Indian J Otolaryngol Head Neck Surg
DOI 10.1007/s12070-017-1197-z

OTHER ARTICLES

Anatomical Correlation Between Nasal Vascularisation and the Design of the Endonasal Pedicle Flaps

Juan R. Gras-Cabrerizo[1] · Elena García-Garrigós[2] · Joan R. Montserrat-Gili[1] · Juan R. Gras-Albert[3] · Rosa Mirapeix-Lucas[4] · Humbert Massegur-Solench[1] · Miquel Quer-Agusti[1]

Received: 5 March 2017 / Accepted: 1 September 2017

Abstract Arteries that supply the nasal septum and the lateral nasal wall include vessels that originate from the external carotid artery and from the internal carotid artery. A variety of local endonasal pedicle flaps can be used in different anatomical areas for endoscopic skull base reconstruction. The main flaps are based on terminal branches of the sphenopalatine artery and on anterior ethmoidal artery. This study will describe the anatomy of these vessels and their relationship with the main flaps.

Keywords Artery · Flap · Maxillary · Ethmoidal · Sphenopalatine

The nasal cavity has a rich vascular network. Arteries that supply the nasal septum and the lateral nasal wall include vessels that originate from the external carotid artery (maxillary and facial artery) and from the internal carotid artery (ophthalmic artery). Appropriate anatomical knowledge of nasal vascularisation is essential to perform a variety of pedicle flaps. They can be used in different anatomical areas such as in the repair of septal perforations, oronasal fistulas, reconstruction of the nasal pyramid, in choanal atresia, and in recent years in skull base reconstruction. Currently local endonasal pedicle flaps (LEPF) are the option of choice in reconstructive nasosinusal and skull base surgery, due to their reliability and quality regarding free grafts. The flaps based on terminal branches of the sphenopalatine artery and on anterior ethmoidal artery are the most widely used LEPF. We describe the anatomy of these vessels in detail and their relationship with the main LEPF.

✉ Juan R. Gras-Cabrerizo
jgras@santpau.cat

[1] Department of Otolaryngology/Head and Neck Surgery, Hospital de la Santa Creu i Sant Pau, Universitat Autònoma de Barcelona, Barcelona, Spain

[2] Department of Radiology, Hospital Universitario de Alicante, Universidad Miguel Hernandez, Alicante, Spain

[3] Department of Otolaryngology/Head and Neck Surgery, Hospital Universitario de Alicante, Universidad Miguel Hernandez, Alicante, Spain

[4] Unit of Anatomy and Human Embriology, Universitat Autónoma de Barcelona, Barcelona, Spain

Branches of the Sphenopalatine Artery (*Arteria Sphenopalatina*)

The sphenopalatine artery is the terminal branch of the maxillary artery (MA), which is one of the two main end arteries from of the external carotid artery. The MA is located behind the neck of the mandible and passes lateral or medial to the lateral pterygoid muscle (Fig. 1), and reaches the pterygopalatine fossa (PF) through the pterygomaxillary fissure. This portion of the MA is called the pterygopalatine segment. The branches of this third segment are, according to their origin from lateral to medial: posterior superior alveolar artery, infraorbital artery, descending palatine artery, artery of the foramen rotundum, artery of the pterygoid canal, pharyngeal branch and sphenopalatine artery [1]. These branches supply the orbit, the nasal cavity, the nasopharynx, the cavernous sinus and the carotid canal (Fig. 2). The sphenopalatine artery emerges from the superomedial part of the PF and enters the nasal cavity through the sphenopalatine foramen. This foramen is usually located in the superior meatus, although it may also be found in the middle meatus or at the

