Analysis of Skull Base Reconstruction in Huge Cranial-Nasal Communication Defect According to the Reconstruction Method: Reverse Temporalis Muscle and Free Tissue Transfer Flap

KONG SREY NUCH

The Graduate School
Yonsei University
Department of Medicine

Analysis of Skull Base Reconstruction in Huge Cranial-Nasal Communication Defect According to the Reconstruction Method: Reverse Temporalis Muscle and Free Tissue Transfer Flap

A Master's Thesis Submitted
to the Department of Medicine
and the Graduate School of Yonsei University
in partial fulfillment of the
requirements for the degree of
Master's of Medical Science

KONG SREY NUCH

June 2024

This certifies that the Master's Thesis
of KONG SREY NUCH is approved.

Thesis Supervisor	HONG, Jong Won
Thesis Committee Member	SONG, Seoung Yong
Thesis Committee Member	CHO, Hyung-Ju

The Graduate School
Yonsei University
June 2024

ACKNOWLEDGEMENTS

When I first started at Yonsei University, I was frustrated and worried at the same time because of living away from my family and studying another language. However, from the very first meeting with the head of my department and especially my supervisor, he introduced me to all the professors and showed me around Severance Hospital, those feelings were gone. He then asked senior residents who also enrolled in the same graduate school to help me with the course enrollment. He also allowed me to observe all of his operations and his outpatient clinic and I have learned many things from him.

During my research study, I would like to express my deepest respect to my supervisor, Professor HONG, Jong Won, MD, Ph.D.; Plastic Surgeon of the Plastic and Reconstructive Surgery Department, Severance Hospital, for his support and encouragement. His invaluable advice and feedback have greatly helped and inspired me to complete the course of my study. He is so warm and kind-hearted. I have never felt stressed when we met. He taught and explained to me so well about his surgical experiences of skull base reconstruction and I also had a chance to see the operation directly for 4 cases so it made me more understandable. Additionally, I am profoundly thankful to my thesis committee members, Professor SONG, Seoung Yong, a Plastic surgeon, and Professor CHO, Hyung-Ju, an Ear-Nose-Thorat Surgeon for the insightful advice and helpful feedback since my first research study plan, preliminary exam, and final defense.

Nobody has been more important to me throughout this journey than my family. I am extremely grateful to my parents for their caring, unconditional love, and sacrifices in educating, supporting, and allowing me to be here alone from my home country, Cambodia. I must thank my younger sister and brother for their unfailing emotional and continuing support and motivation. All of my family members have always been a major source of support throughout my life. This journey would not have been possible if it was not for them. And I dedicate this milestone to them.

Spring 2024
KONG SREY NUCH

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Analysis of Skull Base Reconstruction in Huge Cranial-Nasal Communication Defect According to the Reconstruction Method: Reverse Temporalis Muscle and Free Tissue Transfer Flap

Purpose: Considering the type of surgical methods in skull base reconstruction of the dural defect can be significantly challenging for reconstruction surgeons after tumor resection. Over the last decade, most surgeons have modified reconstructive methods to minimize the complication of CSF leaks, and ascending infection by blocking enough of the communication between the cranium and nasal cavity. The goal of the study was to review and describe the origin of the tumor, pathologic lesion, defect size, defect structure, and the involvement space. Especially, analyzing our experience with the reconstruction methods of the reverse temporalis muscle and free tissue transfer flap will suggest the directions in surgical planning available reconstruction methods to reconstruct huge cranial-nasal communication defects.

Materials and Methods: We retrospectively studied 17 patients who underwent skull base reconstructive surgery and were hospitalized in the plastic and reconstructive surgery department at Severance Hospital between 2017 January to 2023 December. The pathologic lesion involved both the cranial and nasal cavity including tumor and infection. After the removal of the pathologic lesion, the cranial defect mostly extended to the frontal sinus and cribriform plate. The defect made a huge cranial-nasal communication. To cover the defect, we selected and performed the reconstruction method by using a reverse temporalis muscle flap, and a free tissue transfer flap. Then we described the origin of the defect, pathology, radiology studies, defect size, defect structure, and the involvement space. Especially, the reconstruction method in the operation field and the outcome were also analyzed and reviewd in this study.

Result: There were 4 cases of benign tumors, 10 cases with malignant tumors, and 3 cases of mucocele or infection are the directed reasons for skull base reconstruction. The defect

lesion was originally from the nasal cavity in 13 cases and from the cranium in 4 cases. The estimated defect size of the cranial-nasal communication area (cm^2) was 21.9 ± 9.3. There were 8 cases were treated with a temporalis muscle local flap (reverse temporalis muscle flap bilateral 6 cases, reverse temporalis muscle flap unilateral 1 case, and extended galeal flap with temporalis muscle flap bilateral 1 case), and 9 cases of free tissue transfer flap reconstructions using anterolateral thigh flap (ALT flap). There were no major complications in every case such as ascending infection, CSF leakage, and flap failure. Postoperative radiologic imaging was taken and showed that the flaps were well-maintained in all patients.
Conclusion: Successful reconstruction methods were performed using the temporalis muscle and free tissue transfer flap in the huge cranial-nasal communication defect. These two methods were effective in maintaining the barrier and blocking the communication between the sterile intracranial contents and the contaminated nasal cavity.

Keywords: Cranial-Nasal Communication, Skull Base, Reconstruction

I. INTRODUCTION

The huge cranial-nasal communication defect involves the dura, cribriform plate, sphenoid sinus, ethmoid sinus, frontal sinus posterior wall until the sinus floor opens, bilateral frontonasal duct all open, and creates the cranial-nasal cavity communication.[1-3] Due to the defect location, the risk of infection should be paid attention after the skull base reconstruction. In addition, reducing the complication rate of cerebral spinal fluid (CSF) leakage after tumor resection is also essential to be successful in patient recovery.[4-6] So, considering the type of reconstruction methods for a huge defect of skull base reconstruction can be a significantly challenging therapeutic due to the complexity of the anatomy for professional surgeons that require close cooperation between both neurosurgeon and ear-nose-throat (ENT) surgeon for tumor resection. Generally, when the defect invades the intracranial area and is inadequately close, a high rate of morbidity and mortality commonly occurs. It has been marked with minimal bother to the defect area in the ability to remove the lesions and to decrease the postoperative complications.[7-11]

