The impact of adding posterior instrumentation to transpoas lateral fusion: a systematic review and meta-analysis

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OBJECTIVE Transpoas lateral interbody fusion is one of the lateral minimally invasive approaches for lumbar spine surgery. Most surgeons insert the interbody cage laterally and then insert pedicle or cortical screw and rod instrumentation posteriorly. However, standalone cages have also been used to avoid posterior instrumentation. To the best of the authors' knowledge, the literature on comparison of the two approaches is sparse.

METHODS The authors performed a systematic review and meta-analysis of the available literature on transpoas lateral interbody fusion by an electronic search of the PubMed, EMBASE, and Scopus databases using PRISMA guidelines. They compared patients undergoing transpoas standalone fusion (TP) with those undergoing transpoas fusion with posterior instrumentation (TPP).

RESULTS A total of 28 studies with 1462 patients were included. Three hundred and seventy-four patients underwent TPP, and 956 patients underwent TP. The mean patient age ranged from 45.7 to 68 years in the TP group, and 50 to 67.7 years in the TPP group. The incidence of reoperation was found to be higher for TP (0.08, 95% confidence interval [CI] 0.04–0.11) compared to TPP (0.03, 95% CI 0.01–0.06; $p = 0.057$). Similarly, the incidence of cage movement was found to be greater in TP (0.18, 95% CI 0.10–0.26) compared to TPP (0.03, 95% CI 0.00–0.05; $p < 0.001$). Oswestry Disability Index (ODI) and visual analog scale (VAS) scores and postoperative transient deficits were found to be comparable between the two groups.

CONCLUSIONS These results appear to suggest that addition of posterior instrumentation to transpoas fusion is associated with decreased reoperations and cage movements. The results of previous systematic reviews and meta-analyses should be reevaluated in light of these results, which seem to suggest that higher reoperation and subsidence rates may be due to the use of the standalone technique.

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KEYWORDS transpoas; XLIF; lumbar fusion; spine surgery; minimally invasive surgery

ACCORDING to a recent study, low-back pain is the second most common cause of disability in the US⁹ and the reported 1-year incidence rate of any low-back pain ranges from 1.6% to 36%.¹⁷ The pathology is also associated with a huge economic burden, with some studies reporting a cost as high as \$90.7 billion.²⁴ As such, there has been much advancement in both nonsurgical and surgical management of common pathologies leading to low-back pain. Among surgical modalities, minimally in-

vasive techniques have recently been increasingly adopted by neurosurgeons.²¹

A commonly used surgical technique in treating pathologies of the spine is transpoas lateral lumbar interbody fusion. The technique was first described by Ozgur et al. in 2006 and has since been endorsed by many spine surgeons.³⁶ There have been several studies since its first description highlighting the improved outcomes, ease of access, and lower/comparable complications when com-

ABBREVIATIONS GRADE = Grading of Recommendations Assessment, Development and Evaluation; ODI = Oswestry Disability Index; PRISMA = Preferred Reporting Items for Systematic Reviews and Meta-Analyses; TP = standalone transpoas lateral lumbar interbody fusion; TPP = transpoas lateral lumbar interbody fusion with posterior instrumentation; VAS = visual analog scale.

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TABLE 1. GRADE assessment of quality of evidence

