

Nasoseptal Flap Enhancement on Early Postoperative MRI Does Not Predict 3-Month Enhancement nor Postoperative Cerebrospinal Fluid Leak Risk

Mehrdad Pahlevani, MD*, Artak Mukhaelyan, MD*, Keila Angel, MD*, Regin Jay Mallari, BS*, Chester Griffiths, MD**, Daniel F. Kelly, MD**, Garni Barkhoudarian, MD  **

*Pacific Neuroscience Institute, Santa Monica, California, USA; †Saint John's Cancer Institute, Providence Saint John's Health Center, Santa Monica, California, USA

Presented as an abstract at the 2022 North American Skull Base Society Annual Meeting, Phoenix, AZ, in February 16-17, 2022.

Correspondence: Garni Barkhoudarian, MD, Pacific Neuroscience Institute, 2125 Arizona Ave, Santa Monica, CA 90404, USA. Email: Garni.Barkhoudarian@providence.org

Received, July 30, 2024; **Accepted,** August 01, 2024; **Published Online,** October 1, 2024.

Neurosurgery Practice 2024;5(4):e00118.

<https://doi.org/10.1227/neuprac.0000000000000118>

© The Author(s) 2024. Published by Wolters Kluwer Health, Inc. on behalf of Congress of Neurological Surgeons. This is an open access article distributed under the terms of the Creative Commons Attribution-Non Commercial-No Derivatives License 4.0 (CCBY-NC-ND), where it is permissible to download and share the work provided it is properly cited. The work cannot be changed in any way or used commercially without permission from the journal.

BACKGROUND AND OBJECTIVES: The nasoseptal flap (NSF) has been a versatile reconstructive option for extended endonasal skull base surgery, significantly decreasing postoperative cerebrospinal fluid (CSF) leakage rates. One failure mechanism of concern is NSF necrosis. It has been postulated that immediate postoperative MRI flap enhancement can predict flap necrosis. This retrospective study analyzes NSF enhancement to assess for flap viability and CSF leakage.

METHODS: Patients from 2012 to 2020 who underwent extended endoscopic endonasal surgery with NSF reconstruction were assessed. Immediate postoperative MRI and delayed 3-month MRI were compared for NSF enhancement. Enhancement was graded as no enhancement, partial, or complete enhancement. Patient demographics, tumor type, intraoperative CSF leak grade, and postoperative CSF leakage were assessed based on flap enhancement patterns.

RESULTS: Of 713 patients who underwent endoscopic endonasal surgery, 64 required NSF reconstruction. On the immediate postoperative MRI, 45 patients (70%) had complete flap enhancement, 9 (14%) had partial, and 10 (16%) no enhancement. On the 3-month MRI, 59 patients (92%) had complete flap enhancement and 5 (8%) had partial enhancement. There was significant improvement of flap enhancement between immediate postoperative and 3-month MRI ($P = .002$). All patients with no initial enhancement had complete enhancement at 3 months. Of those with partial enhancement, 2 remained partial and 7 had complete enhancement at 3 months. Overall, 44 patients (69%) had no change between MRI scans, 17 (27%) improved, and 3 (5%) had decreased enhancement. There was no correlation between intraoperative CSF leak rates and flap enhancement. Four patients had postoperative CSF leaks, 2 having complete immediate enhancement, 1 partial, and 1 without enhancement ($P = .85$).

CONCLUSION: Overall, immediate postoperative MRI NSF enhancement (or lack thereof) did not predict enhancement at the 3-month MRI and did not correlate with postoperative CSF leakage. Hence, one should not rely solely on postoperative flap enhancement to assess the viability of the dural reconstruction.

KEY WORDS: Endoscopic endonasal surgery, Nasoseptal flap, Flap enhancement, CSF leak, Skull base surgery, Pituitary surgery

The endoscopic endonasal approach has been widely used for the resection of skull base tumors.¹ Effective reconstruction techniques of the tissue barriers between the arachnoid space and the sinonasal cavity has been a major challenge that initially prevented the popularization of endonasal surgical approach.