The reconstructive goals carefully consider repairing the dural defect and eliminating the dead space to prevent postoperative complications such as CSF leakage, chronic inflammation, ascending infection, and flap failure caused by the imperfect closure of the dural defect.[1,6,12-17] In recent progress for some cases of large volume, local flap or free tissue vascularized transfers flap following the tumor resection is always considered. Both flaps can cover a huge defect with excellent surgical outcomes and low complication rates when the pericranial or galea flap alone is absent or of poor quality due to prior surgery or radiation.[1,3,9,18,19] local vascularized flap or free tissue vascularized transfer flap can provide adequate tissue bulk as needed to seal the intracranial space from the subjacent cavity and restore complex craniofacial defects with a reliable and rich blood supply that improves wound healing and decreases hospitalization.[3,7,11]

To achieve this, creating a multilayer to seal a watertight closure of the dura, closing the dead space, and overlying vascularized tissue is necessary to enhance primary healing of the intracranial wound and to prevent postoperative complications, the associated mortality, and increased intracranial pressure when the dura is resected.[2,7,8,12,20-23] Thus, skull base reconstruction also provides more predictable, functional, and aesthetic results that help to reduce the death rate and facilitate the rehabilitation process.[2,7,18] The reconstruction methods can be performed in a way to remove both abnormalities noncancerous and cancerous growth, and post-operative complications of previous surgery and trauma patients.[6,7,21,24]

In this study, depending on defect size, defect structure, the involvement space, presence of infection, and surgeon experience, the selective reconstruction method was a reverse temporalis muscle local flap and free tissue transfer flap. The pathologic lesion was originally both from the cranium and the nasal cavity. The location and the volume of the defect are the important factors that can determine the extension of cranial-nasal communication. The lesion of the nasal cavity may extend to the anterior cranial fossa through the base of the skull and lead to intracranial extension with the involvement of the dura and brain.[2,3,7,8,12,20,21,25]

We analyzed and reviewed our experiences using these two reconstruction methods with excellent surgical outcomes. The reconstruction method has also been described by other studies with similar success.

II. MATERIALS AND METHODS

2.1. Study Cohort and Data Collection

2.1.1. Study Population

We retrospectively studied based on a review of the hospital chart of 17 patients who underwent skull base reconstruction and were hospitalized in the plastic and reconstructive surgery department at Severance Hospital between 2017 January to 2023 December.

2.1.2. Ethical Approval

This study was approved by The Institutional Review Board (IRB) No.4-2024-0234 of Severance Hospital, Yonsei University Health System.

2.1.3. Study Design

(A) Patients

(1) Patients with skull base surgery

(2) Large defect

- The posterior table of the frontal sinus was completely removed
- The frontonasal duct was entirely opened to the cranium
- The galeal flap was also removed and the bone substitute was unable to seal up the skull base properly

(B) Skull base reconstruction flap

- Reverse temporalis muscle flap
- Free tissue transfer flap
- At least a 3-month follow-up

2.1.4. Medical Record and Chart Review

The patient's medical records were reviewed for demographic information including age at the time of surgery and sex. The directed reason for the skull base reconstruction, the origin of the defect, pathologic lesion, radiology studies, defect size, defect structure, and involvement space were evaluated, and reconstruction methods in the

operation field were described. Charts also identified total operation time, hospital stay, and follow-up date. Lastly, particular attention was paid to postoperative complications such as CSF leakage, ascending wound site infection, and bone absorption.

2.2. Operation Method

All the reconstruction methods were done by a single plastic surgeon in surgical pioneering using a multidisciplinary team in collaboration between both neurosurgeon and ear-nose-throat (ENT) surgeon for tumor resection and during all stages of treatment. We select reconstruction methods to cover the huge cranial-nasal communication defect by using the reverse temporalis muscle flap and free tissue transfer flap.

2.2.1. Surgical Flow

Surgery in this area normally takes a long time. Sometimes it can be late and exhausting. The surgical team that performs the reconstruction should differ from the team that removes the defect lesion (Table 1).

Table 1. Surgical workflow

Team sequence	Operation
PS team	Making incision, preparing flap and vessels
NS team	Performing lesson removal in the cranium
ENT team	Performing lesson removal in the nasal cavity
PS team	Main reconstruction

2.2.2. Surgical Technique

We used 2 kinds of reconstruction methods. One was the reverse temporalis muscle flap and the other was the free tissue transfer flap. We already performed the same reconstruction methods which were already well-known and published. [4,6,26,27]

(A). Reverse Temporalis Muscle Flap

Preparation PS team

- The incision line was designed with a marking pen.
- We used the doppler ultrasound to mark the superficial temporal artery.
- Then, bi-coronal was incised from the upper to the ear helix to the apex of the skull. The scalp flap was elevated down to the level of the supraorbital rim.
- The galea flap was elevated from the skull and was used to line the skull base to create the anterior floor**.**
- The vessel supply of the flap from the supraorbital and supratrochlear vessel must be carefully considered when rotating the flap so as not to alter the blood supply.

Defect Resection NS and ENT team

- The craniotomy and tumor removal in the cranium was done by a Neurosurgeon.
- The removal of the tumor in the nasal cavity was done by an ENT surgeon.

Main Reconstruction PS team

- After the wide excision, there was noted a huge cranial-nasal skull base defect (Fig 1B).
- The galeal flap was put to cover the defect primarily at the frontal sinus (Fig 1C).
- Before inserting the flap, the bone defect margin was trimmed to prevent irritation.
- In the temporal area, the bilateral temporalis muscle flap was identified and preserved above the insertion site. Then, the reverse temporalis muscle flap was transposed to cover the remaining defect over the galeal flap to obliterate the communication between the brain and nasal cavity (Fig 1D).
- Previously removed the frontal bone was carved and placed into the proper position.
- Flaps were fixed on the outer table of the frontal bone with nylon #3-0 suture and fixed each other with vicryl #3-0. And scalp was repaired with vicryl #4-0 and a skin stapler. Two 200cc negative drains were inserted from each side (Fig1).