Outcome	No. of Studies	No. of Pts	Inconsistency	Relative Effect (95% CI)	Confidence in Effect Estimates (GRADE)
TP					
VAS (leg) at 1 yr	7	366	Not serious	-3.83 (-4.15, -3.51)	Low
ODI at 1 yr	5	175	Serious	-28.9 (-31.9, -25.9)	Very low
Fusion rate	9	452	Not serious	0.92 (0.90, 0.95)	Very low
Length of stay	5	171	Serious	1.21 (1.11, 1.31)	Very low
Op time	8	415	Not serious	81.3 (79.3, 83.4)	Low
Cage movement	11	565	Serious	0.18 (0.10, 0.26)	Low
Reops	13	926	Serious	0.08 (0.04, 0.11)	Low
Transient deficits	7	391	Serious	0.29 (0.10, 0.47)	Very low
TPP					
VAS (leg) at 1 yr	7	198	Not serious	-3.62 (-3.68, -3.56)	Low
ODI at 1 yr	6	206	Serious	-21.1 (-21.5, -20.8)	Very low
Length of stay	9	235	Not serious	4.20 (3.73, 4.67)	Low
Op time	10	319	Not serious	86.1 (84.2, 88.0)	Low
Fusion rate	6	154	Not serious	0.93 (0.90, 0.97)	Very low
Cage movement	5	160	Not serious	0.03 (0.00, 0.05)	Very low
Reops	8	203	Serious	0.03 (0.01, 0.06)	Very low
Transient deficits	12	284	Serious	0.24 (0.14, 0.34)	Very low

Pts = patients.

"Indirectness" was serious for all variables, and "imprecision" and "other consideration" were not serious for all variables.

pared to other conventional approaches.^{1,7,8,12,13,18,19,27,28} One of the prime objectives is to minimize collateral tissue and muscle trauma while ensuring optimum clinical results. Hence, the standalone transposas lateral lumbar interbody fusion was described, in which the disc space is approached from a lateral trajectory through the psoas muscle and an interbody cage is placed. In addition to the lateral cage placement, posterior fixation is also applied using pedicle or cortical screw-rod instrumentation. Some surgeons employ a standalone technique where the cage is placed without posterior instrumentation.³⁷ Several studies and systematic reviews have compared the lateral fusion technique to other conventional approaches as well as other minimally invasive techniques, such as anterior-to-psoas lumbar interbody fusion.^{6,20,29,45} However, to the best of our knowledge, there is not much literature on comparison of clinical and operative outcomes between standalone transposas lateral lumbar interbody fusion and transposas lateral lumbar interbody fusion with posterior fixation. Therefore, in this paper we present a systematic review and meta-analysis of clinical and operative outcomes between standalone transposas lateral lumbar interbody fusion (TP) and transposas lateral lumbar interbody fusion with posterior instrumentation (TPP).

Methods

This systematic review is reported according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines.³⁰

Search Strategy

An electronic search of the PubMed, EMBASE, and

Scopus databases was performed to identify studies on transposas lateral interbody fusion using PRISMA guidelines. Our search method was as follows: 1) ((stand* adj alone) or standalone).tw. AND lumbar AND (fusion.mp or (llif or xlif or elif or dlif or olif or alif or mis-dlif or plif or tlif or lateral fusion or anterolateral fusion).tw); 2) Cage*1. tw AND (fusion*.mp or (llif or xlif or elif or dlif or olif or alif or mis-dlif or plif or tlif).tw.) AND (lumbar and posterior*).tw; and 3) (1 or 2) and (Exp Treatment outcome/ or outcome*1.mp).

The last date searched was July 27, 2017. Two authors performed an individual literature search (R.A. and M.A.A.). The initial result yielded 909 articles. Articles were grouped according to the type of fusion as follows: TP or TPP.

Study Selection Criteria

Only those articles were included in which: 1) some form of the surgery of interest, i.e., transposas lateral interbody fusion, was employed; 2) a complete description of the technique was available; 3) full-text was available; and 4) at least one of the outcomes was studied. The outcomes were: 1) visual analog scale (VAS) score; 2) Oswestry Disability Index (ODI); 3) length of stay; 4) fusion rate; 5) complication rate, particularly subsidence; 6) readmissions; 7) reoperations; 8) transient neurological deficits; 9) permanent neurological deficits; 10) operative time; and 11) estimated blood loss. Included articles were those that were available in English and had full-text available. If the articles included a comparison of our surgical technique of interest (TP or TPP) with some other technique, we only included the data for the TP or TPP group. Articles were excluded if 1) they included fewer than 8 patients; 2) they

TABLE 2. Assessment of the quality of included studies according to the Newcastle-Ottawa Quality Assessment Scale