The vascularized nasoseptal (Hadad-Bassagasteguy) flap has revolutionized the reconstruction of the skull base defects after endonasal endoscopic skull base surgeries, and it is used as the main tool in reconstruction of large dural defects.^{2,3} This has significantly reduced the postoperative complications and cerebrospinal fluid (CSF) leak rates from 20 % to less than 5% compared with nonvascularized reconstruction.⁴

The nasoseptal flap (NSF) is considered a reliable vascularized flap. Its vascularization is based on the sphenopalatine artery. It is

ABBREVIATION: NSF, nasoseptal flap.

the preferred flap compared with pericranial and temporoparietal fascia flaps because the NSF does not require an external incision and will make it appropriate for the use in keyhole approaches.

One concern with NSFs and other pedicled flaps is the possibility of flap necrosis because of inadequate blood supply or external compression.⁵⁻⁷ Flap necrosis has been associated with postoperative CSF rhinorrhea and other complications.⁷ It has been assumed that early postoperative MRI flap enhancement can predict its viability and failure. Some authors advocate reoperation if there is concern of flap perfusion at the immediate postoperative MRI.

In this study, we present a retrospective study analysis and literature review regarding NSF enhancement to assess the flap viability and CSF leakage and determine the variations in MRI that may suggest potential flap necrosis.

METHODS

After approval by our Institutional Review Board (IRB# JWC1-19-1101), we retrospectively reviewed the imaging and clinical data of 713 endonasal surgery patients over an 8-year period (2012-2020) at our institution. Per Institutional Review Board protocol, patient consent was not necessary as data were retrospective and deidentified. Of these patients, 64 who underwent extended endoscopic endonasal skull base surgery with the elevation of a vascularized NSF reconstruction were assessed. Patient tumor characteristics included parasellar tumors, with or without suprasellar, cavernous sinus or clival extension (Table 1).

All the patients had a preoperative magnetic resonance imaging examination followed by an early postoperative MRI (POD 1) and delayed 3 months. In addition to tumor resection, these were assessed for NSF enhancement. The sequences included on MRI were axial, sagittal, and coronal T1 and T2; precontrast and postcontrast fat saturation T1 images; and further as needed per patient. All postoperative MRI examinations were performed on a 3.0 T Philips MRI scanner.

Postoperative magnetic resonance imaging features that were evaluated included NSF configuration, enhancement patterns, and signal intensity characteristics. Enhancement was qualitatively graded by a single assessor (AM) as no enhancement, partial enhancement, or complete enhancement. Patient demographics, tumor type, intraoperative CSF leak grade, and postoperative CSF leakage rate were assessed for evaluation. Statistical analysis was performed through χ^2 and Fisher exact techniques using the SPSS (IBM) v23 software.

TABLE 1. Pathology of Patients Who Had Nasoseptal Flap Raised

Pathology	N
Craniopharyngioma	22/64 (34%)
Meningioma	18/64 (28%)
Pituitary adenoma	7/64 (11%)
Chordoma	6/64 (9%)
Other ^a	11 (17%)

^aIncludes: sinonasal undifferentiated carcinoma, epidermoid.

