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ORIGINAL ARTICLE

American Rhinologic Society expert practice statement part 2: Postoperative precautions and management principles following endoscopic skull base surgery

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Abstract

The goal of this American Rhinologic Society expert practice statement (EPS) is to summarize the best available evidence regarding postoperative precautions for patients following endoscopic skull base surgery for intradural pathology. These topics include the administration of postoperative nasal hygiene; patient mobilization and activity level; the resumption of continuous positive airway pressure in patients with obstructive sleep apnea; and the timing and capacity with which a patient may be subjected to barotrauma, such as air travel postoperatively. This EPS was developed following the recommended methodology and approval process as previously outlined. Given the diverse practices and limited agreement on the accepted principles regarding postoperative precautions for patients following skull base surgery, this EPS seeks to summarize the existing literature and provide clinically relevant guidance to bring clarity to these differing practice patterns. Following a modified Delphi approach, four statements were developed, all of which reached consensus. Because of the paucity of literature on these topics, these statements represent a summation of the limited literature and the experts' opinions. These statements and the accompanying evidence are summarized below, along with an assessment of future needs.

KEYWORDS

activity restrictions, barotrauma, continuous positive airway pressure, endoscopic endonasal approach, evidence-based medicine, nasal hygiene, nasal irrigations, obstructive sleep apnea, postoperative precautions, skull base reconstruction, skull base surgery

1 | INTRODUCTION

The volume and complexity of endoscopic skull base surgery (ESBS) has grown significantly over the preceding two decades, with endoscopic approaches being used for increasingly larger and more complex lesions.[1] Compared to open approaches, endoscopic endonasal approaches to the skull base have been found to offer comparable or improved extent of resection,[2] functional outcomes,[3] quality of life (QOL),[4] and reduced morbidity and complication profile[5–7] versus matched approaches, and are thus now the mainstay of management of many skull base conditions whenever feasible.[1,8–10]

As previously detailed in part one of the American Rhinologic Society (ARS) expert practice statement (EPS) on skull base reconstruction following ESBS,[11] reconstructive techniques are myriad and nuanced. Part one of the EPS was aimed at achieving some consensus regarding reconstructive approaches with the primary goal of minimizing the risk of postoperative cerebrospinal fluid (CSF) leak. Beyond reconstruction, overall successful outcomes also require diligent care of the patient through the postoperative period. Currently, recommendations on postoperative precautions and patient care principles remain poorly defined. Postoperative precautions including activity level, nasal hygiene, exposure to positive airway pressure (PAP; especially in obstructive sleep apnea [OSA] patients), and barometric pressure changes present the risk of increased intracranial pressure (ICP) with subsequent potential for compromise of the skull base reconstruction and CSF leak, as well as short- and long-term intracranial and sinonasal complications, such as pneumocephalus[12,13] and chronic rhinosinusitis (CRS).[14]

The literature has recently been updated with several systematic review and meta-analyses aimed at bringing clarity to divergent practice patterns.[1,15,16] However, practices detailing postoperative precautions remain heterogeneous, including recent international consensus statements.[1] With this project, we sought to elaborate on part one of the EPS on skull base reconstruction[11] by providing an evidence-based, objective assessment of the current literature surrounding postoperative precautions and management principles following ESBS for intradural pathology with recommendations for best practice.

2 | MATERIALS AND METHODS

This EPS was created using the methodology previously described.[17] The thematic idea and questions were developed by the senior author (E.C.K.), submitted to and supported by the chair of the sponsoring committee (G.W.C., chair of Skull Base and Orbital Section Education Committee), and submitted to the chair of the ARS Quality Improvement Committee for review and approval. Once approved, a working group of subspecialty experts was proposed and approved by the ARS Executive Board before performing the literature review, drafting the EPS, and achieving consensus among the working group.

For this EPS, the working group was comprised of eight fellowship-trained rhinologists. All working group members are members of the ARS. Evidence was based on two existing systematic reviews in the literature, as well as updated with a review of the current literature in areas where systematic reviews did not previously exist. A series of four topic areas addressing postoperative precautions for patients following ESBS were defined based on the literature review. ESBS was defined as endoscopic endonasal approaches to the skull base for intradural pathology. Each working group member was then asked to score each statement using a nine-point Likert scale where: 1 = strongly disagree, 3 = disagree, 5 = neutral, 7 = agree, and 9 = strongly agree. The surveys were disseminated, responses were aggregated and analyzed, and results were distributed to the members for in-person discussion. A statement was considered to have reached consensus if a mean score of ≥7.00 was achieved with no more than one outlier (defined as any score ≥2.0 Likert points from the mean in either direction).[18] A statement was categorized as reaching near consensus if a mean score of ≥6.50 was achieved with no more than two outliers.[18] Those statements that did not meet the criteria of either category were classified as not having reached consensus.[18] These statements and their accompanying evidence are summarized below (Table 1).