Authors & Year	Quality Assessment Criteria					
	Representativeness of Cohort	Ascertainment of Exposure	Outcome of Interest	Assessment of Outcome	Adequate Duration of FU	Adequate FU of Cohort
TP						
Ahmadian et al., 2015	Yes	Yes	Yes	—*	Yes	Yes
Bouthors et al., 2015	Yes	Yes	Yes	Yes	Yes	Yes
Essig et al., 2014	Yes	Yes	Yes	Yes	Yes	Yes
Heini et al., 2013	Yes	Yes	—†	Yes	Yes	Yes
Marchi et al., 2012	Yes	Yes	Yes	Yes	Yes	Yes
Marchi et al., 2013	Yes	Yes	Yes	Yes	Yes	Yes
Nemani et al., 2014	Yes	Yes	Yes	Yes	Yes	Yes
Oliveira et al., 2010 ³⁴	Yes	Yes	Yes	Yes	Yes	Yes
Oliveira et al., 2010 ³³	Yes	Yes	Yes	Yes	—	—
Oliveria et al., 2010 ³²	Yes	Yes	Yes	Yes	Yes	Yes
Pimenta et al., 2013	Yes	Yes	Yes	Yes	Yes	Yes
Tempel et al., 2015	Yes	Yes	Yes	Yes	Yes	Yes
TPP						
Abbasi & Abbasi, 2017	Yes	Yes	Yes	Yes	Yes	Yes
Alimi et al., 2018	Yes	Yes	Yes	Yes	—	Yes
Anand et al., 2008	Yes	Yes	Yes	Yes	Yes	Yes
Anand et al., 2010	Yes	Yes	Yes	Yes	—	Yes
Castellvi et al., 2014	Yes	Yes	Yes	Yes	Yes	Yes
Drazin et al., 2015	Yes	Yes	Yes	Yes	Yes	Yes
Jin et al., 2018	Yes	Yes	Yes	Yes	Yes	Yes
Knight et al., 2009	Yes	Yes	Yes	Yes	Yes	Yes
McAfee et al., 2013	Yes	Yes	Yes	Yes	—	Yes
Tessitore et al., 2017	Yes	Yes	Yes	Yes	—	Yes
Tormenti et al., 2010	Yes	Yes	—‡	Yes	Yes	Yes
Waddell et al., 2014	Yes	Yes	Yes	Yes	Yes	Yes
Wang & Mummaneni, 2010	Yes	Yes	Yes	Yes	Yes	Yes
TP vs TPP					—	
Kim et al., 2012	Yes	Yes	Yes	Yes	—	—
Malham et al., 2017	Yes	Yes	—§	Yes	Yes	Yes
Youssef et al., 2010	Yes	Yes	Yes	Yes	Yes	Yes

FU = follow-up.

* No use of CT or medical records, only hospital length of stay, fusion rates, neurological complications, integrity of construct, and clinical outcome questionnaires.

† Twenty patients had a revision surgery or vertebroplasty after intervention.

‡ Patients had previous lumbar surgeries and comorbidities.

§ Of the 21 patients, 6 had previous lumbar surgeries, 2 patients currently smoke.

were case reports, case series, or cadaveric studies; 3) they did not study outcomes of interest; 4) the study did not differentiate between standalone and posterior instrumentation in their results; and 5) they were editorials or abstracts.

Outcomes

Primary outcomes were fusion rate, reoperation rate, and incidence of subsidence. Other analyses included patient-reported outcomes, such as VAS score and ODI, and other complications, which included transient and permanent neurological deficits. All complication rates, hematomas, vertebral fractures, vascular complications, bowel

perforations, and estimated blood loss were excluded from analyses due to inconsistent reporting. Missing data were imputed using validated methods.¹⁶

Data Extraction and Analysis

Two authors (R.A. and W.W.) reviewed the included studies and abstracted the following variables: 1) patient demographics, including age, sex, ethnicity, and BMI; 2) operative outcomes, including estimated blood loss and operative time; 3) clinical outcomes, including length of stay and fusion rate along with method of reporting fusion; and 4) complications, including all complication rates, hema-

