



Anatomical Description of the Pronator Quadratus Flap in the Colombian Population. Cadaveric Study

Descripción anatómica del colgajo de pronador cuadrado en población Colombiana. Estudio cadavérico

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Abstract

Introduction There is an increase in the use of the pronator quadratus (PQ) as a functional flap for facial and upper limb reconstructions, predominantly based on the pedicle of the anterior interosseous artery and nerve. However, growing literature about the dimensions of the components of the flap, is scarce, especially in the Latin-American population. Therefore, the morphological description of the dimensions of the muscle, artery, nerve, and concomitant veins was carried out.

Materials and Methods Dissections were performed on 10 fresh cadaver upper extremities at CLEMI. Measurements and photographic material were taken of the dimensions of the muscle and neurovascular pedicle, for subsequent statistical analysis.

Results After statistical analysis, an average of 4.3 cm wide, 4.8 cm long, and 0.9 cm thick was established for the muscle. Regarding the anterior interosseous artery (AIA), an average length of 12.5 cm with proximal and distal diameters of 1.6 mm and 2.2 mm respectively, and anastomosis with the posterior interosseous artery (PIA) in 80% of cases. In relation to the anterior interosseous nerve (AIN), it had an average length and diameter of 12.2 cm and 0.9 mm, respectively, with 9.8 cm from the branch of the flexor pollicis longus (FPL) to the pronator quadratus and 13.7 cm from the wrist crease. A single vein was evident in 60% of cases with a diameter of 0.9 mm.

Conclusion A constant anatomy was observed in the pronator quadratus flap, with an artery, vein, and nerve of adequate length and diameter for easy anastomosis and neuroorrhaphy. This was associated with low morbidity of the donor area, configuring it as a useful tool in the reconstructive process.

Keywords

- ▶ pronator quadratus
- ▶ anterior interosseous nerve
- ▶ neurovascular pedicle
- ▶ flap

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Resumen

Introducción Existe un incremento en el uso del pronador cuadrado (PQ) como colgajo funcional para reconstrucciones faciales y en miembro superior predominantemente, basado en el pedículo de arteria y nervio interóseo anterior, no obstante la literatura con relación a las dimensiones de los componentes del mismo, aunque creciente, es escasa especialmente en población Latinoamericana. Por lo cual se realizó la descripción morfológica de las dimensiones del músculo, arteria, nervio y venas concomitantes.

Materiales y Métodos Las disecciones fueron realizadas en 10 antebrazos de 10 componentes cadavéricos en el CLEMI. Se tomaron medidas y material fotográfico de las dimensiones del músculo y pedículo neurovascular, para su posterior análisis estadístico.

Resultados Posterior al análisis estadístico se estableció para el músculo una media de 4.3 cm de ancho, 4.8 cm de largo y 0.9 cm de grosor, en cuanto a la arteria interósea anterior (AIA) se evidenció una longitud media 12.5 cm con diámetro proximal y distal de 1.6 mm y 2.2 mm respectivamente y anastomosis con la arteria interósea posterior (AIP) en 80% de los casos. En relación con el nervio interóseo anterior (NIA), presentó una longitud y diámetro promedio de 12.2 cm y 0.9 mm respectivamente, con una distancia de 9.8 cm desde la rama del flexor pollicis longus (FPL) hasta el pronador cuadrado y 13.7 cm desde el pliegue de la muñeca. Se evidenció una vena única en 60% de los casos con diámetro de 0.9 mm.

Conclusión Se apreció una anatomía constante en el colgajo de pronador cuadrado, con arteria, vena y nervio de adecuada longitud y diámetro para una fácil anastomosis y neurorrafia, asociado a una baja morbilidad de la zona donante, configurándose como una herramienta útil en el proceso reconstructivo.

Palabras clave

- ▶ pronador cuadrado
- ▶ nervio interóseo anterior
- ▶ pedículo neurovascular
- ▶ colgajo

Introduction

The pronator quadratus (PQ) muscle, located on the anterior surface of the distal fourth of the forearm, is dispensable in its function,¹ despite being the primary pronator of the forearm.² Its consistent anatomy, particularly regarding the muscle's dimensions and neurovascular pedicle³, makes it a valuable reconstructive resource applicable in various anatomical areas. Dellon and Mackinnon⁴ in 1984 described for the first time the use of the pronator quadratus as an island flap, to cover nervous structures in the wrist; however, the lack of mobility of the muscle did not allow great advancement, reaching only the proximal row of the carpus even with the wrist in flexion, so Rath et al⁵ establish that after ligating and dividing the anterior interosseous artery, the irrigation to the bone flap of the distal radius is based on retrograde flow and could be mobilized distally up to 6 cm. Later Dautel and Merle⁶ were the first to publish its use as a free flap and since then it has shown its versatility in the literature by being used in palmar defects for the reconstruction of the abductor⁷ facial reconstructions in levator labii,⁸ resuscitation of facial paralysis,⁹ treatment of Kienbock disease,¹⁰ scaphoid pseudoarthrosis¹¹ and coverage of defects in the forearm and wrist.¹²

With the advent and refinement of new microsurgical techniques, the possibility of using the pronator quadratus as a neurotized free flap to provide sensitivity or motor

function has gained relevance, however there is a gap in the literature in relation to the description of the morphology of the flap and its anatomical variants, without evidence of descriptions in the Colombian or Latin American population.

Given that most evidence consists of detailed morphological descriptions of the muscle, artery, and nerve separately, with few studies assessing the flap dimensions, the main objective of this study is to provide a precise morphological description of the dimensions of the PQ muscle and the components of the neurovascular pedicle in 10 cadaveric specimens. This will allow the identification of the greatest number of clinically relevant variables, thus complementing the existing literature to date.

