

Anatomical and Clinical Study of the Posterior Auricular Artery Angiosome: In Search of a Rescue Tool for Ear Reconstruction

Oswaldo J. Gómez Díaz, MD
Mario D. Cruz Sánchez, MD

Background: The retroauricular tissues have been used for a long time for ear reconstruction, but the anatomical bases of flaps of this region are not completely clear. The aim of this study was to estimate blood supply area and location of this on the skin and fascia retroauricular dependent of posterior auricular artery (PAA) to establish safe margins to design flaps for auricular reconstruction.

Methods: Dissection under magnification ($\times 3.5$) of the PAA through a cervical approach; injection of methylmethacrylate in the PAA as a staining technique; retroauricular approach to identify the territory of irrigation of PAA in the retroauricular skin and fascia; measuring and location of the stained area; and report of 2 cases of ear reconstruction with fasciocutaneous and fascia flaps based on PAA, designed according to the anatomical study.

Results: In a sample of 10 cadaveric specimens, the PAA irrigated an area of the retroauricular skin and fascia of 10.7 cm length \times 7.07 cm wide equivalent to 60.44 cm² (95% CI, 37.07–83.81), with a distribution posterior to external auditory canal of 7.15 cm (95% CI, 5.53–8.77) and posterior to the helix insertion of 6.12 cm (95% CI, 4.89–7.35). In the 2 patients treated with fascia and fasciocutaneous flaps based on the PAA, these were good options for ear reconstruction.

Conclusion: A fascia or fasciocutaneous flap from the retroauricular region based on PAA within the dimensions and location found in this study will be a safe option for reconstruction of the ear. (*Plast Reconstr Surg Glob Open* 2016;4:e1165; doi: 10.1097/GOX.0000000000001165; Published online 27 December 2016.)

Blood supply of retroauricular skin and fascia is given by the posterior auricular artery (PAA) and the occipital artery. The PAA is the third posterior branch of the external carotid artery from caudal to cephalic and has an estimated diameter of 0.7 to 1.2 mm and a course anterior to the mastoid process and posterior to the ear giving blood supply to part of the ear and retroauricular region. In 93% of cases, this represents the dominant artery supplying this area; the remaining 7% is the occipital

artery, which is the dominant.¹ Flaps with blood supply by the PAA have been used since the 1960s, starting with Washio.² Several reports of more recent case studies have used the retroauricular skin and fascia for ear reconstruction.^{1,3,4}

Although 2 previous publications have approached the study of surgical anatomy of the PAA with the aim of establishing the anatomical basis of the blood supply of retroauricular skin and/or fascia flaps,^{5,6} the safe dimensions and location of the PAA angiosome have not been widely described nor supported by experimental studies.

This research aims to quantify the blood supply area given by the PAA and set its location in the retroauricular skin and fascia in a sample of cadaver specimens with the objective to establish the safe dimensions and location of the retroauricular skin and/or fascia flaps.

MATERIALS AND METHODS

Dissection of the PAA in 10 human cadaver specimens was conducted based on a technique of a previous publication of this research group.⁷ This study included cadavers

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From the Division of Plastic Surgery, Department of Surgery, School of Medicine, Universidad Nacional de Colombia, Bogotá, Colombia.

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of adult individuals older than 18 years without head and/or neck trauma and without any pathology at this anatomical localization.

Dissection Technique

Dissection technique includes the following: approach through transverse cervicotomy 2 cm lower the mandibular angle of approximately 7 cm of length; careful dissection by anatomical planes with ligation of vascular structures and section of digastric muscle, the hypoglossal nerve and identification of the external carotid artery; dissection with surgical loupes with $\times 3.5$ magnification of all branches of the external carotid artery including the PAA from its origin; ligation of the external carotid artery distal to the origin of the PAA, 4 cm proximal to the origin of the PAA; and ligation of all branches that originated in this segment of the external carotid artery except the PAA.