3 | EXPERT PRACTICE STATEMENTS WITH SUMMARY OF EXISTING EVIDENCE

3.1 | When should postoperative nasal hygiene be started following endoscopic endonasal skull base surgery?

Statement 1. *(consensus = mean score 8.11): Early use of saline nasal sprays after ESBS is safe, with experts initiating therapy as soon as immediately to 72 h postoperatively. Nasal saline irrigations can be started once the concern of immediate postoperative CSF leak has resolved (expert range 7–14 days postoperatively), or after non-dissolvable packing is removed. Judicious nasal debridement can be performed*

TABLE 1 Expert practice statement (EPS) consensus statements.

EPS statements	Mean score	Final outcome
Nasal hygiene: Early use of nasal sprays after ESBS is safe, with experts initiating therapy as soon as immediately to 72 h postoperatively. Nasal saline irrigations can be started once the concern of immediate postoperative CSF leak has resolved (expert median 14 days postoperatively), or when non-dissolvable packing is removed. Judicious nasal debridement can be performed safely without risk of postoperative CSF leak.	8.11	Consensus
Activity level: Depending on the defect size and location, and intraoperative CSF leak flow rate,[a] maneuvers that promote ICP shifts (e.g., straining, Valsalva, heavy lifting, strenuous activities, nose blowing) should be avoided for 3–6 weeks. Head of bed elevation may decrease ICP shifts transmitted to the repair site. Activity limitations (i.e., bedrest) must be balanced with the risk of VTE associated with prolonged immobilization.	8.33	Consensus
Resumption of positive airway pressure: consider positional interventions (e.g., head of bed elevation), close cardiopulmonary monitoring, and decreased opioid use for OSA patients in the postoperative setting. Until further clinical studies are performed to confirm its safety after ESBS and various repairs, PAP should be withheld for at least 2–6 weeks, depending on the defect size and location, in the presence of an intraoperative CSF leak. If the patient's OSA severity requires immediate use of PAP postoperatively (e.g., severe OSA, use of bilevel positive pressure), a nasoseptal flap may be used with PAP resumed immediately and the patient monitored closely.	8.22	Consensus
Barotrauma: Depending on degree of CSF leak,[a] patients with successful skull base repair without clinical evidence of CSF leak can participate in air travel without restriction after 2–4 weeks if deemed appropriate by their surgeon.	8.67	Consensus

Abbreviations: CSF, cerebrospinal fluid; ESBS, endoscopic skull base surgery; ICP, intracranial pressure; OSA, obstructive sleep apnea; PAP, positive airway pressure; VTE, venous thromboembolism.

[a] High-flow CSF leaks are those defined as dural defect >1 cm^2 or greater in size, and/or in continuity with a ventricle or cistern.

safely soon after surgery without risk of postoperative CSF leak (expert mean 7 days).

Aggregate grade of evidence: C

Benefit: Maintenance of postoperative nasal hygiene may help to facilitate restoration of normal nasal function and decreased long-term sinonasal complications such as need for revision surgery.

Harm: Theoretical and anecdotal risk of compromise of skull base reconstruction and subsequent development of postoperative CSF leak. Nasal saline use may confound clinical monitoring for postoperative CSF leak (e.g., rhinorrhea or salty taste).

Cost: Added cost of otolaryngology clinic visits for debridement, and nasal sprays and/or irrigations for postoperative care.

Benefit–harm assessment: Balance of benefit and harm.

Value judgments: Evidence suggests that patients experience lower postoperative QOL in the setting of sinusitis, however, unclear if this is directly improved by postoperative debridement or the use of postoperative nasal saline sprays or irrigations. No clear evidence to suggest that the use of either nasal saline sprays or irrigations leads to an increased risk of postoperative CSF leak. Judicious, targeted debridement appears unlikely to disrupt a healing repair.

In the postoperative management of patients following endoscopic sinus surgery (ESS) for inflammatory disease, attention to postoperative nasal hygiene (e.g., nasal saline sprays or irrigations) is of utmost importance to maintain patency of the paranasal sinuses and prevent scarring.[19,20] However, nasal care regimens following ESBS are less straightforward due to the theoretical risk of mechanical disruption of the skull base reconstruction by the topical therapies and direct manipulation. The instillation of nasal saline may also confound clinical monitoring for postoperative CSF leak if this is of concern, although it has been shown that conventional clinical signs and symptoms have been shown to be poor predictors of postoperative CSF leak.[21] A 2020 publication by Shah et al. evaluating ESBS for neoplasms with sinonasal and skull base involvement demonstrated that approximately 25% of patients undergoing ESBS require subsequent revision ESS, 18% of which were due to the development of CRS.[14] The risk was greatest in those with malignant pathologies and in whom adjuvant radiation or chemotherapy were required. Postoperative nasal hygiene and debridement regimens were not reported.

