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Original Article

Skull Base Reconstruction and Postoperative Cerebrospinal Fluid Leak in Elderly Patients after the Endoscopic Endonasal Skull Base Surgery

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SUMMARY

Background: The endoscopic endonasal approach (EEA) is a minimally invasive technique widely used for skull base tumor removal. Elderly patients present unique challenges due to age-related physiological changes and comorbidities. This study evaluates the impact of reconstruction techniques on postoperative cerebrospinal fluid (CSF) leaks in elderly (≥ 65 years) and non-elderly (< 65 years) patients.
Methods: This retrospective cohort study, conducted at MacKay Memorial Hospital, included 132 patients who underwent EEA with skull base reconstruction between October 2020 and September 2024. Patients were stratified into elderly and non-elderly groups. Data on demographics, tumor characteristics, surgical variables, and postoperative complication of CSF leakage were analyzed.
Results: No statistically significant differences were observed between the two groups in intraoperative CSF leak grading or nasoseptal flap (NSF) usage. Postoperative CSF leaks requiring revision surgery occurred in 3.1% of non-elderly patients and none in the elderly group ($p = 0.569$). Key contributors to CSF leaks included delayed mucosal recovery, residual tumor bleeding, and inadequate patient education.
Conclusion: Advanced age was not associated with increased postoperative CSF leak risk, supporting the safety and efficacy of EEA in elderly patients. Tailored surgical planning and perioperative care remain essential for optimizing outcomes.

1. Introduction

Endoscopic endonasal skull base surgery has become a widely accepted approach for managing various skull base pathologies due to its minimally invasive nature and direct access to critical anatomical structures.[1,2] Despite its advantages, postoperative cerebrospinal fluid (CSF) leak remains a significant concern, as it can lead to complications such as meningitis and prolonged hospitalization. Reported rates of postoperative CSF leaks range from 1% to 15%, depending on factors such as the extent of the surgical defect and the reconstruction method employed.[3]

Among reconstruction techniques, the nasoseptal flap (NSF) is widely recognized for its reliability in addressing high-flow CSF leaks. This vascularized pedicled flap provides robust coverage and has demonstrated excellent efficacy in reducing CSF leak rates.[4,5] For smaller defects or low-flow leaks, middle turbinate grafts (MTG) are often utilized due to their reduced donor site morbidity, though their effectiveness may be limited in larger or more complex defects.[6] The choice of reconstruction technique is further influenced by patient-specific factors such as age, comorbidities, and body mass index (BMI).[7,8]

Elderly patients present unique challenges in skull base surgery due to age-related physiological changes, including diminished vascularity, reduced tissue repair capacity, and a higher prevalence of systemic conditions like diabetes.[9,10] These factors may affect the success of reconstruction techniques and potentially increase the risk of postoperative CSF leaks. However, comparative studies examining reconstruction outcomes between elderly (≥ 65 years) and non-elderly (< 65 years) populations remain limited.[11,12]

This study aims to evaluate the impact of reconstruction techniques on postoperative CSF leak rates in elderly and non-elderly patients undergoing endoscopic endonasal skull base surgery. By analyzing these outcomes, we aim to provide insights to optimize surgical strategies and improve care across diverse age groups.

2. Patients and methods

2.1. Study design

This study is a retrospective cohort analysis conducted at Mac-

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Kay Memorial Hospital, evaluating patients who underwent endoscopic endonasal skull base surgery with skull base reconstruction. Data were collected between October 2020 and September 2024. This study was approved by the institutional review board (IRB) of MacKay Memorial Hospital (IRB number: 25MMHIS023e).

2.2. Patient selection

Patients undergoing endoscopic endonasal skull base surgery with skull base reconstruction during the study period were included. The inclusion criteria were patients' age ≥ 18 years at the time of surgery, undergoing skull base reconstruction at the end of surgery, and having at least three months of postoperative follow-up. Exclusion criteria were age < 18 years, pre-existing CSF leaks unrelated to skull base surgery, and incomplete medical records. Patients were stratified by age into two groups: elderly (≥ 65 years) and non-elderly (< 65 years).

