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LITERATURE REVIEW

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Endoscopic decompression for the treatment of lumbar spinal stenosis: an updated systematic review and meta-analysis

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OBJECTIVE Lumbar stenosis treatment has evolved with the introduction of minimally invasive surgery (MIS) techniques. Endoscopic methods take the concepts applied to MIS a step further, with multiple studies showing that endoscopic techniques have outcomes that are similar to those of more traditional approaches. The aim of this study was to perform an updated meta-analysis and systematic review of studies comparing the outcomes between endoscopic (uni- and biportal) and microscopic techniques for the treatment of lumbar stenosis.

METHODS Following PRISMA guidelines, a systematic search was performed using the Cochrane Central Register of Controlled Trials, Cochrane Database of Systematic Reviews, Ovid Embase, and PubMed databases from their dates of inception to December 14, 2020. All identified articles were then systematically screened against the following inclusion criteria: 1) studies comparing endoscopic (either uniportal or biportal) with minimally invasive approaches, 2) patient age ≥ 18 years, and 3) diagnosis of lumbar spinal stenosis. Bias was assessed using quality assessment criteria and funnel plots. Meta-analysis using a random-effects model was used to synthesize the metadata.

RESULTS From a total of 470 studies, 14 underwent full-text assessment. Of these 14 studies, 13 comparative studies were included for quantitative analysis, totaling 1406 procedures satisfying all criteria for selection. Regarding postoperative back pain, 9 studies showed that endoscopic methods resulted in significantly lower pain scores compared with MIS (mean difference [MD] −1.0, 95% CI −1.6 to −0.4, $p < 0.01$). The length of stay data were reported by 7 studies, with endoscopic methods associated with a significantly shorter length of stay versus the MIS technique (MD −2.1 days, 95% CI −2.7 to −1.4, $p < 0.01$). There was no significant difference with respect to leg visual analog scale scores, Oswestry Disability Index scores, blood loss, surgical time, and complications, and there were not any significant quality or bias concerns.

CONCLUSIONS Both endoscopic and MIS techniques are safe and effective methods for treating patients with symptomatic lumbar stenosis. Patients who undergo endoscopic surgery seem to report less postoperative low-back pain and significantly reduced hospital stay with a trend toward less perioperative blood loss. Future large prospective randomized trials are needed to confirm the findings in this study.

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KEYWORDS endoscopic; decompression; uniportal; biportal; spinal stenosis; lumbar

Lumbar spinal stenosis, characterized by pathological spinal canal narrowing and compression of the thecal sac along with the nerve roots, is one of the most prevalent degenerative conditions that affects older individuals.[1] Symptomatology usually consists of a combination of low-back pain, neurogenic claudication, lower-extremity pain, and decreased ability in ambulating. Initial treatment typically consists of conservative management, including physical therapy, medications, and epidural steroid injections.[2] However, in patients with more acutely severe symptoms such as incapacitating pain and neurological deficits or those in whom conservative management has failed, surgical treatment is often offered.[3] Overall, studies have indicated better clinical outcomes with surgical treatment than with more conservative therapies.[3,4]

The traditional surgical method for lumbar spinal stenosis consists of an open decompression in an effort to decompress the neural structures.[3,4] However, this conventional approach can disrupt the paraspinal muscles and ligaments, which may result in muscle atrophy and low-back

ABBREVIATIONS BESS = biportal endoscopic system; MD = mean difference; MIS = minimally invasive surgery; MOOSE = Meta-analysis of Observational Studies in Epidemiology; ODI = Oswestry Disability Index; UPFE = uniportal full-endoscopic system; VAS = visual analog scale.

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pain and promote iatrogenic instability and the need for reoperation.[5] Minimally invasive surgery (MIS) methods have rapidly developed to minimize damage to the adjacent structures while still providing the same clinical outcomes.[6] Microscopic decompression has become one of the most common procedures offered, as it reduces blood loss and postoperative pain, aids in early ambulation, and leads to shorter hospital stays.[6] Nonetheless, microscopic approaches also have pitfalls, as paravertebral muscles still need to be disrupted to some degree, and there is a limited intraoperative view.[7] More recently, uniportal and biportal endoscopic decompressive approaches have been reported in the literature, with safe and outstanding clinical outcomes.[7–14] One of the primary benefits of endoscopic methods is reducing even further the disruption of the surrounding soft tissue and providing direct visualization of the pathologic process. The uniportal full-endoscopic system (UPFE) involves a single portal containing the optical device and a working channel. Meanwhile, the biportal endoscopic system (BESS) includes separate endoscopic viewing and working channels.[15]

To date and to our knowledge, there have been three meta-analyses comparing endoscopic and microscopic decompression for the treatment of lumbar spinal stenosis. Pairuchvej et al. compared uniportal full-endoscopic and biportal endoscopic spinal surgery with microscopic lumbar decompression, and Chen et al. and Pranata et al. compared BESS with microscopic decompression.[14,17,18] Pairuchvej et al. found that endoscopic procedures led to significantly lower scores for back and leg pain and a lower risk of complications in comparison with microscopic procedures; however, they did not report several important variables, such as blood loss and length of stay.[14] Pranata et al. and Chen et al. found no significant differences between BESS and MIS and similarly concluded that more evidence was necessary to better discern clinical risks and benefits.[17,18] Furthermore, numerous important studies have been published since these prior reviews.[7,10,13,19] Therefore, the aim of this study was to combine all available clinical information by performing an updated meta-analysis of studies comparing the outcomes between endoscopic (uni- and biportal) and microscopic techniques for lumbar stenosis decompression.

