Modified nasal floor and inferior meatus flap for septal perforation repair. Extension and limits*

Alfonso Santamaría-Gadea[1,2,3], Mauricio López-Chacón[1,2,3], Cristóbal Langdon[1,2,3], Laura Van Gerven[4], Meritxell Valls-Mateus[1], Manuel Bernal-Sprekelsen[1], Isam Alobid[1,2,3]

[1] Rhinology and Skull Base Unit, Department of Otorhinolaryngology, Hospital Clinic, Universitat de Barcelona, Spain

[2] Institut d'Investigacions Biomèdiques August Pi i Sunyer (IDIBAPS), Barcelona, Spain

[3] Centro de Investigación Biomédica en Red de Enfermedades Respiratorias (CIBERES), Madrid, Spain

[4] Clinical Division of Otorhinolaryngology, Head and Neck Surgery, University Hospitals Leuven, Leuven, Belgium

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Background: The nasal floor and inferior meatus (NFIM) flap represents an available option for the reconstruction of a septal perforation (SP). This study explores the feasibility of repairing SPs using a modified simple and extended (including inferior turbinate) NFIM flap.

Methods: An anatomic study was achieved in fresh frozen cadaveric specimens to measure the area and lengths of NFIM flap. The repair of SP with simple and extended NIFM flaps was performed in some of these cadaveric specimens. Preoperative radiological evaluation of CT scans allowed studying the reconstruction limits of the simple or extended NFIM flap. A cohort of patients with SP who underwent reconstruction with an NFIM flap was also included.

Results: Complete SP repair with NFIM was achieved in all specimens (n=10). In 38 fresh cadaveric specimens, coronal (2.6±0.4 cm) and sagittal (4.7±0.6 cm) lengths and area (12.3±2.3 cm^2) of simple NFIM flaps were smaller than in extended NFIM flaps (5.7±0.5 cm, 4.7±0.6 cm, 28.8±3.3 cm^2 respectively). The radiological analysis of 75 CT scans revealed that 40.2±5.7% and a 79.6±11.1% of septal height could be reconstructed with a simple and extended NFIM flap, respectively. Complete SP repair was achieved in 5 patients (4 male, mean age 57.4 years) using modified NFIM flaps.

Conclusion: The simple or expanded NFIM flap represents a feasible option to repair small or medium-sized perforations located at the lower 1/3 or 3/4 of the nasal septum.

Key words: nasal floor, inferior meatus flap, inferior turbinate flap, septal perforation, septum reconstruction, endoscopic surgery

Introduction

Septal perforation (SP) is a rather uncommon disorder with an estimated prevalence of 0.9 to 2.5% in the general population [1,2]. Despite some asymptomatic presentations, the majority of SPs cause a whole scale of symptoms, such as intermittent epistaxis, nasal obstruction, crusting, dryness, purulent discharge, and/or nasal whistling [3]. The disturbance of the airflow and the nasal warming function induce the sinonasal symptoms and tend to be worse on anterior or larger perforations [4]. The most frequent aetiologies of SP are incomplete septal surgery, surgery complicated by postoperative infections or other healing disturbances, but they can also be secondary to drug abuse, inhaled substances, trauma, neoplasms, or inflammatory systemic diseases [5,6].

Some patients with symptomatic SPs do not improve with conservative treatment and require surgical repair [7-9]. The goal of surgical treatment is to improve the patient's quality of life by ameliorating nasal symptoms, restoring functional laminar flow and the functioning of the nasal mucosa [4].