Vascular Injection Technique

Based on a previous study made in our service with small-diameter vessels,⁸ we chose to use the methylmethacrylate, a synthetic resin susceptible to polymerize associated with India ink in a proportion of 3: 1. The solution to inject was prepared by mixing 9 mL of liquid monomer with 3 mg of powdered polymer of methylmethacrylate and 1 mL of blue India ink.

The external carotid artery was cannulated 4 cm in the ligated segment with a rigid 5-French polyethylene tubing. The solution with methylmethacrylate was hand injected with a 10-mm syringe until the resulting cutaneous blush did not increase in size; less than 10 mm of the solution was injected in all cases. Postinjection was visualized, the skin was stained by the solution, the area was delimited, and its greatest dimension was measured in centimeters as length and the perpendicular dimension to the length was

measured in centimeters as width. In cases where the area that caught the stain spread to the scalp, it was shaved amply for better viewing. Standardized digital photographs in all cases were taken. After 15 minutes of the injection, a retroauricular approach dissecting the skin in a suprafacial plane was performed to identify the territory of irrigation of the PAA on the retroauricular fascia.

Angiography

To compare the results obtained with the dissections with respect to anatomy of the PAA, its route, and its origin from the external carotid artery, we performed an angiography of the PAA in 2 cadaver specimens after the same dissection and cannulation technique previously described. Additionally, we placed needles in the root of the helix, immediately posterior to the middle third of the helix and at the lobule of the ear to outline the ear and ease the location of the PAA. Less than 10 mm of contrast medium was injected, and immediately an angiography with a fluoroscope was accomplished.

Variables Studied

Specimens' characteristics like sex, age, and laterality of dissection and blood supply area of the PAA on the skin and retroauricular fascia in square centimeters and anatomical variations in location, branching, and irrigation territory were studied.

For a description of angiosome location, 3 anatomical landmarks designated as A, B, and C, corresponding to the insertion of the helix, the external auditory canal, and mastoid process were labeled. From these anatomical landmarks, the distances AD, AE, BF, CG, and CH, were set, corresponding to AD, distance superior to helix insertion until the limit of the stained area; AE, distance posterior to helix insertion until the limit of the stained

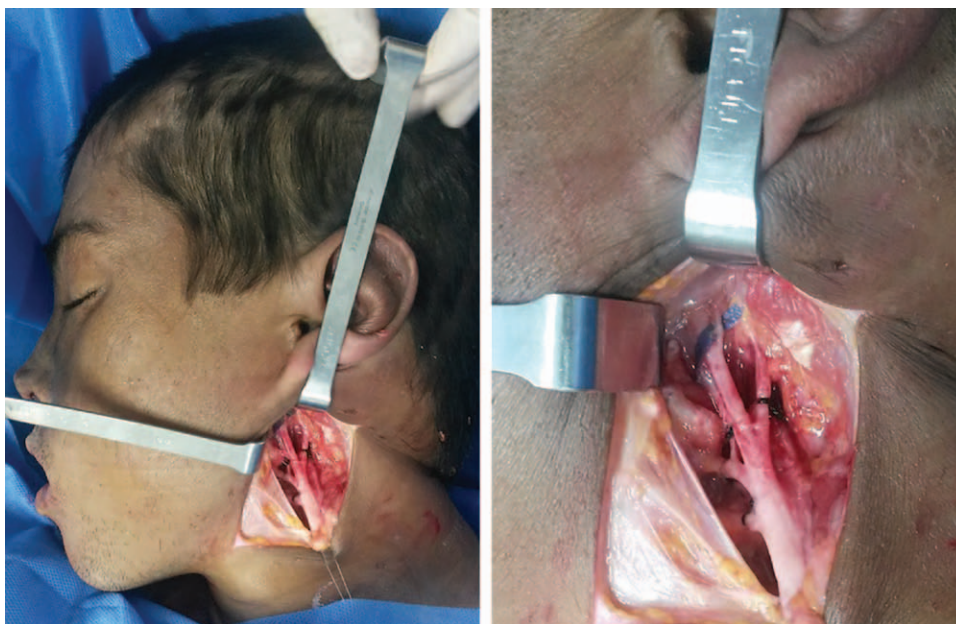


Fig. 1. Dissection of the PAA from its origin in the external carotid artery. The PAA is on the *blue* contrast. The other anterior and posterior branches of the external carotid artery were ligated.



