ORIGINAL ARTICLE

Pedicle Flaps Based on the Sphenopalatine Artery: Anatomical and Surgical Study

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Abstract

Introduction: Local pedicle flaps based on the sphenopalatine artery make it possible to reconstruct large defects of the skull base (SB).

Material and methods: From January 2008 to January 2013, 64 lesions with involvement of SB were analysed. These lesions were treated using endoscopic endonasal approach and required a pedicle flap based on the sphenopalatine artery. In addition, measurements and flexibility of the flaps were examined in 4 cadaveric nasal cavities.

Results: Surgical group. Sixty-four nasoseptal flaps (NSF) were used, in 4 cases associated with a middle turbinate flap (MTF), and in 1 case supplemented with an inferior turbinate flap (ITF). Five cerebrospinal fluid fistulas (8%) were noted. Among patients with initial lesions, 7% presented an anosmia. Cadaveric group. The length of the NSF varied between 5.2 cm and 7.7 cm and the width ranged from 3 cm to 4.5 cm. The ITF provided an anterior–posterior distance between 4.2 cm and 5 cm, with a width between 1.2 cm and 2.8 cm. The mean length of MTFs varied between 3.5 cm and 4.2 cm, with a width between 1.4 cm and 1.9 cm.

Conclusion: The most versatile local flap for the reconstruction of skull base defects is the NSF, and flaps pedicled to the posterolateral nasal artery offer an excellent alternative.

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KEYWORDS
Pedicle flaps; Sphenopalatine artery; Skull base; Endoscopic surgery

CrossMark
Colgajos pediculados procedentes de la arteria esfenopalatina: estudio anatómico y quirúrgico

Resumen
Introducción: Los colgajos locales pediculados a la arteria esfenopalatina permiten reconstruir amplios defectos de la base del cráneo (BC).
Material y métodos: De enero de 2008 a enero de 2013 se analizaron 64 lesiones con afectación de la BC intervenidos con un abordaje endonasal endoscópico que requirieron una reconstrucción con colgajos locales pediculados a la arteria esfenopalatina.
Adicionalmente se estudiaron cuatro fosas nasales correspondientes a dos cabezas de cadáver donde se analizaron endoscópicamente las medidas y la flexibilidad de cada uno de los colgajos.
Resultados: Grupo quirúrgico. Se emplearon 64 colgajos nasoseptales (CNS), en cuatro casos asociados a un colgajo cornete medio (CCM) y en un caso complementado con un colgajo del cornete inferior (CCI). Se evidenciaron 5 fistulas postquirúrgicas (8%). Un 7% de los pacientes con lesiones iniciales presentaron una anosmia definitiva.
Dissección anatómica. La longitud del CNS varió entre 5,2 cm y 7,7 cm oscilando la anchura entre 3 cm y 4,5 cm. El CCI presentó una distancia anteroposterior entre 4,2 cm y 5 cm y una anchura entre 1,2 cm y 2,8 cm. La longitud media del CCM varió entre 3,5 cm y 4,2 cm con una anchura entre 1,4 cm y 1,9 cm.
Conclusión: El CNS es el colgajo local que presenta una mejor versatilidad en el sellado de los defectos craneales, siendo los colgajos pediculados a la arteria nasal posterolateral una excelente alternativa.
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Introduction
The aim of reconstructive surgery of the skull base (SB) is to seal the surgical defect and separate the nasosinusal area from the cranial cavity, thus preventing the presence of cerebrospinal fluid fistulas (CBF) and possible intracranial complications. The use of autologous, or heterologous free grafts obtains excellent results in the repair of the majority of small cranial defects, in general under 1 cm.1-7 For large defects, in patients who have had repeated surgery or patients previously treated with radiation, the vascularised, local or regional flaps, provide vital tissue volume of greater quality enabling more reliable reconstructions by minimising scarring problems and tissue necrosis. Local endonasal flaps were previously used in different areas of the maxillofacial region, such as in the repair of septal perforations, ononasal fistulas, in choanal atresia or reconstruction of the nasal pyramid.4-7 Its application in SB reconstruction is relatively recent, the flap designed by Hadad and Bassagasteguy being the most popular at present. This NSF has been decisive for the advance and expansion of these reconstructive techniques.8,9 At present they seal extensive defects with a post surgical fistula percentage under 5%.3,10,11
The aim of this study is to describe our experience in SB reconstruction using local vascularised flaps, and study the characteristics of the main flaps from different branches of the sphenopalatine artery (SA) in corpses.