No gold standard technique has been recognized for the surgical management of SPs. Many endoscopic techniques are available for septal repair, and the choice depends on the characteris-

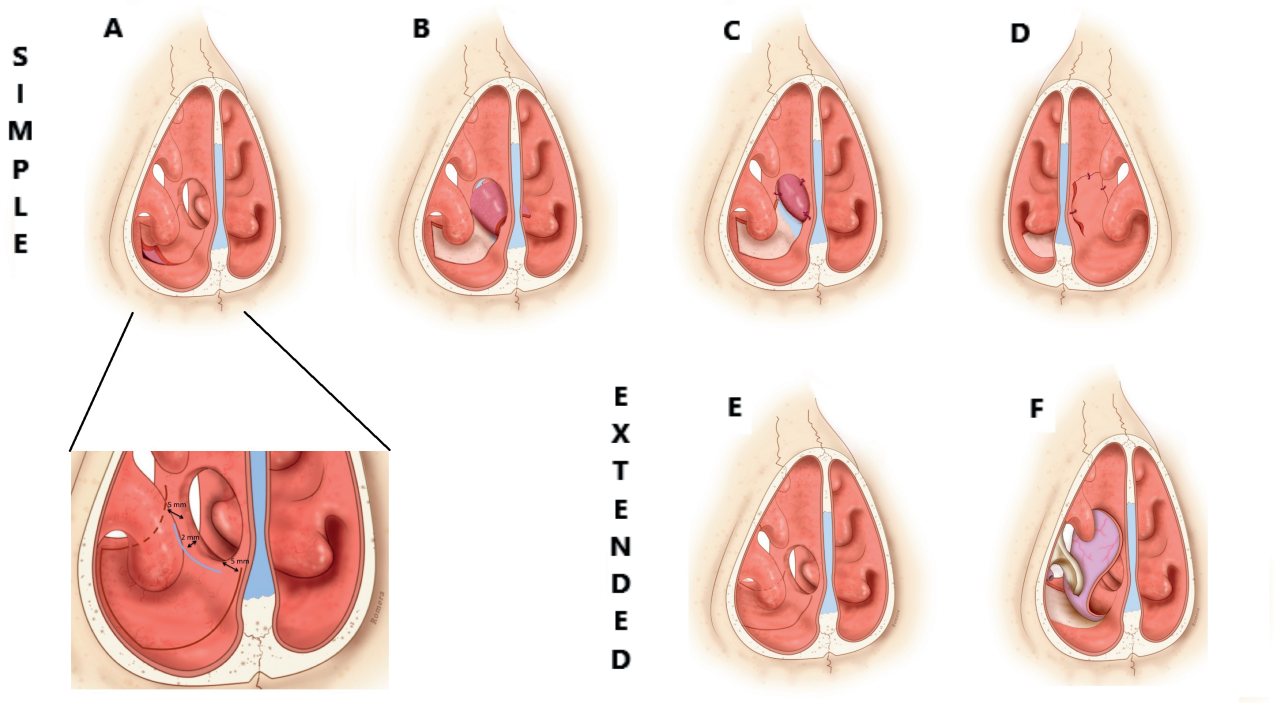

Figure 1. Schematic demonstration of how to harvest a simple or extended nasal floor and inferior meatus flap (SNFIM or ENFIM). A: Shows the incisions of the SNFIM flap. Their zoom shows in detail the distances between the incisions and the septal perforation. B: Shows the SNFIM flap raised and transferred to the other nasal fossae. C: Shows the perforation closed from the right nasal fossae with the flap sutured to the edges of the perforation. D: Shows the perforation closed from the left nasal fossae. E: Shows the incisions of the ENFIM flap. F: Shows the ENFIM flap raised and the nasolacrimal duct cutted.

tics of the perforation (size, location) and the experience of the surgeon [8,10]. Most techniques are based on pedicled endonasal flaps, which can be used to repair small-medium SPs. Endonasal flaps include the bridge-flap [11], inferior turbinate flap [12], inferior meatal flap [10], anterior ethmoidal artery flap [13], lateral nasal wall flap [9], and middle turbinate flap [14]. However, in large perforations, an external nasal flap, such as the pericranial flap for complete closure, may be necessary [15].

Teymoortash and Werner first described the inferior meatal flap in 2009. In their first series, 13 patients with symptomatic SPs underwent an endoscopic septal repair with a complete closure rate [10]. Later on, the same group published a report on a series of 55 patients with SPs treated with an extended inferior meatus flap (extension to the inferior turbinate). The entire cohort of patients achieved symptom resolution, including the three patients who had incomplete closure [6].