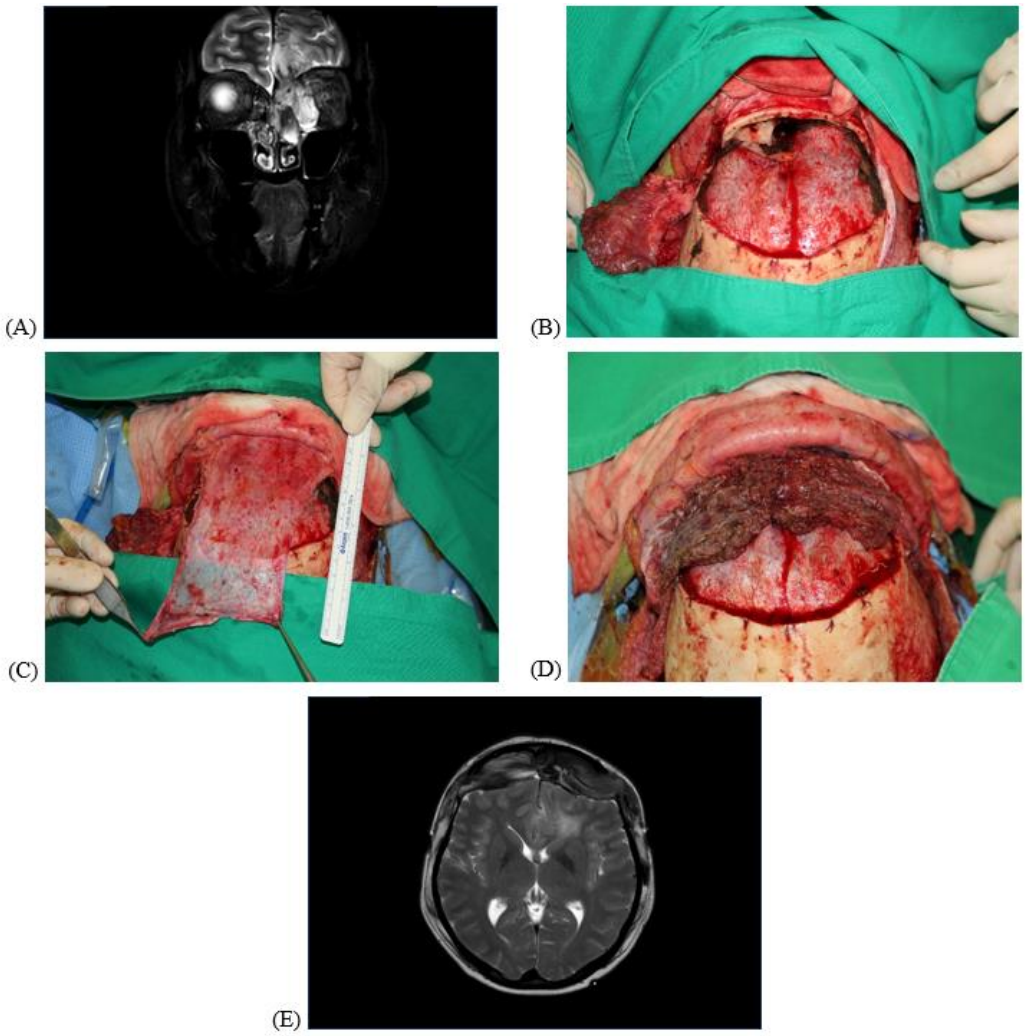

Figure 1. Reverse temporalis muscle flap for skull base reconstruction on a 41-year-old female. (A) The extrapleural solitary fibrous tumor was extended in the cranium, orbit, and nasal cavity in the T2 MRI image. (B) Large cranio-nasal communication after tumor ablation. (C) Galeal flap was also used for the skull base lining. (D) Bilateral reverse temporalis muscle flap in-setting. (E) Reverse temporalis muscle flap block and fill up the defect site in T2 MRI image on postoperative 3 weeks.

(B). Free Tissue Transfer (ALT Flap)

Preparation PS team

<Recipient Site>

- The superior temporal artery was marked by doppler ultrasound.
- We designed a bi-coronal incision along the direction of the superior temporal artery.
- The bi-coronal incision was made and carefully dissected of the superficial temporal artery, and vein to preserve for anastomosis (Fig 2B).

Defect Resection NS and ENT team

- A craniectomy in the frontal area was done by the Neurosurgeon team.
- The turbinectomy widening of the sphenoid sinus under the endoscope was done by the ENT team. A huge cranial-nasal defect was noted, and the cranium was connected to the nasal cavity (Fig 2C).

Main reconstruction PS team

<Donor Site>

- The size anterolateral thigh flap was designed according to the defect area as big as possible approximately 14 x 6cm on the right thigh.
- The flap was carefully elevated, and the rectus femoris muscle and vastus lateralis were exposed. Further dissection was done along the avascular plane of these two muscles.
- Then, the descending branch of the lateral circumflex femoral artery and its vena comittantes were identified and carefully preserved with lidocaine-soaking gauze.
- The flap elevation was completed, and the pedicle of ALT was carefully prepared. To reduce the pedicle volume, the subcutaneous layer was carefully trimmed, and de-epithelization was done (Fig 2D).
- After trimming, the micro-anastomosis was made, and the resected frontal bone

was considered burring and inserted to fix it at the point where the flap could be pressed by a plastic surgeon (Fig 2E).

- The flap was fixed to the recipient site with vicryl #3-0 suture. One silastic drain was inserted into the right temporal area, and a total of three hemovacs were inserted as stated above.
- The bi-coronal repair was done with vicryl #3-0, nylon #4-0, and the skin stapler. The forehead defect was closed with #4-0 nylon. The donor site's primary repair was done on the donor site with #3-0 vicryl, skin stapler & and #4-0 nylon. Aseptic compressive dressing was done. The patient tolerated well during the operation and was sent to the ICU in good condition (Fig2).

2.2.3. Post-Operative Care

For both reconstruction methods after the operation, the head of the patient was elevated at 30 degrees with a continuous irrigation system of the right nostril to minimize the ascending infection. The patient was informed to rigorously avoid coughing and sniffing. A radiologic study was done after the operation to check the complete blockage between the cranium and nasal cavity, and flap survival. The postoperative complications were observed through the MRI and CT scan such as CSF leakage, hematoma, and ascending infection. The postoperative radiologic study was taken for follow-up data normally every 6 months.

2.2.4. Statistical Analysis

All data collection was recorded and extensively analyzed in the Microsoft Excel version.