Fig. 2. Angiography of cadaver specimen after injection of 10 mL of contrast medium in the PAA. Needles were placed at the root of the helix, posterior to the middle third of the helix, and at the lobule of the ear to guide the location of PAA.

area; BF, distance posterior to external auditory canal to the limit of the stained area; CG, distance posterior to the mastoid process to the limit of the stained area; and CH, distance inferior to the mastoid process to the limit of the stained area.

The data were recorded, and calculations were made with Microsoft Excel 2010. Based on digital photographs and us-

ing Adobe Photoshop CS6, we calculated the irregular areas where the tissues caught the staining in square centimeters.

Clinical Experience

Based on the findings of our previous anatomical study⁷ and the results of this anatomical work and the existing clinical publications of retroauricular fascia and fasciocutaneous flaps,^{1,3,4,9-11} we have operated on 2 patients with requirement of auricular reconstruction who received a fascia flap based on PAA (first case) and a fasciocutaneous flap based on PAA (second case) designed according to the dimensions and location found in this anatomical study.

This study was approved by the ethics committee of the National University of Colombia, and the patients and their families gave written informed consent.

RESULTS

In 10 cadaveric specimens of male sex, the average age was 63.4 years (95% CI, 52.5–74.2). In all cases, the PAA was identified as the third posterior branch of the external carotid artery from caudal to cephalic with a location anterior to the mastoid process and posterior to the ear (Fig. 1).

These results were the same in the 2 angiographies made (Fig. 2).

The laterality of the dissection was the right side in 4 cases and left side in 6 cases, and the choice of dissection side was based on the better preserved skin and surface anatomy. Table 1 shows the areas and dimensions of the angiosome estimated in each case.

On average, the area that caught the staining on retroauricular skin and fascia had dimensions of length and width of 10.7×7.07 cm, respectively, which is equivalent to an area of 60.44cm² (95% CI, 37.07–83.81). The angiosome extension found posterior to the external auditory canal was 7.15 cm on average (95% CI, 5.53–8.77), and the extension posterior to the helix insertion was 6.12 cm on average (95% CI, 4.89–7.35). Figures, 3 and 4 show the area of staining on the skin, the retroauricular fascia dissection post methylmethacrylate injection, and a digital

Table 1. Results

| No. of Cadaver Specimen | Sex | Age, y | Angiosome area, cm ² | Angiosome Dimensions L × W, cm | Extension Posterior to the Mastoid Process, cm | Extension Posterior to the External Auditory Canal, cm | Extension Posterior to the Helix Insertion, cm | Extension Superior to the Helix Insertion, cm | Extension Inferior to the Mastoid Process, cm |
|-------------------------|-----|-------------|---------------------------------|--------------------------------|--|--|--|---|---|
| 1 | M | 23 | 8.2 | 4.5×2.7 | 2.0 | 3.1 | // | // | 1.8 |
| 2 | M | 77 | 10.3 | 5.7×3.6 | // | 2.5 | 3.3 | 3.2 | // |
| 3 | M | 64 | 54.6 | 10.8×5.2 | 2.7 | 7.0 | 6.4 | 3.6 | // |
| 4 | M | 50 | 88.4 | 13.8×8.5 | 6.0 | 8.6 | 8.0 | 9.0 | // |
| 5 | M | 72 | 70.4 | 13.8×9.2 | 3.8 | 11.2 | 9.2 | 5.2 | 3.4 |
| 6 | M | 68 | 75.8 | 14.2×9 | 4 | 7.3 | 6.1 | 6.5 | 7.2 |
| 7 | M | 84 | 65.0 | 13.1×8.5 | 3.3 | 7.7 | 4.7 | 3.4 | 6.1 |
| 8 | M | 84 | 44.3 | 10.1×5 | 4.1 | 7.6 | 5.2 | 4.5 | 1.9 |
| 9 | M | 60 | 145.3 | 14.1×12.8 | 6.5 | 10.4 | 8.1 | 5.6 | 3.4 |
| 10 | M | 52 | 42.1 | 7.3 × 6.2 | 3.5 | 6.1 | 4.1 | 3 | 2.1 |
| Average | | 63.4 | 60.44 | 10.7×7.07 | 3.98 | 7.15 | 6.12 | 4.88 | 3.7 |
| SD | | 17.5 | 37.7 | 3.5×2.9 | 1.36 | 2.62 | 1.88 | 1.84 | 1.98 |
| 95% CI | | 52.55–74.25 | 37.07–83.81 | | 3.09–4.87 | 5.53–8.77 | 4.89–7.35 | 3.68–6.08 | 2.23–5.17 |