The objective of our study was to perform a radio-anatomic analysis of the nasal floor and inferior meatus (NFIM) flap, either simple (SNFIM) or extended (ENFIM) to the inferior turbinate. We also present our experience with a series of patients who have undergone this technique for septal repair. Specific practical landmarks to use the modified NFIM flap as well as tips and tricks to achieve complete closure of SP are also discussed.

Materials and methods

This study consists of three parts: 1) an anatomical study of fresh cadaver specimens; 2) a radiological analysis of the reconstruction limits of the NFIM flap with or without extension to the inferior turbinate; 3) a series of patients with SP reconstructed with this technique.

Anatomical study

The dimensions and area of the NFIM flap were measured in 38 fresh cadaver specimens (38 right and 38 left nasal fossae).

- Sagittal length was measured from the pyriform aperture to the posterior limit of the hard palate at the level of the floor of the nose.
- Coronal lengths of the nasal floor were measured as follows: a) from the limit between the nasal septum and nasal floor to the highest part of the inferior meatus, at the level of the Hasner's valve; b) from the upper level of the lower meatus (Hasner's valve) to the upper level of the lower turbinate at this level.

The coronal length of the SNFIM is determined by the first

coronal measurement (a), and the coronal length of the ENFIM is composed of the sum of the two coronal measurements (a+b). Differences between the lengths of SNFIM and ENFIM, the two nasal fossae, and gender were analysed.

Septal repair with the NFIM flap (n=10; simple=5, extended=5) was performed in the Barcelona Skull Base Laboratory using the following technique:

- The inferior portion of the nasal septum was removed under endoscopic view to simulate a septal perforation.
- Coronal plane incisions: Two parallel incisions (anterior and posterior) from the lateral limit of the inferior meatus to 2 mm below the inferior limit of the SP were done. It is highly recommended to place these incisions at least 5 mm distal from the border of the SP (Figure 1A,E).
- Sagittal plane incisions: The lateral limit of the SNFIM flap was incised at the most lateral aspect of the inferior meatus, just below the insertion of the inferior turbinate with the lateral wall (Figure 1A). In case of an ENFIM flap, the lateral incision must be made in the lateral wall along the superior aspect of the inferior turbinate (Figure 1E).
- The mucoperiosteum of the inferior meatus was carefully dissected and elevated. Verification to assure that all incisions are connected and reach the bone so as to dissect the flap without mucosal tearing is important. If an extended flap was needed, the dissection started at the level of the superior aspect of the inferior turbinate. Then the mucosa was separated from the inferior turbinal bone.
- The incisive artery (branch of the greater palatine artery at the level of the incisive canal) of the same side of the flap (ipsilateral) was cut to increase the mobility of the flap. Moreover, the flap continued to be irrigated by the contralateral blood supply.
- The dissection was continued throughout the septum to a few millimetres below the lower edge of the SP. At this level, a horizontal cut of the septal cartilage parallel to the inferior margin of the SP was done leaving a thin sheet of cartilage (2 mm) adhered to mucoperichondrium. This manoeuvre helps to elevate the flap to the other side without damaging the flap at the edge of the perforation (Figure 1B, F).
- At this step, the flap was transposed to the contralateral nasal cavity. A 2-mm mucosa of the superior aspect of the SP of the opposite side was removed to allow direct adhesion of the NFIM flap to the cartilage. The edges of the flap were stitched with the surrounding mucosa (superior, anterior, and posterior) with an absorbable suture (Figure 1C-D).

Radiological study

In this study, 150 nasal cavities (75 right and 75 left nasal cavities) were analysed on 75 high-resolution craniofacial computed tomography (CT) scans (slices of 0.6 mm) with multiplanar reconstruction. These CT scans were initially performed because of intracranial pathology, in patients without a history of previous nasal pathology. In all measurements, differences according to the side of the nasal cavity and gender were analysed. This study was approved by the Institutional Review Board (Nº: CEIC HCB/2017/0268).