Material and Methods
From January 2008 to January 2013 a total of 93 lesions affecting SBs, which underwent surgery using endoscopic endonasal approach (EEA) were diagnosed in our Skull Base Unit. Patients who were not treated by pedicle flap reconstruction and patients diagnosed with a CBF fistula were excluded from the study. 64 lesions were studied in total with analysis of distribution by age and gender, anatomopathological diagnosis, type of surgery used, different flaps used in reconstruction, and post surgical complications. Minimum patient follow-up was 6 months.
In addition, an anatomical study was made in four cadaveric nasal cavities which had been prepared and preserved according to the Thiel technique and with their blood vessels perfused with latex, dextrin, and lead tetroxide.12,13 A computerised tomography was carried out on the para nasal sinuses of two specimens using a 10 cm Somatom Sensation 10® (Siemens) multidetector tomography.
The cavity and SA were then identified and an NSF, a MTF14 and an ITF15,16 were designed in each nasal cavity. The length, extent and the flexibility of each one was analysed by endoscopy. A malleable graduated dilator was used for the different measurements. The NSF length was calculated from the head of the inferior turbinate and from the nasal-limen nasi vestibule to the external third of the choanal arch. The length from the head of the middle turbinate and the inferior turbinate up to its insertion in the upper palatine apophysis was measured. To measure NSF width the largest extension between the superior incision, made approximately 1 cm inferior to the nasal cavity roof, and the inferior incision located in the alveolar ridge was considered. In the middle nasal turbinate and inferior nasal turbinate the greatest distance between the superior and inferior margin of the two was considered. A second measurement was made in the ITF, increasing the inferior incision up to half of the nasal cavity floor. Finally, data were
confirmed by cutting the flaps from their vascular pedicle and carrying out the same measures extranasally (Fig. 1).

Results

Surgical Group

The mean age of the patients at diagnosis was 53, with ages ranged between 16 and 81. 59% of patients (38/64) were women and 41% (26/64) men. The different pathologies included 48 pituitary gland adenomas, 5 chordomas, 4 craniopharyngiomas, 4 meningoceles, 2 basal impressions and one meningioma. 33% (21/64) involved revision surgery. In 93% of interventions a transellar transsphenoidal approach was carried out (60/64), a transellar approach being used in 5 cases, extending to the clivus, in 4 cases extended to the planum sphenoidale and in 5 cases associated with a transpterygoid transmaxillary approach.

In 3 cases an extended transnasal approach was used (2 transodontoid and one transclival approach). In 1 patient a transsphenoidal approach was used to access the lateral wall of the sphenoid sinuses.

64 NSF were used. In four cases these were associated with a MTF and in one case complemented with an ITF. In 10 patients (16%) the flap was directly applied onto the surgical defect and in the other cases grafts of fascia lata and/or abdominal fat were applied prior to this.

5 postsurgical fistulas (8%) were detected. In the 5 patients an NSF was used in reconstruction and in all cases lumbar drain was used immediately after surgery. The fistulas presented in 3 macroadenomas operated on using transellar transsphenoidal approach, in one craniopharyngioma treated by transplanum transsphenoidal approach and one meningocele of the lateral sphenoid recess treated by sphenoid approach.

One patient underwent review surgery after presenting an epistaxis following the removal of the nasal packing. This was successful and flap visibility was not altered.

7% (3/43) of patients with initial lesions presented with anosmia. The 3 patients were operated on for an ACTH-producing adenoma. Olfactory alterations in the reoperated patients were not considered.

Cadaveric Group (Figs. 2–5)

The sphenopalatine cavity and its terminal branches were identified in the four nasal cavities: the posterior septal artery (PSA) and the posterior lateral nasal artery (PLNA). In 3 cases a common trunk was identified and in one nasal cavity SPA division was performed in the pterygopalatine fossa.

The results of the length and width of each flap are shown in Table 1.

Extension of the Reconstruction With the Different Flaps

The NSF area covered the whole area between the upper third and medial planum sphenoidale clivus, including the sellar area. It could be applied separately throughout the cribiform plate area, in the ethmoidal groove and enveloping the whole clival area.

The MTF extended to the sellar region, the tuberculum sellae region, the suppar third of the clivus and covered the ethmoidal groove region.

The extended ITF covered the whole area of the clivus up to the sella turcica depression.

Table 2 shows the viability of each flap according to our surgical experience and the findings from anatomical dissection.

Figure 1 Nasoseptal flap and septal posterior right flap. The 2 primary branches can be seen in the thickness of the septal mucous.
P: posterior artery flap.
Discussion

Free grafts have been widely used as the option of choice in reconstructive head and neck surgery but their lower reliability and quality resulted in their being progressively replaced by vascularised local or regional flaps. At present, in large SB defects this has become the reconstructive technique of choice. In one recent meta analysis a lower percentage of CBF (6.7%) fistulas were present in patients operated on for large dural effects with vascularised flaps.