Published online: 06 September 2017

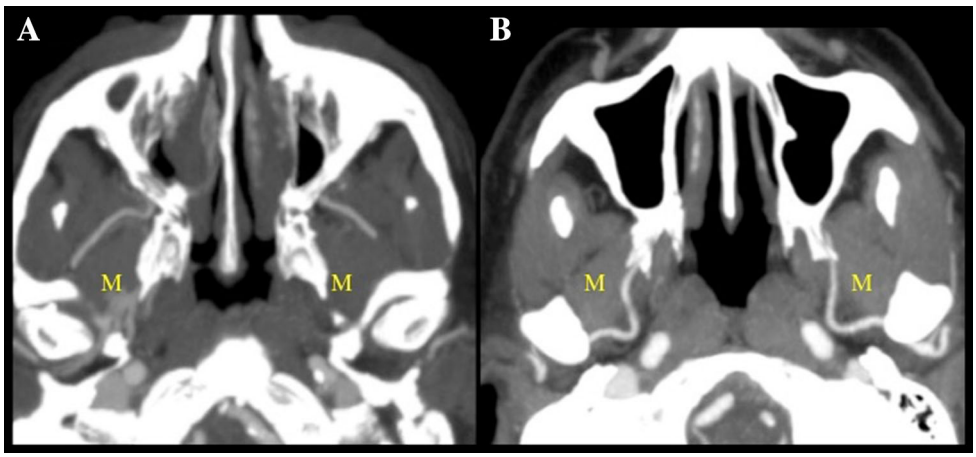

Fig. 1 Axial computed tomography angiography (CTA) image with maximum intensity projection (MIP): the maxillary artery pass lateral (**a**) and medial (**b**) to the lateral pterygoid muscle (M)

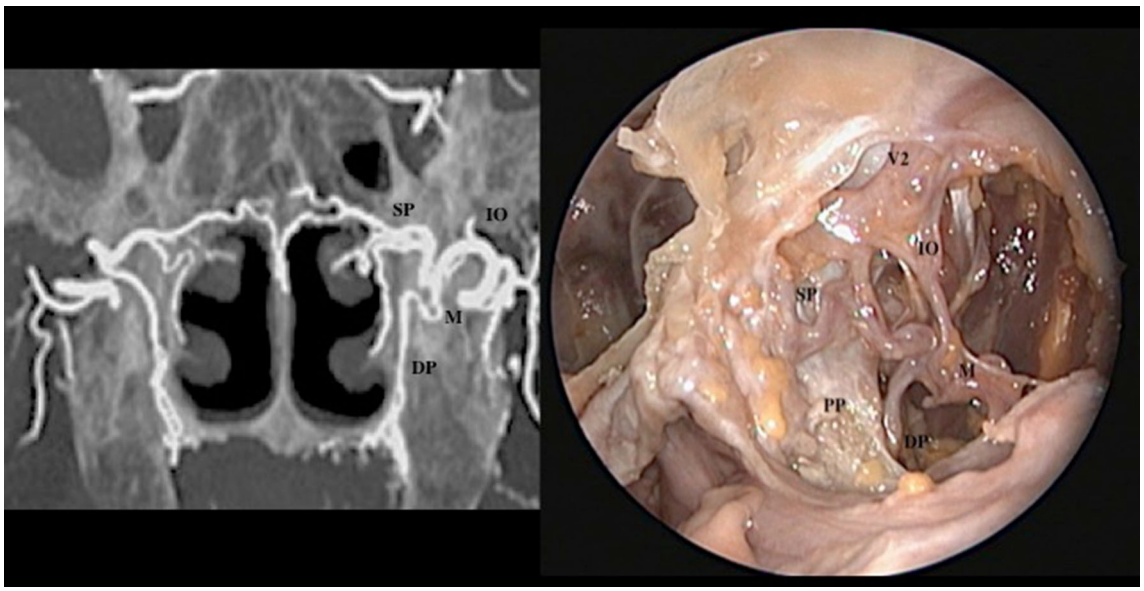

Fig. 2 Pterigopalatine segment of the maxillary artery (M) and its main branches. *SP* sphenopalatine artery, *IO* infraorbital artery, *DP* descending palatine artery, *PP* perpendicular plate

transition of both meatuses, according to its location above or below the ethmoidal crest. This bone reference is the best anatomic landmark to localize the sphenopalatine artery. It gives off two main branches, the posterior lateral nasal artery (PLNA) and the posterior septal artery (PSA) [2, 3] which can be divided into one or two trunks medial to the ethmoidal crest, before or after crossing the sphenopalatine foramen. It is rarely possible to identify more than two trunks [2, 4] (Fig. 3).

1. The PLNA supplies the region of the lateral nasal wall giving off branches to inferior turbinate (inferior turbinate artery), to middle turbinate (middle turbinate artery), to mucosa of the fontanelle and to mucosa of the maxillary sinus [5] (Fig. 4). In approximately 20% of cases this artery supplies the superior turbinate [6].