RESULTS

Demographics and Prior Treatments

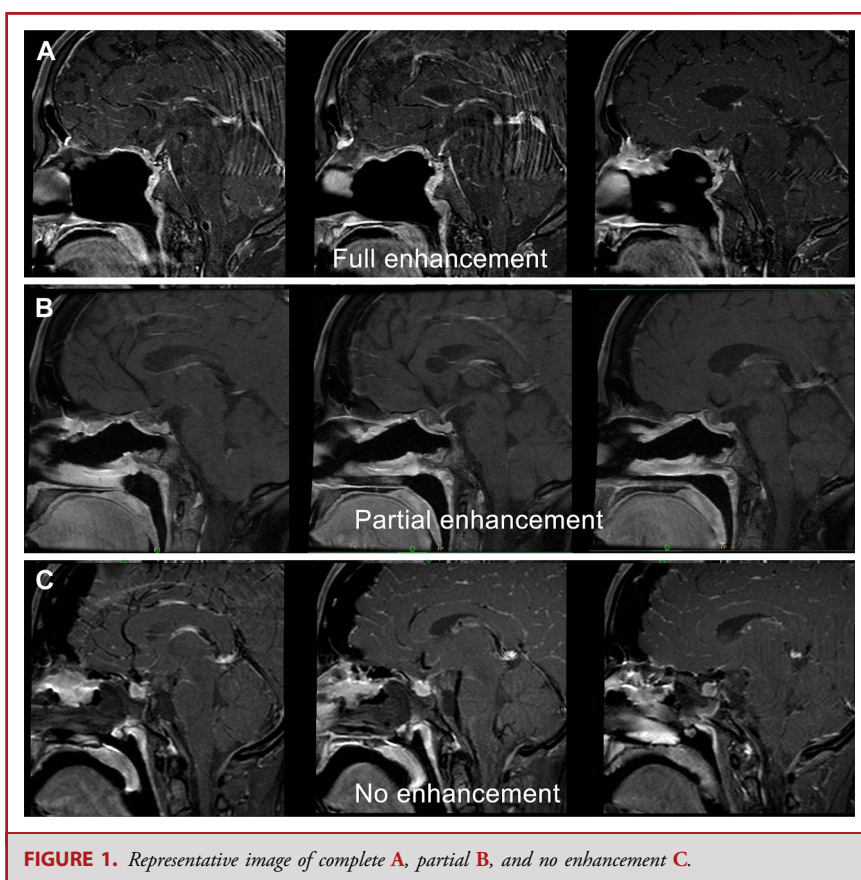
In total, 713 patients underwent endoscopic endonasal surgery during the study period (2012-2020), and a total of 64 required NSF reconstruction. The tumor types in this cohort included craniopharyngioma, meningioma, pituitary adenoma, chordoma, and other pathologies (Table 1).

All 64 patients had detectable skull base defects on MRI scans. A C-shaped configuration of the flap adjacent to the operative skull base defect on both the coronal and sagittal projections was demonstrated in all patients. On the early postoperative MRI, 45 patients (70%) had complete flap enhancement, 9 patients (14%) had partial enhancement, and 10 patients (16%) had no enhancement (Figure 1). On the 3-month MRI, 59 patients (92%) had complete flap enhancement and 5 patients (8%) had partial enhancement (Table 2).

There was significant improvement of flap enhancement between early postoperative and 3-month MRI ($P = .002$). Among the patients with no initial enhancement, all 10 patients had complete enhancement at 3 months (Figure 2). In the patient group with partial enhancement, 2 remained partial at 3 months and 7 had complete enhancement at 3 months (Table 3). Overall, 44 patients (69%) had no change between MRI scans, 17 patients (27%) improved, and 3 patients (5%) had decreased enhancement at 3 months (Table 3, Figure 3). These 3 patients initially had complete enhancement on the early postoperative MRI and decreased to partial enhancement at 3 months.

Regarding the CSF leak rates, 56 patients (88%) had grade 3 intraoperative CSF leaks, 3 patients (4.5%) had grade 2, 2 patients (3%) had grade 1, and 3 patients (4.5%) had no intraoperative CSF leak.^{4,8} Postoperative CSF leak rate was 6.25 % (4 patients), all of whom had grade 3 intraoperative leaks (Table 4). Four of 64 patients who underwent endoscopic endonasal surgery with NSF reconstruction experienced CSF leak postoperatively (6.25%). The pathologies of these 4 cases were craniopharyngioma, chordoma, meningioma, and sinonasal adenocarcinoma. All had an extended endonasal approach, and their time to CSF leak from the operation was on average 24.5 days.

Of those 4 patients with postoperative CSF rhinorrhea, on the immediate postoperative MRI, 2 had complete flap enhancement, 1 with partial flap enhancement, and 1 without any flap enhancement (Table 5). The postoperative CSF leak cases with complete immediate enhancement required surgical repair on 6th and 14th postoperative day; these patients presented a technically inadequate reconstruction and coughing episode, respectively. The patient with partial enhancement required surgical repair as well on the 68th postoperative day, within a context of immunosuppression and neutropenia. The last patient who showed no enhancement presented a coughing episode and sign of CSF leak on 10th postoperative day and only required lumbar drain and resolved. Table 6. There was no correlation between postoperative CSF leak rates and flap enhancement ($P = .85$), demonstrated statistically significant no association of postoperative day 1



enhancement and CSF leak. There was no statistically significant correlation between immediate postoperative MRI flap enhancement and CSF leak development. This was assessed both with the trichotomized categories and with dichotomized assessment of any diminished flap enhancement v complete enhancement ($P = .85$ and $P = .30$, respectively—Tables 6 and 7).

