A New Technique for the Endoscopic Reconstruction of Skull Base Defects Using Multiple-balloon Catheters

Asuka Fujino,1 Yoji Tanaka,1 Daisu Abe,1 Yosuke Ariizumi,2 Motoki Inaji,1 and Taketoshi Maehara1

1Department of Neurosurgery, Tokyo Medical and Dental University, Tokyo, Japan
2Department of Head and Neck Surgery, Tokyo Medical and Dental University, Tokyo, Japan

Abstract

Cerebrospinal fluid (CSF) leakage is a major complication following endoscopic endonasal skull base surgery. Various skull base reconstruction methods are available, and the use of a vascularized nasoseptal flap (NSF) in skull base reconstruction has greatly contributed to a decrease in the CSF leak rate. A balloon catheter such as a sinus balloon or a Foley catheter is often used to support an NSF; however, in cases wherein nasal and/or paranasal structures supporting the balloon are lacking following the surgery, the NSF is not properly fixed and postoperative CSF leak may occur. Here we introduce a new technique of using multiple-balloon catheters to fix an NSF in such cases and provide the results of our analysis of the new technique’s efficacy. Eight patients who underwent endonasal endoscopic surgery for the following cases were included: olfactory neuroblastoma (n = 6), recurrent craniofacial meningioma (n = 1), and recurrent chordoma (n = 1). After tumor resection, multilayered reconstruction with vascularized NSF was performed. Given that the Foley catheter was not stable to fix the flap in each case, we used an additional nasal catheter to support the Foley catheter. No complications such as postoperative CSF leak and necrosis of the vascularized flap were observed. These results suggest that the multiple-balloon catheter technique is a useful method for fixing the NSF to the skull base even when nasal cavity structures are missing due to surgical removal.

Keywords: neuroendoscopy, skull base reconstruction, balloon catheter, cerebrospinal fluid leak

Introduction

The development of the endoscopic endonasal approach has contributed to better results in neurosurgery and has helped decrease the damage to tissues such as nerves and vascular structures caused by retraction. The approach can also reach deep lesions with better visualization and illumination compared to that of open surgery.1-3 Thus, the surgical indications for the use of endoscopic endonasal surgery have gradually expanded.3,4

Cerebrospinal fluid (CSF) leakage, which sometimes induces meningitis and subdural hematoma, is a major complication of endoscopic skull base surgeries.5 Various multilayered skull base reconstruction techniques have been developed to prevent CSF leakage.6-7 The use of a vascularized nasoseptal flap (NSF) has greatly reduced the CSF leak rate to 4%-7% of the cases studied.8 A balloon catheter such as a sinus balloon or a Foley catheter is used to physically support the NSF, and the balloon is usually fixed by rigid structures such as the sphenoid bone.2,3 However, if surrounding constructions are lacking due to their removal during the surgery, the balloon catheter does not fix the reconstruction materials properly.

In such cases, we have introduced an additional balloon catheter (Epistat nasal catheter, Medtronic, Minneapolis, MN, USA) to fix the balloon catheter at the appropriate position (Fig. 1). The Epistat nasal catheter was originally used for the epistaxis management of the nasal cavity. The objective of this technical report was to present our new technique for the endoscopic reconstruction of skull base defects using multiple-balloon catheters. This study was approved by the Institutional Review Board of the Tokyo

Received May 13, 2022; Accepted June 24, 2022

Copyright © 2022 The Japan Neurosurgical Society
This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives International License.
Medical and Dental University (M2021-402).

Case Report

A 50-year-old man with no remarkable past medical history visited an otorhinolaryngologist complaining of nose obstruction. The magnetic resonance imaging showed a mass within the right nasal cavity and the ethmoid sinus (Fig. 2). A biopsy gave the histologic diagnosis of olfactory neuroblastoma. Then, the patient was referred to our hospital to undergo surgery.

The tumor was resected by an extended endoscopic endonasal approach. After the tumor resection (Fig. 3a), we first placed a free fascia lata graft, which was obtained from a femur, intradurally as the first layer of skull base reconstruction, and we then sutured the dura and graft (Fig. 3b). Another fascia lata graft was laid in the epidural space, followed by a vascularized NSF (Fig. 3c). Fibrin glue was applied to fix the materials at each step. Given that most of the nasal structures were also removed, it was difficult to fix a Foley catheter to assist the NSF in staying at the proper position (Fig. 3d). Therefore, we introduced the Epistat nasal catheter to support the Foley catheter. The inflation of each balloon was monitored under endoscopic guidance while paying close attention to avoid moving the grafts (Fig. 3e). A lumbar drain was not placed after surgery.

The postoperative computed tomography (CT) scan demonstrated that the Epistat nasal catheter supported the Foley catheter (Fig. 4). The patient began to walk 2 d after the surgery, and the balloons were removed 5 d post-surgery. No CSF leak was observed before or after the removal of the balloons. After the patient’s surgery, he received radiotherapy: 66 Gy in 33 fractions. During his regular follow-up at our hospital, no complications have been observed and no recurrence has been detected.

