on a higher level of evidence and larger sample sizes.

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Disclosures

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Author Contributions

Conception and design: Oh, AY Chan. Acquisition of data: Oh, AY Chan, Lien, Choi, Brown, Gattas, Kirillova, Horton, Fote. Analysis and interpretation of data: Oh, AY Chan, Lien, Choi, AK Chan, Hanna, Lopez, Brown, Gattas, Kirillova, Horton, Fote. Drafting the article: Oh, AY Chan, Lien, Choi, AK Chan, Hanna, Lopez, Brown, Gattas. Critically revising the article: Oh, AY Chan, AK Chan, Hanna, Lopez, Brown, Perry, Lee, Golshani, Hsu. Reviewed submitted version of manuscript: Oh, AY Chan, Lien, Hanst, Perry, Lee, Golshani, Hsu. Statistical analysis: Oh, AY Chan, Choi. Administrative/technical/material support: Oh, AY Chan, Choi. Study supervision: Oh, Golshani, Hsu.

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