The full description of these 4 patients with CSF leak which had successful management is as below:

Patient #1 was a 47-year-old man who underwent an endoscopic endonasal transclival and trans-right cavernous sinus skull

base approach for near-complete removal of clival chordoma and repair of intraoperative grade 3 CSF leak with abdominal fat graft, NSF, collagen sponge, and bioglue. The patient did well until POD#11 who developed CSF rhinorrhea after bouts of coughing. His CSF leak was successfully managed with placement of lumbar drainage for several days and antibiotics for 8 days although he did not have any signs of infection or meningeal irritation. The final CSF culture came back negative, and his new brain MRI with and without contrast showed only mild meningeal enhancement and no new pneumocephalus or lesion.

Patient #2 was a 27-year-old man who had endoscopic endonasal extended approach for gross total resection of cranio-pharyngioma with stalk preservation and did well initially after surgery except diabetes insipidus managed with desmopressin. He was seen in the clinic 1 week after surgery who was noted to have significant rhinorrhea consistent with a CSF leak. Consequently, he was returned to surgery at the same day and underwent an uneventful repositioning of his septal bone graft into the skull base defect and repositioning of the nasal septal flap. He did well since his reoperation with no further rhinorrhea.

Patient #3 was a 41-year-old man with an extensive poorly differentiated sinonasal intestinal type adenocarcinoma with a large intracranial extension who underwent endoscopic endonasal

TABLE 2. Nasoseptal Flap Enhancement on POD 1 and Follow-up MRI

Date of MRI	No enhancement	Partial enhancement	Complete enhancement
POD 1	10 (16%)	9 (14%)	45 (70%)
3-mo follow-up	0 (0%)	5 (8%)	59 (92%)

POD 1, postoperative day 1.

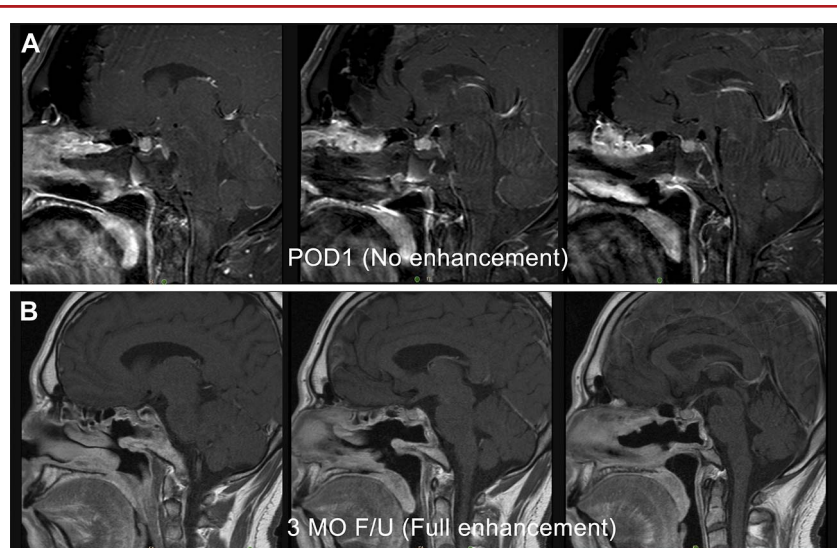


FIGURE 2. **A.** Early postoperative sagittal T1-weighted image postcontrast with fat suppression shows a C-shaped flap underlying the operative defect with no enhancement of the flap. **B.** 3-month follow-up MR imaging of sagittal T1-weighted postcontrast shows robust and thicker enhancement of the flap. POD 1, postoperative day 1.

transcribriiform and transthemoid debulking of tumor. He did well from his first surgery and was subsequently started on chemotherapy, but he developed a delayed CSF leak secondary to partial necrosis of the NSF postchemotherapy 38 days after his first surgery. Consequently, redo endoscopic endonasal repair of CSF leak with abdominal fat graft and other adjunctive reconstruction material as well as temporary CSF diversion with lumbar drain for 3 days was performed. He recovered well after his second surgery, and no further CSF leak had been noted since the repair.