2.3. Surgical techniques

All procedures were performed under general anesthesia by a multidisciplinary team of neurosurgeons and otolaryngologists.[13] Patients were positioned supine with the head secured in a Mayfield head holder. Intraoperative navigation was employed, using preoperative contrast-enhanced CT scans conducted within 24 hours before surgery. The binostril, four-handed technique was used with 0°, 30°, and 45° endoscopes (Karl Storz, Tuttlingen, Germany). Nasal decongestion was achieved with tampons soaked in 1:200,000 Bosmin. The middle turbinates were lateralized or removed to improve access. Wide sphenoidotomy was performed with a microdebrider (Medtronic, Fridley, MN, USA) and Kerrison rongeur, exposing key landmarks such as the sellar floor, lateral optico-carotid recess, optic prominence, and carotid prominence. Tumor removal was performed using pituitary forceps, suction, and microinstruments, with Doppler ultrasonography confirming the carotid artery course. Hemostasis was achieved using bipolar cautery and thrombin-infused gelatin matrix (FloSeal; Baxter, Deerfield, IL, USA).

Reconstruction was guided by intraoperative CSF leak grades proposed by Esposito et al.:[14] Grade 0 (no CSF leak), Grade 1 (low-flow), and Grades 2–3 (high-flow). Grade 0 (no CSF leak) refers to the absence of visible CSF leakage during surgery. Grade 1 (low-flow) is defined as minimal CSF leakage appearing as a "weeping" leak, without an apparent diaphragmatic defect or with only a minor disruption. Grade 2 (high-flow) refers to a clear and continuous CSF leak with an identifiable diaphragmatic defect. Grade 3 (high-flow) is characterized by a large CSF leak associated with extensive dural or diaphragmatic defects, typically resulting from expanded approaches to the suprasellar, anterior skull base, or clival regions. No or low-flow leaks were repaired with inlay dura substitutes combined with MTG.[15] High-flow leaks were repaired with inlay dura substitutes and vascularized NSF.[4,16] Reconstruction for Rathke's cleft cysts depended on CSF leaks: cases without leaks were repaired with MTG, while those with leaks required NSF.[17] Defects at the anterior skull base were repaired using inlay dura substitutes combined with onlay fascia lata and vascularized nasoseptal flaps. Clival defects were addressed with inlay dura substitutes, onlay fascia lata, fat grafts, and vascularized nasoseptal flaps.[18] External lumbar drains were placed for anterior skull base or clival dura defects larger than 1 cm × 1 cm and removed three days postoperatively.[1]

2.4. Data collection and outcome definitions

Data collected from electronic medical records included demographics (age, sex, BMI, and comorbidities such as diabetes and smoking history), tumor characteristics (diagnosis and tumor location), and surgical variables (intraoperative CSF leak grading, reconstruction technique, and external lumbar drain use).[19] Postoperative CSF leak was defined as clear, non-viscous nasal discharge, typically increasing with positional changes like leaning forward or bending down. Confirmation was performed via sinoscopy to identify leakage at the intranasal operative site. Persistent CSF leaks one week postoperatively required revision surgery.

2.5. Statistical analysis

Statistical analyses were performed using MedCalc Statistical Software version 23.1.1 (MedCalc Software bv, Ostend, Belgium). Continuous variables were summarized as mean ± standard deviation (SD) and compared using independent t-tests or Mann-Whitney U tests, depending on normality. Categorical variables were analyzed using chi-square or Fisher's exact tests. A p-value < 0.05 was considered statistically significant.

3. Results

A total of 132 patients were included, with 98 patients (74.2%) categorized as non-elderly (< 65 years) and 34 patients (25.8%) as elderly (≥ 65 years). Gender distribution was similar, with males comprising 55.1% in the non-elderly group and 55.9% in the elderly group ($p = 0.937$). The mean age was 46.6 ± 11.1 years (range: 18–63 years) in the non-elderly group and 71.3 ± 6.5 years (range: 65–87 years) in the elderly group.

