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Are lumbar drains necessary in endoscopic trans-sellar surgery with an intraoperative high-flow leak? A systematic review and meta-analysis

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ABSTRACT

Background: Cerebrospinal fluid (CSF) leaks are a serious complication of endoscopic trans-sphenoidal surgeries that can lead to meningitis, pneumocephalus and a risk to life. Neurosurgeons have used perioperative lumbar drains to facilitate the healing of the dura and prevent postoperative CSF leaks. However, the use of lumbar drains is controversial and has primarily been left to individual surgeon preference. Sellar and suprasellar lesions form most pathologies treated by skull base surgeons using the endoscopic trans-nasal approach. Through meta-analysis, we aim to determine whether lumbar drains effectively reduce the risk of postoperative CSF leak in the context of a high-flow intraoperative leak in trans-sellar and trans-tuberculum approaches.
Method: A systematic review using PRISMA guidelines was conducted. Databases used in literature searching include PubMed, Ovid (including Embase and Medline), Scopus and Cochrane Library. De-duplication, title and abstract screening were performed on the Rayyan platform. Studies were selected according to the inclusion and exclusion criteria. The random-effects model was used in statistical analysis.
Results: A total of 2623 non-duplicated articles were identified. After screening and full-text reviews, 21 studies were included. Lumbar drains did not significantly lower the rates of postoperative CSF leaks ($p = 0.65$; 95 % CI 1.24–0.78).
Conclusion: Lumbar drains are not proven to be beneficial for patients who undergo endoscopic endonasal trans-sellar surgery with a concurrent intraoperative high-flow leak. For trans-sellar pathologies, a meticulous repair is sufficient. As repair techniques continue to improve, the role of the lumbar drain is likely to be further diminished.

1. Introduction

Endoscopic trans-sphenoidal surgery is a well-established and widely used method for treating skull base tumours. Post-operative cerebrospinal fluid (CSF) leak remains an important complication from this approach and can cause serious adverse events such as meningitis, pneumocephalus and a risk to life.[1,2] A recent meta-analysis found the prevalence of CSF leak after trans-sphenoidal surgery to be 3.4 %.[3] As a result, patients sometimes have lumbar drains (LD) inserted or undergo further surgery to treat postoperative CSF leaks.

Since the development of the Hadad-Bassagasteguy Nasoseptal flap in 2006,[4] as well as other closure techniques such as the 'gasket-seal',[5] postoperative CSF leaks have reduced.[6,7] The question remains whether lumbar drains are still relevant in endoscopic trans-sellar approaches in the context of a high-flow intraoperative CSF leak. The definition of a high-flow intraoperative CSF leak varies, but most clinicians agree it to be on entering into an arachnoid cistern or ventricle or a Grade 3 leak as defined by Esposito et al.[8,9] Risk factors for a high-flow intraoperative CSF leak include large pituitary tumours, suprasellar extension and rupture of the diaphragm sellae.[10]

Whether lumbar drains should be used continues to be a highly debated topic. Some surgeons believe that LDs help prevent CSF leaks by reducing tension across a meningeal breach and encouraging healing of the dura.[11–13] Intraoperative LDs can also inject fluorescein to detect

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Table 1
Characteristics of the 21 included studies and data collected.