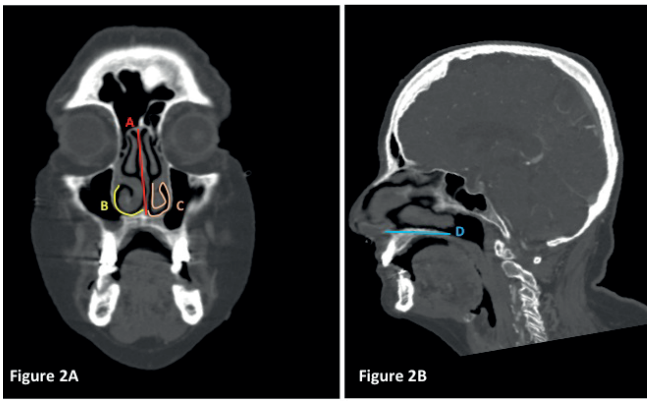

Figure 2. Measurements performed in the radiological study. A: in the midline of the sagittal plane. A: Coronal view of a CT scan. Line A: Anterior height of the septum. Line B: Anterior length of the SNFIM flap. Line C: Anterior length of the ENFIM flap. B: Sagittal view of a CT scan in the middle line. Line D: Sagittal length of the SFIM and ENFIM flaps.

An open source DICOM viewer Horos ® (Pixmeo, Switzerland), which allows reliable estimations of surface areas and distances between landmarks, was used for the radiological measurements.

The objectives of this radiological analysis were to measure the lengths and area of the flap and estimate the limit of reconstruction of this technique.

Length, width, and area of the NFIM flap with or without extension to the inferior turbinate were measured. The lacrimal duct was used as a landmark to measure the anterior limit of the NFIM flap. The posterior edge of the hard palate was used as a landmark to measure the posterior limit of the flap. Besides, height, length, and septal area were also measured. In addition, the incisive artery foramen was located. The distance between the incisive foramen and the pyriform aperture was measured in the sagittal plane. All these measurements are detailed in Table 1 and schematized in Figure 2.

To avoid incomplete closures of the SP because of the contracture process and scar maturation during flap healing, an additional 30% was added to each length of the flap.

Clinical cases

Four NFIM flaps with or without extension to the inferior turbinate were handled for the closure of symptomatic SP in 5 patients. Four patients had a previous history of nasal surgery, and one had a self-inflicted SP. Nevertheless, a complete study was carried out to exclude systemic diseases (general blood test,

Table 1. Summary of the measurements and landmarks of the nasal septum and NFIM (n=75).

Measurements and landmarks	Abbreviations
Anterior limit of the NFIM flap at the level of the nasolacrimal duct in a coronal plane	SNFIM flap anterior (Line B. Figure 2A)
Posterior limit of the NFIM flap at the level of the hard-soft palate junction in a coronal plane	SNFIM flap posterior
Anterior limit of the ENFIM flap at the level of the nasolacrimal duct in a coronal plane	ENFIM flap anterior (Line C. Figure 2A)
Posterior limit of the ENFIM flap at the level of the hard-soft palate junction in a coronal plane	ENFIM flap posterior
Medial length of the NFIM flap from the pyriform aperture to the posterior limit of the hard palate. Midline of the sagittal plane	Length of the NFIM flap (Line D. Figure 2B)
Height of the septum at the level of the nasolacrimal duct in a coronal plane	Anterior height of the nasal septum (Line A. Figure 2A)
Height of the septum at the level of the hard-soft palate junction in a coronal plane	Posterior height of the nasal septum

NFIM: Nasal floor and inferior meatus flap. SNFIM: Simple nasal floor and inferior meatus flap. ENFIM: Extended nasal floor and inferior meatus flap. All measurements were obtained using open source DICOM viewer Horos (Pixmeo, Switzerland).