FIG. 1. Flow diagram depicting the literature review, search strategy, and selection process.

tomas, vertebral fractures, transient and permanent neurological deficits, vascular complications, bowel perforations, subsidence, readmissions, and reoperations. Meta-analysis was performed for eight variables: VAS scores, ODI, number of reoperations, cage movements, fusion rates, transient deficits, operative time, and length of hospital stay. Meta-regression was used for the continuous variables: VAS scores, ODI, operative time, and length of hospital stay. A random-effects model (DerSimonian and Laird approach¹⁰) was used to account for the high variability of the populations between single-institution studies. A t-test of weighted averages was used to compare estimated blood loss. Primary outcomes were reported as incidence for categorical values and means for continuous data. A p value < 0.05 was considered significant. All analyses were performed using Stata (version 14, StataCorp LP).

Methodological Quality and Quality of Evidence

Risk of bias of each study was assessed using the modified Newcastle Ottawa Scale⁴⁴ focusing on cohort selection and removing comparability. The quality of evidence (i.e., certainty in the estimate of effect) was assessed using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach (Table 1).¹⁴ Given the methodology of the current systematic review and meta-analysis, assessment of outcome was found to be the best

indicator of the quality of the studies. We modified the assessment criteria by removing some components that were not suitable for indirect comparisons. The assessment can be found in Table 2.

Results

Description of Studies

After applying the exclusion criteria to 909 studies retrieved from the initial search, 28 studies were included in the meta-analysis that consisted of a total of 1462 eligible patients. Figure 1 outlines the study flow chart. Thirteen studies compared TPP with other techniques, involving a total of 374 patients and 759 treated levels.^{1,3,4,5,8,11,19,23,28,40–43} Twelve studies compared TP to some other fusion technique, including a total of 956 patients and 1733 treated levels.^{2,7,12,15,26,27,31–34,38,39} Three studies compared stand-alone TP with TPP, involving a total of 132 patients and 211 levels treated.^{22,25,46}

Mean age ranged from 45.7 to 68 years in the TP group, and 50 to 67.7 years in the TPP group. Mean BMI ranged from 26.7 to 31.0 for the TPP group, and 25.0 to 27.5 for the TP group. The proportion of females ranged from 53.3% to 76.38% for the TP group, and 33.33% to 76.1% for the TPP group. The mean number of levels of fusion was 1.74 levels per patient for the TP group, compared with 1.38