CI, confidence interval; l, length; M, male; W, width ; //, no extension of the staining to this area. Reprinted with permission from *Revista Colombiana de Cirugía Plástica y Reconstructiva*. 2015;21:22–26.



Fig. 3. Staining on the retroauricular skin post methylmethacrylate and blue India ink injection.

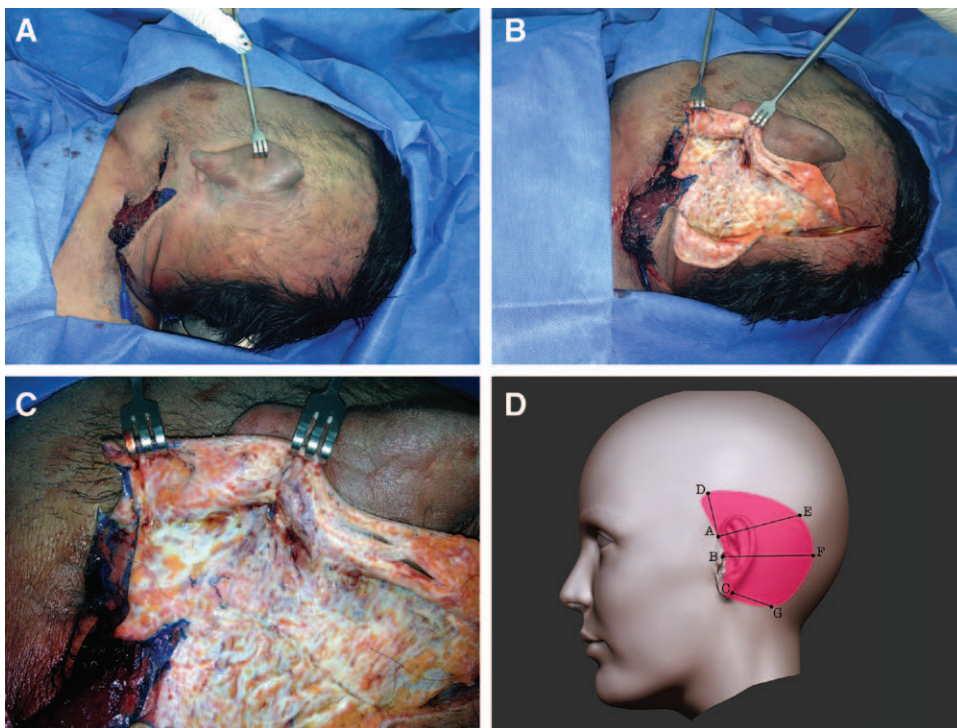


Fig. 4. A, Area of stained skin after methylmethacrylate injection. The irrigation area in the retroauricular skin and scalp dependent of PAA is shown. B and C, Retroauricular approach and suprafascial dissection of the stained area of the skin are shown (A). There is a dye uptake by the vessels of the retroauricular fascia dependent of the PAA. D, Digital reconstruction model of the irrigated area dependent of the PAA with the software Adobe Photoshop CS6 of the case shown in (A) and (B). Points A, B, and C, corresponding to the insertion of the helix, the external auditory canal, and the mastoid process. The AD, AE, BF, and CG distances corresponding to distance superior to helix insertion until the limit of the stained area, distance posterior to helix insertion until the limit of the stained area, distance posterior to external auditory canal to the limit of the stained area, and distance posterior to mastoid process to the limit of the stained area. In this case, the angiosome dimensions were 10.8 cm of length \times 5.2 of width with a calculated area of 54.6 cm². AD, AE, BF, and CG distances were 3.6, 6.4, 7, and 2.7 cm, respectively.

reconstruction model of the stained area in 2 of the evaluated cases (Fig. 5).