Study	Country	Study Type	Data collected	Mean age (years)	Outcomes: CSF Leak/Total	Risk of Bias
Ackerman et al.[14]	United States	Retrospective cohort study	2006–2011	Not specified	LD: 2/21 No LD: n/a	6/9[a]
Alharbi et al.[37]	Saudi Arabia	Retrospective cohort study	Dec 2006–Jan 2013	50.3 ± 16.1	LD: 1/51 No LD: 7/135	7/9[a]
Caggiano et al.[38]	United States	Retrospective cohort study	2008–2017	47.2	LD: 1/16 No LD: 3/22	7/9[a]
Chabot et al.[40]	United States	Retrospective cohort study	2009–2014	56.3	LD: n/a No LD: 1/31	6/9[a]
Cohen et al.[39]	United States	Retrospective cohort study	June 2008–July 2015	57	LD: 0/23 No LD: 2/2	8/9[a]
Eloy et al.[15]	United States	Retrospective cohort study	Dec 2008–Aug 2011	49.1	LD: n/a No LD: 1/55	7/9[a]
Hannan et al.[41]	United Kingdom & Ireland	Retrospective cohort study	July 2006–June 2015	50.1	LD: n/a No LD: 6/56	8/9[a]
Hara et al.[42]	Japan	Prospective cohort study	June 2012–May 2015	52.3	LD: n/a No LD: 1/33	8/9[a]
Hu et al.[11]	China	Prospective cohort study	Oct 2009–Feb 2013	50.6	LD: 3/23 No LD: n/a	8/9[a]
Ishii et al.[43]	Japan	Retrospective cohort study	Apr 2001–Jan 2014	Not specified	LD: n/a No LD: 1/15	7/9[a]
Ishikawa et al.[44]	Japan	Retrospective cohort study	Apr 2013–Mar 2017	56.7	LD: n/a No LD: 2/35	7/9[a]
Khan et al.[45]	Canada	Retrospective cohort study	May 2006–Jan 2013	53	LD: n/a No LD: 2/17	8/9[a]
Kim et al.[46]	Korea	Retrospective cohort study	Oct 2012–Oct 2018	46.8	LD: n/a No LD: 4/225	7/9[a]
Liu et al.[35]	China	Retrospective cohort study	Jan 2013–Dec 2017	46.3	LD: 4/119 No LD: 8/70	9/9[a]
Mehta and Oldfield[12]	United States	Retrospective cohort study	2008–2011	49	LD: 2/44 No LD: 6/114	8/9[a]
Nation et al.[47]	United States	Retrospective cohort study	June 2014–March 2018	11.7	LD: n/a No LD: 0/8	6/9[a]
Patel et al.[48]	United States	Retrospective cohort study	Not specified	49.4	LD: 0/53 No LD: n/a	6/9[a]
Van Gerven et al.[29]	Belgium	Retrospective cohort study	2008–2018	50	LD: n/a No LD: 3/9	6/9[a]
Yadav et al.[49]	India	Retrospective cohort study	Jan 2011–Dec 2013	42	LD: 4/44 No LD: n/a	7/9[a]
Youngerman et al.[50]	United States	Retrospective cohort study	Not specified	53	LD: 1/21 No LD: 0/1	7/9[a]
Zwagerman et al.[21]	United States	Randomised control trial	Feb 2012–Mar 2015	51.6	LD: 2/43 No LD: 4/42	Low risk[b]

[a] Newcastle Ottawa scale.
[b] Cochrane risk of bias tool 2 (Fig. 5).

occult leaks or adjust the pressure across the diaphragm to help with tumour removal.[14,15] Others believe that meticulous reconstruction techniques instead play a critical role in preventing CSF leaks, and the risks of LD outweigh the benefits.[15] The complications are significant and include low-pressure headaches, retained catheter fragments and meningitis.[16,17] Rare complications include tension pneumocephalus and death.[18] There may also be increased rates of thromboembolic events, such as deep vein thromboses (DVT) or pulmonary embolisms (PE), as patients with LDs are more likely to be immobilised.[19]

A previous systematic review by D'Anza et al emphasised the lack of good-quality evidence for LD usage in endonasal skull base surgery.[20] Five studies were used in their systematic review, which concluded that the confounding factors were significant and affected the data analysis. The only blinded, randomised controlled trial (RCT) on this topic by Zwagerman et al.[21] found LD to reduce postoperative CSF leak rate overall. This was a single-institution trial, and all patients received the same repair technique. This study included patients with pathologies on the entire ventral spectrum of the skull base, from olfactory groove meningiomas to posterior fossa lesions like clival meningiomas. However, on subgroup analysis for suprasellar pathologies alone, no significant difference in postoperative CSF leak was found with the use of LD.[21] This may be because patients undergoing trans-sphenoidal surgery for suprasellar pathologies, such as craniopharyngiomas, pituitary adenomas and certain meningiomas, tend to have smaller dural defects, hence lower risk of CSF leak.

Despite the controversy, some centres continue to routinely use lumbar drainage in standard trans-sphenoidal surgery where a high-flow CSF leak is expected or encountered. For example, the UK CRANIAL study demonstrated perioperative LD use in 20 of the 187 patients included from data collected across twelve tertiary neurosurgical centres in the United Kingdom.[22] Therefore, this study uses meta-analysis to answer whether LDs should be used in trans-sellar and trans-tuberculum approaches with an intraoperative high-flow leak.