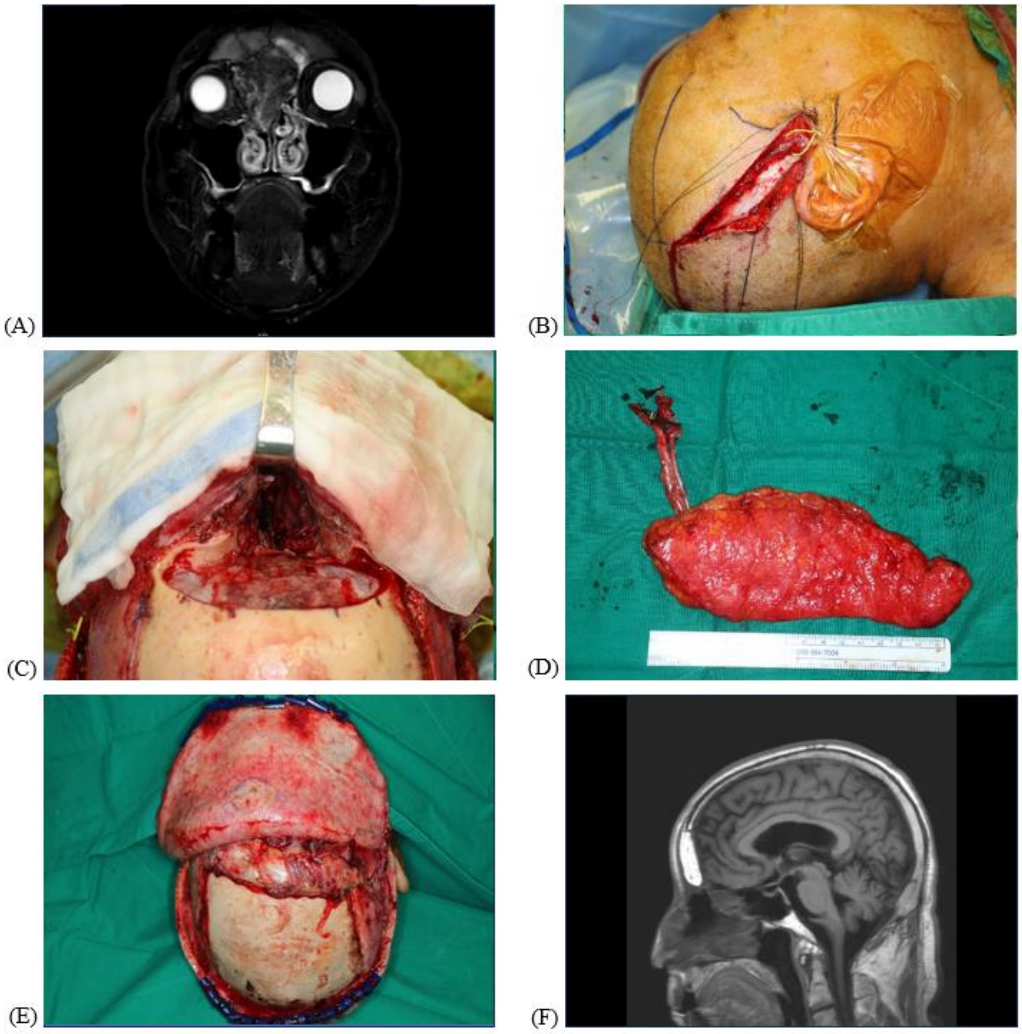

Figure 2. Free tissue transfer flap (ALT flap) for skull base reconstruction on a 67-year-old male. (A) Metastatic renal cell carcinoma was extended in the cranium, orbit, and nasal cavity in the T2 MRI image. (B) Superficial temporal artery and vein were identified and prepared. (C) Large cranio-nasal communication after tumor ablation. (D) ALT flap was harvested. The epidermis must be removed. (E) ALT free flap block and filled the defect site. (F) T2-weighted MRI 3 weeks after surgery.

III. RESULTS

3.1. Diagnosis

A total of 17 of the patients who underwent skull base reconstructions were studied and analyzed in the plastic and reconstructive surgery department at Severance Hospital. There were 12 men and 5 women, with an average age of 55:39 years. (Table 2).

Table 2. Patient characteristics (n =17) undergoing skull base reconstruction

Sex	M	F
Age (average)	55	39
Age (range)	30-75	26-63
Total (n)	12	5

4 patients had benign tumors while 10 patients of malignant tumors. The most common malignant tumors were squamous cell carcinoma (n=5), and olfactory neuroblastoma (n=2). 3 cases underwent one previous operation and had the complication of mucocele/infection which was the direct reason for them to receive the skull base reconstruction for their secondary operation. (Table 3).

Table 3. Direct reason for skull base reconstruction

Direct reason for skull base reconstruction		n	Total
Benign	Meningioma	1	
	Schwanomma	1	
	Extrapleural solitary fibrous tumor	1	
	Inverted papilloma	1	4
Malignancy	Squamous cell carcinoma	5	
	Olfactory neuroblastoma	2	

	Adenocarcinoma	1	
	Metastatic cancer (renal cell carcinoma)	1	
	Spindle cell sarcoma	1	10
Others	Mucocele/infection	3	3
		Total	17

Patients presented with different tumor pathology leading to different sizes and the qualities of skull base reconstruction (Table 4).

Table 4. Tumor pathology of the skull base reconstruction

Pathology	n
Transitional meningioma	1
Squamous cell carcinoma	4
Non-keratinizing squamous cell carcinoma	1
Metastatic renal cell carcinoma	1
Adenocarcinoma	1
Olfactory Neuroblastoma	2
Schwannoma	1
Extrapleural solitary fibrous tumor	1
Spindle cell sarcoma (Malignant peripheral nerve sheath tumor)	1
Inverted papilloma	1
Total	14

The origin of the tumor was 13 cases from the nasal cavity and 4 cases were from the cranium which caused a huge cranial-nasal communication (Table 5)

Table 5. Tumor origin of the huge cranial-nasal communication

Origin	n
Nasal cavity	13
Cranium	4

The patients presented with involvement space after the defect lesion removal from the cranium were the frontal lobe (n=17), and from the nasal cavity including the frontal sinus (n=17), ethmoid sinus (n=17), sphenoid sinus (n=1), and orbit (n=8) (Table 6).