ANA, cANCA, RF, ESR, Chest x-ray, nasosinusal CT) or intranasal drug abuse (urine drug test). The Ethics Committee of our institution approved the study, and the patients gave signed informed consent (Nº: CEIC HCB/2017/0268).

The nasal floor was infiltrated with a solution of bupivacaine (0.25%) and epinephrine (1:100.000) to achieve hydro-dissection of the flap in the subperiosteal and subperichondrial plane. Anterior, posterior, and lateral incisions were performed as explained previously. The NFIM flap was harvested and passed to the opposite nasal cavity with a 2-mm cartilaginous sheet adhered to the flap. The incisive artery, ipsilateral to the side of the flap, was cut to raise the flap. Two mm of the other mucosal margins of the contralateral side were removed to obtain bleeding edges and to avoid overlapping between the NFIM flap and septal mucosa. It is highly important to avoid suture tension that decreases blood supply and, consequently, could cause flap necrosis. During the follow-up period or during the surgery, any complication was recorded.

Statistical analysis

All standard deviations (SD) and 95% confidence intervals (95% CI) were calculated using Matlab (Version 2016a; MathWorks).

Table 2. Average measurements of the NFIM flap in cadaver specimens (n=38).

	Coronal length (cm)	Sagittal length (cm)	Area (cm^2)
SNFIM	2.6 ± 0.4	4.7 ± 0.6*	12.3 ± 2.3*
ENFIM	5.7 ± 0.5§	4.7 ± 0.6*	28.8 ± 3.3*§

NFIM: Nasal floor and inferior meatus flap. SNFIM: Simple nasal floor and inferior meatus flap. ENFIM: Extended nasal floor and inferior meatus flap. T: Total. M: Male. F: Female. All measurements were obtained under endoscopic view in cadaver specimen. No significant differences between the sides of the nasal fossa were found. (*)Sagittal length and area were significantly larger in male than in female cadavers. (§) Coronal length and area were significantly larger in ENFIM than SNFIM. A P value of <0.05 was considered statistically significant. Both SNFIM and ENFIM have the same sagittal length (From valve of Hasner to the posterior edge of the hard palate).

The normality of the variables was checked with the Jarque-Bera test. However, when it was rejected, and given the sample size, the Student t distribution was used to construct the confidence interval. Wilcoxon rank sum test was used to probe the null hypothesis that male and female data are samples from continuous distributions with equal medians, against the alternative that they are not. The test assumes that the 2 samples are independent and equivalent to a Mann-Whitney U-test. The differences between the sides of the nasal cavity were also tested with the same method. A P value of <0.05 was considered statistically significant.

Results

Anatomical study

All measurements of the coronal and sagittal lengths of the NFIM flap were performed in 38 specimens (n=38; 24 females), and the SP repair, from the pyriform aperture to the posterior limit of the hard palate (1.5-3.0 cm), was completed in 10 specimens. Mean age 82.4 ± 8.2 (68-94).

The coronal lengths and area of the ENFIM were significantly larger than the SNFIM flap (Table 2). No significant differences between the sides of the nasal fossa were found. However, sagittal length and estimated area were larger in men than in women, in both SNFIM and ENFIM flaps.

To simulate a SP, we removed the inferior third of the septum, and SP reconstruction with the NFIM flap was performed according to the technique described above. Complete SP repair was achieved in all specimens (simple=5, extended=5).

Radiological study

Of all CT scan, 42 (56%) were performed on women subjects,

Table 3. CT scan results of the measurements and landmarks, related to the NFIM flap and nasal septum (n=75).