TABLE 3. Demographics and characteristics of included studies

Authors & Year	Country	Study Design	Sample Size	No. of Levels	Females (%)	Mean Age (yrs)	Mean BMI (kg/m ²)	Mean FU	Included Deformity Pts?
TP									
Ahmadian et al., 2015	USA & Australia	Retrospective	59	96	61	59	NA	14.6 mos	Yes
Bouthors et al., 2015	France	Retrospective	60	74	NA	NA	NA	19 mos	Yes
Essig et al., 2014	USA	Retrospective	55	115	72.7	NA	NA	67.5 mos	Yes
Heini et al., 2013	Switzerland	Prospective (observational)	95	179	73.68	68	NA	12 mos	Yes
Marchi et al., 2012	Brazil	Prospective (observational)	52	52	73.1	67.6	27.4	24 mos	No
Marchi et al., 2013	Brazil	Prospective (observational)	74	98	64.86	57	25.0	12 mos	No
Nemani et al., 2014	Austria	Retrospective	117	239	70.9	63.6	27.5	15.6 mos	Yes
Oliveira et al., 2010 ³³	Brazil	Prospective (observational)	21	43	66.67	67.6	NA	NA	No
Oliveria et al., 2010 ³²	Brazil, USA	Prospective (observational)	15	15	53.3	45.7	NA	2 yrs	No
Oliveira et al., 2010 ³⁴	Brazil	Prospective (RCT)	43	77	NA	66.3	25.6	12 mos	No
Pimenta et al., 2013	Brazil	Retrospective	30	30	60	47.4	NA	36 mos	No
Tempel et al., 2015	USA	Retrospective	335	715	NA	NA	NA	NA	Yes
TPP									
Abbasi & Abbasi, 2017	USA	Prospective (observational)	9	15	33.3	50	31.0	12 mos	No
Alimi et al., 2018	USA	Retrospective	84	145	61.9	64.6	NA	17.7 mos	Yes
Anand et al., 2008	USA	Prospective (observational)	12	44	41.6	72.8	NA	75.5 days	Yes
Anand et al., 2010	USA	Retrospective	28	99	NA	67.7	NA	22 mos	Yes
Castellvi et al., 2014	USA	Retrospective	44	117	47.73	66	29.4	12 mos	Yes
Drazin et al., 2015	USA	Retrospective	20	NA	45	54.5	26.7	9 mos	No
Jin et al., 2018	Korea	Retrospective	22	22	59	66.9	NA	NA	Yes
Knight et al., 2009	USA	Retrospective	58	79	74.13	61	NA	15 mos	No
McAfee et al., 2013	USA	Retrospective	25	78	65.9	NA	NA	24.6 mos	Yes
Tessitore et al., 2017	Switzerland	Retrospective	20	22	50	67.5	NA	9.8 mos	No
Tormenti et al., 2010	USA	Retrospective	8	23	NA	60	NA	10.5 mos	Yes
Waddell et al., 2014	USA	Retrospective	21	54	76.1	66.6	NA	12 mos	Yes
Wang & Mummaneni, 2010	USA	Retrospective	23	61	74	64.4	NA	13.4 mos	Yes
TP vs TPP									
Kim et al., 2012	Korea	Retrospective	8 (4 + 4)	20	87.5	65.8	NA	3 mos	Yes
Malham et al., 2017	Australia	Prospective (observational)	40 (19 + 21)	54	70	64	26.9	12 mos	Yes
Youssef et al., 2010	USA	Retrospective	84 (38 + 46)	137	NA	NA	NA	12 mos	Yes

NA = not available; RCT = randomized controlled trial.

levels per patient for the TPP group. Patient demographics and characteristics of included studies are shown in Table 3. Various outcomes have been summarized in Supplemental Tables 1–3.

Reoperations

For the TP group, 13 studies (926 patients) reported data on reoperations. For the TPP group, 8 studies (203 patients) included data on reoperation. Mean incidence of reoperation was found to be marginally greater in the TP group (0.08, 95% CI 0.04–0.11) compared to the TPP group (0.03, 95% CI 0.01–0.06; $p = 0.057$). These results are further assessed as forest plots (Fig. 2).

Cage Movement

Eleven studies (565 patients) reported data on cage

movement (which includes subsidence and migration) for the TP group. As for the TPP group, 5 studies (160 patients) reported data on this outcome. The mean incidence of cage movement was found to be greater in the TP group (0.18, 95% CI 0.10–0.26) compared to the TPP group (0.03, 95% CI 0.00–0.05; $p < 0.001$). These results are also further assessed as forest plots (Fig. 3).

Fusion Rate

Nine studies (452 patients) reported data on fusion rate for the TP group, while 6 studies (154 patients) reported data on fusion rate for the TPP group. Of these 15 studies, 2 reported data on this outcome for both groups. Five of 9 studies in the TP group reported fusion by CT at 1 year, 2 by CT and radiography at 1 year, 1 by CT and radiography at last follow-up, and 1 by CT at last follow-up. Five

FIG. 2. Forest plot of reoperations for TP and TPP groups. ES = effect size. Figure is available in color online only.

of 6 studies in the TPP group reported fusion by CT at 1 year, and 1 study reported fusion by CT at last follow-up. The mean incidence rate of fusion was found to be similar between the two groups with a rate of 0.92 (95% CI 0.90–0.95) for the TP group and 0.93 (95% CI 0.90–0.97) for the TPP group ($p = 0.650$). These results are further assessed as forest plots (Fig. 4).