Table 6. Involvement space of the skull base reconstruction

Involvement space	n
<Cranium>	
Frontal lobe	17
Temporal lobe	0
<Nasal Cavity>	
Frontal sinus	17
ethmoid sinus	17
sphenoid sinus	1
orbit	8

The overall defect structure of the huge cranial-nasal communication in the skull base reconstruction, including the floor of frontal sinus (n=17), posterior table of frontal sinus (n=17), anterior table of frontal sinus (n=3), orbital roof (n=9), orbital wall (medial) (n=7), cribriform plate (n=4) (Table 7).

Table 7. Defect structure of the huge cranial-nasal communication

Defect structure	Local flap	Free flap	Total (n)
Floor of frontal sinus	8	9	17
Posterior table of frontal sinus	8	9	17
Anterior table of frontal sinus	1	2	3
Orbital roof	4	5	9
Orbital wall(medial)	4	3	7
Cribriform plate	2	2	4

According to the radiology image studied, the average defect size is 8.3cm (width), and 2.7cm (length), an area (cm^2) of 22.7 ± 9.3 (Table 8).

Table 8. Estimated defect size of the huge cranial-nasal communication according to the final reconstruction radiologic study image

Defect size	AP length (cm)	Width (cm)	Area(cm^2)
Average (±SD)	8.3 ± 2.2	2.7 ± 1.1	21.9 ± 9.3
Minimum size	4.2	1.5	12.3
Maximum size	11.3	5.5	37.8

3.2. Operation

There were 8 cases were treated with a temporalis muscle local flap (reverse temporalis muscle flap bilateral 6 cases, reverse temporalis muscle flap unilateral 1 case, and extended galeal flap with temporalis muscle flap bilateral 1 case), and 9 free tissue transfer flap reconstructions using anterolateral thigh flap (Table 9).

Table 9. Reconstruction method in patients (n=17)

Skull base reconstruction	Operation method	Total (n)
Temporalis muscle local flap	Reverse temporalis muscle flap, bilateral	6
	Reverse temporalis muscle flap, unilateral	1
	Extended galeal flap with temporalis muscle flap, bilateral	1
Free flap	ALT free flap	9

The reconstruction method according to the year in which the patient received the surgery with the skull base reconstruction see details (Figure 3).

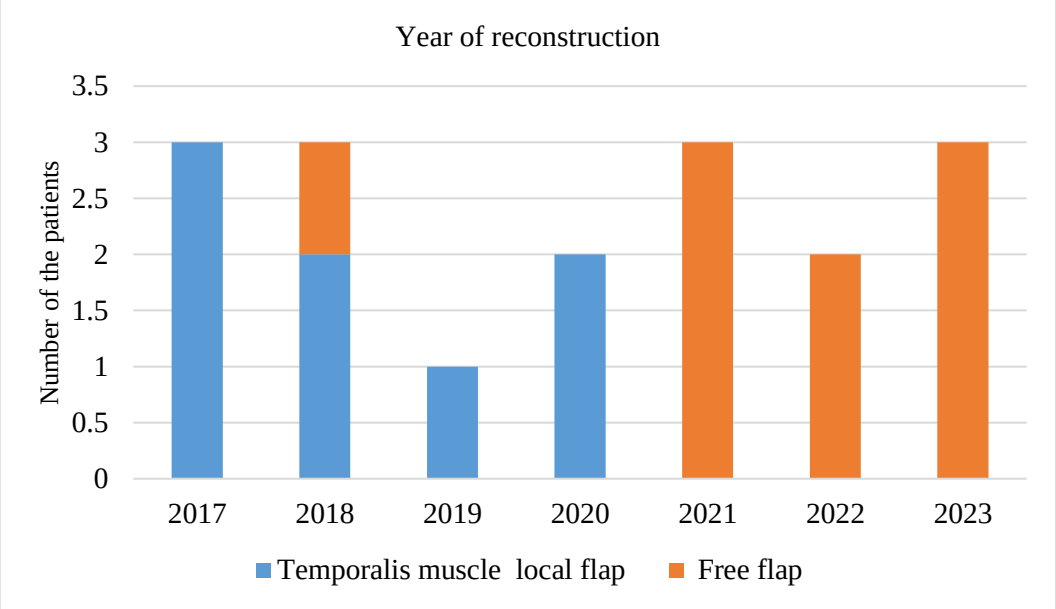

Figure 3. Reconstruction method according to the year

In addition, the average total operation time including the PS, NS, and ENT team was 15.7 ±SD hours with a range of (10.3-25.2 hours) in the reverse temporalis muscle local flap and an average of 14.4 ±SD hours with a range of (9.1-17.6 hours) in the free flap reconstruction. There was no significant difference between the average of hospitals of both flaps and the average follow-up period from the date of the skull base reconstruction to the last date of the radiologic study was 44.5 ±SD months with a range of (23.4-63.9 months) associated with the reverse temporalis muscle local flap and 15.8 ±SD months with a range of (3.2-53.2 months) in patients with underlying the free flap reconstruction (Table 10).

Table 10. Operation time, hospital stay, and follow-up date of the skull base reconstruction

Outcome	Local flap (n=8)	Free flap (n=9)
Total operation time (hours)	15.7 ±SD (10.3-25.2)	14.4 ±SD (9.1-17.6)
Hospital stays (days)	30.8 ±SD (12-25.2)	38 ±SD (15-131)
Follow-up date (months)	44.5 ±SD (23.4-63.9)	15.8 ±SD (3.2-53.2)

3.3. Outcome

A radiologic study of all 17 patients was done and showed that the flap had complete survival, good maintaining separation, and effectively blocked communication between the sterile intracranial contents and the contaminated nasal cavity. There was no evidence of CFS leakage in delayed postoperative complications in skull base reconstruction. There was 1 case with flap partial necrosis on the left side which required a secondary operation of debridement. Only 4 patients suffered from the wound site infection which was reverse temporalis muscle 2 cases and free tissue transfer flap 2 cases. 3 cases of bone absorption occurred within 14 to 18 months after the reverse temporalis muscle local flap reconstruction. There were no significant differences between the overall numbers of

postoperative complications occurring at each skull base reconstruction method (Table 11).

Table 11. Postoperative complication

Complication	Temporalis muscle local flap(n=8)	Free flap(n=9)	Total (n)
Flap partial necrosis on the left side	1	0	1
Wound site infection	2	2	4
Bone absorption	3	0	3

In the secondary operation, 1 patient underwent reoperation of coverage with the local flap advancement of the soft tissue defect in the left temporal area. 2 patients required debridement of the skin defect of chronic infection. The patient received cranioplasty in 2 cases (Table 12).