2. Methods

To conduct this systematic review, we followed the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement and checklists.[23] The PRISMA checklist was completed at each review stage; This study is not registered on PROSPERO due to an existing review yet to be completed at the time. The following databases were searched on the 9th of June 2021: PubMed, Scopus, Cochrane Library, and Ovid (including Embase and Medline). As the Hadad-Bassagasteguy flap has helped reduce postoperative CSF leaks,[4] only articles published in 2006 or later were searched. We used the search terms 'endoscopic', 'skull base', 'lumbar drain', 'pituitary', 'meningioma', 'craniopharyngioma', 'transsphenoidal', 'CSF leak'. Appendix 1 illustrates the search strategy used for all the databases.

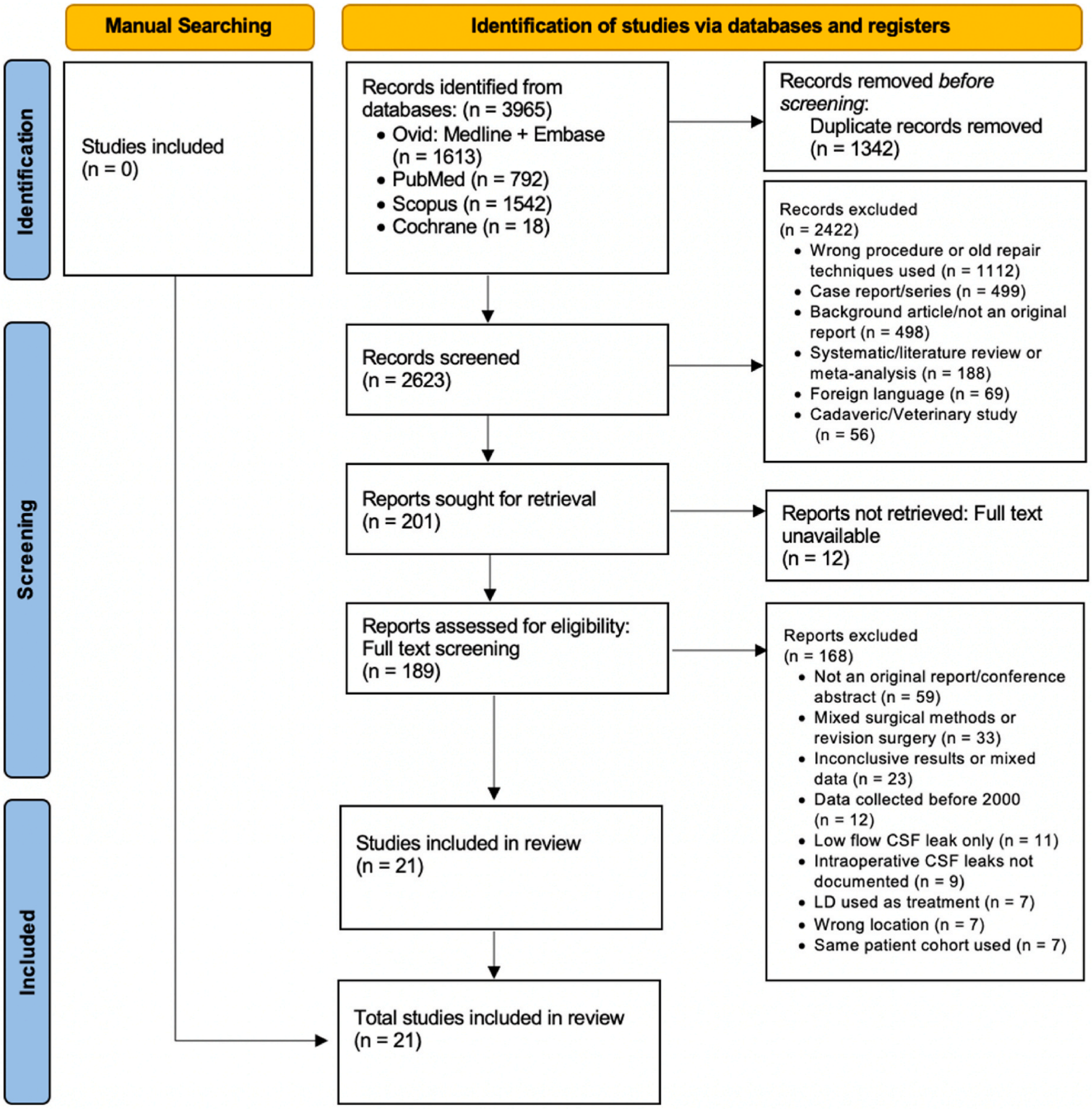

Fig. 1. PRISMA 2020 flow diagram for updated systematic reviews, which included searches of databases and registers only.