Regarding body measurements, the mean body height was 165.8 ± 8.6 cm in the non-elderly group and 161.2 ± 8.3 cm in the elderly group ($p = 0.785$). Mean body weight was 70.2 ± 16.2 kg and 63.7 ± 13.2 kg in the non-elderly and elderly groups, respectively ($p = 0.179$). The mean BMI was slightly higher in the non-elderly group (25.4 ± 4.8 kg/m^2) than in the elderly group (24.4 ± 4.1 kg/m^2), but this difference was not statistically significant ($p = 0.248$). Comorbidities, including type 2 diabetes mellitus (17.3% vs. 20.6%, $p = 0.797$) and smoking history (22.4% vs. 14.7%, $p = 0.461$), were comparable between the two groups (Table 1).

The distribution of tumor types differed slightly. Pituitary adenomas were the most common in both groups, accounting for 53.1% in the non-elderly and 58.8% in the elderly group. Rathke's cleft cysts were identified in 6.1% of non-elderly patients and 2.9% of elderly patients, while arachnoid cysts and meningiomas were more common in the elderly group (11.8% and 8.8%, respectively) than in the non-elderly group (3.1% and 4.1%). Rare tumors, such as craniopharyngiomas and chordomas, were exclusively found in the non-elderly group (Table 2). Tumors in both groups were predominantly located in the sellar and suprasellar regions (75.5% in the non-elderly vs. 79.4% in the elderly group). Other locations, such as the anterior skull base (7.1% vs. 5.9%) and middle cranial fossa (2% vs. 5.9%), were less common (Table 3).

Intraoperative cerebrospinal fluid (CSF) leak grades were comparable between groups. In the non-elderly group, 27.6% had Grade 0 (no CSF leak), 18.4% had Grade 1 (low flow CSF leak), 18.4% had Grade 2 (high flow CSF leak), and 35.6% had Grade 3 (high flow CSF leak). In the elderly group, 38.2% were Grade 0, 17.6% were Grade 1, 20.6% were Grade 2, and 23.6% were Grade 3. No significant differences were observed in CSF leak grading ($p > 0.05$ for all comparisons) (Table 4).

The use of nasoseptal flaps (NSF) for skull base reconstruction was similar between groups, with NSF utilized in 63.3% of non-

Table 1
Demography of each group (Non-elderly group: 18–64 years old group; Elderly group: ≥ 65 years old group).

	Non-elderly group	Elderly group	*p* value
Total patient number	98	34	
Gender (%)			0.937
Male	54 (55.1%)	19 (55.9%)	
Female	44 (44.9%)	15 (44.1%)	
Mean age at surgery	46.6 ± 11.1 (18–63)	71.3 ± 6.5 (65–87)	
Body height (cm)	165.8 ± 8.6 (150–183)	161.2 ± 8.3 (142–175)	0.785
Body weight (kg)	70.2 ± 16.2 (40.5–140)	63.7 ± 13.2 (38.7–99)	0.179
BMI [BW (kg)/BH^2 (m)]	25.4 ± 4.8 (16.2–44)	24.4 ± 4.1 (17–34.3)	0.248
Type 2 diabetes mellitus (%)			0.797
Yes	17 (17.3%)	7 (20.6%)	
No	81 (82.7%)	27 (79.4%)	
Smoking (%)			0.461
Yes	22 (22.4%)	5 (14.7%)	
No	76 (77.6%)	29 (85.3%)	

BH: body height, BMI: body mass index, BW: body weight.

Table 2
Pathology types of each group (Non-elderly group: 18–64 years old group; Elderly group: ≥ 65 years old group).

	Non-elderly group	Elderly group
Pituitary adenoma		
Macroadenoma	44 (44.9%)	19 (55.9%)
Microadenoma	8 (8.2%)	1 (2.9%)
Rathke's cleft cyst	6 (6.1%)	1 (2.9%)
Arachnoid cyst	3 (3.1%)	4 (11.8%)
Craniopharyngioma	1 (1%)	0
Meningioma	4 (4.1%)	3 (8.8%)
Nasopharyngeal carcinoma	4 (4.1%)	1 (2.9%)
Olfactory neuroblastoma	4 (4.1%)	1 (2.9%)
Chordoma	1 (1%)	0
Others	23 (23.4%)	4 (11.9%)
Total	**98 (100%)**	**34 (100%)**

Table 3
Lesion locations of each group (Non-elderly group: 18–64 years old group; Elderly group: ≥ 65 years old group).