Table 12. Secondary operation of the skull base reconstruction

Secondary operation	Local flap (n=8)	Free flap (n=9)	Total (n)
Coverage with local flap advancement	1	0	1
Debridement	2	0	2
Cranioplasty	2	0	2

IV. DISCUSSION

The skull base reconstruction in the huge cranial-nasal communication defect requires evaluating the size of the defect extent and deciding how much the needed flap will be used, and the esthetics result after resection of the defect lesion. It will need to harvest a sufficient amount to fill, block the soft tissue loss, restore its function, and aesthetic results.[4,9,16] In our experiences, due to the complex anatomy of the defect lesion after resection, we chose to perform two different reconstruction methods which were reverse temporalis muscle flap (bilateral) and free tissue transfer flap.[3,4,12,26]

The goal of reconstruction was to provide reliability and focus on maintaining enduring separation between the sterile intracranial contents and contaminated extracranial compartments (nasal cavity), creating support of the brain involving the sufficient closure of dead space, closure of CSF leakage, providing full lining for the nasal cavity, and returning of the function and contour.[1,12-14,16,25,28] Reconstruction, preoperative and postoperative radiotherapy also a significant clinical challenge is regarded as the standard for malignant treatment and being aware of the radiation portals and dosage. Both recipient and donor sites can be affected by radiation injury. Similarly, preoperative and postoperative chemotherapy is also considered to affect wound healing.[5,11]

The small to medium-sized defects somehow did not require the obliteration of the dead space. A pericranial flap or galea flap as a local flap was adequate for the repair of the defect of the skull base reconstruction.[8] However, This flap alone was not enough in the size of the huge cranial-nasal communication defect. It could carry a high risk of infection, chronic inflammation, flap failure, and tend necrosis. Moreover, some patients needed to receive preoperative and postoperative radiotherapy. So, in the case of radiation local tissue may not be a sufficient amount to be utilized which impacts the reconstructive surgeon’s choice for defect repair to make well-vascularized tissue for a successful reconstruction.[1,19,29]

Before designing this research study, it was heavily thought about which of these two reconstruction methods is most effective for the patient and successfully operates and

prevents the postoperative complication as mentioned above. On the other hand, both reconstruction methods are equally effective, but it depends on which patient is right to receive the treatment of the reconstruction option. In particular, based on the surgeon's experiences or the surgeon's specializes in analyzing the patients. This has happened to conduct a research study to analyze these two reconstruction methods and describe the origin of the tumor, pathologic lesion, defect size, defect structure, the involvement space, and also its complication. The patients we studied, underwent skull base reconstruction, at least a 3-month follow-up. The defect lesion was considered to be huge enough that the posterior table of the frontal sinus was completely removed, and the frontonasal duct was entirely open to the cranium.

In our hospital, surgeons used the reverse temporalis muscle flap (bilateral) and the free tissue transfer flap to accomplish satisfactory reconstruction in the huge cranial-nasal communication. It provides reliable, well-vascularized, and enough volume to fill the dead space.[1,7,8,11,12,26,29,30] Both flaps can be used in combination with the galeal flap of the skull base repair because it can provide a good skull base lining.[1,7,31,32] For the reverse temporalis muscle flap, we elevated the muscle bilateral because it can supply more tissue bulks and improve the wound-healing process. If the patients are under radiotherapy or chemotherapy, this healthy muscle flap provides vascularity for tolerating chronic infection.[4,6,7,26,29] If we look at the free tissue transfer flap, we also can harvest tissue bulk as large as possible. Then, we designed the flap and removed the unnecessary tissue later during the reconstruction. Another benefit of donor tissue was lying outside the irradiated area and the donor site morbidity was very low. It can permit two teams to approach at the same time, saving and decreasing the operation time. [2,9,11,12] There was also a good choice due to pre-operative and post-operative tissue bed which was a well-known risk factor for impaired tissue healing.[3,5,7,33]

Although the surgeon can perform the free tissue transfer flap and has the experience, the free tissue transfer flap, and micro anastomosis are stressful procedures and burdens to the surgeon. [6] It is not easy the select the suitable flap for the patient. Especially,

when the free flap fails and does not survive, it means the mortality rate for the patients is high compared to the reverse temporalis muscle local flap.[6] Additionally, most patients who received the reverse temporalis muscle flap often leave patients complaining about the cosmetic result because of the concave deformity of the temporalis area compression and depression.[17] Moreover, the temporalis muscle flap has the limitation of the travel distance. If the patient has a short head, the maximum arc of rotation is considered. It can interfere with the blood supply to the flap and tends to necrosis if we reverse it to the frontal area too much.[4,7,8,30] The reverse temporalis muscle was mostly harvested through the bilateral incision and could be difficult to dissect, requiring additional surgical time. As you can see (Table 10), the average time of the reverse temporalis muscle flap is longer than the free tissue transfer flap since the donor and receiver sites are on the same site. It cannot allow the NS, ENT, and PS teams to perform at the same time.

The follow-up period of both reconstruction methods was not accurate because radiology studies were taken based on an unplanned plastic surgery and neurosurgery visit. In addition, the follow-up period was a wide range from 3 to 63 months in both flaps. However, the results showed the reverse temporalis muscle flap and anterolateral thigh flap had complete survival and well-maintained lining and volume. They revealed no CSF leakage with excellent healing of the skull base.