	Mean ± SD		
SNFIM flap anterior	2.8 ± 0.4 cm	M	3.0 ± 0.4
		F	2.7 ± 0.4
SNFIM flap posterior	2.2 ± 0.3 cm	M	2.3 ± 0.2*
		F	2.1 ± 0.3
ENFIM flap anterior	5.5 ± 0.7 cm	M	5.8 ± 0.7*
		F	5.3 ± 0.7
ENFIM flap posterior	4.1 ± 0.6 cm	M	4.2 ± 0.6
		F	4.0 ± 0.5
Length of the NFIM flap¶	5.4 ± 0.4 cm	M	5.6 ± 0.4
		F	5.2 ± 0.3
Anterior height of the nasal septum	4.6 ± 0.3 cm	M	4.7 ± 0.4
		F	4.6 ± 0.3
Posterior height of the nasal septum	4.4 ± 0.3 cm	M	4.5 ± 0.4
		F	4.3 ± 0.3
Percentage of septal length reconstruct with SNFIM flap	40.2 ± 5.7 %	M	41.9 ± 5.7
		F	38.9 ± 5.3
Percentage of septal length reconstruct with ENFIM flap	79.6 ± 11.1 %	M	82.4 ± 10.2*
		F	77.4 ± 11.3
SNFIM flap area	13.4 ± 1.9 cm^2	M	14.5 ± 1.7
		F	12.5 ± 1.5
ENFIM flap area	25.9 ± 3.6 cm^2	M	27.9 ± 3.5*
		F	24.2 ± 2.8
Septal area	24.2 ± 2.5 cm^2	M	25.3 ± 2.5
		F	23.3 ± 2.1
Incisive artery from the pyriform aperture	1.5 ± 0.2 cm	M	1.5 ± 0.2
		F	1.4 ± 0.2

NFIM: Nasal floor and inferior meatus flap. SNFIM: Simple nasal floor and inferior meatus flap. ENFIM: Extended nasal floor and inferior meatus flap. It was assumed that the inferior meatus flap was in need of being one-third (33%) larger to complete closure of the septal perforation because of the healing and potential side effects of a scar contracture. No significant differences between the sides of the nasal fossa were found. Sagittal length and area were significantly larger in males than in females (*). A P value of <0.05 was considered statistically significant. ¶ Both SNFIM and ENFIM have the same sagittal length (From valve of Hasner to the posterior edge of the hard palate).

and the mean age was 71.0 ± 14.6 (range, 32-95 years). Anterior and posterior lengths and the estimated area of the SNFIM flap were smaller than for the extended flap. Both flaps had the same sagittal length. The septal height at the level of the nasolacrimal duct was 4.6 ± 0.3 cm and 4.4 ± 0.3 cm at the junction of hard and soft palate. The incisive artery was located in the floor of the nasal cavity at 1.5 ± 0.2 cm posterior to the pyriform aperture (Table 3). No differences between the sides of the nasal fossa were found. Some measurements were significantly higher in men than in women, and in the other measurements, a clear tendency in this direction was noted (Table 3).

The limit of the septum that could be repaired with a simple or extended NFIM flap was calculated using septal height and anterior flap lengths. Flap lengths were reduced into a third, taking into account the retraction that occurs during the healing process.

The percentage of septal height from its inferior portion that could be reconstructed was larger in the ENFIM flap (79.6 ± 11.1 %) compared with the SNFIM flap (40.2 ± 5.7 %). Furthermore, the superior margin of the SP regarding the nasal floor was 3.7 ± 0.5 cm to be reconstructed with the extended flap and 1.9 ± 0.3 cm with the simple flap.

We mainly used the anterior septal height and the anterior flap length to reconstruct anterior SP, because patients with posterior SP do not usually have sinonasal symptoms.

Clinical case

A cohort of 5 patients (4 male, mean age 57.4 years) with symptomatic inferior SP underwent a surgical repair with a NFIM flap. A simple NFIM flap was harvested in 3 cases (2 right and 1 left side) and an extended flap was required in 2 cases (1 right side and 1 left). The flap was raised from the floor of the nose and the inferior meatus and passed to the opposite side of the nasal cavity through the SP. Then the refreshed margins of the SP and the edges of the flap were sutured, according to the technique detailed above. Absorbable sutures (4/0) were used. Silicone nasal splints were placed in both nasal fossa along the septum and anchored to the anterior septal zone, with a betamethasone and gentamicin ointment. Soft bilateral packing was used for 48 hours (Figure 3).