We used this multiple-balloon catheter technique in eight cases, including the above case, between April 2018 and July 2021. The eight cases comprised four males and four females, whose ages ranged from 25 to 67 years. There were six patients with olfactory neuroblastomas at Kadish stage A, one with a recurrent craniofacial meningioma, and one with a recurrent chordoma. We investigated the postoperative complications, including CSF leaks, infection, and necrosis of a vascularized flap. All eight patients were mobilized on postoperative day (POD) 2 or 3 (mean 2.1). Catheters were removed on POD 4 to 7 (mean 5.5). There were no complications including CSF leak, infection, and necrosis of the vascularized flap. No patients felt discomfort related to the balloon catheters. Patients were followed up for an average of 14.5 months, and no complications have been revealed.

Discussion

Our retrospective analysis of eight cases demonstrated that the multiple-balloon catheter technique was useful for endonasal endoscopic skull base reconstruction and prevented postoperative CSF leakage in patients lacking the nasal structures to support a balloon catheter.

Although the endonasal endoscopic approach is widely used for skull base surgeries, this approach has a risk of CSF leakage, which can lead to fatal complications such as meningitis, encephalitis, subdural hematoma, and intracranial hypotension. Therefore, it is important to reduce the incidence of CSF leak after surgeries. A postoperative CSF leak rate of 30%-40% at early stages after the use of the endoscopic approach has been reported. The invention of the vascularized NSF provided a revolutionary decrease in the CSF leakage rate to <5%.

Vascularized tissue allows faster healing process, and proper tissue sealant plays a key role in promoting skull base epithelization. To support vascularized flaps directly, a balloon catheter such as a Foley catheter or a sinus balloon is placed by fixation with bone structures such as sphenoid sinus walls. However, a balloon or a catheter does not work properly in cases in which nasal structures have been destroyed by a tumor or removed by surgical resection.

We used two balloons, a Foley catheter and the Epistat nasal catheter for such cases. We have initially tried to use two Foley catheters to support the flap, but the balloons slipped each other and could not fix the balloon at the appropriate position. The Epistat nasal catheter has two silicon balloons of large ellipsoid shape and small spherical shape. The large balloon is placed in the nasal cavity to control epistaxis. The small balloon is placed at the poste-
Fig. 2 Preoperative coronal and axial T2-weighted magnetic resonance (MR) images (upper row) and gadolinium-enhanced coronal and axial T1-weighted MR images (lower row). The tumor occupied the right nasal cavity and the right ethmoid sinus without intracranial extension.

rior nasal aperture to stabilize the catheter and to prevent nasal blood from leaking out to pharynx. These balloons are inflated with maximum of 30 mL saline and 10 mL saline for each balloon. The main balloon of the Epistat nasal catheter is large enough to fill in the nasal cavity, and its ellipsoid shape may enlarge the contact area between the balloons of the Foley catheter and the Epistat catheter. Thus, it was speculated that the use of a combination of the Foley catheter and the Epistat catheter is suitable to fix the Foley catheter in the desired position without slipping. No CSF leak occurred in the eight patients, and no complications were observed. These results suggest that a balloon catheter supported by the Epistat nasal catheter fixed the vascularized flap properly, and CSF leak was prevented by promoting the epithelization of the skull base.

Postoperative CSF leakage also results in a longer hospital stay, an increased risk of the need for reoperation for repairs, disruption of adjunctive therapies, and higher medical costs. Thus, techniques to avoid postoperative CSF leaks are necessary. None of the patients in the present study experienced CSF leak, and all of them were able to be mobilized early and be discharged on the date planned before the surgery. Therefore, we propose that the multiple-balloon technique described herein can be a treatment option for skull base reconstruction. Moreover, no patients had a complaint about the placement of the two balloons in their nostrils for several days. We suspect that the multiple-balloon technique does not lead to a decline in the patients’ quality of life during their hospital stay.

Necrosis of an NSF is one of the complications that can cause CSF leak. This can occur when a vascularized flap receives too much pressure from a fixed balloon. It interferes with the blood supply to the NSF that is usually vascularized by the sphenopalatine artery. We placed the Foley catheter and the Epistat nasal catheter under monitoring by endoscopic inspection, with attention to proper inflation. Then, 5 mL saline was injected into the Foley catheter, and 10 mL saline was injected into the balloon of the Epistat nasal catheter placed in the nasal cavity. In all of the cases we encountered, regular follow-up consultations by the otorhinolaryngologists demonstrated the absence of
Fig. 3  Intraoperative case images. (a) The dura in the olfactory groove was removed. (b) Fascia lata was inserted inside the dura and sutured. (c) A nasoseptal flap was placed on the dura. (d) We tried to apply a Foley catheter to fix the nasoseptal flap, but the Foley catheter was not stable, given that the structures in the nostril were removed. (e) The Epistat nasal catheter supported the Foley catheter, and the nasoseptal flap was properly fixed.