Tien et al. published a protocol of irrigations started immediately after surgery in the setting of no intraoperative CSF leak or 1 week following surgery if intraoperative CSF leak was present.[22] Debridement of the anterior nasal cavity was performed in all patients at 1 week postoperatively, and in patients with either no evidence of or a low-flow intraoperative CSF leak, packing directly overlying the reconstruction was additionally removed.[22] Two expert surveys on this topic have demonstrated that the majority of skull base surgeons start saline sprays immediately or within 2 weeks postoperatively, while irrigations are typically started within 2 weeks postoperatively.[23,24] Additionally, some surgeons vary their practice based on the presence or absence of a comorbid diagnosis of OSA, with saline irrigations started earlier (mean 4.9 days postoperatively) in the absence of OSA versus 7 or 10.5 days postoperatively in the setting of OSA and either a small or large intraoperative CSF leak, respectively.[24]

A 2015 retrospective cohort study by Little et al. evaluated 100 patients undergoing ESBS for pituitary lesions in association with postoperative debridement and sinonasal QOL.[25] Seventy-six percent of patients underwent postoperative debridement; however, the study did not report on associated sinonasal QOL.[25] Lower postoperative sinonasal QOL was shown to be associated with the presence of sinusitis, advanced age, and the use of nasal splints and absorbable packing. However, it is important to note that only 55% of cases in this study were performed jointly with an otolaryngologist, significantly impacting the postoperative debridement protocol and monitoring for sinonasal QOL.

A 2023 retrospective review by Salmon et al. evaluated the utility of mometasone nasal irrigations on QOL in skull base tumor patients, with results showing improved 2-year 22-item Sinonasal Outcome Test SNOT-22 score compared with patients using budesonide and/or saline nasal irrigations.[26] Additionally, a pilot randomized controlled trial of 20 patients undergoing endoscopic approaches for skull base lesions found improved postoperative SNOT-22 and nasal endoscopy scores when using mupirocin nasal irrigations.[27] However, neither of these publications commented on potential complications such as CSF leak.

It can also be helpful to consider the literature investigating the use of irrigations following ESS for CRS. Specifically, Snidvongs et al. in 2013 found that topical budesonide and/or betamethasone yielded improvements in SNOT-22 and endoscopy scores to nearly 6 months postoperatively.[28] A subsequent randomized controlled trial by Harvey et al. in 2018 further demonstrated corticosteroid nasal irrigations to be superior to corticosteroid nasal sprays, with significant improvements in nasal obstruction, Lund–Mackay score, and modified Lund–Kennedy score at 12 months postoperatively.[29]

In summary, the literature is limited but does not appear to show an association between the early use of nasal saline sprays or irrigations and an increased rate of postoperative CSF leak. Expert consensus appears to lean toward the use of nasal saline sprays in the early postoperative period while reserving irrigations for longer-term management of sinonasal hygiene. Independent of this, debridement seems to be performed in most patients following an early healing period (at 7 days postoperatively on average; Tables 2 and 3).

3.2 | How should patients undergoing endoscopic skull base surgery be counseled on activity level?

Statement 2. *(consensus = mean score 8.33): Depending on the defect size and location, and intraoperative CSF leak flow rate*[1]*, maneuvers that promote ICP shifts (e.g., straining, Valsalva, heavy lifting, strenuous activities, nose blowing) should be avoided for 3–6 weeks. Head of bed elevation may decrease ICP shifts transmitted to the repair site. Activity limitations (i.e., bedrest) must be balanced with the risk of venous thromboembolism (VTE) associated with prolonged immobilization.*

Aggregate grade of evidence: D

Benefit: Early mobilization minimizes the risk of postoperative pulmonary and cardiovascular complications.

Harm: Increased activity levels lead to shifts in ICP and subsequently increased strain on the skull base reconstruction.

Cost: Nominal additional cost of physical therapy and nursing resources. Significant added cost in the setting of pulmonary and/or cardiovascular complications which may require increased level of care, length of stay, or hospital readmission.

Benefit–harm assessment: Balance of benefit and harm.

Value judgments: Activity limitations may limit shifts in ICP on an otherwise tenuous skull base reconstruction, although there are no studies that have directly examined this. There are no studies that determine time frame when skull base healing is complete. Care should be paid to mobilize patients as early as safely feasible and to ensure appropriate prophylaxis for VTE (i.e., at least mechanical prophylaxis).

Variations in head position, straining, and activity levels can lead to significant shifts in ICP. In the early postoperative period following ESBS, these maneuvers place increased strain on an incompletely healed skull base reconstruction. Conservative management with bedrest has also been shown to successfully treat a postoperative CSF leak following ESBS,[30,31] and duration of conser-

[1] High-flow CSF leaks are those defined as dural defect >1 cm^2 or greater in size, and/or in continuity with a ventricle or cistern.

TABLE 2 Initiating nasal hygiene after endoscopic skull base surgery (ESBS).

