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HEAD AND NECK

The median forehead flap reviewed: a histologic study on vascular anatomy

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Abstract Local skin flaps can be divided into two types: random flaps and axial flaps. An axial flap is defined as a flap containing a named artery in its pedicle. For the paramedian forehead flap (PMFF) a lot of surgeons insist on the point that the pedicle must contain the supratrochlear artery. To demonstrate that median forehead flaps (MFF) need not contain a named artery, we selected first 8 patients with a PMFF and further 12 patients who had undergone reconstructive surgery using a MFF. After division, we analysed the pedicle of the flap histologically and measured the diameter of the arteries or arterioles and compared them to anatomical descriptions of the frontal arteries. In none of the 12 cases could we find a functional artery of approximately 1 mm in diameter that could correspond to the supratrochlear artery. The MFF is an axial flap but not in accordance with the current definition of this term. In contrast to published literature, we show that only in a part of cases a named artery was present in the pedicle. Despite this fact, the MFF is a secure flap for full thickness defect repair on the nose.

Keywords Median frontal flap · Paramedian frontal flap · Flap · Repair of the nose · Mohs surgery · Reconstruction of the nose · Basal cell carcinoma · Squamous cell carcinoma · Oncologic surgery

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Introduction

The median forehead flap (MFF) is one of the most important flaps for repair of full thickness defects of the nose. Since its rediscovery in the 19th century, this flap has been the preferred method for full nasal reconstruction. Although the reconstructive use of this flap was already widely practiced in Indian medicine from 700 B.C. with no preoperative imaging (but presumably acceptable results), medicine of the 20th century has increasingly tended to be evidence based and has changed the pre-requisites of this flap since its rediscovery in western medicine. Today the MFF has more and more shifted to the paramedian forehead flap (PMFF) and is defined as an axial flap that should—according to the majority of authors—contain a named artery in its pedicle, i.e., the supratrochlear artery [1–3]. This culminates in the point Baker [4] make that the PMFF for nasal reconstruction has replaced the MFF because it has a more axial design, narrower base and greater effective length. What about the MFF, is it an axial flap or an over-dimensioned random pattern flap, where is the proof for a less axial design and why should it have a wider base?

Anatomy

The vascular pedicle of these two flaps is located at the glabella. The glabella is a meeting point of several different arteries. There are a large variety of anastomosing vessels but principally we find two major arteries described in the textbooks; the supratrochlear artery, which arises from the supratrochlear foramen or notch and more medially, the dorsal nasal artery which arises from the angular artery. Soon after perforating the muscle depressor supercilii this artery divides into several branches, which themselves connect with the dorsal nasal branches from the