Methods

Search Strategy

Our literature search was based on the following PICO question: Do lumbar spinal stenosis patients (Population) treated with an endoscopic approach (Intervention) compared with those treated with MIS (Comparator) differ in clinical outcomes (Outcome)? We conducted this search according to the stipulations of the PRISMA guidelines and recommendations.[20] We performed our searches using the following electronic database platforms from their dates of inception to December 14, 2020: Ovid Embase, PubMed, Cochrane Central Register of Controlled Trials and Cochrane Database of Systematic Reviews. We utilized the following MeSH terms when searching for all comparative studies: "lumbar stenosis," "endoscopic," "minimally invasive," "MIS," and "microscopic." For each study that satisfied initial criteria, we reviewed the reference bibliography to identify any potentially pertinent relevant studies for further review. All primary and secondary articles identified by our search were then systemically screened against our predefined selection criteria. Neither this review nor the protocol used was registered.

Selection Criteria

We used the following inclusion criteria to identify all pertinent articles to our search: 1) studies comparing endoscopic (either uniportal or biportal) with minimally invasive approaches, 2) patient age ≥ 18 years, and 3) diagnosis of lumbar spinal stenosis. Studies that involved revision spine surgery as well as other procedures that did not involve lumbar stenosis decompression were excluded. If there were articles published from the same institution with overlapping or identical cohorts, we chose the study with the longest follow-up time. We only evaluated publications in the English language involving human subjects. Due to the concern of publication bias and confounding, patients described in abstracts, case reports, conference presentations, editorials, and expert opinions were not considered.

Data Extraction and Critical Appraisal

Data utilized in our study were derived from article texts as well as tables and figures. Each article was independently reviewed by two investigators (R.J.P.R. and W.G.), and, in the case of disagreement with respect to selection criteria, consensus was reached after discussion with the senior author. Additionally, each included study was independently assessed by the same two investigators independently for quality assurance, using the Meta-analysis of Observational Studies in Epidemiology (MOOSE) criteria.[16]

Meta-Analysis

In this study, we used either the mean difference (MD) or odds ratio (OR) to statistically summarize the metadata. We relied on a random-effects model, as it was suited to account for the likely heterogeneity between the included studies. To assess for heterogeneity, chi-square tests were utilized, and the I^2 statistic was used to estimate the percentage of total variation across studies. Funnel plots were used to evaluate for publication bias for each outcome. Statistical significance was set using 2-sided p values < 0.05. All statistical analysis was conducted using Review Manager Version 5.4 (Cochrane Collaboration, Software Update).

Results

Literature Search

The search strategy identified a total of 470 studies (Fig. 1). After removal of 146 duplicate studies, inclusion and exclusion criteria were applied to titles and abstracts of the 324 articles. From these, 123 articles were noncomparative, 49 articles were reviews or meta-analyses, and 136 articles focused on other pathology or surgical