Study	Year	LOE	Study design	Study groups	Clinical endpoint	Conclusion
Abiri et al.[15]	2022	2	Systematic review	1. Saline nasal sprays (2 studies) 2. Nasal irrigations (5 studies) 3. Nasal debridement (6 studies)	N/A	• Saline nasal sprays: favor initiating early but poor literature support regarding its use • Nasal irrigations: no evidence supporting or opposing its use • Nasal debridement: no clear evidence but surgeons may consider regular debridement until sinonasal healing is achieved
Rezende et al.[60]	2020	4	Case series	ESBS	Time to clearance of nasal crusting	• POD7 and subsequent debridement recommended • Nasal crusting impacted by reconstruction technique • Mean time to clearance of nasal crusting 124 days
Little et al.[25]	2015	4	Retrospective cohort on a prior prospective cohort	ESBS for pituitary lesions (100 patients)	Sinonasal QOL Endoscopy findings	• 76% of patients underwent postoperative nasal debridement (did not report presence or absence of association with postoperative QOL) • Lower postoperative sinonasal QOL associated with the presence of sinusitis, advanced age, and the use of nasal splints and absorbable packing
Hussaini et al.[61]	2020	5	Expert opinion	N/A	N/A	• Timing to initiation of irrigations related to extent of approach
Wannemuehler et al.[23]	2018	5	Expert survey (70 participants)	N/A	N/A	• Majority of respondents start saline sprays immediately or within 2 weeks postoperatively • Majority of respondents start saline irrigations within 2 weeks postoperatively
Choi et al.[24]	2018	5	Expert survey (71 participants)	N/A	N/A	• No history of OSA: saline rinses started mean 4.9 days postoperatively • History of OSA, small CSF leak: saline rinses started mean 7.0 days postoperatively • History of OSA, large CSF leak: saline rinses started mean 10.5 days postoperatively
Roxbury et al.[41]	2018	5	Expert survey (121 participants)	N/A	N/A	• No leak: 22% of surgeons do not use irrigations • Low-flow leak: 25% do not use irrigations • High-flow leak: 28% do not use irrigations • Time to initiation of irrigations correlates with rate of CSF leak
Tien et al.[22]	2016	5	Expert opinion	N/A	N/A	• Debridement: POD7 independent of leak status • No CSF leak: Irrigations POD0 • Low-flow leak: Irrigations POD7

Abbreviations: CSF, cerebrospinal fluid; LOE, level of evidence; POD, postoperative day; QOL, quality of life.

TABLE 3 Expert practice patterns for duration and timing of postoperative precautions.

Precaution	Median (min–max)
High-flow leak	
Duration of bedrest	1 day (0–2)
Duration of head of bed elevation	1 day (0–14)
Duration of Foley	1 day (1–2)
Performance of tilt test	6 experts do not tilt, 1 tilts if suspicious, 2 routinely tilt (1 before discharge)
Initiation of saline sprays	1 day (0–3)
Initiation of saline irrigations	14 days (2–42)
Debridement of the skull base repair site	7 days (7–42)
Duration of activity restrictions (e.g., heavy lifting, strenuous activities)	4 weeks (3–6)
Allowance of postoperative air travel	3 weeks (1–6)
Resumption of PAP for patients with mild/moderate OSA	2 weeks (1–6)
Allowance of immediate postoperative use of straws	8 experts yes, 1 holds for a few weeks
Low-flow leak	
Duration of bedrest	1 day (0–1)
Duration of head of bed elevation	1 day (0–14)
Duration of Foley	0 days (0–2)
Performance of tilt test	6 experts do not tilt, 1 tilts if suspicious, 2 routinely tilt (1 before discharge)
Initiation of saline sprays	1 day (0–2)
Initiation of saline irrigations	7 days (2–28)
Debridement of the skull base repair site	7 days (7–28)
Duration of activity restrictions (e.g., heavy lifting, strenuous activities)	4 weeks (3–6)
Allowance of postoperative air travel	3 weeks (1–6)
Resumption of PAP for patients with mild/moderate OSA	2 weeks (1–4)
Allowance of immediate postoperative use of straws	8 experts yes, 1 holds for a few weeks

Abbreviations: OSA, obstructive sleep apnea; PAP, positive airway pressure.

vative management correlated with success rate of CSF leak resolution in post-traumatic leaks.[32–35] It is therefore of great importance that careful consideration be given to postoperative activity levels following ESBS. However, disparate protocols for guidance regarding postoperative activity exist, with some studies showing that bedrest is not necessary to prevent postoperative CSF leaks.[1,16,36,37] Additionally, prolonged periods of bedrest and restrictions in patient mobility are associated with a significantly increased risk of VTE in a patient cohort who is already at elevated VTE risk following neurological surgery.[38,39] Additionally, urinary catheters are often placed while patients are bedrest; however, this may elevate the risk of urinary tract infection.[40] Chemical VTE prophylaxis and judicious use of indwelling urinary catheters are important considerations while activity restrictions are in place.