	Non-elderly group	Elderly group
Anterior skull base	7 (7.1%)	2 (5.9%)
Sellar and suprasellar	74 (75.5%)	27 (79.4%)
Middle cranial fossa	2 (2%)	2 (5.9%)
Posterior cranial fossa	2 (2%)	1 (2.9%)
Others	13 (13.4%)	2 (5.9%)
Total	**98 (100%)**	**34 (100%)**

Table 4
Intra-operative CSF leak grade and intra-operative skull base reconstruction nasoseptal flap usage (Non-elderly group: 18–64 years old group; Elderly group: ≥ 65 years old group).

	Non-elderly group	Elderly group	*p* value
Intra-operative CSF leak grade			
Grade 0 (No CSF leak)	27 (27.6%)	13 (38.2%)	0.245
Grade 1 (Low flow CSF leak)	18 (18.4%)	6 (17.6%)	0.926
Grade 2 (High flow CSF leak)	18 (18.4%)	7 (20.6%)	0.777
Grade 3 (High flow CSF leak)	35 (35.6%)	8 (23.6%)	0.193
Nasoseptal flap usage			0.877
Nasoseptal flap used	62 (63.3%)	21 (61.8%)	
No nasoseptal flap used	36 (36.7%)	13 (38.2%)	
Total	**98 (100%)**	**34 (100%)**	

CSF: cerebrospinal fluid.

Table 5
Persistent postoperative CSF leak necessitates revision surgery (Non-elderly group: 18–64 years old group; Elderly group: ≥ 65 years old group).

	Non-elderly group	Elderly group	*p* value
Revision CSF leak repair surgery	3 (3.1%)	0	0.569
No persistent CSF leak	95 (96.9%)	34 (100%)	
Total	**98 (100%)**	**34 (100%)**	

CSF: cerebrospinal fluid.

elderly patients and 61.8% of elderly patients ($p = 0.877$) (Table 4).

Postoperative outcomes showed that 3.1% of non-elderly patients required revision surgery for persistent CSF leaks, compared to none in the elderly group ($p = 0.569$). Most patients in both groups recovered without persistent CSF leakage (96.9% in the non-elderly vs. 100% in the elderly group) (Table 5).

Overall, intraoperative CSF leak grades, NSF usage, and postoperative complication of CSF leakage were comparable between the two groups. Although the elderly group demonstrated higher proportions of Grade 0 leaks and no revision surgeries, these differences were not statistically significant.

4. Discussion

The endoscopic endonasal approach (EEA) has transformed skull base surgery by enabling minimally invasive access to complex regions with reduced morbidity compared to open techniques.[3,6] Its adoption has grown over the past decade due to advancements in instrumentation, refined techniques, and enhanced anatomical understanding, ensuring safer management of skull base disorders.[2,7]

Elderly patients undergoing endoscopic skull base surgery face challenges due to comorbidities like diabetes, hypertension, and cardiovascular diseases, which impair vascular health and delay mucosal healing.[2,10] These factors increase the risk of postoperative CSF leaks, necessitating vigilant surgical planning, precise reconstruction, and careful postoperative management to optimize outcomes.[1]

Middle turbinate graft (MTG) is suited for small defects with no or low-flow CSF leaks, minimizing donor site morbidity. Nasoseptal flap (NSF), the gold standard for high-flow CSF leaks, provides robust vascular support and effective sealing for large defects.[4] These tailored techniques optimize outcomes by addressing specific defect and leak severity.[6]

Baseline characteristics, including gender, body measurements, and comorbidities like type 2 diabetes and smoking, were similar between elderly and non-elderly patients. This homogeneity ensures a stable basis for comparing postoperative outcomes. The elderly group had slightly lower body weight and BMI than the non-elderly group, likely reflecting age-related changes like reduced muscle mass or nutritional challenges.[20,21] The lack of significant differences supports the suitability of elderly patients for EEA. The prevalence of type 2 diabetes and smoking was similar between groups, minimizing confounding effects. Lower smoking rates in the elderly may reflect generational differences or cessation due to health conditions like cardiovascular disease.