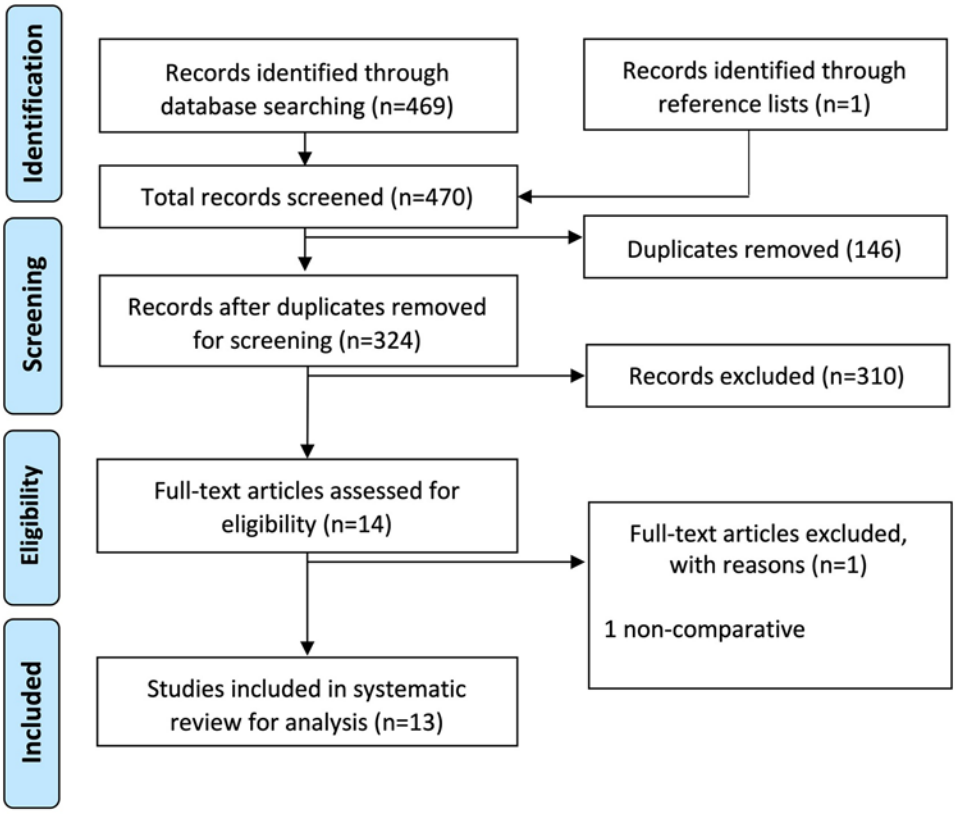

FIG. 1. Search strategy results per PRISMA guidelines. Data added to the PRISMA template [from Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *PLoS Med.* 6(7): e1000097] under the terms of the Creative Commons Attribution License. Figure is available in color online only.

techniques and were removed. This yielded 14 studies that underwent full-text analysis. Thirteen comparative studies were included in this current review for quantitative analysis, with data used for analyses presented among all tables and figures.[7–13,19,21–25]

Demographics

There was a total of 1406 patients across all studies. Of these patients, 537 were female and 869 were male. The average age was 65.7 years, with a range from 49 to 80 years of age. There were 718 patients in the endoscopic methods group and 573 patients in the MIS group. Of the 13 studies, 7 solely utilized microscopic decompression as the MIS method, while 6 of them included a combination in which tubular decompression was included. Overall, the patients underwent follow-up for mean ± SD of 11.8 ± 7.6 months (range 3 months to 2.4 years) following surgery. All preoperative visual analog scale (VAS) and Oswestry Disability Index (ODI) scores were statistically comparable between groups.

Pain Outcomes

The VAS was used to interpret pain outcomes. In terms of postoperative back pain (Fig. 2), 9 studies showed that endoscopic methods resulted in significantly lower pain scores compared with MIS (MD –1.0, 95% CI –1.6 to–0.4, $p < 0.01$). At the final follow-up among 8 studies, back pain remained significantly lower after endoscopic methods compared with MIS (MD –0.2, 95% CI –0.3 to –0.03, $p = 0.02$). In terms of postoperative leg pain (Fig. 3), 8 studies did not show a statistically significant difference between endoscopic methods and MIS approaches ($p = 0.36$), which remained in 6 studies at the final follow-up ($p = 0.30$). No differences were noted in the comparisons based on unilateral and bilateral techniques used in the endoscopic methods group.

Functional Outcomes

The ODI was used to interpret functional outcomes (Fig. 4). In terms of postoperative function, 6 studies did not show a statistically significant difference between endoscopic methods and MIS approaches ($p = 0.14$), which remained in all 6 studies at the final follow-up ($p = 0.22$). No differences were noted in the comparisons based on unilateral and bilateral techniques used in the endoscopic methods group.

Surgical Outcomes

Blood loss was reported by 4 studies, and no statistically significant difference was found between endoscopic methods and MIS approaches ($p = 0.06$) (Fig. 5A). Operative time was reported by 10 studies, where there