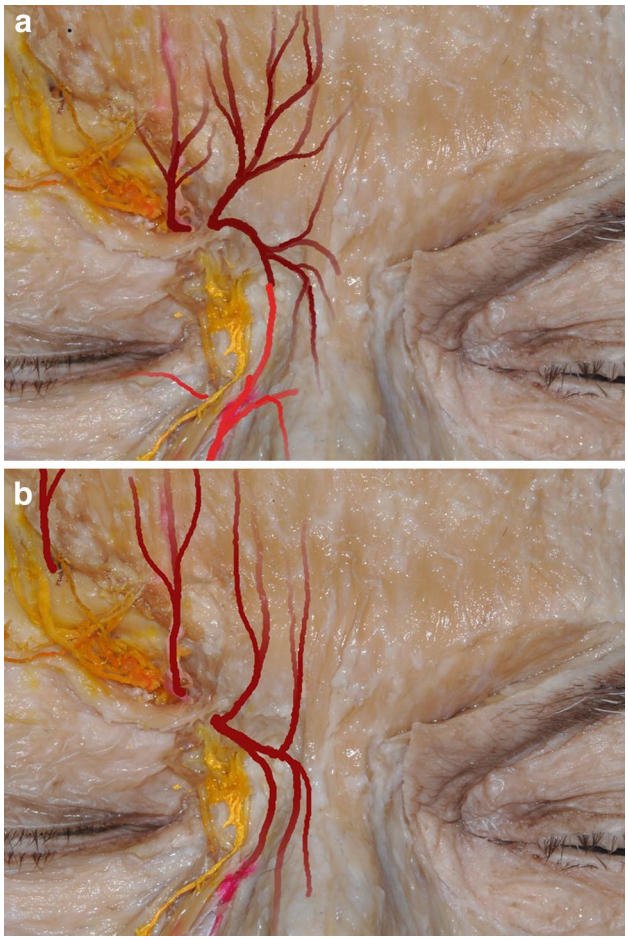

Fig. 1 **a** Classical illustration of the named arteries of the glabella: named arteries are supraorbital, supratrochlear. **b** Modification after Kleintjes and in correspondence with Burget et al.: dorsal nasal and central artery

opposite side, forming a dense network over the glabella. The terminal arteries from this network all have a caudocranial orientation to provide blood to the median part of the forehead, as illustrated by Fig. 1a [5]. In contrast, the venous system of the forehead is formed by central and parallel supratrochlear veins which converge over the glabella to drain into the angular veins on both sides of the nose. To conclude, the glabella is actually a junction of arterial supply and venous drainage and a narrow point in frontal irrigation and drainage, and therefore an ideal location for a flap pedicle.

Methods

Patient selection

We performed histologic analysis of the pedicle of eight PMFF. In none of them, an artery with bigger vessel diameter than 0.7 mm was detectable (non published data). Therefore, we decided that finally a MFF can be as well functional as a PMFF. We selected 12 MFFs in our private practice. These were all reconstructions of full thickness defects or defects up to the cartilage after MOHS surgery on the dorsum, ala and tip of the nose for basal or squamous cell carcinoma. The reconstruction was performed in all patients on the day of Mohs surgery under local tumescent anaesthesia. Division of the flap pedicle took place between 12 and 21 days after repair. Of the 12 cases thorough histologic analysis was performed (Table 1). All patients gave their agreement for histologic examination of the specimen.

Table 1 Summary of the patients: median forehead flap (MFF), diameter of biggest artery

Patients	M/PM	Sex	Age	Muscle	Arterioles	Venules	No slides	Diameter
SM	M	F	85	+	++	++	4	0.5
RM	M	F	82	++	++	++	3	0.5
PC	M	F	62		++	++	4	0.3
SG	M	F	67	+	++	++	2	0.4
SP	M	F	76	++	++	++	4	0.5
LE	M	M	72	+++	+++	++	2	0.9 (thromb) 0.6
RC	M	F	64	+	+	+	8	0.9 (thromb) 0.5
PC	M	M	83	++	++	++	4	0.6
MR	M	M	84	+	+	+		0.2
CF	M	F	92	++	++	+	6	0.3
FF	M	M	43	+	+	+	6	0.55
VE	M	M	74	+++	+	+	6	0.55