Literature surrounding postoperative activity level is limited and varied. Early expert surveys by Wannemuehler et al.[23] and Roxbury et al.[41] in 2018 surveying both otolaryngologists and neurosurgeons found that the majority of respondents employed some form of activity restrictions for 2–8 weeks postoperatively; however, significant surgeon-specific differences exist. A more recent 2021 expert survey by Favier et al. with 39 respondents showed that 46.2% systematically recommended bedrest independent of the presence or absence of an intraoperative CSF leak, while 46.2% recommended bedrest variably based on size and site of intraoperative CSF leak.[42]

Choi et al. performed a retrospective cohort study of patients undergoing ESBS for suprasellar pathology closed with a nasoseptal flap (NSF) and measured ICP on the NSF in the 3 days following surgery.[43] Results showed that sinonasal pressure is lower in Fowler's position (head of bed 45°–60°) compared with supine positioning, and was independent of age, sex, body mass index (BMI), tumor size, and comorbid hydrocephalus, with recommendation for consideration of placement of patients in Fowler's position following ESBS.[43] The recent systematic review by Abiri et al.[15] identified four studies, which evaluated postoperative activity levels and demonstrated no discrete evidence regarding the role of bedrest, head of bed positioning, timing of return to work, and restrictions in exercise and driving. Expert agreement appeared to favor some restriction, but there was no consensus as to the exact duration. Furthermore, expert consensus regarding the use of straws in the perioperative period favored no restrictions. Consideration may be given to limiting activities and positions that overtly increase the ICP; however, no clear evidence exists on which to base these practices. Expert consensus appears to lean toward some degree of limitations in activity levels across the board (Tables 4 and 3).

3.3 | In patients with obstructive sleep apnea undergoing endoscopic skull base surgery, when may continuous positive airway pressure be resumed?

Statement 3. *(consensus = mean score 8.22): Consider positional interventions (e.g., head of bed elevation), close cardiopulmonary monitoring, and decreased opioid use for OSA patients in the postoperative setting. Until further clinical studies are performed to confirm its safety after ESBS and various repairs, PAP should be withheld for at least 2–6 weeks, depending on the defect size and location, in the presence of an intraoperative CSF leak. If the patient's OSA severity requires immediate use of PAP postoperatively (e.g., severe OSA, use of bilevel positive pressure), a NSF may be used for reconstruction with PAP resumed shortly postoperatively and the patient monitored closely.*

Aggregate grade of evidence: C

Benefit: Respiratory and cardiovascular risks of untreated OSA.

Harm: Risk of disrupting fidelity of skull base reconstruction, potentially causing postoperative CSF leak and/or pneumocephalus (tension or otherwise).

Cost: Minimal to no added cost of starting positive pressure ventilation. Significant added cost with postoperative complications such as CSF leak or pneumocephalus.

Benefit–harm assessment: Harm of skull base reconstructive failure greatly outweighs the benefit in the setting of close respiratory and cardiovascular monitoring postoperatively.

Value judgments: Cadaver modeling studies have demonstrated transmission of air pressure intranasally from PAP use, although a NSF may be protective.[44] Early initiation of positive pressure ventilation should be avoided in the vast majority of ESBS patients, especially those with larger defects, in favor of close postoperative respiratory and cardiovascular monitoring. However, this should be considered within the context of the patient's overall OSA severity and individual medical needs.

OSA exhibits a prevalence of 15%–30% in adult males and 0%–15% in adult females, with the first-line standard of care for treatment being the use of PAP.[45–47] It is classified as mild, moderate, or severe as defined by the apnea–hypopnea index (mild: 5–14.9, moderate: 15–29.9, severe: >30). Patients with OSA are at a significantly increased risk of postoperative respiratory complications, a pattern which has been replicated specifically in the ESBS literature.[48,49] It is also well-established that opioid analgesics present an added risk of pos ents.[50] Given the high pressures that positive pressure ventilation delivers to the oropharyngeal and nasal cavities, initiation of PAP in the early postoperative period following ESBS is often restricted due to concern for compromise of the skull base repair, particularly in the setting of intraoperative CSF leak. There has, however, been conflicting data as to an increased risk of CSF leak rate in OSA patients, with Huyett et al.[48] showing no significant difference while Zimmermann et al.[51] showing among patients with postoperative CSF leak rate, those with OSA developed leaks earlier than those without OSA.

Additionally, the theoretical risk of pneumocephalus exists, with a two case reports[52,53] and one case series[54] identified in the literature, in addition to those cases reported within the expert survey by Choi et al.[24] This expert survey evaluated the responses of 71 participants and found that time to resumption of PAP varied by intraoperative CSF leak status.[24] In the setting of no intraoperative leak, respondents resumed PAP on average 10.1 days postoperatively, compared with 14.3 and 20.7 days with small and large CSF leaks, respectively. Of note, the cohort disclosed five cases of tension pneumocephalus and two cases of orbital emphysema within their practices. A second expert survey by Wannemuehler et al.[23] evaluated the responses of 70 participants and noted that the majority of respondents allowed for the resumption of PAP 2–6 weeks postoperatively.