Fig. 4  (a) Postoperative sagittal computed tomography (CT) image showing the Epistat nasal catheter (arrow) supporting the Foley catheter (arrowhead). (b) Schematic drawing of the multiple balloons in the nasal cavity. The balloon of Foley catheter was placed immediately below the flap. The main balloon of the Epistat catheter was placed to stabilize the Foley catheter, and the other balloon was placed at the posterior aperture to fix the Epistat catheter itself.

NSF necrosis.

For the placement of these balloons with proper pressure in skull base reconstruction, it is important to use an endoscope to check whether the pressure is appropriate. If the pressure is too much, not only is it possible that the NSF becomes necrotic but the balloons may also rupture by getting caught on the sharp edges of the sinus walls. If the pressure is not high enough, the flap is not fixed, and the healing process will be delayed.

The multiple-balloon technique for skull base reconstruction was shown to be particularly useful in the cases in which a tumor had destroyed structures of the skull...
base and nasal cavity and those in which the surgery requires extensive resection of surrounding tissue. In addition to the application of the multiple-balloon technique in olfactory neuroblastoma, craniofacial meningioma and chordoma which we encountered in this study, this technique could also be useful in cases of malignant tumors in a nostril or paranasal sinus area with intracranial extension. To explore this possibility, the multiple balloon technique should be considered in more patient cases.

In conclusion, dural closure is important in skull base surgeries to prevent postoperative CSF leakage. The multiple-balloon technique is useful for skull base reconstruction in cases in which nasal cavity structures are defective or absent due to tumor extension or surgical resection. Further research is awaited to clarify the validity and the appropriate indications for the use of this new technique.

Conflicts of Interest Disclosure
All authors have no conflict of interest to declare.

References
1) Sarría-Echegaray P, Carnevale C, Tomás-Barberán M, et al.: Endoscopic reconstruction of large anterior skull base defects with opening of the sellar diaphragm. Experience at a tertiary level university hospital. J Laryngol Otol 133: 889-894, 2021
2) Horiguchi K, Murai H, Hasegawa Y, Hanazawa T, Yamakami I, Saeki N: Endoscopic endonasal skull base reconstruction using a nasal septal flap: Surgical results and comparison with previous reconstructions. Neurosurg Rev 33: 235-241, 2010
3) Hannan CJ, Kelleher E, Javadpour M: Methods of skull base repair following endoscopic endonasal tumor resection: A review. Front Oncol 10: 1614, 2020
4) Toda M: Endoscopic endonasal skull base approach. Jpn J Neurosurg (Tokyo) 24: 770-779, 2015
5) Umamaheswaran P, Krishnaswamy V, Krishnamurthy G, Mohanty S: Outcomes of surgical repair of skull base defects following endonasal pituitary surgery: A retrospective observational study. Indian J Otolaryngol 71: 66-70, 2019
6) Jolly K, Okonkwo O, Tsermoulas G, Ahmed SK: A novel technique for endoscopic repair of large anterior skull base defects: The PDS wrap. Am J Rhinol Allergy 34: 70-73, 2019
7) Amit M, Abergel A, Gil Z: Tetrahedral silicon balloon for endoscopic skull base reconstruction. Laryngoscope 122: 973-976, 2012
8) Hadad G, Bassagasteguy L, Carrau RL, et al.: A novel reconstructive technique after endoscopic expanded endonasal approaches: Vascular pedicle nasoseptal flap. Laryngoscope 116: 1882-1886, 2006
9) Kassam AB, Gardner PA, Snyderman CH, Mintz A, Carrau R: Expanded endonasal approach: Fully endoscopic, completely transnasal approach to the middle third of the clivus, petrous bone, middle cranial fossa, and infratemporal fossa. Neurosurg Focus 19: E6, 2005
10) Xuejian W, Fan H, Xiaobiao Z, et al.: Endonasal endoscopic skull base multilayer reconstruction surgery with nasal pedicled mucosal flap to manage high flow CSF leakage. Turk Neurosurg 23: 439-445, 2013
11) El-Banhawy OA, Halaka AN, Altuwaijri MA, Ayad H, El-Sharnoby MM: Long-term outcome of endonasal endoscopic skull base reconstruction with nasal turbinate graft. Skull Base 18: 297-308, 2008
12) Mortuaire G, Vandevelle S, Assaker R, Chevalier D: Endoscopic repair of anterior or middle skull base cerebrospinal fluid leaks after tumour resection. Eur Ann 129: 77-81, 2012
13) Kessler RA, Garzon-Muvdi T, Kim E, Ramanthan M, Lim M: Utilization of the nasoseptal flap for repair of cerebrospinal fluid leak after endoscopic endonasal approach for resection of pituitary tumors. Brain Tumor Res Treat 7: 10-15, 2019

Corresponding author: Yoji Tanaka, MD, Ph.D
Department of Neurosurgery, Tokyo Medical and Dental University, 1-5-45 Yushima, Bunkyo-ku, Tokyo 113-8510, Japan.
e-mail: tanaka.nsrg@tmd.ac.jp