<table>
<thead>
<tr>
<th>Fossa</th>
<th>NSF L1-L2 × A cm</th>
<th>CCM L × A cm</th>
<th>CCI L × A-A1 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.1-7.0 × 4.0</td>
<td>4.0 × 1.5</td>
<td>4.2 × 1.3-2.4</td>
</tr>
<tr>
<td>2</td>
<td>6.2-7.1 × 3.1</td>
<td>3.5 × 1.4</td>
<td>4.6 × 1.3-2.5</td>
</tr>
<tr>
<td>3</td>
<td>5.2-6.0 × 3.0</td>
<td>4.2 × 1.9</td>
<td>5.0 × 1.4-2.8</td>
</tr>
<tr>
<td>4</td>
<td>6.4-7.7 × 4.5</td>
<td>3.6 × 1.5</td>
<td>4.7 × 1.2-2.2</td>
</tr>
</tbody>
</table>

A: width; A1: width including inferior meatus and fossa floor; L: length; L1: length to inferior turbinate flap; L2: length to limen nasi; CCI: inferior turbinate flap; CCM: middle turbinate flap; NSF: nasoseptal flaps.

Table 1 Vascularised Flaps: Length and Width Measurements.
Notwithstanding, a found demonstrated

\[ \text{Figure 4} \] Lower turbinate with its vascularisation from the posterior lateral nasal artery in the left nasal fossa. The inferior turbinate flat is observed, including inferior meatus dissection and fossa floor. ANPL: posterior lateral nasal artery; CCI: inferior turbinate flap; CI: inferior turbinate; CM: middle turbinate; S: septum.

\[ \text{Figure 5} \] Endoscopic view of the 3 pedicle flaps to the left sphenopalatine artery. AEP: sphenopalatine artery; inferior: inferior turbinal artery; middle: middle turbinal artery; NPL: posterolateral nasal artery; SP: posterior septal artery.

were simple, the vascular pedicle was not identified and the flap rotated around a pivot with random vascularisation. Hadad and Bassagasteguy succeeded in popularising this flap in the AEE context, with a detailed description of its design, rotation and vascularisation.\(^a\)

\textbf{Table 2} Versatility of Each Vascularised Flaps.

<table>
<thead>
<tr>
<th>Defect</th>
<th>NSF</th>
<th>CCM</th>
<th>CCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selar</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Planum sphenoidale</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Ethmoidal groove</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Cribiform</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>Clivus</td>
<td>YES</td>
<td>YES (^b)</td>
<td>YES</td>
</tr>
</tbody>
</table>

CCI: inferior turbinate flap; CCM: middle turbinate flap; NSF: nasoseptal flaps.

\(^a\) Tuberculum sellae area.

\(^b\) Upper third of the clivus.

\textbf{Nasoseptal Flap}

The nasoseptal flap is the pedicle flap with the greatest versatility in SB reconstruction. In our study the flap length ranged between 5.2 cm and 6.4 cm increasing to 7.7 cm when the anterior incision extended to the \textit{limen nasi}. Pinheiro-Neto et al.\(^19\) demonstrated a similar length, ranging between 5.8 cm and 8.6 cm between the anterior and posterior flap limit.

Shah RN et al.\(^20\) found a mean length of 6.22 cm in 10 adults studied and Shin JM et al.\(^21\) a length of 7.7 cm and 7.4 cm in two patients analysed. In our dissection the NSF width ranged between 3 cm and 4.5 cm. It should be noted that it is possible to increase its amplitude by

compared with the reconstruction with free grafts (15.6%).\(^3\) Success of pedicle flaps requires appropriate anatomical knowledge of vascularisation. The flaps depend upon terminal branches of PEA, PLNA and PSA are the most widely used endonasal flaps. Oscar Hirsch was the first one to use a septal flap to endonasally close a postoperative CBF fistula in 1952.\(^15\) Notwithstanding, these first rotation flaps
increasing the inferior incision further than the maxillary crest, including the mucous membrane of the nasal fossa floor. In our anatomical study this technique was not completed. These dimensions lead to the longitudinal reconstruction of the anterior SB defect, of the sphenoid sinuses and the clivus in separate approaches. It is also possible to cover a wide defect extending from the posterior wall of the frontal sinus to the anterior wall of the sphenoid sinus or of the planum sphenoidale, the mean distance of which is 42 cm and 5.44 cm respectively.\textsuperscript{19,20}

Any anterior SB defect may therefore be transversely reconstructed. Batra PS et al.\textsuperscript{22} demonstrated a mean interorbital distance in an anatomical study on level of the anterior and posterior ethmoid arteries of 2.35 cm and 1.91 cm respectively, whilst Waitzman AA et al.\textsuperscript{23} discovered a mean distance between both medial orbital walls of 2.7 cm and 2.9 cm, in radiological analysis, including 33 patients between 16 and 17 years of age.