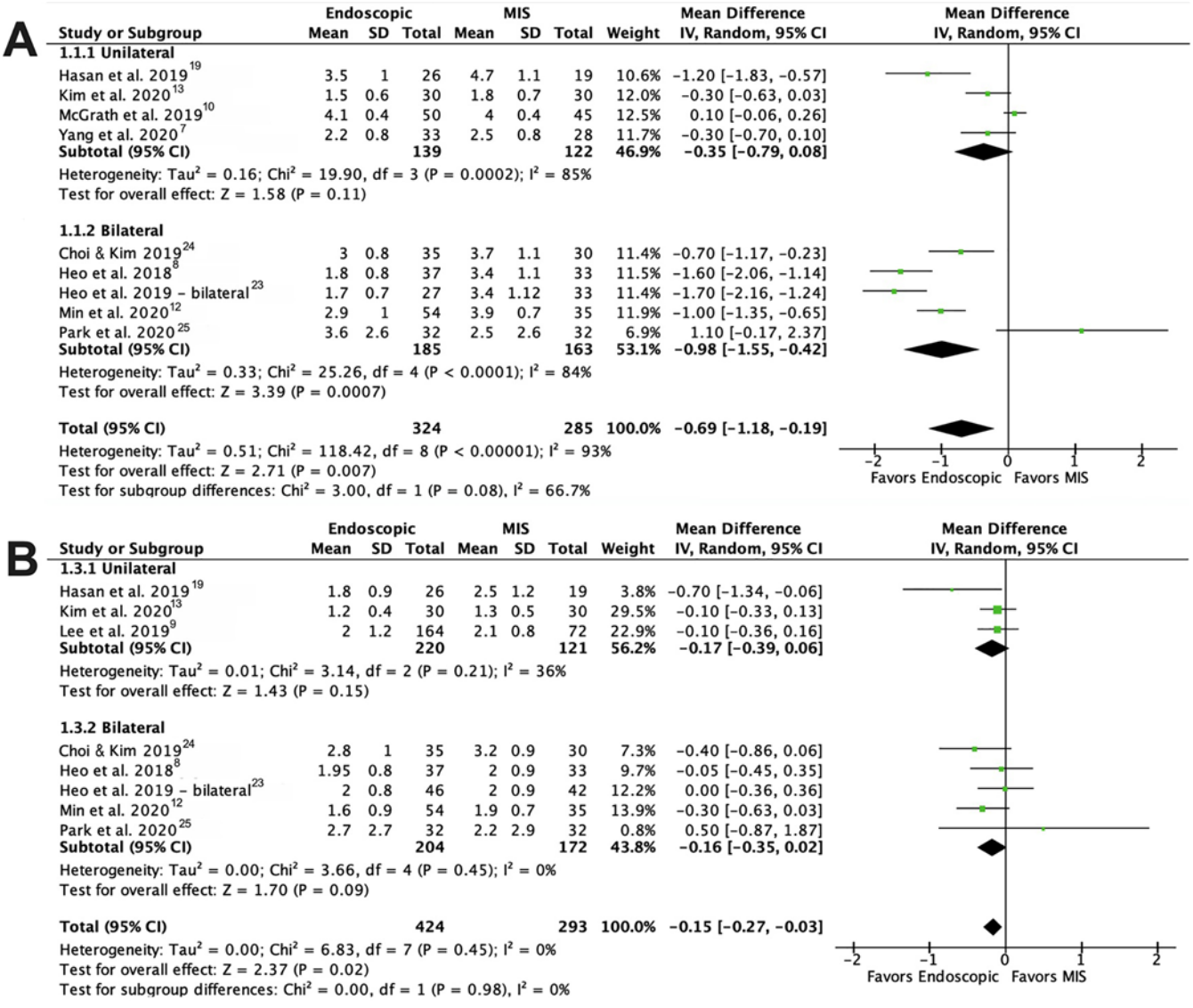

FIG. 2. Forest plots comparing back pain outcomes postoperatively (**A**) and at final follow-up (**B**) according to the VAS between endoscopic and MIS approaches. IV = inverse variance. Figure is available in color online only.

was also no statistically significant difference between endoscopic methods and MIS approaches (p = 0.26) (Fig. 5B). Length of stay data were reported by 7 studies (Fig. 6A); endoscopic methods were associated with significantly shorter length of stay versus MIS (MD –2.1 days, 95% CI –2.7 to –1.4, p < 0.01). Operative complications were reported by 10 studies, with no statistically significant difference in likelihood of complications between endoscopic methods and MIS approaches (p = 0.28) (Fig. 6B).

Study Bias Assessment

Using the MOOSE criteria, there were no obvious sources of bias risk among included studies. Publication bias was evaluated using funnel plots, which did not demonstrate any obvious asymmetry on generation indicating nonsignificant risk of this type of bias.

Discussion

Lumbar stenosis treatment has evolved over the last decade with the introduction of minimally invasive techniques, which have proven to be an effective way of treating patients with neurogenic claudication. By potentially decreasing muscle disruption, blood loss, and length of stay, MIS techniques seem to be an attractive alternative in older patients with multiple comorbidities affected by symptomatic stenosis. Endoscopic methods take the concepts applied to MIS a step further, with multiple studies showing that either BESS or UPFE has similar outcomes to more traditional methods.[7–9,26]

Unilateral or bilateral leg pain has been reported to be one of the most common symptoms in patients with spinal stenosis.[2] Heo et al. reported that after BESS, VAS leg pain scores decreased from a mean of 7.96 to 1.87 when compared with the MIS group, which improved from 7.76