The literature surrounding this topic has become increasingly robust in recent years, with a 2020 retrospective review by Gravbrot et al. evaluating 42 patients with OSA undergoing ESBS. There was a 48% incidence of intraoperative CSF leak and 90.5% of patients resumed PAP on average 3.5 weeks postoperatively (range, 2–9 weeks). There were no episodes of postoperative pneumocephalus or CSF leak. Approximately 10% of patients required supplemental oxygen on discharge, and there was a 2.4% reintubation rate which occurred in the setting of a myocardial infarction. Chaskes and Rabinowitz[55] subsequently performed a systematic review in 2021, which found a paucity of objective data within the literature on

TABLE 4 Activity level and restrictions after endoscopic skull base surgery (ESBS).

Study	Year	LOE	Study design	Study groups	Clinical endpoint	Conclusion
Abiri et al.[15]	2022	2	Systematic review (4 studies)	N/A	N/A	• Bedrest, return to work, exercise, and driving a. No discrete evidence regarding the role of their restriction b. Expert agreement that there should be some restriction, no consensus on duration • Head of bed: no evidence to clearly evaluate the risk–benefit ratio
Pang et al.[40]	2024	4	Retrospective cohort	ESBS	UTI	• UTIs are uncommon in ESBS patients • Advanced age, length of stay, duration of indwelling urinary catheter, and comorbid genitourinary conditions may increase UTI risk
Choi et al.[43]	2022	4	Retrospective cohort	ESBS for suprasellar pathology closed with NSF	Sinonasal pressure in Fowler's (HOB 45°–60°) and supine positions	• Sinonasal pressure is lower in Fowler than supine position, independent of age, sex, BMI, hydrocephalus, tumor size • Consider placing patients in Fowler's position following ESBS
Riley et al.[30]	2019	4	Case series	ESBS with NSF, patients completed questionnaire survey	Demographics, quality of life, CSF leak, sinonasal complications	Bedrest can treat postoperative CSF leak
Ogiwara et al.[36]	2018	4	Case series	ESBS with intraoperative CSF leak (173 patients)	Association of type of skull base reconstruction with postoperative CSF leak rate	Postoperative CSF leak can be avoided without bedrest or lumbar drain except for in the setting of high-risk features (e.g., prior ESBS, chemoradiotherapy, obesity)
Fujimoto et al.[31]	2015	4	Case–control	ESBS for pituitary adenoma	• Intraoperative and postoperative CSF leak • Flap-related complications	• Postoperative CSF leaks can be successfully managed with bedrest and lumbar drains
Favier et al.[42]	2021	5	Expert survey (39 participants)	N/A	N/A	• 92.3% of respondents at least sometimes recommend bedrest (Fowler's, upright, or supine) following ESBS a. 46.15% systematically recommend bedrest b. 46.15% recommend bedrest variably based on size or site of CSF leak
Roxbury et al.[41]	2018	5	Expert survey (121 participants)	N/A	N/A	• Trend toward activity restrictions (e.g., driving) in patients following ESBS • No consensus on specific recommendations on postoperative activity restrictions
Wannemuehler et al.[23]	2018	5	Expert survey (70 participants)	N/A	N/A	Majority of respondent employ activity restrictions for 2–8 weeks, significant variability

Abbreviations: BMI, body mass index; CSF, cerebrospinal fluid; LOE, level of evidence; NSF, nasoseptal flap; UTI, urinary tract infection.

when it is safe to resume PAP following ESBS, although some cadaveric studies and case series they evaluated suggested resumption could be considered earlier than commonly practiced.

In a recent editorial, Rabinowitz et al.[56] advocated a measured approach, with the decision to restart PAP tailored to each patient based on OSA severity, operative findings, and type of skull base reconstruction, with earlier resumption of PAP being considered in patients with more robust reconstruction. When restarting, the lowest possible pressure settings were recommended. Care should also be taken to minimize the use of opioid analgesics in this at-risk patient population. More research is needed regarding management of this in the setting of clival or anterior cranial fossae defects. More recently, Abiri et al.[15] identified nine studies evaluating the question of timing to restart of postoperative PAP following ESBS, demonstrating a consensus that PAP should be held a minimum of 2 weeks in the setting of an intraoperative CSF leak. This is in slight contrast to a more recent publication by Risbud et al.[57] showing the relatively safety of resumption of PAP less than 2 weeks postoperatively. While additional studies are needed and individual patient factors must be considered, evidence is in favor of holding PAP for a period following ESBS with intraoperative CSF leak. This must be considered within the larger context of the patient's severity of OSA, with patients with severe OSA with a stronger indication for earlier initiation of PAP than those with mild or moderate OSA (Tables 5 and 3).

3.4 | When and in what capacities can ESBS patients be subjected to barotrauma (e.g., air travel)?

Statement 4. *(consensus = mean score 8.67): Depending on degree of CSF leak1, patients with successful skull base repair without clinical evidence of CSF leak can consider participation in air travel without restriction after 2–4 weeks if deemed appropriate by their surgeon.*

Aggregate grade of evidence: D

Benefit: Return to baseline patient lifestyle and QOL.