Inclusion criteria:

(1) Studies written in the English language
(2) Defined outcome of CSF leak and lumbar drain complications
(3) Lumbar drain placed perioperatively, not for the treatment of a postoperative CSF leak
(4) Studies published in 2006 or after
(5) Paediatric or adult patients
(6) Trans-sphenoidal or extended trans-sphenoidal approaches
(7) Parasellar pathology only – adenoma, craniopharyngioma or tuberculum sella meningioma with high-flow CSF leak. Studies must mention a high-flow leak (i.e. Esposito Grade 3) or involve tuberculum sellae meningiomas/craniopharyngiomas which are intra-arachnoid.

Exclusion criteria:

(1) Duplicated studies
(2) Abstract only
(3) Not an original report
(4) Microscopic or mixed approach
(5) Case report/series or where the total patient sample size was less than 15
(6) Revision or repair surgery

The initial search on the 9th of June 2021 identified 3965 articles. De-duplication was conducted using the Rayyan online platform followed by manual checking.[24] Title and abstract screening of 2623 articles was performed by VP and CH independently on the same platform. Full-text articles were reviewed and selected according to the criteria. VP cross-checked references and similar suggestions for selected studies to identify any relevant studies. Screening difficulties were resolved through discussion with final decisions made by the lead author CH. Due to the limited number of randomised controlled trials (RCTs), studies where no patient had a perioperative LD, were included to increase the sample size for the control group. Studies where all patients had LDs, or a mixture were also included to increase the sample size. A second search was conducted on the 14th of April 2024 to screen for newer articles for inclusion which did not yield any results.

Data extraction: Information collected from the selected studies

Table 2
Reported complications associated with the use of lumbar drainage from included studies.

Condition	Studies and patients
Headaches	• Ackerman et al.[14] had 5 patients (11.6 %) • Alharbi et al.[37] had 2 patients (3.9 %) • Cohen et al.[39] had 4 patient (16 %) who also needed medication • Zwagerman et al.[21] had 2 patients (2.4 %) who also required a lumbar blood patch
Retained catheter	• Mehta and Oldfield[12] had one case (2.3 %) where 4 cm of a lumbar subarachnoid catheter broke off during removal but caused no symptoms • Zwagerman et al.[21] had one case (1.2 %) where a catheter remained but had no consequence
Pneumocephalus	• In the study by Ackerman et al.,[14] all patients had some degree of intracranial air on postoperative imaging but had no cases of tension pneumocephalus • Liu et al.[35] had 3 cases of pneumocephalus (2.5 %)
DVT/PE	• Ackerman et al.[14] had 2 patients (4.7 %) develop DVTs • Zwagerman et al.[21] had 9 patients (10.6 %) develop a DVT or PE compared to 5 (5.9 %) patients in their control group
Meningitis	• Liu et al.[35] had 2 patients (1.7 %) develop meningitis • Yadav et al.[49] had 1 patient develop meningitis (2.3 %)
Nausea and vomiting	• Ackerman et al.[14] had 8 (16.6 %) with nausea and vomiting

includes study design, data collection period, study location, use of LDs, complications from LDs, tumour type, and postoperative CSF leak. Only data from patients with intraoperative high-flow leaks using trans-sellar or trans-tuberculum approaches for adenoma, tuberculum meningioma or craniopharyngiomas were included in this study.

To perform a quality assessment of included studies, the Newcastle Ottawa scale was used for the cohort studies, and the Cochrane collaboration's tool for risk of bias was used for the RCT.[25] The risk of bias for each study is shown in Table 1 and Fig. 5 and the risk of publication bias was evaluated through a funnel plot.

Statistical analysis: The platform used for analysis was R.[26] Pooled data were analysed using a random effects model due to data heterogeneity. The primary outcome measured was the postoperative CSF leak rate, and the secondary outcome was the complications of lumbar drainage. A *p-value* of <0.05 was deemed to be significant. A narrative evaluation is provided for LD complications where the data is insufficient for statistical analysis. Tests for heterogeneity were conducted using the chi-squared test and I^2.