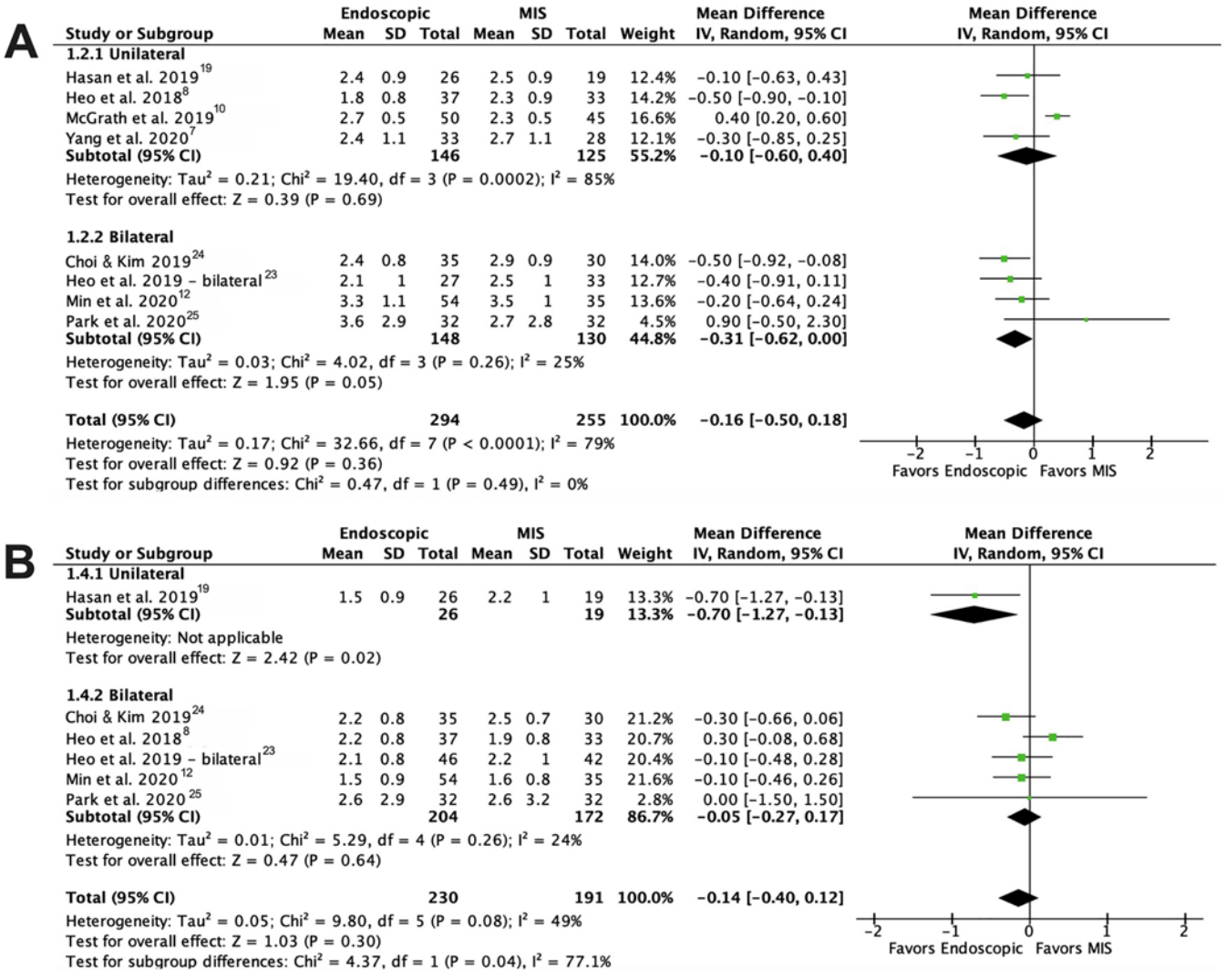

FIG. 3. Forest plots comparing leg pain outcomes postoperatively (**A**) and at final follow-up (**B**) according to the VAS between endoscopic and MIS approaches. Figure is available in color online only.

to 2.50 immediately after surgery, but at final follow-up at 14.5 months, there was no difference.[8] McGrath et al. reported lower VAS leg pain scores at 1-year follow-up when comparing their UPFE cohort with the microscopic cohort (1.3 ± 0.3 vs 3.0 ± 0.5, respectively; $p < 0.01$).[10] More recently, Yang et al. looked at a group of 61 patients with a follow-up of 12 months and found no difference between the microscopic group and UPFE group with respect to VAS leg pain scores.[7] In our meta-analyses, there was a trend toward reduced postoperative VAS pain scores in the endoscopic group, but it was not statistically significant ($p = 0.36$). In addition, there was no difference seen between the endoscopic method and the MIS cohort.

On the other hand, VAS back pain scores in the perioperative period seem to be lower in patients treated endoscopically. Lee et al. evaluated 270 patients and observed statistically significant lower VAS back pain scores in patients treated with UPFE when compared with those treated with microscopic techniques immediately after surgery ($p = 0.008$), but the results were similar at final follow-up.[9] Another study showed that the benefits extended to 2 months after surgery.[12] Our pooled analysis showed that at final follow-up among the 8 studies, VAS back pain scores remained significantly lower after an endoscopic approach compared with MIS (MD −0.2, 95% CI −0.3 to −0.03, $p = 0.02$). This can be explained by the less-invasive nature of endoscopic surgery, which translates into decreased muscle disruption demonstrated in multiple studies by lower postoperative levels of serum creatine phosphokinase when compared with other techniques.[9,13] When analyzing functional outcomes measured by the ODI, both groups had significantly lower scores postoperatively when compared with the scores before surgery, but the scores did not differ between the endoscopic and MIS cohorts.

Surgical time was no different between the endoscopic and MIS groups. Kang et al. reported a significantly shorter mean operative time for the BESS group than that for the microscopic surgery group (36 ± 11 minutes vs 54 ±