The delayed complications included flap partial necrosis on the left side which required reoperation of debridement. For the wound site infection, 1 patient required debridement of the skin defect (chronic infection), and 1 patient underwent reoperation of coverage with local flap advancement (soft tissue defect of left temporal area). The rest two cases were wound site infection itself and wound infection periorbital area on the left side which received conservative treatment. Three cases of bone absorption occurred within 14 to 18 months after receiving the reverse temporalis muscle flap. We believed that the cause may be from the ascending infection and tended to inflammation. Thus, the patient's behaviors themselves are like sneezing. Another factor could be from the midline distal end part of the reverse temporalis muscle due to travel distance, the vascularity was not in good

condition and led to a tissue defect around the frontal area. Another relevant study by Ahmed Eldaly et al.[17] also reported partial necrosis was mainly seen in the form of dehiscence at the distal end of the flap 14.6% due to the extensive dissection required to mobilize the flap that might have partially compromised the flap's blood supply. However, two of them received cranioplasty for their secondary operation and the left one has not received the cranioplasty yet. The patient is under conservative treatment and will get the PEEK implant of cranioplasty in the future as planned. The effect of both flaps showed no reduction in the overall complication rate, this may be explained that the reconstructive method depends on the defect size, defect structure, the presence of infection, history of previous surgery, patient age, history of radiation, the involvement space, tumors extension, and surgeon experience. So, comparing the complication rates from different reconstructive methods is meaningless.[11]

In this study, the plastic surgeon performed the skull base reconstruction in a huge cranial-nasal communication defect and performed a reverse temporalis muscle flap and free tissue transfer flap successfully. We did not expect any different outcomes with both surgical techniques. In our opinion, although both flap also has advantages and limitations, achieving the goal of skull base reconstruction by carefully considering repairing the dural defect, and elimination of dead space after tumor resection is significant to prevent and minimize postoperative complications such as CSF leakage and ascending infection. The choice of reconstruction method was considered by the surgeon on defect size, location, patient factors, radiation, and the surgeon's experience. Future studies should explore other factors related to the patients and defects to describe them in detail to guide the reconstructive surgeon in determining the appropriate surgical plan. The retrospective data analysis was the main limitation. Another issue, a few recent prospective patients treated with free tissue transfer flaps have been included in this study and it must consider the follow-up period which is relatively low to analyze delayed complications.

V. CONCLUSION

Skull base reconstruction was successfully performed and effectively achieved using the reverse temporalis muscle flap and the free tissue transfer flap in the huge cranial-nasal communication defect. These two methods can be used to maintain separation and effectively block the communication between the sterile intracranial contents and the contaminated nasal cavity. The reverse temporal muscle flap is a powerful adjunct in some select cases and may be sufficient alone for the skull base reconstruction. As such, the use of a free tissue transfer flap is well represented and can provide sufficient tissue bulk as needed with a reliable and rich blood supply that improves the wound healing process and fills the volume of the dead space after tumor removal as well as reinforces dura closures to prevent cerebrospinal fluid leakage.

REFERENCES

1. Moyer JS, Chepeha DB, Teknos TN. Contemporary skull base reconstruction. Current Opinion in Otolaryngology & Head and Neck Surgery 2004;12:294-9.
2. Wang W, Vincent A, Sokoya M, Kohlert S, Kadakia S, Ducic Y. Free-Flap Reconstruction of Skull Base and Orbital Defects. Semin Plast Surg 2019;33:72-7.
3. Imola MJ, Sciarretta V, Schramm VL. Skull base reconstruction. Curr Opin Otolaryngol Head Neck Surg 2003;11:282-90.
4. Shin D, Yang CE, Kim YO, Hong JW, Lee WJ, Lew DH, et al. Huge Anterior Skull Base Defect Reconstruction on Communicating Between Cranium and Nasal Cavity: Combination Flap of Galeal Flap and Reverse Temporalis Flap. J Craniofac Surg 2020;31:436-9.
5. Yong M, Wu YQ, Su S, Hanna E, Prisman E, Thamboo A, et al. The effect of prior radiation on the success of ventral skull base reconstruction: A systematic review and meta-analysis. Head Neck 2021;43:2795-806.
6. Kwon SG, Kim YO, Rah DK. Anterior cranial base reconstruction with a reverse temporalis muscle flap and calvarial bone graft. Arch Plast Surg 2012;39:345-51.
7. Kwon D, Iloreta A, Miles B, Inman J. Open anterior skull base reconstruction: a contemporary review. Seminars in Plastic Surgery: Thieme Medical Publishers; 2017. p.189-96.
8. Liu JK, Niazi Z, Couldwell WT. Reconstruction of the skull base after tumor resection: an overview of methods. Neurosurg Focus 2022;12.
9. Bell EB, Cohen ER, Sargi Z, Leibowitz J. Free tissue reconstruction of the anterior skull base: A review. World J Otorhinolaryngol Head Neck Surg 2020;6:132-6.
10. Garcia-Navarro V, Anand VK, Schwartz TH. Gasket Seal Closure for Extended Endonasal Endoscopic Skull Base Surgery: Efficacy in a Large Case Series. World Neurosurgery 2013;80:563-8.
11. Pusic AL, Chen CM, Patel S, Cordeiro PG, Shah JP. Microvascular reconstruction of the skull base: a clinical approach to surgical defect classification and flap selection. Skull Base 2007;17:5-15.
12. Hoffmann TK, El Hindy N, Müller OM, Schuler PJ, Bergmann C, Hierner R, et al.

Vascularised local and free flaps in anterior skull base reconstruction. Eur Arch Otorhinolaryngol 2013;270:899-907.

13. Yeo IS, Kim S-H, Park MC, Lim H, Kim JH, Lee IJ. Successful Reconstruction of irradiated Anterior Skull Base Defect Using the Dual Flap Technique involving Local Pericranial Flap and Radial Forearm Free Flap. J Craniofac Surg 2014;25:1376-8.
14. Mady LJ, Kaffenberger TM, Baddour K, Melder K, Godse NR, Gardner P, et al. Anatomic Considerations of Microvascular Free Tissue Transfer in Endoscopic Endonasal Skull Base Surgery. J Neurol Surg B Skull Base 2022;83:e143-e51.
15. Patel MR, Shah RN, Snyderman CH, Carrau RL, Germanwala AV, Kassam AB, et al. Pericranial flap for endoscopic anterior skull-base reconstruction: clinical outcomes and radioanatomic analysis of preoperative planning. Neurosurgery 2010;66:506-12.
16. Nameki H, Kato T, Nameki I, Ajimi Y. Selective reconstructive options for the anterior skull base. Int J Clin Oncol 2005;10:223-8.
17. Eldaly A, Magdy EA, Nour YA, Gaafar AH. Temporalis myofascial flap for primary cranial base reconstruction after tumor resection. Skull Base 2008;18:253-63.
18. Urken ML, Catalano PJ, Sen C, Post K, Futran N, Biller HF. Free tissue transfer for skull base reconstruction analysis of complications and a classification scheme for defining skull base defects. Arch Otolaryngol Head Neck Surg 1993;119:1318-25.
19. Dolci RLL, Todeschini AB, Santos A, Lazarini PR. Endoscopic endonasal double flap technique for reconstruction of large anterior skull base defects: technical note. Braz J Otorhinolaryngol 2019;85:427-34.
20. Soudry E, Psaltis AJ, Lee KH, Vaezafshar R, Nayak JV, Hwang PH. Complications associated with the pedicled nasoseptal flap for skull base reconstruction. The laryngoscope 2015;125:80-5.
21. Ein L, Sargi Z, Nicolli EA. Update on anterior skull base reconstruction. Current opinion in otolaryngology & head and neck surgery 2019;27:426-30.
22. Cavallo LM, Solari D, Somma T, Cappabianca P. The 3F (Fat, Flap, and Flash) Technique For Skull Base Reconstruction After Endoscopic Endonasal Suprasellar Approach. World Neurosurgery 2019;126:439-46.
23. Sagheer SH, Swendseid B, Evans J, Rabinowitz M, Nyquist G, Rosen MR, et al. Free tissue transfer for central skull base defect reconstruction: Case series and surgical technique.