3. Results

Database searching resulted in 2623 individual articles. A total of 2422 articles were excluded by title and abstract screening, and 201 full-text articles were reviewed. Twenty-one studies were selected for meta-analysis. PRISMA flow chat has been used to depict the selection process (Fig. 1). 12 out of 21 included papers had defined a high-flow leak in line with this study, the other papers were selected based on their tumour type and location.

From 18 retrospective cohort studies, two prospective cohort studies and one RCT, a total of 1328 patients' data were reviewed and pooled. Study characteristics, number of patients included, and relevant data extracted can be found in Table 1.

The RCT was considered to have a low risk of bias according to the Cochrane risk of bias tool 2.[27] The risk of bias for the cohort studies has scores ranging from 6 to 9 out of 9 (Table 1).

Seven studies reported several complications associated with the use of LDs (Table 2). Sample sizes for the complications are too small to conduct quantitative analysis. A breakdown of tumour pathologies in the included patients is shown in Fig. 2, some of the pathologies were unable to be extracted from the included data due to its presentation in the included studies.

3.1. Statistical analysis

Data from the 21 studies were pooled in our analysis to form a forest plot (Fig. 3). Postoperative CSF leak occurred in 20/458 (4.4 %) patients in the LD group versus 61/870 (7.0 %) in the non-LD group ($p = 0.65$; 95 % CI 1.24–0.78).

From the I^2 of 37.1 %, there is a moderate degree of heterogeneity. Possible sources of heterogeneity include the difference in study design, repair protocols and the RCT by Zwagerman et al.[21] The symmetry of the funnel plot (Fig. 4) suggests no significant publication bias.

4. Discussion

This meta-analysis found no significant benefit of LD placement in endoscopic trans-sphenoidal surgery for suprasellar tumours with an intraoperative high-flow leak. Rigorous closure techniques such as the vascularised nasoseptal flap are likely sufficient to reduce the risk of postoperative CSF leak without needing a LD.

In recent years, several meta-analyses have been undertaken to answer the question about the utility of LD in preventing postoperative

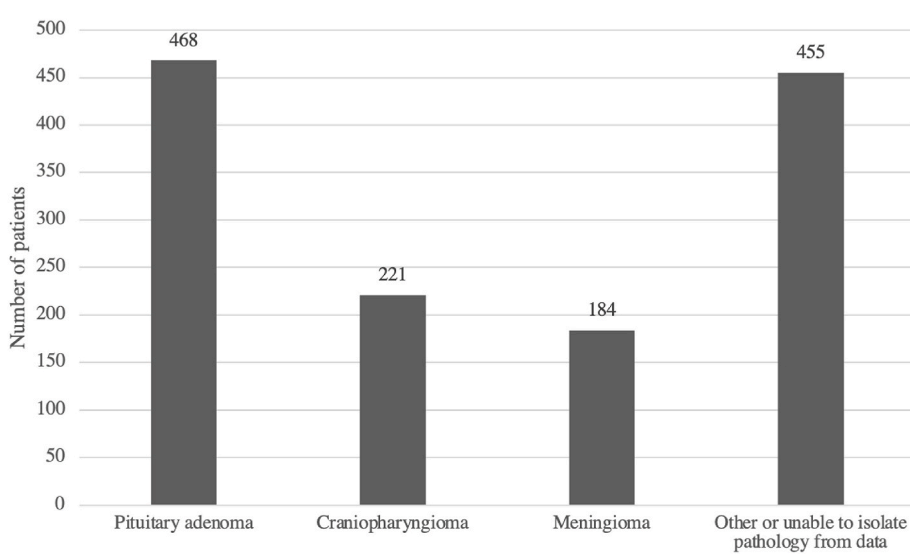

Fig. 2. Breakdown of tumour pathologies in the included patients.