CASE REPORTS

Case 1

A male patient of 8 years of age with right microtia was carried to the first stage of auricular reconstruction with Brent technique.¹² The patient had a rib cartilage graft exposure caused by mechanical trauma in the early postoperative period. Because of this, it was necessary to make a temporal fascia flap and partial thickness skin graft from scalp to cover the defect. After 1 month of the first surgery, important resorption of the cartilaginous framework was noted, a fact that led to a surgical revision 1 year after the first procedure placing a new rib cartilage graft. In the postoperative period of this revision, the patient again presented rib cartilage graft exposure associated again with local trauma. Then, he was taken to a new surgical revision, which consisted of retroauricular fascia flap based on the PAA and partial thickness skin graft from scalp, achieving a stable coverage.

The surgical technique in this patient consisted of incision by previous scar on neo ear and suprafascial dissection of retroauricular skin. The design of retroauricular fascia flap without exceeding the dimensions and after the location of angiosome of the PAA is shown in Figure 5.

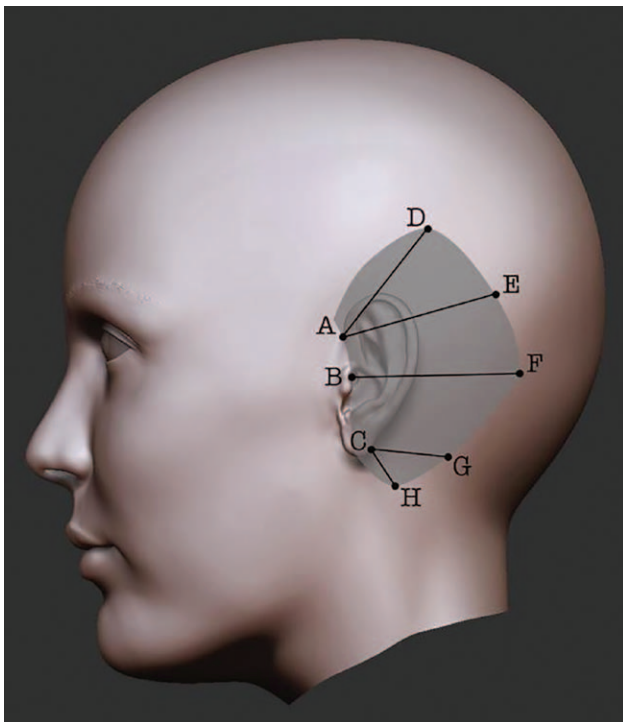


Fig. 5. Reconstruction model made by the software Adobe Photoshop CS6 of average irrigated area and location of the angiosome dependent of PAA based on the analysis of the results of the 10 cases evaluated. In the model, the dimensions AD, AE, BF, CG, and CH were 4.8, 6.1, 7.15, 3.9, and 3.7 cm, respectively. Reprinted with permission from *Revista Colombiana de Cirugía Plástica y Reconstrucción*. 2015;21:22–26.

Subsequently, a subfascial dissection of the flap was performed from cephalic to caudal, protecting the anatomical location of the pedicle of PAA until the achievement of adequate transposition of the flap into the defect in the neo ear. Dissection of the PAA was not necessary for flap transposition. Figure 6 illustrates this case and postoperative clinical outcome.

Case 2

Case 2 was a 78-year-old male patient with a history of basal cell carcinoma of trabecular type in the left ear resected 5 years ago. One year ago, he had a new basal cell carcinoma of nodular type with dispersed advance front in the surgical scar of the previous resection of his left ear. He was carried by dermatology to Mohs micrographic surgery to resect the new tumor exposing the temporal bone. The patient did not accept auricular reconstruction and was referred to plastic surgery to cover bone exposure. It was decided to conduct a retroauricular fasciocutaneous flap based on the PAA.