Notwithstanding, if a major defect is to be reconstructed, which includes the whole anterior SB and the clivus, it may not be sufficient owing to the fact that the distance ranges between 9.82 cm and 11.92 cm.\textsuperscript{11} In these cases it is advisable to design a bilateral NSF, or complete it with other pedicle flaps or with free flaps.

Other alternatives must be found when the NSF is considered excessive or when it is not possible to use it, such as in previously operated patients with extensive septal resections, or when the lesions to be treated include septal mucosa.

**Turbinate Flaps**

Pedicle flaps based on the PLNA are a good alternative to NSF. The PLNA descends vertically over the vertical apophysis of the palatine, irrigates the lateral wall regions of the nasal fossa and joins up with the anterior and posterior branches of the ethmoid arteries. It presents two terminal branches, one for the middle turbinate and the other for the inferior turbinate. In 15% of cases the inferior turbinate may receive supplementary irrigation from the palatine artery branches of the descending palatine artery and those coming previously from the angular artery.\textsuperscript{24,25}

The ITF presents an excellent anteroposterior distance, between 4.2 cm and 5 cm, its width being its main limitation, which ranges between 1.2 cm and 1.4 cm according to our results.

Amit M et al.\textsuperscript{16} obtained similar results with a mean length and width of 4.8 cm and 1.8 cm respectively in 11 corpses analysed. However, Harvey RJ et al.\textsuperscript{26} obtained a similar length (5.4 cm), but with greater width (2.2 cm). This greater extension may be explained by the inferior flap incision, which can be increased by extending its dissection to the inferior meatus and/or fossa floor. In our study we succeeded in duplicating the flap width using this technique (Fig. 4).

This is an ideal flap for sealing defects in the clivus area Fortes FS et al.\textsuperscript{15} used ITF successfully in 3 patients to reconstruct the clival area and in one patient with a sellar defect. Harvey RJ et al.\textsuperscript{26} demonstrated that it is the best flap for posterior SB defects but that it only covers 2/3 of the anterior cranial fossa.

In our experience, its limited rotation angle only reliably enables the reconstruction of defects in the clival area, due to the tension from extension to the sellar and suprasella region.

The MTF is pedicled to the middle turbinate artery emerging in the majority of PLNA cases through the sphenopalatine cavity. In 12% of cases this may occur in the most distal section of the PLNA, adjacent to the inferior turbinate tail.

The mean length of the middle turbinate ranges between 4 cm and 4.7 cm with maximum width of 1.5 cm.\textsuperscript{14,27}

In our series MTF length was similar, with a superior width between 1.4 cm and 1.9 cm, due to the design of the same which uses both the medial surface and lateral surface mucous. Prevedello DM et al.\textsuperscript{11} confirmed these findings describing a mean extension of 2.8 cm in the 12 flaps analysed. In this study they demonstrated that the MTF can cover sellar defects in 83% of cases and up to 100% of defects which affect the planum sphenoidale or the ethmoidal groove.

This flap presents the most technical difficulties, due to anatomical variations of the turbinate and fixture instability, which together with the presence of a thin and friable mucous turbinate, hinders its subperiostic dissection. Similarly to the ITF it has less flexibility compared with the NSF. In our experience the MTF can separately cover sellar defects of the tuberculum sellae area, defects of the upper third of the clivus and defects in the ethmoidal groove area. It can probably also reach the suprasellar area, but in our dissection we were not able to reliably reconstruct this area.

In our institution we always used the MTF as an additional flap in AEE reconstruction and never as the only flap.

The morbidity of these pedicle flaps depends on their design and size, with more frequent morbidity when there are crurts. In most cases this is related to septal mucous regeneration time used in the NSF, with mean time at 3 months.\textsuperscript{28} The design of these flaps, NSF and MTF, may alter the olfactory function.\textsuperscript{26,29} De Almeida JR et al.\textsuperscript{28} found a diminished sense of smell in 7.9% of patients and anosmia in 1.6%. 7% (3/43) of our patients who had been operated on for initial lesions presented anosmia.

**Conclusion**

Pedicle flaps based on the SPA offer an excellent reconstructive option in SB defects. The NSF is the most versatile with pedicle flaps being used as a good alternative to PLNA when NSF cannot be used.

**Conflict of Interests**

The authors have no conflict of interests to declare.

**References**