Patient #4 was a 53-year-old man with a large petroclival, parasellar, and cerebellopontine angle meningioma, which was first debulked through left retromastoid approach and then after almost 40 days through an endonasal endoscopic transsellar and transclival approach with NSF repair of defect. However, he gradually developed hiccups, nausea, and vomiting after his second surgery with headache and fever, and after 12 days since his second surgery, without any obvious rhinorrhea, he was brought to the emergency department, where the clinical evaluation and head CT

scan confirmed significant pneumocephalus extending into the ventricular system and subarachnoid space of sylvian cistern, parasellar area, and prepontine cistern. So, with the impression of pneumocephalus related to intermittent CSF leak, he was returned to the operating room for repair of the skull base which was shown to have displaced NSF from its desired place over the defect and was subsequently elevated successfully over the defect again and sealed and augmented with the abdominal fat graft.

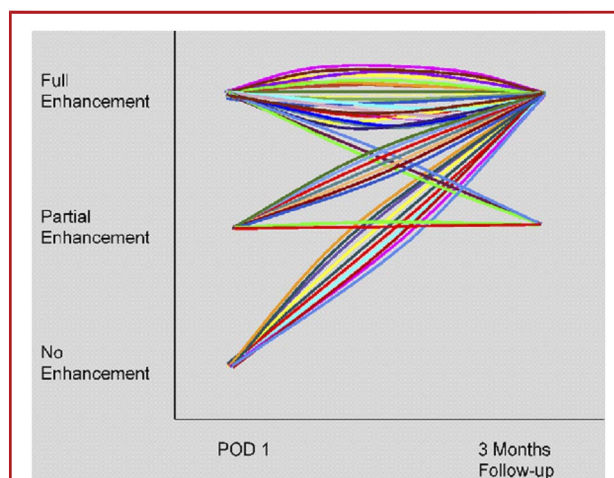


FIGURE 3. Graph representing change of nasoseptal flap enhancement between POD 1 and follow-up MRIs. POD 1, postoperative day 1.

TABLE 3. Change of Enhancement From Postoperative Day 1 to Follow-up MRI

Change	Frequency (%)
Increase	17/64 (27%)
Decrease	3/64 (5%)
No change	44 (69%)

TABLE 4. Intraoperative and Postoperative CSF Leak (n = 61/64)		
Intraoperative CSF leak grade	Frequency	Postoperative CSF leak
1	2/61 (3%)	0
2	3/61 (4.9%)	0
3	56/61 (91%)	4 (7.1%)

CSF, cerebrospinal fluid.

TABLE 6. Association Between Postoperative Day 1 Enhancement and CSF Leak		
	CSF leak	No CSF leak
No enhancement	1	9
Partial enhancement	1	8
Complete enhancement	2	43

CSF, cerebrospinal fluid.
P-value of association of postoperative day 1 enhancement and CSF leak is 0.85.

DISCUSSION

The vascularized NSF has been a cornerstone in decreasing the incidence of CSF leakage after endoscopic endonasal approach. It has been hypothesized that this is secondary to the preserved vascularity of the flap, which lends itself to a mucosal integration of the flap. Although this method of repair is widely used in clinical centers around the world, there has been a corresponding increase in the incidence of related complications. One failure mechanism is NSF necrosis. The vascularized NSF is supplied by the posterior nasoseptal arteries, which arise from the sphenopalatine artery that is the terminal branches of the internal maxillary artery. The intact vascular supply of the flap pedicle and perfusion can be confirmed intraoperative with Doppler ultrasound and postoperatively on MRI examination.⁹ It has been assumed that early postoperative MRI flap enhancement can predict flap necrosis, and early postoperative enhancement of the flap would correlate with a lower CSF leak rate.

Kang et al¹⁰ in 2009 described the enhancement patterns of NSFs on MRI in 10 patients at different time points after endonasal endoscopic approach, within 48 hours and delayed postoperative (after 3-7 months of surgery). They reported that 2 of the patients had minimal to no enhancement on early MRI,

with enhancement pattern changed in one of the patients on delayed imaging, showing that the MRI images can vary 3.