Pituitary adenomas were the most common tumor type in both groups, aligning with the established prevalence of sellar region pathologies as the primary indication for EEA.[22] This highlights the utility of EEA in managing sellar and suprasellar lesions across age groups. Meningiomas and arachnoid cysts were more common in the elderly group, consistent with studies linking meningiomas to age-related genetic and epigenetic changes.[23,24] The higher arachnoid cyst prevalence may reflect incidental findings during neuroimaging.[25] Clinicians should consider age-specific tumor variations. The sellar and suprasellar regions were the predominant tumor sites in both groups (> 75%), reflecting the anatomical suitability of EEA for these areas.[22,26] This consistency highlights EEA's applicability across age groups.

Our findings showed no significant differences in intraoperative CSF leak grading or revision surgery rates between groups, indicating age alone does not affect outcomes. Elderly patients had more Grade 0 leaks (38.2% vs. 27.6%), while younger patients had more Grade 3 leaks (35.6% vs. 23.6%), likely due to more aggressive tumor dissection or larger invasive lesions in younger patients.[2] Nasoseptal flap (NSF) usage was similar between non-elderly (63.3%) and elderly (61.8%) patients, with no significant differences ($p = 0.877$). Age did not influence the decision to use NSF, highlighting its consistent application during endoscopic skull base surgery. NSF is a reliable method for repairing high-flow CSF leaks and extensive skull base defects.[27] Its consistent usage across age groups reflects uniform CSF leak grading, indicating that surgical decisions of reconstruction methods depend on intraoperative findings rather than patient demographics. Middle turbinate grafts, as effective alternatives for lower-grade CSF leaks, may explain the cases where NSF was not used. These techniques help reduce donor site morbidity, especially when NSF is unnecessary.[28]

Revision surgery for persistent CSF leaks was rare, with no cases in elderly patients and only 3.1% in non-elderly patients. These outcomes highlight the effectiveness of reconstruction techniques and may reflect stricter perioperative management in elderly patients.[14,27,28] Comparable outcomes demonstrate the feasibility and safety of endoscopic endonasal surgery in elderly patients, consistent with studies showing advanced age is not a contraindication when care is optimized.

Three patients (2.2%) required reoperation for CSF leaks, offering insights into contributing factors and emphasizing the need for tailored surgical strategies and postoperative care. The first case involved a 35-year-old male with a pituitary macroadenoma and intraoperative Grade 1 low-flow CSF leak. He developed a CSF leak after inserting a cotton swab into his nasal cavity postoperatively. Revision surgery successfully resolved the issue, underscoring the importance of postoperative patient education. The second case was a 57-year-old female with a pituitary giant adenoma (> 9 cm). Subtotal resection with an intraoperative Grade 3 high-flow CSF leak, worsened by residual tumor bleeding displacing the nasoseptal flap. Revision surgery resolved the issue, highlighting the need for meticulous hemostasis in such cases. The third case involved a 49-year-old male with lung cancer and a pituitary metastatic tumor. Subtotal resection with an intraoperative Grade 3 high-flow CSF leak led to delayed nasal healing due to poor nutritional status. Revision surgery resolved the CSF leak, but the patient died from lung cancer two months later, highlighting the need for tailored perioperative care in malignancy cases. These cases highlight the multifactorial nature of postoperative CSF leaks and emphasize that prevention — through education, hemostasis, and nutritional support — is key to reducing reoperations and improving outcomes.

This study has limitations. Its retrospective design introduces selection bias and limits causal inferences. As a single-center study, findings may not be generalizable to other institutions. The sample size, while adequate for preliminary analyses, may lack power for subgroup analyses. Future multicenter, prospective studies with larger cohorts and longer follow-up are needed to validate these results and investigate additional factors affecting CSF leak rates.

5. Conclusion

This study demonstrates that while elderly patients may experience delayed nasal mucosal healing, advanced age itself is not linked to an increased risk of postoperative CSF leaks. These findings affirm the safety and efficacy of the EEA for skull base tumor removal in older individuals.

Key factors contributing to postoperative CSF leaks include delayed mucosal recovery, residual tumor bleeding, and inadequate patient education. Mitigating these risks through meticulous surgical planning and robust postoperative care is crucial for reducing complications.

Declaration of any financial and non-financial conflicts of interest

None.

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