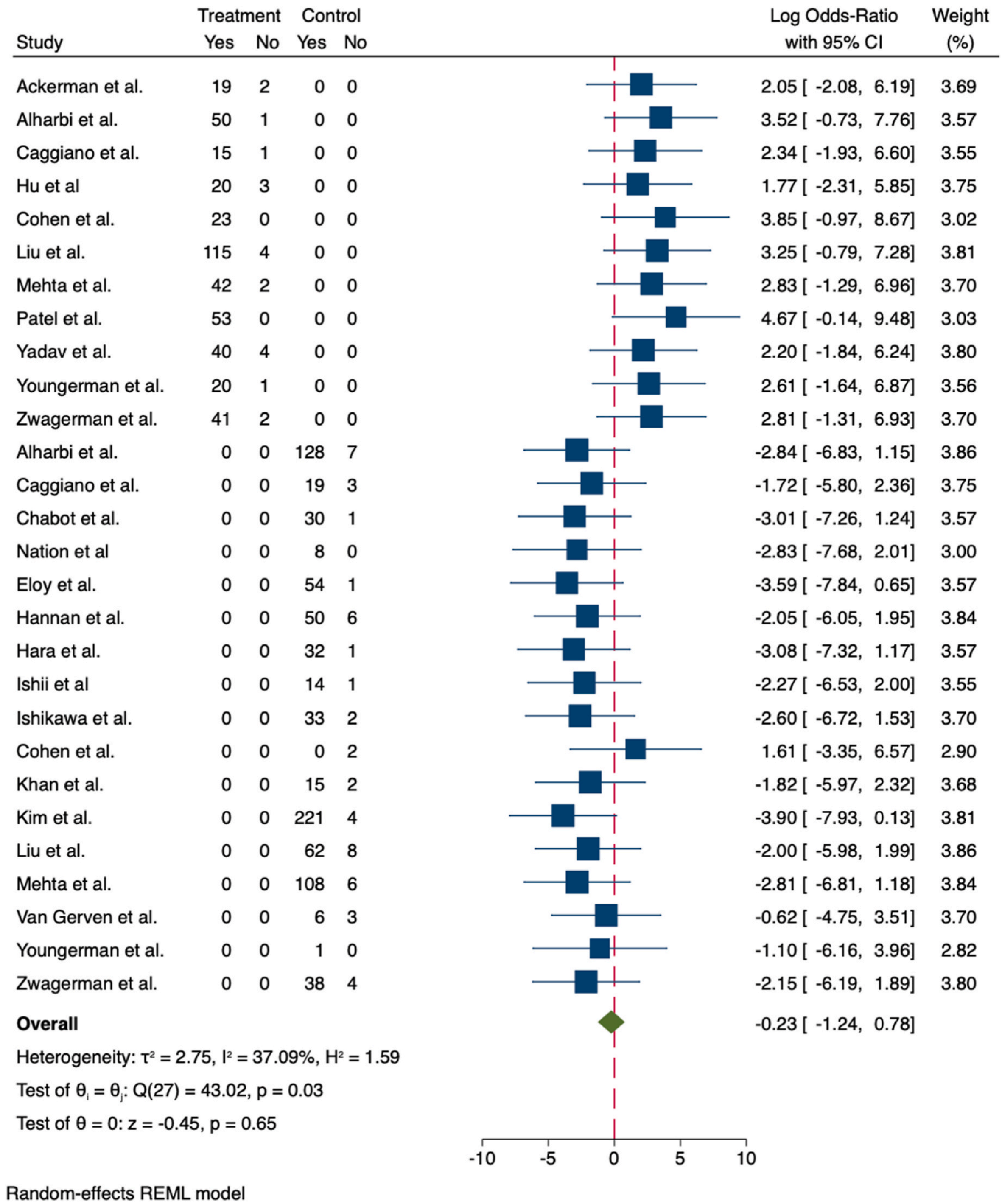

Fig. 3. Forest plot to analyse the effects of perioperative LD in preventing CSF leaks.

CSF leaks after trans-nasal skull base surgery. Tan et al found that LD reduces the risk of intraoperative and postoperative CSF leaks after trans-sphenoidal surgery.[28] Although this study focused on pituitary adenomas it encompassed both endoscopic and microscopic trans-sphenoidal surgery and did not differentiate between high- and low-flow CSF leaks. The utility of LDs may differ depending on the type of surgery or the flow rate of CSF leaks and hence should be studied separately. In addition, Tan et al looked at only five studies with a total of 678 cases and omitted the best conducted RCT on the subject by Zwagerman et al.[21,28] The present meta-analysis included only endoscopic cases but did include single-arm observational studies, resulting in the inclusion of twenty-one studies with a total of 1328 subjects. The larger data sample in this study may explain the difference in results obtained. In another meta-analysis, Guo et al (2020) found no overall benefit in LD preventing postoperative CSF leaks. However, in their subgroup analysis of four studies ($n = 313$ patients), a reduction in high-flow postoperative CSF leaks was associated with LD use. This post-hoc analysis based on a much smaller sample size is one of the issues our present meta-analysis looks to address by increasing the sample size through the inclusion of single-arm observational studies of sufficient quality. There is class 1 evidence from Zwagerman et al showing that LD reduces post-operative CSF leak in anterior skull base and posterior-fossa surgery overall, but not obviously for suprasellar lesions.[21] It must not be understated that sellar and suprasellar tumours