Two thrombosed supratrochlear arteries with 0.9 mm diameter

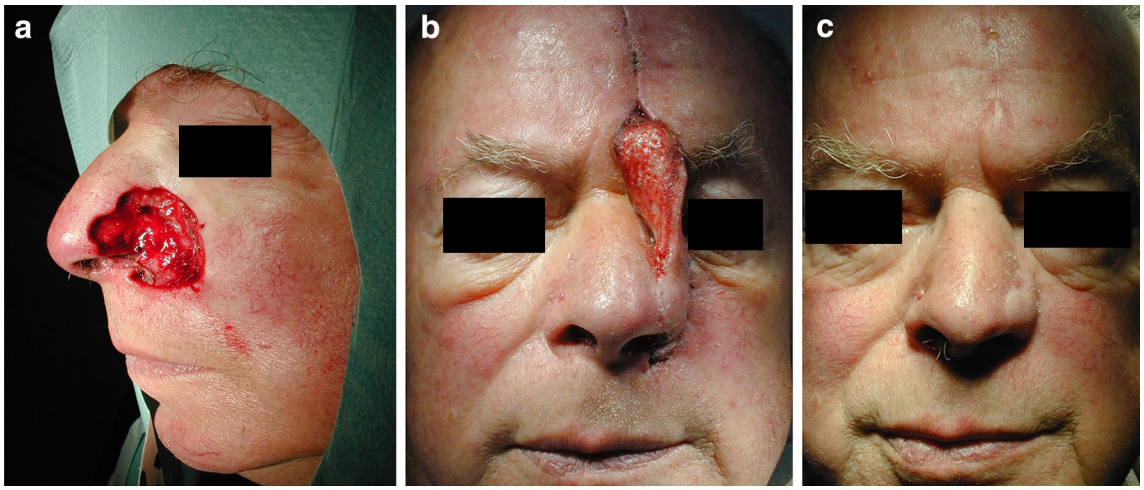

Fig. 2 **a** Nasal defect before repair, **b** 7 days after, **c** 1 month later. Please note that this is the design of a paramedian forehead flap and the pedicle is at the height of the eyebrow

Fig. 3 **a** Nasal defect before repair, **b** 15 days after, **c** 9 weeks after. The median scar goes on the back of the nose. **d** Difference of scars between a paramedian and a median forehead flap

There were 7 women and 5 men, with a mean age of 75.1 years (range 43–92 years). None of the patients showed signs of ischemia, flap necrosis or infection at follow-up. One patient, who needed a full thickness skin graft inside the nose as well as cartilage grafting, showed partial graft necrosis of the skin graft. No patient developed postoperative infection.

Surgical technique

Design of the PMFF evolved during our practice to a MFF. In the beginning, we drew a mid-line and added 1.2–1.5 cm laterally to define the pedicle. The median incision line was initially down to the nasofrontal angle. The lateral incision line ended at the height of the median eyebrow; this corresponded to a PMFF, as described by various authors [10, 12]. An example is given in Fig. 2a–c. The flap was harvested cranially in the subcutaneous layer and caudally above the periosteum. Histologic analysis of the pedicle of 8 of these flaps showed in none of them an artery with bigger vessel diameter than 0.7 mm. In consequence in the following 12 cases the incision took its origin medially on the back of the nose and laterally at the border of the orbit, which meant that the incision line started caudal to the nasofrontal angle on the back of the nose angle with a width of 1.0–1.2 cm. On the glabella and the forehead, we placed the flap more in the middle line. The incision line on the glabella was 5–6 mm either side of the mid-line so

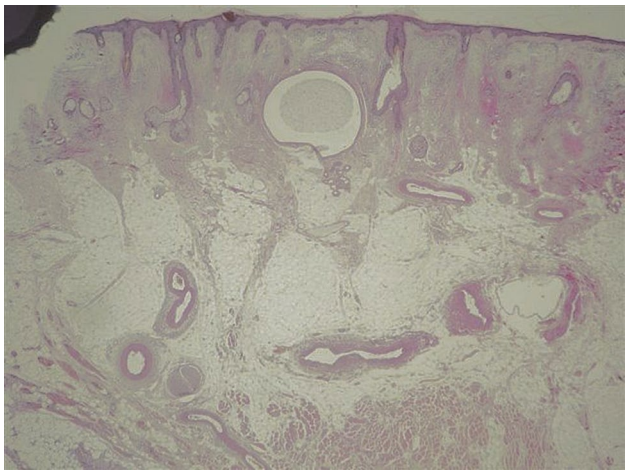

Fig. 4 Histology HE of a pedicle of a median forehead flap. Note the presence of muscle fibres and the dense network of vessels which explain the good blood supply of this axial pattern flap (HE 20×)

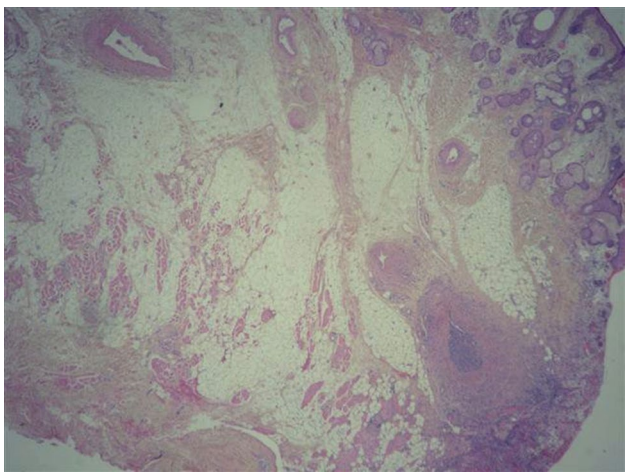

Fig. 5 Histology of one bigger vessel, which corresponds to the thrombosed supratrochlear artery at the border of the pedicle of a MFF. The tunica media are nearly the double of layers compared to the other arteries observed (VG 100×)