Transient Deficits

Transient deficits included transient numbness or transient weakness of the thigh. For the TP group, 7 studies (391 patients) reported data on transient deficits. For the TPP group, 12 studies (284 patients) included data on this complication. The mean incidence of transient deficits was found to be similar between the two groups with an incidence rate of 0.29 (95% CI 0.10–0.47) for the TP group and 0.24 (95% CI 0.14–0.34) for the TPP group ($p = 0.654$). These results are further assessed as forest plots (Fig. 5).

VAS Score

Seven studies (366 patients) reported radicular leg

pain VAS scores after a 12-month follow-up for the TP group. Seven studies (198 patients) reported VAS scores for the TPP group. Of these 14 studies, 1 reported VAS scores for both groups. There was no statistically significant difference in VAS scores ($p = 0.253$) between the two groups.

ODI Scale

Five studies (175 patients) reported ODI scores for the TP group, while 6 studies (206 patients) reported ODI scores for the TPP group. Of these 11 studies, 1 reported ODI scores for both groups. There was no statistically significant difference in ODI scores ($p = 0.071$) between the two groups.

Length of Hospital Stay

Five studies (171 patients) reported length of stay for the TP group, while 9 studies (235 patients) reported length of stay for the TPP group. Of these 14 studies, 1 reported length of stay for both groups. There was a statistically significant difference in length of hospital stay ($p = 0.02$) between the two groups.

FIG. 3. Forest plot of cage movement for TP and TPP groups. Figure is available in color online only.

Operative Time

Eight studies (415 patients) reported operative time for the TP group, while 10 studies (319 patients) reported operative time for the TPP group. Of these 18 studies, 1 reported operative time for both groups. There was a statistically significant difference in operative times ($p = 0.007$) between the two groups.

Estimated Blood Loss

Six studies (354 patients) reported estimated blood loss for the TP group, while 10 studies (319 patients) reported this variable for the TPP group. There was no statistically significant difference in estimated blood loss ($p = 0.335$) between the two groups.

Quality of Evidence

The overall quality of evidence for most outcomes obtained through this meta-analysis is low (Table 1). Also,

as evident from Table 2, we were unable to demonstrate the selection of an unexposed cohort (control group) and comparability of cohorts in these studies as part of the Newcastle-Ottawa assessment. Hence they were removed from the assessment criteria and might have introduced measurement bias in our analysis.

Discussion

Minimally invasive techniques are increasingly being considered for lumbar interbody fusion. Transposas lateral fusion is one of the most commonly employed techniques. This is either performed as a standalone approach or combined with additional posterior instrumentation. Only 3 studies compared the standalone technique to posterior fixation and were included in these analyses.

Studies that compared these two approaches directly reported higher blood loss, longer operative times, and a longer length of stay for the combined approach.^{22,25,46} These results were consistent with our findings. One pos-

FIG. 4. Forest plot of fusion rates for TP and TPP groups. Figure is available in color online only.

sibility for this difference between the approaches is that the combined approach includes pedicle screws, requiring additional surgery. On the other hand, the standalone approach is much more cost-effective.¹⁵ Most of the studies that were excluded from the meta-analysis were due to nondelineated results. However, their findings were compared to our analysis. Ozgur et al.³⁵ reported VAS and ODI scores for 62 patients who underwent TP or TPP. The mean VAS score decreased by 2.1 after a 1-year follow up, in contrast to our calculated mean VAS score improvement of 3.62 for both treatment groups together (Table 1). Mean ODI score decreased by 21, compared to our calculated mean ODI improvement of 24.3 after 1-year follow-up (Table 1). Joseph et al.²⁰ in 2015 conducted a systematic review and meta-analysis to compare outcomes between minimally invasive transforaminal lumbar interbody fusion and lateral fusion. They reported a pooled subsidence rate of 10.84%, which is similar to the rate of 12% that we found for both groups combined. However, it is interesting to note the stark difference between the subsidence rate of standalone TP (18%) and TPP (3%), which seems to suggest that the high rate of subsidence reported in the literature may be because of the standalone (TP) approach.