1a. The inferior turbinate artery enters a bone canal and runs anteriorly along the turbinate. It usually gives off two terminal branches, within or adjacent to the bone, supplying the mucosa of the turbinate (Fig. 5). An inferior turbinate flap (ITF) may be designed by employing the medial and lateral mucosal surface of the turbinate. The ITF presents an excellent anteroposterior distance, between 4.2 and 5 cm, with a width between 1.2 and 1.4 cm [7]. Based on this posterior pedicle it is an optimal flap to seal posterior skull base defects, particularly in the clival area [8, 9]. Carrau and Hadad (C–H flap) improved this posterior ITF incorporating the mucoperiosteum of the lateral nasal wall and the mucoperiosteum of the floor of the nasal cavity [10]. The C–H flap obtains three times the surface of the posterior ITF and it should be considered a surgical

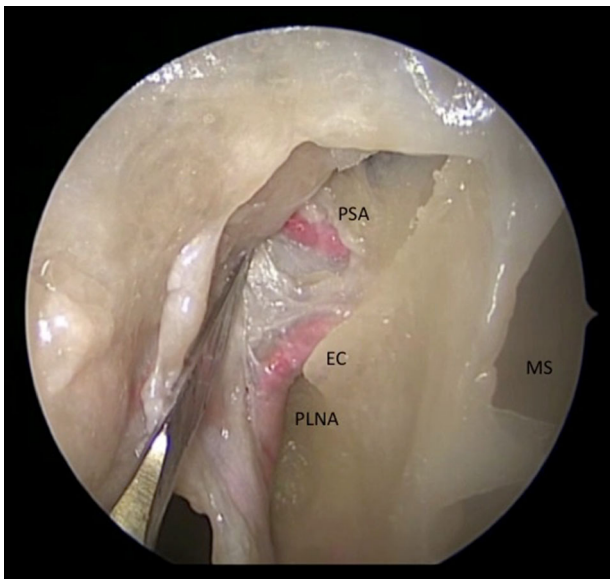

Fig. 3 The ethmoidal crest (EC) in the left nasal cavity. The two main branches of the sphenopalatine artery are posterior to this crest. *PSA* posterior septal artery, *PLNA* posterior lateral nasal artery, *MS* maxillary sinus

option when the posterior ITF is not sufficiently large. Some branches from the facial artery, the superior labial artery (*arteria labialis superior*) and the lateral nasal artery (*arteria lateralis nasi)* can reach the head of the inferior turbinate (Fig. 6). Therefore the inferior turbinate receives a dual blood supply allowing to perform not only a posterior ITF but also an anterior turbinate flap. Based on its anterior pedicle, the mucoperiosteum surface of the ITF can reconstruct pyramid defects or anterior septum perforation [11, 12]. Oronasal fistulas can also be closed with the ITF using both pedicles, anterior and posterior [13].

1b. The middle turbinate artery gives off several branches, some of which run along the medial surface of the turbinate while the other branches supply the lateral turbinate surface and the anterior ethmoidal complex (Fig. 4). Taking into account the entrance of the artery on the posterior attachment of the middle turbinate, a middle turbinate flap (MTF) can be designed. The lateral and medial mucosa surfaces are dissected from the turbinate bone, which will later be removed. It is possible to create a flap with approximately a length of 4 cm and a width of 1.5 cm. [7]. The MTF presents technical difficulties, due to anatomical variations and the instability of the turbinate. It is optimal to cover the ethmoidal groove and it can be used to seal defects of the upper third of the clivus and sellar area [14]. Recently the MTF has been described to repair posterior septal perforations [15].

The ITF and the MTF could be used in patients in which the septal flap pedicle to the PSA is not available, such as when the tumours involve the nasal septum, in large posterior septectomies and in wide sphenoidotomies.

2. The PSA courses the anterior wall of the sphenoid sinus on a subperiostical plane, between the choana and sphenoidal ostium. In most cases the artery bifurcates into superior and inferior branches. In this area it supplies superior turbinate (superior turbinate artery), sphenoid