that the flap was more central, this corresponded to a MFF (Fig. 3a–d). This design allowed an increase of more than 1–1.5 cm in length and diminished the twist of the pedicle, which ensured that the flap would not become strangulated (Fig. 3d). In some cases, as in Fig. 3, the whole flap had to be oblique to increase its length.

Histology

All the pedicles were sectioned 2–3 mm above the insertion at the nasoglabella region, leaving 2–3 mm to reinsert the pedicle. We transsectioned a 5-mm-broad band of the pedicle for histologic examination. Histology allowed to view the whole transsected area of 10–12 mm. All specimens were examined with haematoxylin–eosin (HE), Van-Giesen (VG) and Elastin stains in 4–8 serial sections, which allowed to view the whole transsected area on one slide. Each pedicle was analysed for the presence of muscle fibres, arterioles, arteries and veins. The differentiation of arterioles and arteries was made according to the guidelines of the histology atlas of the Leeds University [6]. According to this definition, an arteriole has a lumen of about 0.1–0.3 mm, a total diameter of <1 mm, and an internal elastic lamina layer. The tunica media layer has mostly 1–2 layers but maximum six (there is no definitive consensus in literature) concentric rings of smooth muscle, and the tunica adventitia layer is approximately the same size as the tunica media.

Results

For each flap pedicle we had 4–12 slides. The pedicles included epidermis, subcutis and muscle in 11 out of 12 (Fig. 4). In one case there were only a few muscle fibres visible. In nearly all the pedicles we observed small arterioles and veins which were approximately 0.5 mm in diameter (Table 1; Fig. 5). These arterioles and veins formed a dense network as we can see in Figs. 4 and 5. In two patients (LE and RL, both MFF) there was one artery close to the lateral border of the flap pedicle of about 0.9 mm in diameter, which showed thrombosis and which probably corresponded to the supratrochlear artery. These two arteries differed strongly by its thickness and number of muscle layers of the tunica media and their diameter compared to all other observed arteries (Fig. 5). The thickness of the tunica media corresponded nearly to the double compared to the other arteries. The 12 patients' slides were analysed more precisely for the size and density of veins, arteries and the presence of muscle tissue. All the flaps had a 100 % survival rate and none showed signs of ischemia, infection or necrosis.

Discussion

The incidence of non-melanoma skin cancer (NMSC) is constantly increasing in the general population. Often NMSC is situated on the nose where surgical repair is challenging. Tumour excision around orifices needs correct preoperative evaluation and clinical accuracy to keep recurrences and costs low. Dermatologists who have the opportunity to perform Mohs surgery and to compare histopathology directly with clinical appearance are well placed to perform this surgery. Tumour excision in these regions should—where possible—only be undertaken after Mohs micrographic surgery (MMS) to avoid unnecessarily wide

margins, to avoid recurrence and to keep the final defect small.

Although we use this technique for most epidermal tumours on the face that cannot be closed side by side, unfortunately it is sometimes impossible to avoid large postsurgical defects that need reconstruction by a MFF. Reconstruction by MFF uses a donor site, which is precious for nose reconstruction; therefore, we must ensure that the whole tumour has been excised first and this can only be accomplished by micrographic surgery (MMS). The decision to choose a MFF is largely influenced by the extension and depth of the defect. This flap should be reserved for full thickness defects or large defects which involve cartilage, as Melette mentioned in his review about interpolation flaps [12]. Limitations on the use of this flap are either that the patient refuses to accept an additional scar on the forehead or is a heavy smoker and unable to stop smoking.