Patients were discharged the day after the surgery. The silicone splints were removed 3 weeks later. After an average 10 months of follow-up, sinonasal symptoms were resolved and nasal endoscopy revealed complete closure of the SP. No further complications were found during the follow-up period.

Discussion

The main findings of our study are 1) anatomical measurements demonstrated that the inferior third of the nasal septum could be repaired using a NFIM flap, 2) radiological analysis confirmed that more than one-third (40%) of inferior SPs could be repaired with a SNFIM flap and more than three-quarters (79%) by an ENFIM flap, 3) five clinical cases of inferior perforation were successfully treated using NFIM flaps (3 simple, 2 extended). This raises the possibility that this technique might become the standard approach for repairing inferior SP in the case of lack of osteo-cartilaginous support.

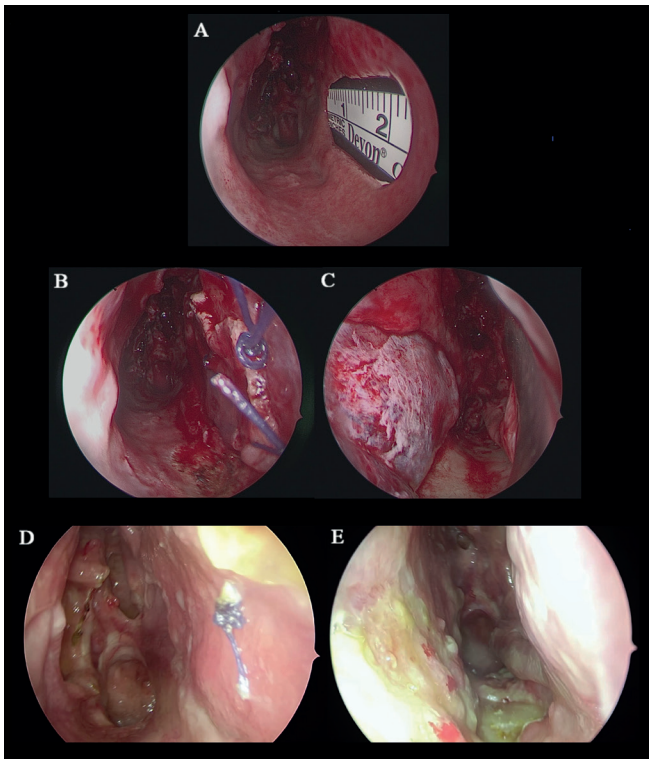

Figure 3. Pre- and postoperative images of a septal perforation treated with an SNFIM flap in a real patient. This patient A: Picture of the inferior septal perforation from the right nasal fossae. B: Picture of the right nasal fossae at the end of the surgery. The septal perforation is completely closed with a left SNFIM flap. C: Picture of the left nasal fossae at the end of the surgery. The septal perforation is completely closed with a left SNFIM flap. D: Picture of the right nasal fossae 4 weeks postoperatively. The septal perforation is closed and the SNFIM flap is integrated with the remnant mucosa of the septum. E: Picture of the right nasal fossae 4 weeks postoperatively. The septal perforation is closed and the SNFIM flap is integrated with the remnant mucosa of the septum. The nasal floor is in a phase of reepithelialization.

Several techniques have been reported in the literature for the SP repair [16]. However, no standard approach has been approved, so the technique used is chosen according to the osteo-cartilaginous support and the experience of the surgeon. Likewise, the progress of endoscopic surgery in recent decades has led to the development of various "pure endoscopic" techniques for septal reconstruction [9]. The crossover technique and anterior ethmoidal artery flap are alternative procedures to repair small-medium SPs in case of adequate osteo-cartilaginous support. The authors demonstrate that a simple NFIM flap represents a feasible and advisable option for inferior SP repair in case of lack of osteo-cartilaginous support. In addition, for those SPs located in the middle area, the flap may extend to the inferior turbinate, achieving enough length for its reconstruction.