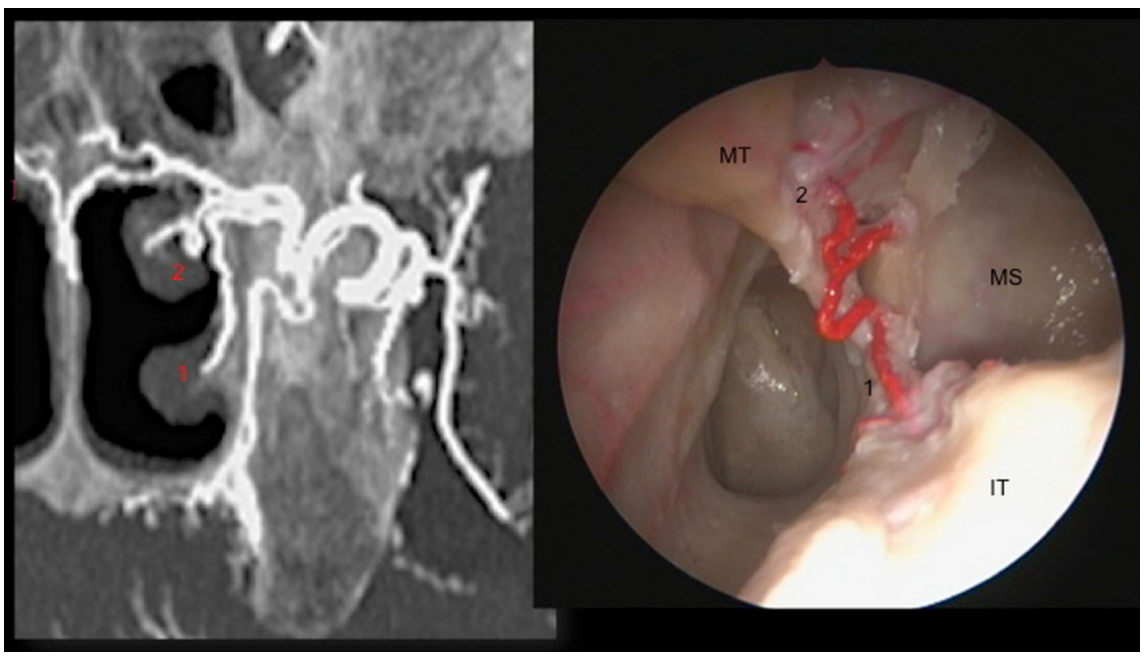

Fig. 4 Coronal CTA and endoscopic view. The PLNA in the left nasal cavity gives off the inferior turbinal artery (1) and the middle turbinate artery (2). *IT* inferior turbinate, *MT* middle turbinate, *MS* maxillary sinus

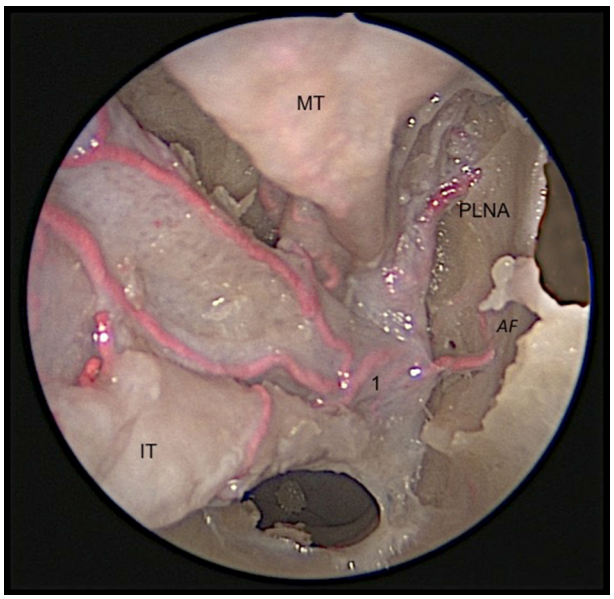

Fig. 5 Two terminal branches of the inferior turbinate artery (1) along the inferior turbinate in the left nasal cavity. *IT* inferior turbinate, *MT* middle turbinate, *PLNA* posterior lateral nasal artery, *AF* accessory foramen

sinus and posterior ethmoid complex (Figs. 3, 7). The superior turbinate artery can arise from the superior division of the PSA or directly from the trunk of the PSA [16]. The PSA distributes on the nasal septum irrigating mainly the inferior two thirds. The distal extreme of the inferior branch of the PSA, the nasopalatine artery, vascularizes the inferior septal area and ends in the incisive canal where it anastomoses with the greater palatine artery [1–3]. Furthermore, the PSA presents anastomosis in the septal area with the ethmoidal arteries and with branches from the superior labial artery (Fig. 8). The flap designed by Hadad and Bassagasteguy and the subsequent modifications [17–19] are based on the PSA and its posterior septal branches. This is the endonasal flap with greatest versatility in the paranasal sinuses and skull base reconstruction due to its great measurements. The flap length ranges between 5.2 and 6.4 cm increasing to 7.7 cm when the anterior incision extends to the *limen nasi*. The width ranges between 3 and 4.5 cm and it is possible to increase its amplitude by increasing the inferior incision further than the maxillary crest [7]. It can be used for reconstructing extensive defects of the anterior, middle, clival and parasellar skull base, for covering defects in the nasal floor and for the reconstruction of the medial and inferior orbit [18–20].