A limited number of studies have reported postoperative rates of NSF necrosis and its correlation with contrast-enhanced MRI in the early postoperative period^{7,10-12} with reported rate that varies between 0% and 1.3%. It is likely that there is under-reporting because this complication often goes unnoticed when the patient has a normal postoperative period. Adappa et al.¹³ presented a retrospective cohort study of 19 patients who underwent expanded endoscopic resections of skull base lesions, of which 3 developed postoperative CSF leaks, all 3 with enhancing vascular pedicles. By contrast, they had 3 patients without evidence of flap enhancement, none of whom developed a postoperative CSF leak. They did not notice an association between enhancement of the flap and lower CSF leak rate. Chabot et al⁷ presented a series of 601 patients with the use of NSF of 1285 endonasal endoscopic approach. A total of 141 returned to the OR for several causes, 49 of these patients for signs and symptoms of meningitis with suspicion of CSF leak, of which 8 (1.3%) were found to have NSF necrosis on re-exploration. The other 41 patients with viable NSF required no re-exploration. All patients with necrotic flaps had undergone contrast-enhanced MRI in the

TABLE 5. Demographic and Patient Details of Postoperative CSF Leak Group									
Patient	Age	Pathology	Approach	Early postoperative enhancement on MRI	3 months enhancement on MRI	Intraoperative CSF leak grade	Postoperative CSF leak presentation day	CSF leak proposed etiology	CSF leak repair technique
1	53	Meningioma	EE transclival, transsellar, and transplanum	Complete	Complete	3	6	Inadequate reconstruction (technical)	Surgical repair
2	47	Chordoma	EE transclival trans right cavernous sinus	No	Complete	3	10	Coughing spell	Lumbar drainage
3	41	Sinonasal adenocarcinoma	EE transcribriform	Partial	Complete	3	68	Immunosuppression including neutropenia	Surgical Repair
4	27	Craniopharyngioma	EE transsellar and transplanum	Complete	Complete	3	14	Coughing spell	Surgical Repair

CSF, cerebrospinal fluid; EE, extended endonasal.

TABLE 7. Association of CSF Leak and Postoperative Complete or Incomplete Enhancement

Enhancement	CSF leak	No CSF leak
Incomplete enhancement	2	17
Complete enhancement	2	43

CSF, cerebrospinal fluid.

P-value of association of CSF leak and POD 1 complete or incomplete enhancement is 0.3.

early postoperative period, and flap enhancement was absent in 7 of 8 cases. Only 1 case (12.5%) showed partial enhancement. In the viable NSF group, 38 patients (97%) showed complete enhancement of flap. Although only 2 of 8 patients (25%) with necrotic NSF presented with a CSF leak, all 8 of them displayed the signs or symptoms of meningitis. This study related the findings on MRI, appearance of the NSF on re-exploration, and CSF leak rates, highlighting the lack of correlation between them.

In our analysis, 4 patients (6.25%) had postoperative CSF leaks, all with grade 3 intraoperative CSF leak. Two of them had complete immediate enhancement, 1 partial enhancement, and 1 without enhancement. Like the aforementioned studies, we note that the lack of enhancement does not correlate with an increased risk of a postoperative CSF leak, $P = .85$ (3 category assessment) or 0.30 (2 category assessment).^{7,13}

In addition, we only noted one case with delayed flap necrosis due to chemotherapy regimen. This patient had partial flap enhancement at the immediate postoperative MRI.

There was a significant improvement of flap enhancement between immediate postoperative and 3-month MRI ($P = .002$). The percent of the patients who had complete flap enhancement increased from 70% (45 patients) to 92% (59 patients) between the early postoperative MRI and delayed 3-month MRI.

The variations of enhancement are difficult to correlate with flap failure because there is overlap in the imaging appearance of an enhancing flap and granulation tissue, particularly on the delayed scans. In addition, the mechanisms of CSF leakage are multifactorial and depend on the reconstruction viability as well as transient or sustained increased intracranial pressure and general systemic conditions, such as immunosuppression. Mechanisms of poor enhancement in the immediate phase include flap compression can be due to packing material, variable contrast load by technicians, and early flap hypoperfusion. Theoretically, the early postoperative images would be more helpful to evaluate the enhancement of the flap because there would be less time for granulation tissue to form. In our series, most patients developed complete enhancement at 3 months, and the lack of early enhancement was not predictive in persistent hypoenhancement at 3 months. There was no correlation with early or late flap enhancement and postoperative CSF leak development.

Limitations

The limitations of our study were the retrospective design of the study and low number of study samples that could potentially affect any causal relationship observed. A prospective study assessing postoperative imaging and flap viability would be helpful to further address the literature gap on this topic.