The surgical technique in this patient consisted of location of the PAA in the retroauricular region with a handheld Doppler. Then, we designed the flap based on a mold of the defect. The size and location of the flap in the retroauricular region were according to the findings of this anatomical study, as illustrated in Figure 5, and without exceeding these dimensions. In this case, the flap had a dimension posterior to the external auditory canal of 7 cm. This flap was incised and dissected in a subfascial plane from cephalic to caudal, protecting the anatomical localization of PAA pedicle. The dissection of this artery was not necessary for transposition of the flap. Subsequently, an anterior transposition of the flap was made into the defect with bone exposure, leaving a small posterior residual area with muscular exposure in the donor site that was covered with a total thickness skin graft from the groin, 2 weeks after the first reconstructive surgery in a second procedure with the objective that the defect in the donor site was filled with granulation tissue to prevent a depressed scar. Figure 7 illustrates this clinical case.

DISCUSSION

Multiple clinical cases published^{1–4,9–11,13,14} have reported the use of fascia or fasciocutaneous flaps of the retroauricular region with several reconstructive objectives including the auricular reconstruction. Wang et al¹ described a procedure for auricular reconstruction in 2 stages using autologous rib cartilage and neurovascular retroauricular fascia finding that for coverage of cartilaginous framework, a fascia flap of 7×4.5 cm has proven to be adequate, with favorable postoperative outcomes. Sharma et al⁹ published the case of a patient with a coverage defect of 5×8 cm in the temporoparietal region after resection of a skin tumor. This was treated with a flap based on the PAA in 1 surgical stage and V-Y closure type of the donor site. Several authors have reported various uses of the flaps of the retroauricular region for treating defects at the ear. These uses range from reconstruction after trauma to use in otoplasty.¹¹ However, the safe dimensions, area, and



Fig. 6. A, Eight-year-old male patient with right microtia. B, First time of auricular reconstruction with Brent technique. C, Exposure of the second rib cartilage graft. D, Clinical follow-up 2 mo after retroauricular fascia flap and partial thickness skin graft from the scalp achieving a stable coverage.

location of such flaps based on PAA have not been clearly established by experimental studies.

Kolhe et al⁵ in 1987 reported a study with 39 dissections of the posterior auricular vessels, 26 in cadavers, and 13 in clinical cases; this was a first approach to this question. They carried out India ink injection in 5 cadavers and found that the PAA perfused a constant area of skin, which was represented by both nonhair-bearing and hair-bearing skin. The auriculomastoid skin and adjacent area of neck skin over the sternomastoid muscle, extending 2 to 3 cm behind and below the earlobe, were the nonhair-

bearing area. Adjacent to this area, a 2- to 3-cm strip of scalp extending toward the occipital and temporal area was also perfused by the PAA.

In our study, we did not observe the uptake of staining on the posterior auricular skin in 2 cases of the 10 as shown in Figure 3. In the remaining 8 specimens, there were staining of the posterior auricular skin as evidenced in Figures 4A–C. This finding indicates that is predominant the perfusion given by the PAA to this anatomical area as seen in the reconstruction model of the PAA angiosome based on the 10 cadavers (Fig. 5).



Fig. 7. A, Seventy-eight-year-old male patient with a postresection defect of basal cell carcinoma in the left ear with bone exposure. B, Location of PAA in the retroauricular region with Doppler and flap design based on the mold of the defect and results of this anatomical study illustrated in Figure 5. C, Subfascial dissection of PAA fasciocutaneous flap. D, Transposition of the flap. E, Immediate postoperative result. F, Follow-up at the 5 postoperative months of the PAA flap and 4.5 mo postoperative of skin graft in the small residual area with muscular exposure in the donor site that is not visible.