Branches of the Anterior Ethmoidal Artery (*Arteria Ethmoidalis Anterior*)

The ethmoidal arteries arise from the ophthalmic artery in their intraorbital route. The anterior ethmoidal artery (AEA) passes through the superior oblique muscle and the medial rectus muscle describing a curvature before being placed on the ethmoidal roof. The posterior ethmoidal artery (PEA) runs superior to the superior oblique muscle. Both ethmoidal arteries reach the roof of the ethmoidal complex through the ethmoidal foramina going through lamina papyracea. The arteries run along the ethmoidal

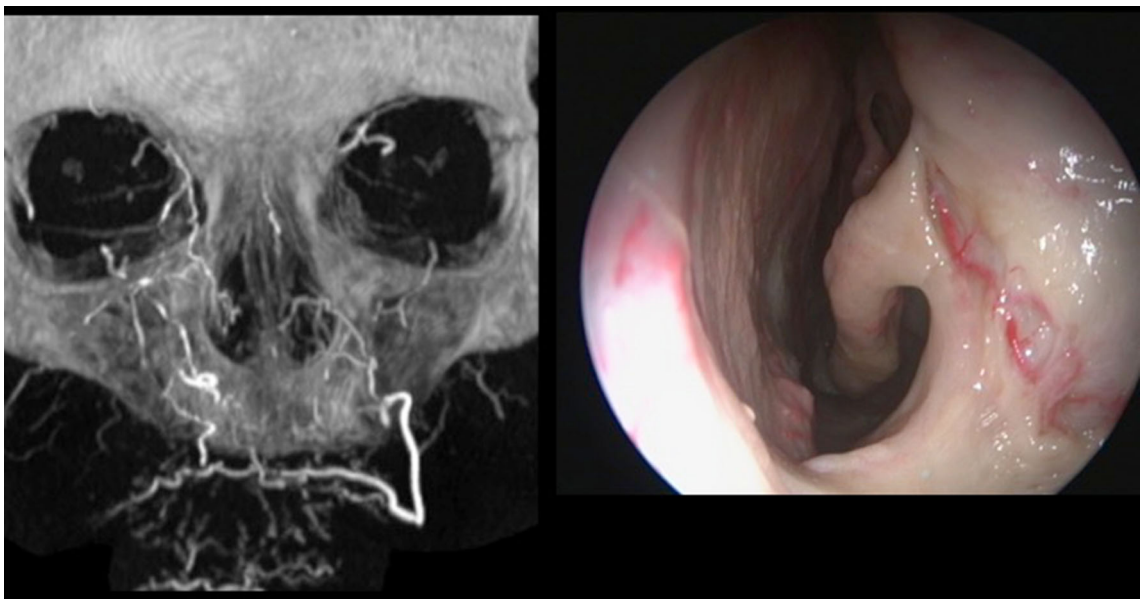

Fig. 6 Coronal CTA and left nasal vestibule. Branches from the lateral nasal and from the artery superior labial artery supplying the nasal vestibule and the head of the inferior turbinate

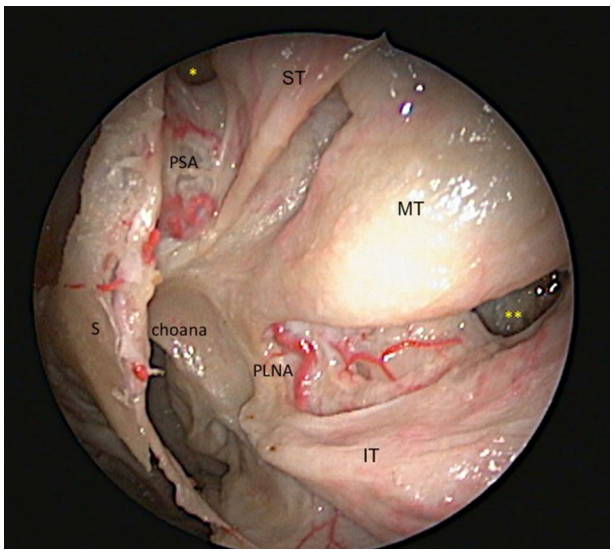

Fig. 7 The PSA courses between the choana and the sphenoidal ostium (asterisk) in the left nasal cavity. The artery bifurcates into superior and inferior branches. The PLNA gives off branches to the mucosa of the fontanelle and maxillary sinus (double asterisk). *IT* inferior turbinate, *MT* middle turbinate, *ST* superior turbinate, *PLNA* posterior lateral nasal artery, *S* nasal septum, *PSA* posterior septal artery

roof from lateral to medial, reaching the lateral lamella of cribriform plate (Fig. 9).