It is widely described in the literature that the anterior perforations are usually the most symptomatic [17]. Therefore, it is important to take into account that the NFIM flap cannot reach the caudal-most area of the nasal septum. The NFIM would be able to reconstruct the entire lower area of the nasal septum except for the more caudal SP.

Teymourtash et al.[6] have the largest series reported of this flap until now. In 2011, they performed a radiological analysis of the limits of the ENFIM flap. Their radiological measurements were similar to those in our study: 1) 4.42 ± 0.46 cm instead of 4.6 ± 0.3 cm in the anterior height of the septum at the level of the nasolacrimal duct; 2) 5.07 ± 0.75 cm instead of 5.5 ± 0.7 cm in the anterior limit of the extended NFIM flap. They concluded that the entire septum could be reconstructed with the flap; however, they did not take into account the retraction process during the healing of the flap. Moreover, the analysis was only conducted in 36 patients.

Our radiological study shows that a SNFIM flap could reconstruct 40% of the height of the nasal septum, or a SP with an upper limit that does not exceed 1.9 cm of nasal septum height. In the case of the ENFIM flap, the percentage of the height of the septum that could be reconstructed is 79.6%, and the superior edge of the septal perforation could be located up to 3.7 cm of the anterior septal height. Here is a simplified rule for surgery: the lower third of the septum could be reconstructed with a SNFIM flap and the lower three-quarters of the septum with an ENFIM flap. However, we have to take into the account, the limitation of the flap in the most caudal area of the septum. We suggest that the anterior limit of the SP that the SNFIM or ENFIM flaps can reconstruct would be the pyriform aperture.

Additionally, Teymourtash et al.[6] did not consider the retraction process in their preoperative measurements; they assumed that the entire length of the flap is useful in reconstruction. No studies quantify the retraction of the flap during the healing process. Nonetheless, several series describe similar measurements, such as Patel et al. [18] who added 30 mm to each measurement for the pericranial flap. As a consequence, our experience in this and other techniques make us feel that if the flap is sutured with tension, closure failure is a high risk. Therefore, as in other series published regarding other flaps [15,19], we discounted one-third of the length of the flap to take into account the retraction process.

Study limitations

The main limitations of our study are based on the number of patients. Only five patients were enrolled in the cohort. Although no closure failures or complications were found, more studies are needed with larger series of patients to compare septal reconstruction with the NFIM flap with other techniques. This would help to protocolize the treatment of SPs and obtain a proper assessment of the different techniques and their results. Scar healing after SP repair was not assessed. We assumed that adding one-third of the original flap length would be enough to counteract the scar contraction. No studies in the literature

report the retraction process of endonasal flaps. However, some studies use similar references, such as that described by Patel et al. [18] who added 30 mm to each measurement for the pericranial flap.

Anatomical and radiological studies demonstrated significant differences between males and females in some of the measurements of the flap with a clear trend to be larger in men. It is reasonable that in longer series significant differences would be found in all measurements.

Conclusion

Many approaches have been described for SP repairs. The choice of the technique is based on the experience of the surgeon, the location of the SP, and osteo-cartilaginous support. The simple or expanded NFIM flap represents a simple and feasible option to repair small- or medium-sized perforations located at the lower and middle area of the nasal septum. A SNFIM is able to reconstruct the lower one-third and ENFIM the lower three-quarters of the nasal septum.

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Authorship contribution

Data collection: ASG, MLC, LVG, MVM; Cadaver dissection: ASG, MLC, MVM; Radiological measurements: ASG; Surgeon for patients: CL, IA; Study design: ASG, MLC, CL, MBS, IA; Manuscript writing/editing: ASG, CL, MBS, IA.

Conflict of interest

None.

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Isam Alobid
Rhinology and Skull Base Unit
Dept of Otorhinolaryngology
Hospital Clínic
Barcelona. c/ Villarroel 170
08036 Barcelona
Spain

Tel: +34 932279872
Fax: +34 932275050
E-mail: isamalobid@gmail.com