Harm: Theoretical risk of pressure shifts and disruption of fidelity of skull base repair, causing risk of postoperative CSF leak or pneumocephalus.

Cost: Significant added cost in the setting of postoperative complications such as CSF leak or pneumocephalus requiring increased level of care, readmission, or repeat surgery. If patients are restricted from traveling home from a distant treatment site, this may have financial implications.

Benefit–harm assessment: Harm largely outweighs the benefits of early resumption of barotraumatic events such as air travel.

Value judgments: Anecdotally, commercial air travel generally poses very limited risk to healed skull base repairs. Nevertheless, without more robust evidence, caution should be paid when advising patients on exposure to postoperative barotrauma.

Following recovery from ESBS, patients are understandably eager to return to normal activities. One commonly encountered question is when they may resume activities that result in significant barotrauma such as air travel. The concern with premature resumption of these activities centers around the pressure gradients created by resulting elevation changes, which have the potential to disrupt the fidelity of skull base repair with a theoretical risk of postoperative CSF leak and pneumocephalus. Unfortunately, a paucity of literature exists evaluating this question.

Oakley et al.[16] reviewed the literature in 2016, with only a few case reports of patients recently status post-neurotologic surgery or with skull base bony defects developing pneumocephalus or bacterial meningitis after air travel. Additionally, a single in vitro study by Lim et al.[58] measured changes in ICP with changes in cabin pressure in the setting of intracranial air (ICA). Changes in ICP increased directly with ICA volume, with the largest change in ICP being 5 mmHg. They concluded that an ICA volume of 20 mL and an initial ICP of 15 mmHg may be an appropriate threshold for safe air travel in patients with pneumocephalus, although it is challenging to correlate this to clinical or radiographic data. However, it should also be noted that during a normal postoperative recovery course, with the absence of persistent leak or tension physiology, pneumocephalus typically resolves within 2–3 weeks.[59] Therefore, in patients who have undergone successful skull base reconstruction, time to theoretical safety of air travel may be earlier than is currently practiced by experts in the field. Due to the poor quality of literature regarding this question, and the potentially devastating consequences of unidentified pneumocephalus, particularly if tension physiology is present, caution should be paid when counseling patients on postoperative barotrauma including air travel (Table 3). There is no evidence regarding the risk that deep sea activities pose to skull base reconstruction and thus, no recommendations can be made at this time.

4 | NEEDS ASSESSMENT

With endoscopic endonasal approaches now representing the mainstay of management of skull base disease both

TABLE 5 Resumption of positive airway pressure after endoscopic skull base surgery (ESBS).

Study	Year	LOE	Study design	Study groups	Clinical endpoint	Conclusion
Risbud et al.[57]	2023	2	Systematic review	N/A (5 studies)	N/A	• Early (<2 weeks postoperatively) resumption of PAP is relatively safe • 4% postoperative CSF leak rate • No reports of pneumocephalus
Abiri et al.[15]	2022	2	Systematic review	N/A (9 studies)	N/A	• Consensus that PAP should be held minimum 2 weeks in the setting of intraoperative CSF leak
Chaskes and Rabinowitz[55]	2021	2	Systematic review	N/A	N/A	• Paucity of objective data on when it is safe to resume PAP following ESBS • Some cadaveric studies and small case series suggest safe to resume earlier than commonly practiced following ESBS
Huyett et al.[48]	2018	3	Cohort	ESBS with and without OSA	• Postoperative respiratory events • Surgical complications	• Patients with OSA more likely to have postoperative respiratory events • No difference in postoperative CSF leak rate
Gravbrot et al.[62]	2020	4	Retrospective review	ESBS with OSA (42 patients)	Intraoperative and postoperative CSF leak, PAP status, reintubation, hospital LOS	• 48% intraoperative CSF leak rate • 90.5% resumed PAP (mean 3.5 weeks postoperatively, range 2–9 weeks) • No postoperative CSF leak • No postoperative pneumocephalus • 2.4% reintubation rate (postoperative MI) • 10% required supplemental nocturnal home O_2
Rieley et al.[49]	2020	4	Cohort	ESBS for pituitary pathology • OSA on PAP • No OSA	Postoperative complications	• $n = 8$ patients with PAP in the PACU, no episodes of pneumocephalus • OSA patients had more respiratory complications than those without OSA • No difference in surgical complications
Zimmermann et al.[51]	2019	4	Case series	• ESBS with OSA • ESBS without OSA	Time to CSF leak	• Initiation of PAP at 2 weeks postoperatively or later • Patients with OSA have shorter time to postoperative CSF leak compared with patients without OSA

(Continues)

TABLE 5 (Continued)