Depending on the pneumatisation of the ethmoidal roof, the ethmoidal arteries may be more or less evident. The bulging of the artery canal is usually more evident for the AEA than for the posterior canal. The AEA describes an oblique route allowing to identify a beak in the lamina papyracea. In some cases the AEA can present a mesentery suspended from the skull base and it is possible to be dehiscent inferiorly [21]. The most superior part of the basal lamella of the ethmoidal bulla is the landmark to find the AEA due to the fact that, in most cases, it is located behind this wall. The AEA gives off the anterior meningeal artery, which enters intracranial below the dura mater and descends through the cribriform plate, supplying the anterior superior part of the septum (anterior septal branch) and the anterior ethmoidal cells, the frontal sinus and the middle turbinate (anterior lateral nasal branches) [2, 3]. The AEA can be absent unilaterally in 7–14% cases and in 2% bilaterally. In these cases a branch from the PEA supplies the vascularisation [22, 23].

1. Anterior septal branch.

The anterior septal branch has its origin in the superior area of the nasal septum, between 5.5 and 8.7 mm posterior to the septal projection of the axilla of the middle turbinate [24]. The artery descends anteriorly and obliquely giving off two or three branches (Fig. 8). This septal branch may be used to perform the flap described by Castelnuovo (CF) [25]. The CF involves the mucoperiosteum of the nasal septum, the floor of the nasal cavity and the inferior meatus. This flap has an excellent anterosuperior rotation pivot to seal septal perforations, essentially for perforation smaller than 2 cm. This mucosal septal flap may also be used in the endonasal frontal surgery. The flap may be displaced superiorly in order to decrease the incidence of restenosis in recess frontal surgery [26].

2. Anterior lateral nasal branches.

The branches from the AEA, which supply the lateral nasal wall, can be used to perform the anterior pedicle lateral nasal wall flap or Hadad–Bassagaisteguy flap 2 (HB2) [27]. The pedicle includes not only branches from the AEA but

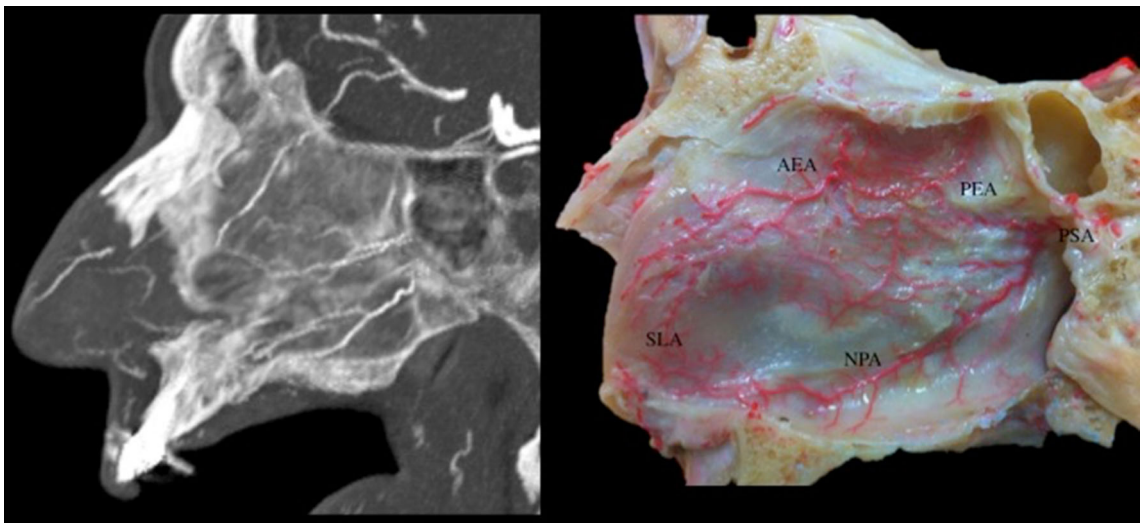

Fig. 8 Sagittal CTA image and nasal septum vascularisation. *NPA* nasopalatine artery, *SLA* superior labial artery, *AEA* anterior ethmoidal artery, *PEA* posterior ethmoidal artery, *PSA* posterior septal artery