One possible explanation to the 2 cases that did not uptake the staining on the posterior auricular skin can be obtained from the fact that we tied all the branches of the external carotid artery except the PAA, which is different from Kolhe et al,⁵ who did not tie any branch of the external carotid artery. In our experience, we found that the ink tends to flow through the other branches of the external carotid artery after the India ink injection if these were not tied. The previously commented fact from Wang et al¹ that in 93% of cases, the PAA represents the dominant artery to the posterior auricular skin but in the remaining 7%, the dominant vessel was the occipital artery could explain that 2 cases of the 10 had had dominant blood supply of the posterior auricular skin by the occipital artery that was tied.

In another study of 8 cadaver specimens published by McKinnon et al⁶ in 1999, they performed ink and latex injections. This was the second study to approach the PAA angiosome; it described a territory in the retroauricular region dependent of the PAA measured from the upper portion of the tragus with average dimensions of 6.88 cm to the superior border, 5.31 cm to the posterior border, and 7.59 cm to the inferior border of the stained area. Additionally, they accomplished measurements from the tip of the mastoid process with average distances of 9.99 cm to the superior border, 6.68 cm to the posterior border, and 3.99 cm to the inferior border of the stained area.

With the previous review of the literature performed, we considered some unresolved questions regarding the angiosome of the PAA that was responded with this investigation.

These were the calculation of the average area of blood supply of the PAA on the retroauricular region (60.44 cm²), the average dimensions of length (10.7 cm) and width (7.07 cm) of the angiosome, and a more accurate localization that included 3 cardinal points to do the measurements (the insertion of the helix, the external auditory canal, and the mastoid process) and not 2 as previously done.

The purpose of the 2 angiograms was to assess the anatomy of the PAA, its route, and its origin from the external carotid artery to compare these findings with the anatomical dissections. Therefore, we consider that establishing the relationship of the PAA with the outline of the ear that was marked by placing needles at the root of the helix, immediately posterior to the middle third of the helix and at the earlobe, allowed us to meet this goal. Because it was not intended to calculate areas of blood supply with the angiographies, no interventions were made to eliminate the interference produced by the angiographic shadow of the posterior auricular skin on the soft tissue of the mastoid process.

Tokugawa et al¹⁵ recently proposed a classification of PAA based on their angiographic appearance; this research was based on angiograms made because of intracranial pathologies to 234 patients. These authors proposes 4 types of PAA with their respective frequency: type A (15.1%), PAA terminates between its origin and the center of the external auditory canal; type B (34.9%), PAA terminates between the center of the external auditory canal and the top of the helix; type C (48.8%), PAA terminates between the top of the helix and the vertex; and type D (1.2%), PAA reaches up to the vertex. This author proposes that if a patient has PAA of type A, a large skin flap of this area may not be a good option. On the other hand, if the patient has type C or D, a larger skin flap will be more probably a good option.

Additionally, our study had an initial clinical phase where the versatility and the vascular safety of fascia or fasciocutaneous flaps of the retroauricular region dependent of PAA for auricular reconstruction were evident. Following the principles found in this anatomical work (location, dimensions, and area of the angiosome), it was possible to reconstruct defects of very different etiologies in 1 child and 1 elderly patient.

CONCLUSIONS

The anatomy of the PAA was constant in the studied specimens. The retroauricular skin area irrigated by the PAA is equivalent to the retroauricular fascia area irrigated by the same artery. The location and average dimension of the angiosome of the PAA based on this anatomical study are outlined in Figure 5. The extension of the angiosome was constant posterior and superior to the 3 cardinal points (insertion of the helix, the external auditory canal, and the mastoid process). The extension inferior to the mastoid process was not constant. Based on these findings and the clinical cases described, we can conclude that a fascia or fasciocutaneous flap from the retroauricular region based

on PAA within the dimensions and location found in this study would be safe for reconstruction of the ear.

Mario D. Cruz Sánchez, MD

Division of Plastic Surgery

School of Medicine

Universidad Nacional de Colombia

Avenida Caracas # 1-13

Oficina de especialidades quirúrgicas

Piso 3. Edificio de consulta externa

Bogotá, Colombia

E-mail: mdcruz@unal.edu.co

PATIENT CONSENT

Patients and guardians provided written consent for the use of the patients' image.

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