CONCLUSION

This study demonstrates that early postoperative MRI imaging of the NSF does not predict delayed flap perfusion or postoperative CSF leakage. Hence, the postoperative MRI findings should not be the sole factor to guide decisions for reoperation for skull base reconstruction. This decision should be taken in the context of the patient's clinical examination, intraoperative CSF leak grade, and repair construct.

Funding

This study did not receive any funding or financial support.

Disclosures

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article. Garni Barkhoudarian is a consultant to Cerevasc Inc. and Medexus Inc. Daniel F. Kelly receives royalties from Mizuho America.

REFERENCES

1. Lobo B, Heng A, Barkhoudarian G, Griffiths CF, Kelly DF. The expanding role of the endonasal endoscopic approach in pituitary and skull base surgery: a 2014 perspective. *Surg Neurol Int.* 2015;6:82.
2. Hadad G, Bassagasteguy L, Carrau RL, et al. A novel reconstructive technique after endoscopic expanded endonasal approaches: vascular pedicle nasoseptal flap. *Laryngoscope.* 2006;116(10):1882-1886.
3. Kassam AB, Thomas A, Carrau RL, et al. Endoscopic reconstruction of the cranial base using a pedicled nasoseptal flap. *Neurosurgery.* 2008;63(1 Suppl 1):ONS44-ONS53.
4. Conger A, Zhao F, Wang X, et al. Evolution of the graded repair of CSF leaks and skull base defects in endonasal endoscopic tumor surgery: trends in repair failure and meningitis rates in 509 patients. *J Neurosurg.* 2019;130(3):861-875.
5. Lavigne P, Faden DL, Wang EW, Snyderman CH. Complications of nasoseptal flap reconstruction: a systematic review. *J Neurol Surg B Skull Base.* 2018;79(Suppl 4):S291-S299.
6. Selber JC, Kurichi JE, Vega SJ, Sonnad SS, Serletti JM. Risk factors and complications in free TRAM flap breast reconstruction. *Ann Plast Surg.* 2006;56(5):492-497.
7. Chabot JD, Patel CR, Hughes MA, et al. Nasoseptal flap necrosis: a rare complication of endoscopic endonasal surgery. *J Neurosurg.* 2018;128(5):1463-1472.
8. Esposito F, Dusick JR, Fatemi N, Kelly DF. Graded repair of cranial base defects and cerebrospinal fluid leaks in transsphenoidal surgery. *Oper Neurosurg.* 2007;60(4 Suppl 2):ONS-295-ONS-304.
9. Learned KO, Adappa ND, Loevner LA, Palmer JN, Newman JG, Lee JY. MR imaging evaluation of endoscopic cranial base reconstruction with pedicled nasoseptal flap following endoscopic endonasal skull base surgery. *Eur J Radiol.* 2013;82(3):544-551.
10. Kang M, Escott E, Thomas A, et al. The MR imaging appearance of the vascular pedicle nasoseptal flap. *AJNR Am J Neuroradiol.* 2009;30(4):781-786.
11. Soudry E, Psaltis AJ, Lee KH, Vaezafshar R, Nayak JV, Hwang PH. Complications associated with the pedicled nasoseptal flap for skull base reconstruction. *Laryngoscope.* 2015;125(1):80-85.

12. Thorp BD, Sreenath SB, Ebert CS, Zanation AM. Endoscopic skull base reconstruction: a review and clinical case series of 152 vascularized flaps used for surgical skull base defects in the setting of intraoperative cerebrospinal fluid leak. *Neurosurg Focus*. 2014;37(4):e4.
13. Adappa ND, Learned KO, Palmer JN, Newman JG, Lee JY. Radiographic enhancement of the nasoseptal flap does not predict postoperative cerebrospinal fluid leaks in endoscopic skull base reconstruction. *Laryngoscope*. 2012;122(6):1226-1234.

Acknowledgments

Author Contributions: Study Design/Concept: GB, DFK, CG, MP. Data Collection: MP, AM, KA, RJM. Data Analysis/Interpretation: MP, AM, KA, RJM. Manuscript Writing/Critical Revisions: All authors. Final Approval of Manuscript: GB. Administrative/Technical/Material Support: GB, DFK. Overall Study Supervision: GB, DFK.