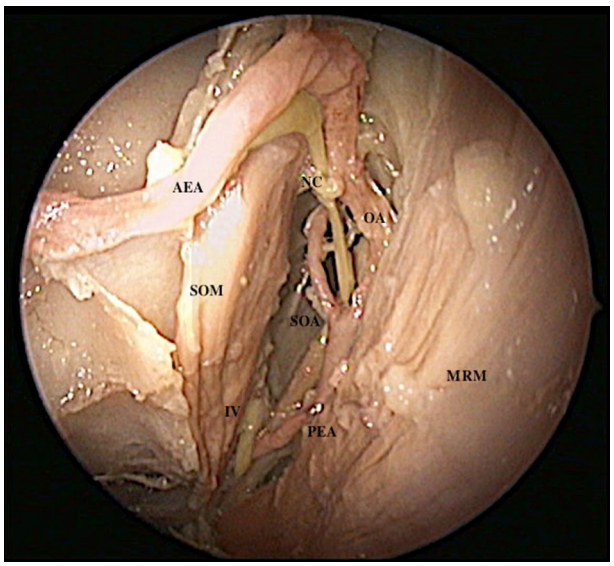

Fig. 9 Intraorbital origin of the ethmoidal arteries in the left nasal cavity. The ophthalmic artery (OA) runs parallel to the nasociliar nerve (NC). *AEA* anterior ethmoidal artery, PEA *posterior ethmoidal artery*, *SOM* superior oblique muscle, *MRM* medial rectus muscle. Trochlear nerve (IV)

also branches of the facial artery, the anterior supply of the inferior turbinate. The HB2 can cover large anterior skull base defects and provides an alternative to the nasoseptal flap [27, 28].

Conclusion

The rich vascular network of the nasal cavity allows to perform a great variety of nasal vascularised pedicle flaps. The sphenopalatine artery provides the branches for posterior nasal flaps, and branches of the anterior ethmoidal artery and facial artery are the vessels supplying the anterior nasal flaps.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have not competing interest.

Ethical Standards Cadaveric specimens are given at the moment that the corpse enters at the anatomy institute for scientific investigation following the local laws.

References

1. Drake L, Gray H (2008) Gray's atlas of anatomy, 1st edn. Churchill Livingstone, Philadelphia
2. Lund VJ, Stammberger H, Fokkens WJ, Beale T, Bernal-Sprekelsen M, Eloy P, Georgalas C, Gerstenberger C, Hellings P, Herman P, Hosemann WG, Jankowski R, Jones N, Jorissen M, Leunig A, Onerci M, Rimmer J, Rombaux P, Simmen D, Tomazic PV, Tschabitscherr M, Welge-Luessen A (2014) European position paper on the anatomical terminology of the internal nose and paranasal sinuses. Rhinol Suppl 24:1–34
3. Dauber Wolfgang (2007) Feneis: Nomenclatura anatómica ilustrada/Wolfgang Dauber, 5th edn. Elsevier Masson, Barcelona
4. Gras-Cabrerizo JR, Ademá-Alcover JM, Gras-Albert JR, Kolanczak K, Montserrat-Gili JR, Mirapeix-Lucas R, Del Campo FS, Massegur-Solench H (2014) Anatomical and surgical study of the sphenopalatine artery branches. Eur Arch Otorhinolaryngol 271(7):1947–1951
5. Rosano G, Taschieri S, Gaudy JF, Del Fabbro M (2009) Maxillary sinus vascularization: a cadaveric study. J Craniofac Surg 20(3):940–943
6. Lee HY, Kim HU, Kim SS, Son EJ, Kim JW, Cho NH, Kim KS, Lee JG, Chung IH, Yoon JH (2002) Surgical anatomy of the sphenopalatine artery in lateral nasal wall. Laryngoscope 112(10):1813–1818
7. Gras-Cabrerizo JR, Gras-Albert JR, Monjas-Canovas I, García-Garrigós E, Montserrat-Gili JR, Sánchez del Campo F, Kolanczak K, Massegur-Solench H (2014) Pedicle flaps based on the sphenopalatine artery: anatomical and surgical study. Acta Otorrinolaringol Esp 65(4):242–248
8. Fortes FS, Carrau RL, Snyderman CH, Prevedello D, Vescan A, Mintz A, Gardner P, Kassam AB (2007) The posterior pedicle inferior turbinate flap: a new vascularized flap for skull base reconstruction. Laryngoscope 117(8):1329–1332
9. Harvey RJ, Sheahan PO, Schlosser RJ (2009) Inferior turbinate pedicle flap for endoscopic skull base defect repair. Am J Rhinol Allergy 23(5):522–526
10. Rivera-Serrano CM, Bassagaisteguy LH, Hadad G, Carrau RL, Kelly D, Prevedello DM, Fernandez-Miranda J, Kassam AB (2011) Posterior pedicle lateral nasal wall flap: new reconstructive technique for large defects of the skull base. Am J Rhinol Allergy 25(6):e212–e216
11. Vuyk HD, Versluis RJ (1988) The inferior turbinate flap for closure of septal perforations. Clin Otolaryngol Allied Sci 13:53–57
12. Murakami CS, Kriet JD, Ierokomos AP (1999) Nasal reconstruction using the inferior turbinate mucosal flap. Arch Facial Plast Surg 1:97–100
13. Penna V, Bannasch H, Stark GB (2007) The turbinate flap for oronasal fistula closure. Ann Plast Surg 59:679–681
14. Prevedello DM, Barges-Coll J, Fernandez-Miranda JC, Morera V, Jacobson D, Madhok R, dos Santos MC, Zanation A, Snyderman CH, Gardner P, Kassam AB, Carrau R (2009) Middle turbinate flap for skull base reconstruction: cadaveric feasibility study. Laryngoscope 119(11):2094–2098
15. Hanci D, Altun H (2015) Repair of nasal septal perforation using middle turbinate flap (monopedicled superiory based bone included conchal flap): a new unilateral middle turbinate mucosal flap technique. Eur Arch Otorhinolaryngol 272(7):1707–1712
16. Zhang X, Wang EW, Wei H, Shi J, Snyderman CH, Gardner PA, Fernandez-Miranda JC (2014) Anatomy of the posterior septal artery with surgical implications on the vascularized pedicled nasoseptal flap. Head Neck 37(10):1470–1476
17. Hadad G, Bassagasteguy L, Carrau RL, Mataza JC, Kassam A, Snyderman CH, Mintz A (2006) A novel reconstructive technique after endoscopic expanded endonasal approaches: vascular pedicle nasoseptal flap. Laryngoscope 116(10):1882–1886
18. Suh JD, Chiu AG (2013) Sphenopalatine-derived pedicled flaps. Adv Otorhinolaryngol 74:56–63
19. Tang IP, Carrau RL, Otto BA, Prevedello DM, Kasemsiri P, Ditzel L, Muto J, Kapucu B, Kirsch C (2015) Technical nuances of commonly used vascularised flaps for skull base reconstruction. J Laryngol Otol 129(8):752–761