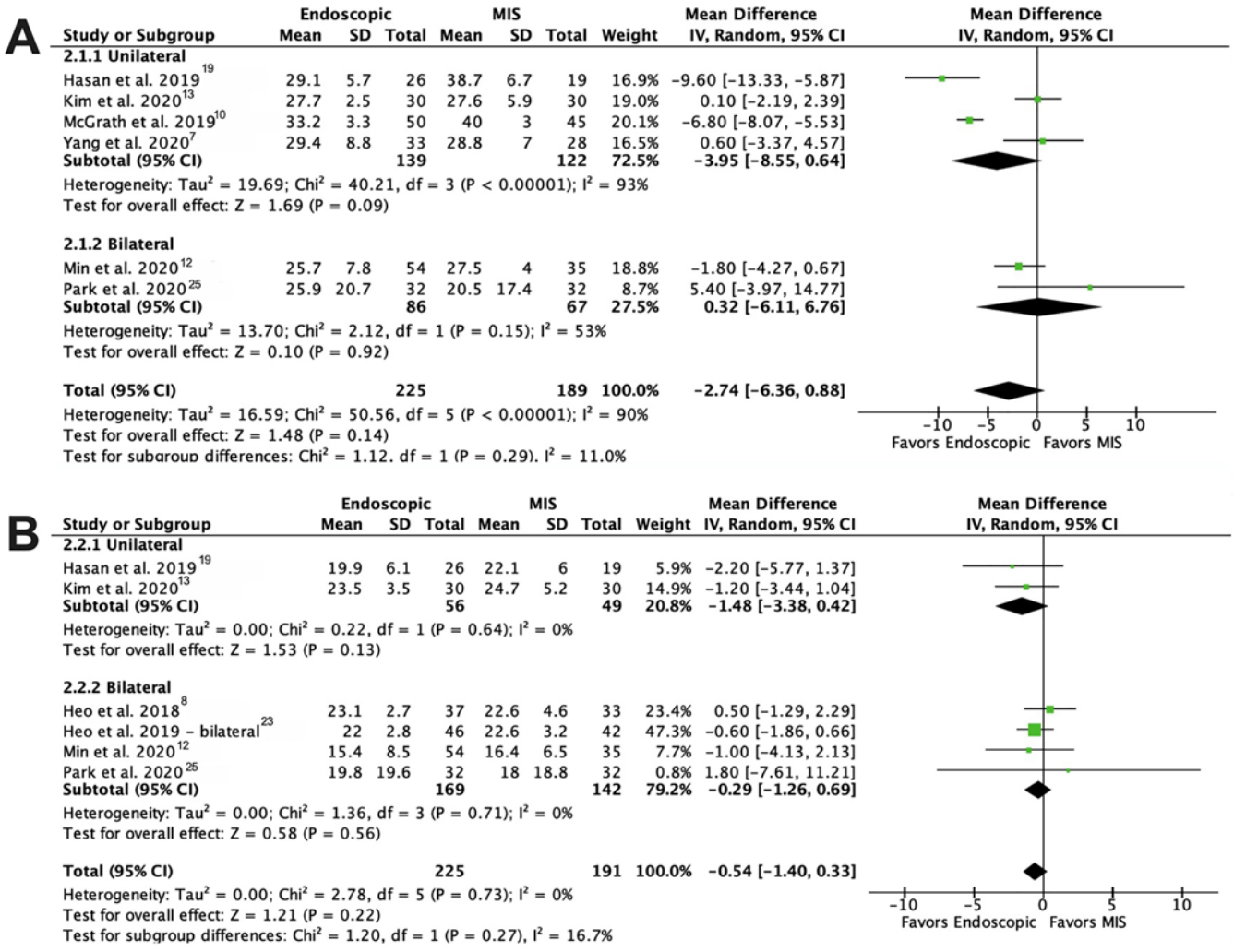

FIG. 4. Forest plots comparing functional outcomes postoperatively (**A**) and at final follow-up (**B**) between endoscopic and MIS approaches. Figure is available in color online only.

9 minutes, p = 0.02).[11] On the contrary, McGrath et al. reported that the surgical time for the endoscopic technique was significantly longer per level compared with MIS (161.8 ± 6.8 minutes vs 99.3 ± 4.6 minutes, p < 0.001), but, as expected, after a learning curve, there was a significant reduction in the surgical time per level in the endoscopic group.[10] In addition, Heo et al. concluded that approximately 30 procedures may be required to overcome the learning curve of endoscopic methods.[8] Although there was no difference in postoperative complications and blood loss in our analyses, there was a strong trend toward decreased blood loss in both endoscopic modalities (p = 0.06), with multiple studies supporting this tendency.[8,9]

Our results showed most importantly that the length of stay was significantly reduced in the endoscopic group when compared with the microscopic cohort (MD –2.1 days, 95% CI –2.7 to –1.4, p < 0.01). In one of the largest series published, Lee et al. reported that patients who underwent UPFE procedures experienced shorter hospital stays on average (2.12 vs 4.85 days, p ≤ 0.001).[9] This was further accentuated in a study that looked at patients 65 or older in which the average hospital stay was significantly reduced when compared with the microscopic counterpart (3.65 vs 7.13 days, p ≤ 0.001).[7] This difference can be potentially reduced even further with the use of awake surgeries and perioperative optimization.[26]

It is important to highlight that the bulk of the studies included in our analysis are from Asian countries. The incentive of outpatient procedures and early discharge protocols outside the US seem to be different and not as prominent. In addition, there are several studies suggesting that patients of Asian race require a longer length of hospital stay.[27] Furthermore, there are some studies suggesting that patient satisfaction scores may be higher in patients who underwent an endoscopic procedure. Kim et al. showed that the Macnab criteria were higher immediately 1 week after surgery and favored the endoscopic cohort at 1 year postoperatively (p ≤ 0.001).[13] Other studies have suggested that patient satisfaction tends to be higher for endoscopic procedures, but they failed to show any difference statistically.[7,9]