The fact that the MFF is an axial flap [1–4] is unanimously and consistently expressed in literature on the subject. Most authors follow the principle of Baker SR and Swanson NA who define an axial flap as a flap with a named artery which, in the case of the PMFF, is the supratrochlear artery [4, 7]. This point is not completely evidence based and so the definition of an axial flap needs clarification. Another axiom of Swanson in reconstructive surgery claims that the length of a flap should not exceed three times its width when it is a random flap [8]. In conclusion, these two axioms suggest not to use a pedicle flap without a named artery when the length of the flap exceeds three times its width, apart from exceptional circumstances, such as in the case of delayed flaps [8]. These two definitions are limiting the use of the MFF as this flap has up to existing anatomical nomenclature no named artery and the principle design of this flap hurts the axiom of Swanson. Having no proof of having verified the existence of a named artery in case of complications may create a precedent.

Kleintjes [9] showed that in anatomical sections of 60 hemiforeheads the diameter of the supratrochlear artery was about 1 mm in diameter. On the other hand, he proved that a so-called central artery of <1 mm could be found consistently in 43 hemiforeheads (71.6 %), and that this artery originated from the dorsal nasal artery and always showed an anastomosis with the opposite central artery. This artery could not be followed up above the upper third of the forehead. In 21 hemiforeheads (35 %), there was a so-called paracentral artery, which also originates from the angular artery as the main continuation to the forehead. There was a dense anastomosis system among these three arteries [9]. There is no mention of whether the non-existence of a central artery favoured the presence of a paracentral artery.

One could argue that this study could have been done on fresh cadavers by searching the vessels afterwards in the flap which would correspond nearly to the study of Kleintjes [9]. We think that this would not have added any information as there would be no confirmation about the survival of the flap and it would probably only falsify the results. Anatomy on cadavers is not the same as in vivo operation (concerning finding such small vessels), it might be different with preoperative silicone injection on fresh cadavers but we would have to pay at least 2,000 Euro for one sample which was above our budget.

Another possibility would have been instead of histologic analysis of the vessels—which might imply some errors due to methodology as discussed below—one could have referred to magnetic enhanced angiography or computed tomographic angiography scanning. This point was discussed with the head of the department of AngioRadiology of the University of Lausanne which is specialized in this field. The head of the department was clear about the fact that this kind of investigation in elderly patients as we had would be a too high risk and not justified for this kind of study.

The central and paracentral arteries are not mentioned in anatomy textbooks and therefore are not known as named arteries, but Burget and Menick [10] illustrate these clearly in their textbook, in Fig. 4, without naming the central and paracentral artery. These authors did not use the term of axial flaps and/or random flaps, but they agree on the fact that "a rich anastomotic plexus, centred on the medial canthus, can supply a unilaterally based flap, even after division of the supraorbital, supratrochlear and infratrochlear vessels. The PMFF is abundantly perfused by this vertically oriented axial blood supply". Mellette and Ho [12] use the same illustration, despite they mention only the PMFF with the presence of a supratrochlear artery in their publication. This statement was later confirmed by Jackson et al. who conclude in their anatomic analysis of 12 cadavers that within the paranasal and medial canthal region, there is an anastomotic relationship among the supratrochlear, infraorbital, and branches of the facial arteries, and branches from the contralateral side, creating a rich vascular arcade. This allows a MFF to be narrowly based at the level of the medial canthus [13]. This opens the discussion concerning the terminology of anatomy in dermatologic surgery; prompting the questions of whether or not the terminology on arteries in textbooks is adapted for reconstructive surgery, whether or not the definition of random and axial flaps is appropriate and whether or not an adaption of this terminology is necessary.