20. Chhabra N, Healy DY, Freitag SK, Bleier BS (2014) The nasoseptal flap for reconstruction of the medial and inferior orbit. Int Forum Allergy Rhinol 4(9):763–766
21. Monjas-Cánovas I, García-Garrigós E, Arenas-Jiménez JJ, Abarca-Olivas J, Sánchez-Del Campo F, Gras-Albert JR (2011) Radiological anatomy of the ethmoidal arteries: CT cadaver study. Acta Otorrinolaringol Esp 62(5):367–374
22. Lang J, Schäfer K (1979) Ethmoidal arteries: origin, course, regions supplied and anastomoses. Acta Anat (Basel) 104(2):183–197
23. Yang YX, Lu QK, Liao JC, Dang RS (2009) Morphological characteristics of the anterior ethmoidal artery in ethmoid roof and endoscopic localization. Skull Base 19(5):311–317
24. Gras-Cabrerizo JR, García-Garrigós E, Ademá-Alcover JM, Sarandeses-Garcia A, Martel-Martin M, Montserrat-Gili JR, Gras-Albert JR, Massegur-Solench H (2016) A unilateral septal flap based on the anterior ethmoidal artery (Castelnuovo's flap): CT cadaver study. Surg Radiol Anat 38(6):723–728
25. Castelnuovo P, Ferreli F, Khodaei I, Palma P (2011) Anterior ethmoidal artery septal flap for the management of septal perforation. Arch Facial Plast Surg 13(6):411–414
26. Seyedhadi S, Mojtaba MA, Shahin B, Hoseinali K (2013) The Draf III septal flap technique: a preliminary report. Am J Otolaryngol 34(5):399–402
27. Hadad G, Rivera-Serrano CM, Bassagaisteguy LH, Carrau RL, Fernandez-Miranda J, Prevedello DM, Kassam AB (2011) Anterior pedicle lateral nasal wall flap: a novel technique for the reconstruction of anterior skull base defects. Laryngoscope 121(8):1606–1610
28. Amit M, Cohen J, Koren I, Gil Z (2013) Cadaveric study for skull base reconstruction using anteriorly based inferior turbinate flap. Laryngoscope 123(12):2940–2944