Patients with deformity may represent a clinically heterogeneous population, which may influence the outcomes that were studied in the current review. However, we found

that among studies on combined cage and posterior fixation, 13 of 16 included patients with deformity. Of the studies that did not include deformity (n = 3), only 1 study reported subsidence. Similarly, among 15 studies on TP, 6 included patients with deformity. Therefore, a sensitivity analysis could not be performed to isolate the effect of deformity on subsidence and fusion rate.

The reoperation rate reported by the previous systematic review was 3.74%²⁰ compared to 6% found in this current paper for both approaches combined. Again, the higher rate of reoperation may be attributed more to the standalone approach (8%) than the combined approach (3%) as reported in this paper.

These results appear to suggest that while adding posterior instrumentation to lateral fusion might result in slightly less pain relief, it significantly reduces the risk of subsidence and reoperation. It is worth reporting here that none of the devices being currently utilized for lateral fusion have FDA approval for standalone use. This means that the use of these device sets as a standalone approach may be considered off-label.

Limitations

The limitations of this study, first and foremost, are akin to those of any indirect systematic review, meaning that most of these studies analyzed either approach, except for 3 studies that directly compared the two approaches.^{22,25,46}

FIG. 5. Forest plot of transient deficits for TP and TPP groups. Figure is available in color online only.

Indirect comparisons do not allow robust comparisons and thus the level of evidence obtained is low. Moreover, all of these studies were retrospective in nature. Furthermore, some outcomes, such as blood loss, could not be fully analyzed due to missing or inconsistent data. There was also a lack of reporting of basic patient characteristics (such as BMI and comorbidities) in most studies that could have influenced some of the outcomes analyzed. Nonetheless, we have reported mean BMI for studies that have included them. In addition, some studies compared standard and wide cages, which may have created some bias in the results.^{26,34} Some studies were also at risk of selection bias; patients who received treatment were previously diagnosed with spondylosis or degenerative disc disease. These diagnoses might involve an increased number of spinal levels that could have an impact on outcomes that were analyzed. Ten of 13 studies among combined cage and posterior fixation studies, 6 of 12 studies among standalone fixation, and all 3 studies comparing the two techniques included deformity patients, and the heterogeneity of these patients should be acknowledged because they represent a more complex set of patients. Additionally, the method of and modality used in determining fusion was explained in some of the articles while others did not comment in much

detail; any discrepancy in methodology and modality may have skewed the results. Moreover, we combined “cage subsidence” and “cage migration” into one outcome even though some experts have argued that these might be different clinical entities. However, given the small number of studies that analyzed these outcomes separately, the outcomes were grouped into one category. The main criteria for selection of studies for this review was complications, which is why we acknowledge that some studies that did not report complications were excluded. Given our findings of significantly higher subsidence and reoperations in standalone studies, we encourage future investigators to prioritize these outcomes. Finally, because only studies with available full-text were included, there might have been some selection bias. However, most of the studies included have been used in previous systematic reviews and the current study is intended to help the reviewers reevaluate the outcomes of the technique when categorized by the type of approach.

Conclusions

To the best of our knowledge, the current study is the first of its kind to compare the two approaches of trans-

psoas fusion. The standalone procedure was found to be associated with a higher rate of reoperation as well as cage movement/subsidence in comparison to combined fusion.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Alvi. Acquisition of data: Alvi, Alkhataybeh, Wahood. Analysis and interpretation of data: Alvi, Alkhataybeh, Wahood. Drafting the article: Alvi, Alkhataybeh, Wahood. Critically revising the article: Bydon, Alvi, Alkhataybeh, Kerezoudis, Goncalves, Murad. Reviewed submitted version of manuscript: Bydon, Alvi, Wahood, Kerezoudis, Goncalves, Murad. Statistical analysis: Bydon, Alvi, Wahood, Murad. Administrative/technical/material support: Bydon, Kerezoudis, Goncalves, Murad. Study supervision: Bydon.

Supplemental Information

Online-Only Content

Supplemental material is available with the online version of the article.

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