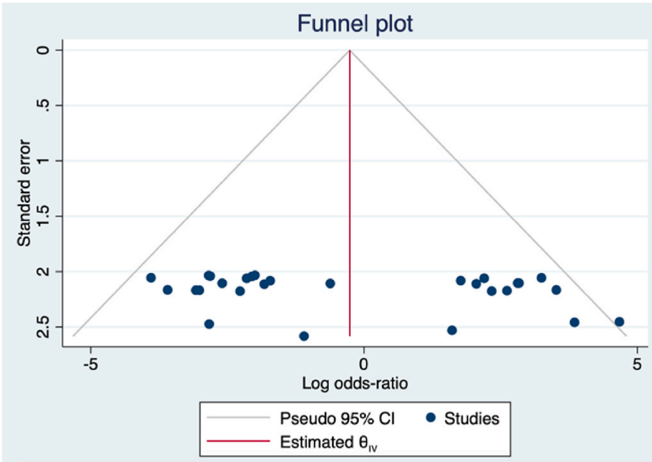

Fig. 4. Funnel plot of the included studies in the meta-analysis.

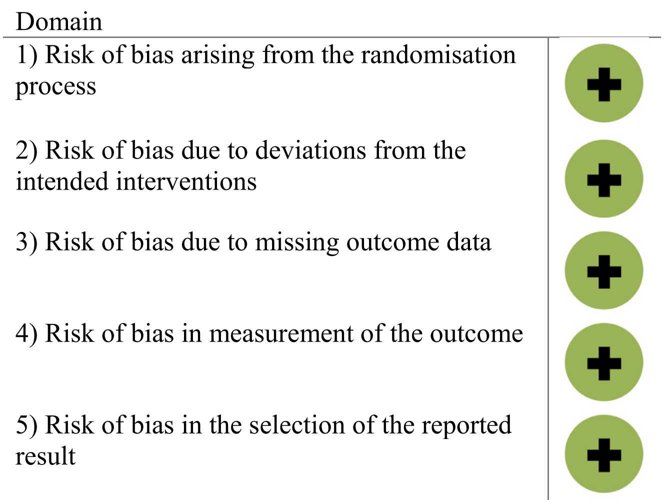

Fig. 5. Cochrane risk of bias tool 2 assessment of the RCT by Zwagerman et al.

are the majority of tumours treated via endonasal approach by skull base surgeons.[29,30] The subset of these lesions where a high-flow CSF leak is likely to be encountered includes pituitary adenomas with significant suprasellar extension, craniopharyngiomas and tuberculum sella meningiomas. Whether a perioperative LD reduces the risk of a postoperative CSF leak in the largest group of tumours treated surgically, had yet to be ascertained and remains a knowledge gap. The present meta-analysis specifically pooled data of suprasellar lesions with a high-flow CSF leak, building upon the RCT of Zwagerman et al.[21] and showed a limited benefit with the utility of LD in suprasellar lesions.

The anatomy and design of the widely adopted pedicled nasoseptal flap is optimised for suprasellar defects and has greatly reduced the incidence of postoperative CSF leaks.[31] A study found that in cases with an intraoperative low-flow CSF leak, reconstruction with multi-layered free grafts and biosynthetic materials have a similar efficacy to the pedicled nasoseptal flap. However, in cases with an intraoperative high-flow leak, the nasoseptal flap remained superior.[32,33] High quality reconstruction after a high-flow leak using multi-layered closures and a nasoseptal flap is likely to obviate the need for LD.[34]