Strengths of this study include the fact that our col-

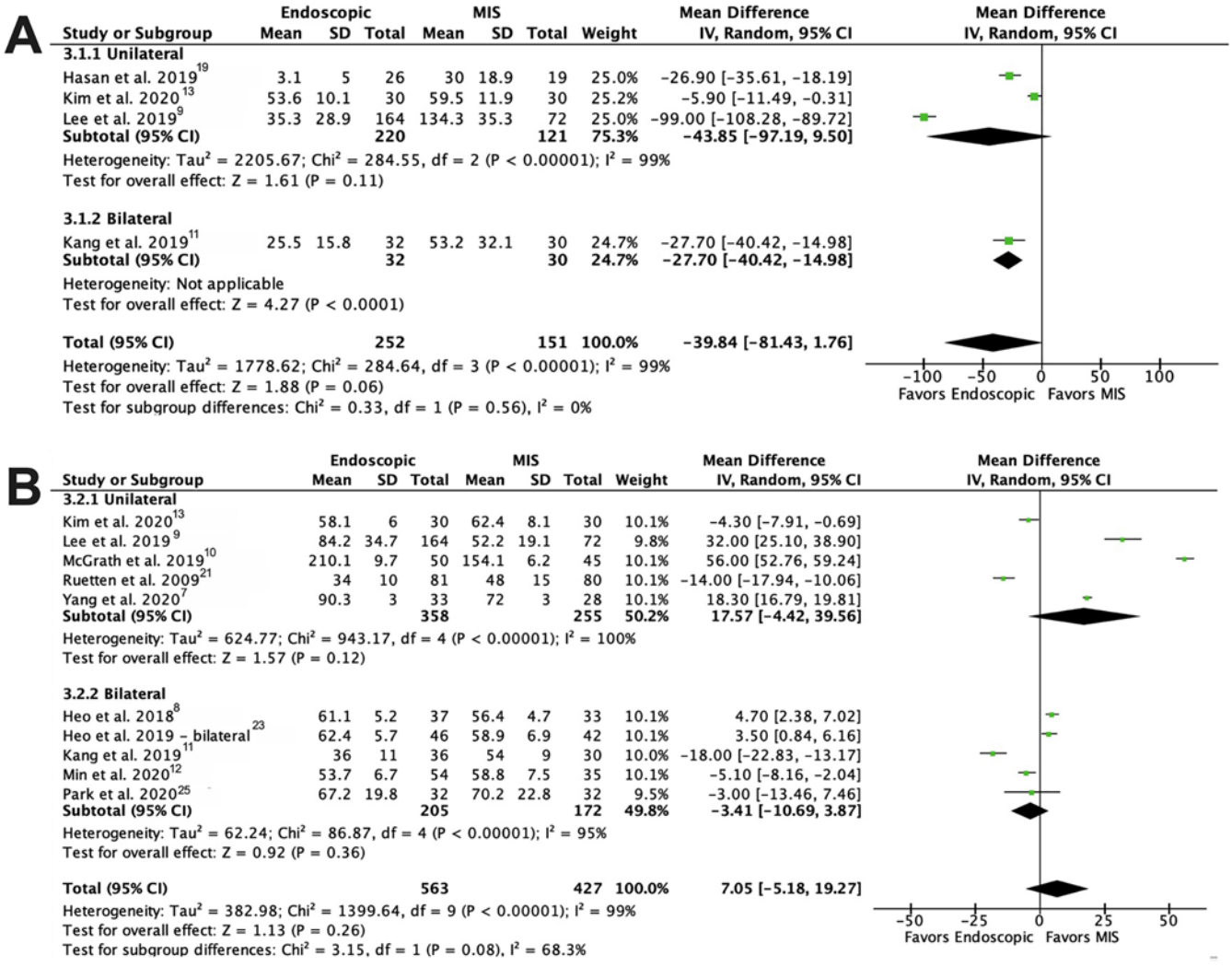

FIG. 5. Forest plots comparing surgical outcomes of estimated blood loss (**A**) and operative time (**B**) between endoscopic and MIS approaches. Figure is available in color online only.

lated metadata represents the largest to date with analysis of multiple postoperative parameters not reported before. These will provide the greater confidence in interpreting and translating these findings into clinical decision-making algorithms. Furthermore, by utilizing random-effects modeling only, we ensure that our results are more reliable and conservative in nature, key elements when processing spine metadata.[28]

There are limitations to this study. First is the limitation of relying majorly on retrospective cohort experiences, inhibiting the validation and standardization of the metadata extraction. Although somewhat minimized by utilization of a random-effects model, it is difficult to increase certainty of our results further without significant randomized prospective data. Second is the limitation of incorporating both uniportal and biportal endoscopic approaches into the same cohort, as it highlights how clinical heterogeneity may trend significantly toward the statistical null if they are truly different. We were able to do subgroup analysis based on these two portal approaches, and promisingly, the disparities between final results were less common than final results being congruent. Additionally, there is some concern of the comparability between studies assessing endoscopic methods and MIS techniques. This is universal for a vast majority of spine procedures, as there is an inherent difference between several aspects involved in treating such a population, which range from patient's unique pathology, surgeon's preferences, and surgical technique. While this is difficult to control, some of the strengths of our study include 4 randomized controlled trials, similar baseline clinical characteristics (age and VAS and ODI scores), and assessment of publication bias for each study. Finally, outside the call for more cohort data, practice-changing metrics such as cost-benefit analyses will greatly enhance the understanding of how our findings can translate into practice.