Study	Year	LOE	Study design	Study groups	Clinical endpoint	Conclusion
D'Ignazio et al.[52]	2021	4	Case report	N/A	N/A	• PAP may cause postoperative pneumocephalus
Kopelovich et al.[53]	2012	4	Case report	N/A	N/A	• PAP may cause postoperative pneumocephalus
Sawka et al.[54]	1999	4	Case series	N/A	N/A	• PAP is a risk factor for postoperative tension pneumocranium
Rabinowitz et al.[56]	2021	5	Editorial	N/A	N/A	• Decision to restart PAP should be tailored to each patient based on OSA severity, operative findings, and type of skull base reconstruction • Consider restarting PAP on patients with more robust reconstruction • If restarting, use lowest possible pressure setting • Limited to no data on transclival or anterior cranial fossa defects
Wannemuehler et al.[23]	2018	5	Expert survey (70 participants)	N/A	N/A	Majority of respondents allow for resumption of PAP 2–6 weeks postoperatively
Choi et al.[24]	2018	5	Expert survey (71 participants)	N/A	N/A	• No intraoperative CSF leak: PAP resumed mean 10.1 days postoperatively • Small CSF leak: PAP resumed mean 14.3 days • Larger CSF leak: PAP resumed mean 20.7 days • Five cases of tension pneumocephalus, two cases of orbital emphysema among four surgeons
Roxbury et al.[41]	2018	5	Expert survey (121 participants)	N/A	N/A	• Low-flow leak: PAP held until at least 2 weeks postoperatively by 81% of respondents • High-flow leak: PAP held until at least 2 weeks in 88% of respondents

Abbreviations: CSF, cerebrospinal fluid; LOE, level of evidence; LOS, length of stay; MI, myocardial infarction; OSA, obstructive sleep apnea; PAP, positive airway pressure.

in the adult and pediatric population, the development of a clinical consensus as to the preoperative, intraoperative, and postoperative management of patients is of utmost importance. Herein, we have reviewed the current literature on postoperative precautions and patient care principles following ESBS with a focus on developing clinical best practices These topics include methods of maintaining nasal hygiene, postoperative activity levels, resumption of PAP in patients with OSA, and the exposure to barotrauma, such as air travel. The consensus identified here is limited by the quality of the literature currently available, which has been summarized for review.

Postoperative nasal hygiene is optimized in a number of ways, and expert consensus appears to lean toward the use of nasal saline sprays at a minimum in the short-term, with irrigations being favored for maintenance of long-term sinonasal health. Consideration can be paid to the addition of corticosteroids and/or antibiotics to the nasal lavage as adjunctive measures. However, there is a dearth of literature as to the disease-specific benefit of and the frequency with which both nasal saline sprays, irrigations, and postoperative debridement should be undertaken. Postoperative activity levels have been better studied, with a consensus in favor of some activity restriction but no definitive evidence on which to base duration of activity restrictions. It is imperative that studies more clearly delineate type and timing of activity liberalization while additionally reviewing associated VTE rate to provide more evidence-based recommendations. These recommendations are both well-supported by the systematic review of Abiri et al.[15]

When considering the resumption of PAP postoperatively, more research is needed regarding the use of PAP in the setting of posterior or large anterior cranial fossa defects which present larger and more complex skull base defects with greater associated morbidity should pneumocephalus develop. Similarly, the return to barotraumatic events such as air travel has minimal to no robust studies evaluating specifically in the ESBS population, with much of the current data coming from the general neurosurgical literature following craniotomy, which is a group significantly different from the ESBS cohort.

From a global perspective, the literature on postoperative precautions following ESBS is largely based on expert surveys and retrospective studies, with more prospective, well-controlled, granular studies needed. Multi-institutional and international collaboration will be critical to ensure these studies are adequate powered given the unique pathology. It must be emphasized that patient-specific factors play a significant role in guiding recommendations for postoperative precautions, as risk factors, such as defect size and location, manner of skull base reconstruction, patient BMI, tumor type, and need for adjuvant chemoradiotherapy all may play a role in the risk of postoperative complications. We have attempted to bring evidence-based recommendations for postoperative precautions and patient care principles following ESBS for intradural pathology as it relates to nasal hygiene, activity levels, resumption of PAP, and return to barotraumatic events such as air travel.

5 | QUALIFYING STATEMENT

This EPS should serve only to help guide the decision making for approaches to postoperative management and patient guidance following ESBS for intradural pathologies. Medical and surgical care should be individualized to the patient and their contextual situation.

6 | EXPIRATION

This EPS should be reviewed within 3 years from the date of publication and updated if current evidence and common practice has significantly changed.

CONFLICT OF INTEREST STATEMENT

Nithin Adappa, MD, is a consultant for Acclarent and Optinose. Garret Choby, MD, is a consultant for Tissium and Medtronic. Raj Sindwani, MD, is a consultant for Acclarent, Stryker, and Optinose; and he receives royalties from Sage Publications (EIC of American Journal of Rhinology and Allergy) and Elsevier (textbooks). Bradford A. Woodworth, MD, is a consultant for Cook Medical, Medtronic, and Smith and Nephew. Edward Kuan, MD, MBA, is a consultant for Stryker ENT and 3-D Matrix. These conflicts of interest are not relevant to this article. The remaining authors report no relevant conflicts of interest or financial disclosures.

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