Complications related to LD generally appear to be small. Headaches were the most reported complication from lumbar drainage. Other complications include nausea, vomiting, thromboembolic events and pneumocephalus. In the study by Liu et al.,[35] of 119 patients with LDs, two patients developed meningitis, and three had pneumocephalus. However, the results of the intervention group were not statistically different from the control group This is consistent with the results of complication data shown by Zwagerman et al.[21] and Guo et al.[36] Although these studies have not shown a significant increase in complications with LD use, other factors such as cost, additional surgical time and length of stay in hospital need to be taken into consideration. Interestingly, a study by Chang et al.[19] found that longer durations of LD usage in endoscopic skull base surgery were associated with an increased risk of venous thromboembolism (VTE). Their study analysed the risk of VTE for every 10 h of LD usage (OR 1.16, 95 % CI 1.08–1.25) and provided a more holistic view compared to the included RCT, which only looked at whether an LD was used. Furthermore, an increase in length of stay was reported in two of the included studies. Alharbi et al.[37] and Caggiano et al.[38] found that patients with LDs stayed on average 2.0 and 3.23 days, respectively, more than those without.

The RCT by Zwagerman et al.[21] found no significant difference between patients with high and normal body mass index (BMI). In contrast, Cohen et al, which only looked at patients with a raised BMI, suggested that LDs may help reduce CSF leak risk in these patients.[39] Although the result was statistically significant, it only had two patients without a lumbar drain, which limited the reliability of the results. This study was also unable to elicit and statistically analyse the risk factors for a high-flow CSF leak and, therefore, the subgroup of patients who may still benefit from using an LD. For these reasons, further research is necessary through observational studies and randomised or pragmatic controlled trials to confirm the benefits of LDs in high-risk patients.

The main limitation of this meta-analysis is the potential confounding effects due to the paucity of class I research evidence. The included studies also have some degree of heterogeneity in LD protocols, for example the duration and target amount of CSF drainage. 12 of 21 included studies had defined a high-flow leak in line with our meta-analysis, other papers were selected by the tumour type and location which are in fact high-flow CSF leak by nature of the disease. Other sources of heterogeneity include variable duration of follow-up, size of defect and postoperative rehabilitation. There is also heterogeneity in the repair protocols of the included studies, e.g. the number, type and order of multi-layered closures, and the surgical expertise of each centre.

In addition, patient groups were selectively included to tailor our analysis for a target population, which might have engendered a potential selection bias. This study included many pituitary adenomas, and we were not able to isolate some of the pathologies in the included studies. It may have the effect of diluting the pool of patient at a high risk of developing a postoperative CSF leak. All included studies were limited to the English Language, which may cause a language and geographical bias.

5. Conclusion

Lumbar drains are not proven to be beneficial for patients who undergo endoscopic endonasal trans-sellar surgery with a concurrent intraoperative high-flow leak. For trans-sellar pathologies, a meticulous repair is sufficient. As repair techniques continue to improve, the role of the lumbar drain is likely to be further diminished.

CRediT authorship contribution statement

Hei Yi Vivian Pak: Writing – review & editing, Writing – original draft, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Peter Taylor:** Validation, Software, Formal analysis, Data curation. **Dhruv Parikh:** Writing – review & editing, Writing – original draft, Supervision, Methodology. **Caroline Hayhurst:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Ethical approval

Not applicable.

Availability of data and materials:

Not applicable.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix 1. Search strategy for all databases

Combinations:

(1) Endoscopic* AND skull base AND lumbar drain
(2) Endoscopic* AND pituitary AND lumbar drain
(3) Endoscopic* AND transsphenoidal AND lumbar drain
(4) Endoscopic* AND craniopharyngioma AND lumbar drain
(5) Endoscopic* AND meningioma AND lumbar drain
(6) Endoscopic* AND transsphenoidal AND CSF leak
(7) Endoscopic* AND craniopharyngioma AND CSF leak
(8) Endoscopic* AND skull base AND CSF leak
(9) Endoscopic* AND pituitary AND CSF leak
(10) Endoscopic* AND meningioma AND CSF leak

Limits:

(1) Published after 2006
(2) English Language

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Abbreviation List:

BMI: Body mass index
CSF: Cerebrospinal fluid
DVT: Deep vein thromboses
LD: Lumbar drain
PE: Pulmonary embolism
PRISMA: Preferred reporting items for systemic reviews and meta-analyses
RCT: Randomised controlled trial
VTE: Venous thromboembolism