We clearly showed that none of our pedicles contained a functional artery of 1 mm or more in diameter. 8 out of 12 cases had an artery of 0.5–0.6 mm diameter on formalin fixed slides. If we apply, by analogy, the observation of Park et al. [11] that an artery will shrink 24 % after formalin fixation we have to conclude that these arteries would

Table 2 Classification of flaps

Type of flap	Arterial flow	Example
Random pattern	Random pattern, network like	Rotation flap, etc.
Axial pattern	Axial, without named artery	Median forehead flap, melolabial transposition flap
Axial	Axial with named artery	Paramedian forehead flap with pedicle on supratrochlear or supraorbital

have a diameter of 0.65–0.78 mm in vivo. One could argue that it is inappropriate to state that a big arterial vessel was absent in all pedicles based on the expected vessel diameter. The pedicle may undergo fibrotic changes during the 3-week period prior to division. This could cause the diameter to appear smaller than expected. This might be possible but there is not only the diameter which is different. As we have seen in two bigger vessels corresponding probably to the supratrochlear artery, the number of muscle layers of the tunica media is much more important than in the other observed arteries. This means that the other arteries cannot correspond to the supratrochlear artery but they might correspond in 8 out of 12 (66.6 %) cases to the so-called central or paracentral arteries of Kleintjes [9], which originate from the dorsal nasal artery. 4 out of 12 cases (33.3 %) had only smaller arteries but all the cases had a dense network of arterioles and veins present as shown in Fig. 5.

The length of all flaps greatly exceeded three times the width of 1.0–1.2 cm. None of the flaps fulfilled the axiom that a random flap should not exceed three times its length, but contrary to conventional expectations the survival rate of all the flaps was 100 %.

We think that this axiom in reconstructive surgery is too narrow in its definition and that the term axial pattern flap would be far more appropriate in these circumstances. The term axial flap should be reserved for flaps that have a named artery in their pedicle (Table 2). As I have shown in the results there are several small arteries, arterioles and veins which are oriented in the axis of the flap but which are not properly named arteries, eventually the dorsal nasal and central and paracentral artery after Kleintjes. In 4 out of 12 cases not even these arteries could be found. So they could not be described as axial flaps using the proper definition of the term. After all, flap creation causes many changes in the blood flow of the flap. AV shunts are closed, collateral flow is dramatically increased, and profound changes in vessel arborization likely occur which allows the flap to survive. The term axial pattern flap takes into consideration these small vessels, which are sufficient for vascularization and excellent survival of this flap, as I have shown in this study.

On the other hand, the so-called central and paracentral artery which originates from the dorsal nasal artery described by Kleintjes [9] supports the definition of an axial flap and may be contained in the pedicle of MFF originating approximately 1–1.5 cm below the medial angle of the eyebrow. This allows a MFF to be pedicled on the dorsal nasal artery with excellent clinical results. But these two arteries are not named as such in anatomic and dermatologic textbooks, wherefore a reflection has to be done whether the dermatosurgical and/or anatomic terminology has to be adapted.

Finally, we think that (1) there is no need to track the supratrochlear artery when practicing a paramedian or MFF, (2) the axiom on random flaps width–length ratio 1:3 is probably wrong for certain localizations and therefore need to be revised, and (3) the classification of axial flaps–random flaps only is insufficient and inadapted for practical surgery.

Conclusion

Under the actual accepted anatomical nomenclature for arteries the MFF is an axial pattern flap (after our proposed definition) and does not need an anatomically named artery in its pedicle. An axial pattern flap is a flap where the axis of the flap is oriented in the main direction of small arterioles and veins in a specific region, and therefore guarantees excellent viability despite the fact that the length of the flap exceeds three times its width (Table 2). A flap with a named artery should be defined as an axial flap; this would help to prevent confusion in dermatologic reconstructive surgery (Table 2).

The dorsal nasal and central and paracentral arteries, which originate from the dorsal nasal artery, but which are not mentioned in anatomic textbooks, allow the pedicle of the MFF to originate caudal to the nasofrontal crease and in 66.6 % (8 out of 12 cases) of cases produce probably an axial flap. In the remaining 33.3 % (4 out of 12 cases) an axial pattern flap was sufficient for survival of the flap. In all 12 cases, a more caudal pediculation allowed less twisting of the pedicle, a shorter distance between donor site and defect and an extended donor site for reconstruction of the nose. The MFF is a valuable and sure alternative to the PMFF for reconstruction of full thickness defects of the nose.

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