Oral Oncol 2021;115:105220.

24. Zanation AM, Snyderman CH, Carrau RL, Kassam AB, Gardner PA, Prevedello DM. Minimally invasive endoscopic pericranial flap: a new method for endonasal skull base reconstruction. The Laryngoscope 2009;119:13-8.
25. Harvey RJ, Parmar P, Sacks R, Zanation AM. Endoscopic skull base reconstruction of large dural defects: a systematic review of published evidence. The Laryngoscope 2012;122:452-9.
26. Kim SH, Lee WJ, Chang JH, Moon JH, Kang SG, Kim CH, et al. Anterior skull base reconstruction using an anterolateral thigh free flap. Archives of Craniofacial Surgery 2021;22:232-8.
27. Kim YO, Park BY. Reverse temporalis muscle flap: treatment of large anterior cranial base defect with direct intracranial-nasopharyngeal communication. Plast Reconstr Surg 1995;96:576-84.
28. Sughrue ME, Aghi MK. Reconstruction of dural defects of the endonasal skull base. Neurosurg Clin N Am 2010;21:637-41, vi.
29. Gil Z, Abergel A, Leider-Trejo L, Khafif A, Margalit N, Amir A, et al. A comprehensive algorithm for anterior skull base reconstruction after oncological resections. Skull base 2007:025-37.
30. Schmalbach CE, Webb DE, Weitzel EK. Anterior skull base reconstruction: a review of current techniques. Current opinion in otolaryngology & head and neck surgery 2010;18:238-43.
31. Atabey A, Vayvada H, Menderes A, Kirişoğlu U, Barutçu A. A combined reverse temporalis muscle flap and pericranial flap for reconstruction of an anterior cranial base defect: a case report. Ann Plast Surg 1997;39:190-2.
32. Guinto G, Guinto Y. Reconstructive Techniques in Skull Base Surgery. World Neurosurgery 2015;83.
33. Hanasono MM, Silva A, Skoracki RJ, Gidley PW, DeMonte F, Hanna EY, et al. Skull base reconstruction: an updated approach. Plastic and reconstructive surgery 2011;128:675-86.

PUBLICATION LIST

Kong SN, Hong JW. Reconstruction methods for large cranial-nasal communications: surgeons' concerns about proper anterior skull base reconstruction. Archives of Hand and Microsurgery 2024;29 (2).

ABSTRACT (IN KOREAN)

거대 두개강-비강 교통이 있는 광범위 결손에 대한 두개저 재건 분석- 역측두근 피판과 유리피판술

목적: 경막 결함의 두개저 재건에서 수술 방법의 유형을 고려하는 것은 종양 절제 후 재건외과 의사에게 상당히 어려울 수 있다. 지난 10 년 동안 많은 의사들은 두개골과 비강 사이의 연결을 충분히 차단하여 뇌척수액 누출 및 감염의 합병증을 최소화하기 위해 다양한 재건 방법을 고안하였다. 연구의 목표는 종양의 기원, 병리학적 병변, 결손 크기, 결손 구조 및 침범 공간을 분석하고자 한다. 즉히 연구자의 측두근 피판 및 유리피판술 검토연구가 수술계획을 제시하고 적합한 수술방법의 선택에 도움을 주고자 한다.

방법: 2017 년 1 월부터 2023 년 12 월까지 세브란스병원 성형외과에 입원하여 두개골기저 재건 수술을 받은 환자 17 명을 후향적으로 연구하였다. 병리학적 병변은 종양 및 감염을 포함하여 두개강과 비강 모두를 침범한 환자를 대상으로 하였다. 병변을 제거한 후 두개저 결손은 대부분 전두동과 체판으로 확장되었다. 결함으로 인해 두개강-비강 교통이 광범위하게 발생하였다. 재건 방법으로는 측두근 피판 혹은 유리피판술을 시행하였다. 결손의 원인, 조직병리, 결손구조, 침범공간, 재건크기를 분석하였다.

결과: 양성종양이 4 예, 악성종양이 10 예, 점액낭종이나 감염이 3 예가 두개저 재건의 직접적인 원인이었다. 비강에서 13 예,원병변은 두개강에서 4 예에서 발생하였다. 두개강-비강 의사소통 영역(cm^2)의 예상 결손 크기는 21.9 ± 9.3 이었다. 국소 피판술로 치료한 경우는 8 예(역측두근 피판 양측 6 예, 역측두근 피판 단측 1 예, 양측 측두근 피판을 동반한 확장 횡문 피판 1 예), 유리피판술 9 예였다. 유리피판술은 모두 전외측 허벅지 피판을 이용하였다. 모든 증례에서 감염, 뇌척수액 누출, 피판괴사 등의 주요 합병증은 발생하지 않았다. 수술 후 방사선 영상을 촬영한 결과 모든 환자에서 피판이 잘 유지되어 있는 것으로 나타났다.

결론: 거대 두개강-비강 교통 결함에서 측두근을 이용한 국소피판 혹은 유리피판술을 사용하여 성공적인 재건되었다. 이 두 가지 방법 모두 거대 두개강-비강 교통을 효과

적으로 차단하였고, 두개강과 비강을 분리 유지할 수 있었다.

핵심되는 말 : 두개강-비강 교통, 두개저, 재건