Conclusions

Both endoscopic and MIS techniques are safe and effec-

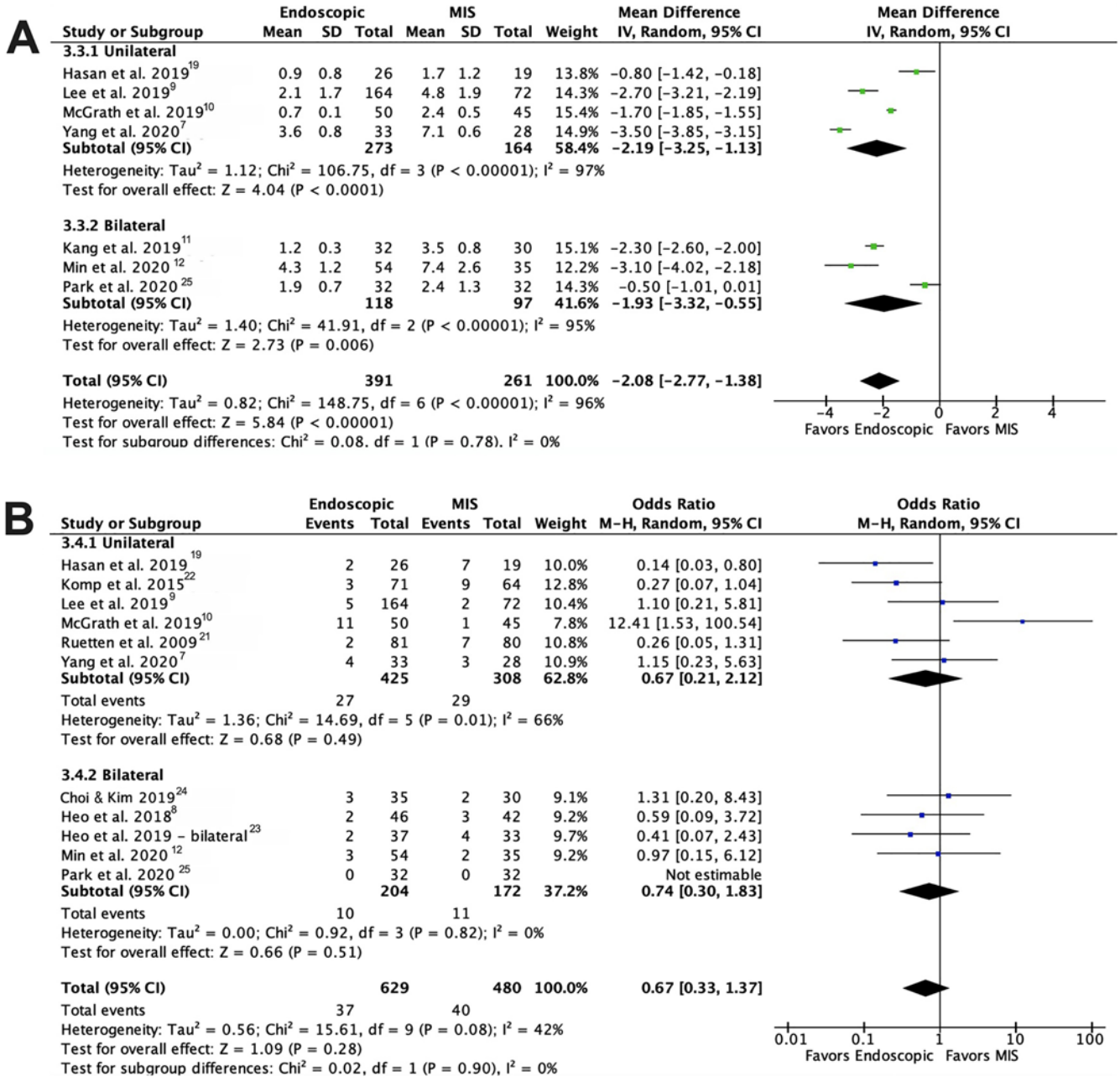

FIG. 6. Forest plots comparing surgical outcomes of length of stay (**A**) and complications (**B**) between endoscopic and MIS approaches. M-H = Mantel-Haenszel. Figure is available in color online only.

tive methods in treating patients with symptomatic lumbar stenosis. Patients who undergo endoscopic surgery seem to report less postoperative low-back pain and significantly reduced hospital stay with a trend toward less perioperative blood loss. Future large prospective randomized controlled trials are needed to confirm the findings in this study.

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Author Contributions

Conception and design: all authors. Acquisition of data: Perez-Roman, Gaztanaga, Lu. Analysis and interpretation of data: Perez-Roman, Lu. Drafting the article: all authors. Critically revising the article: Perez-Roman, Wang. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Perez-Roman. Statistical analysis: Perez-Roman, Lu. Study supervision: Wang.

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