Materials and Methods

A descriptive anatomical study was carried out on 10 corpses at the Latin American Research Center (CLEMI) in the city of Bogotá, Colombia, year 2023. Fresh, adult corpses without apparent traumatic or congenital injuries causing alterations in the anatomy of the forearm were included. All measurements were taken with the same instrument and were expressed in the decimal metric system. For the dissection of the muscle and neurovascular pedicle, the technique proposed by Carlson et al³ was used with slight modifications according to the study's objectives.

By making a straight incision along the anterior surface of the forearm, from the wrist flexion crease to the antecubital fossa, and after incising the deep fascia, the flexor tendons and the median nerve were identified. The tendon sheath of the flexor carpi radialis (FCR) was dissected and shifted toward the ulnar side to improve visualization.

The plane between the flexor digitorum superficialis (FDS) and the flexor digitorum profundus (FDP) for the ring and long fingers was identified and approached, using a bolster on the dorsum of the hand to keep the wrist in flexion, thereby relieving tension in the anterior compartment of the forearm and minimizing the force required for retraction. After dissecting along the described interval, the PQ muscle was identified.

The dissection of the muscle and pedicle was performed from distal to proximal, starting with the PQ muscle, which was first detached from the ulna and then from the radius, taking care not to damage the pedicle branches on its posterior surface, particularly the branch of the anterior interosseous artery (AIA) that anastomoses with the posterior interosseous artery (PIA). The presence of this anastomosis was confirmed before ligating or sectioning it to proceed with the proximal dissection of the pedicle up to its origin, using the branch of the flexor pollicis longus (FPL) and its bifurcation as reference points.

The dissections were performed with the cadaver in the supine position and the shoulder abducted at 90°. The process was documented with digital photographs. Measurements were taken for the following: (1) the length, width, and thickness of the pronator quadratus; (2) the length, diameter, and branching patterns of the pedicle; and (3) the distance from the wrist flexion crease and the proximal border of the pronator quadratus to the branch of the FPL and the pedicle bifurcation. All measurements were recorded in centimeters and millimeters. For each parameter, the mean, standard deviation, and range were calculated (► Fig. 1).

The statistical analysis was presented descriptively, measurements are presented as average and standard deviation. The analysis was performed using SPSS Statistics software version 29.0.1.0 with statistical blinding by co-author N.A.

This study has the approval of the institutional ethics committee and the Latin American Research Center (CLEMI).

Results

10 cadaveric forearms were included, where 70% (N = 7) of the sample were male. Case number two presented difficulty in the morphological description of the AIA and AIN since it presented an anatomical variant in which they did not continue as the only vessel and nerve, but instead branched approximately 3 cm proximal to the border of the PQ. A synthesis and demographic characterization can be observed in ► Table 1.

Regarding the muscle, we found an average width of 4.3 cm (SD 0.46), with a minimum of 3 cm and a maximum of 5 cm; an average length of 4.8 cm (SD 0.57), ranging from 4.2 to 6.0 cm; and an average thickness of 0.9 cm (SD 0.23), with a minimum of 0.5 cm and a maximum of 1.2 cm.

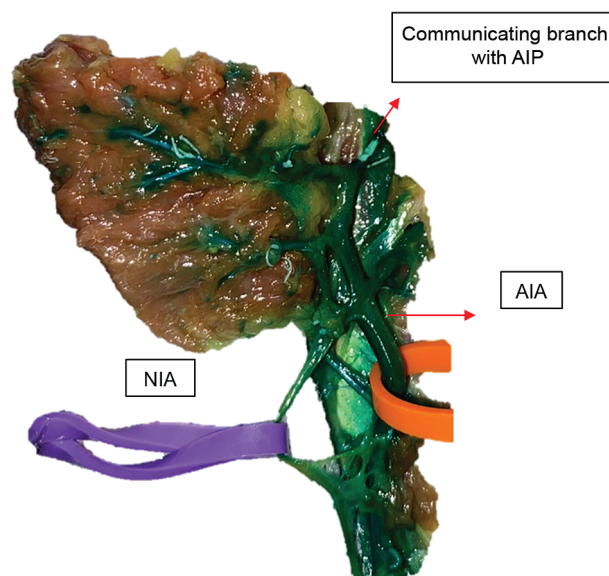


Fig. 1 Entry of the neurovascular pedicle into the pronator quadratus. AIN: Anterior interosseous nerve, AIP: Posterior interosseous artery, AIA: Anterior interosseous artery.

The anterior interosseous artery had a mean length of 12.5 (1.75 SD) cm, a minimum of 11.0 and maximum of 16.5 cm; a proximal diameter of 1.6 mm (0.63 DS) minimum of 0.8 and maximum 3 mm; and distal 2.2 mm (0.50 DS) minimum 1.5 and maximum 3 mm.

Regarding the number of veins, 60% (N = 6) of the components had a single vein, and the remaining 40% (N = 4) had 2 veins, where the average diameter of those with a single vein was 0.9 mm (0.13 DS), minimum 0.6 and maximum 1 mm; and the mean diameter of those who had two veins was also 0.9 mm (0.10 SD), minimum 0.8 and maximum 1 mm.

Regarding the anterior interosseous nerve, an average length of 12.2 cm (1.4 SD) was identified, a minimum of 10 and maximum of 14.3 cm; with an average of 0.9 mm (0.12 DS) in diameter, minimum of 0.7 mm and maximum of 1.2 mm. The distance from the FPL branch to the proximal edge of the pronator quadratus and wrist crease was taken with a mean of 9.8 cm (1.5 SD) and 17.3 cm (0.9 SD) respectively.

Additionally, the anastomosis of the AIA with the AIP was evaluated, where we identified that 80% (N = 8) of the forearms evaluated presented the same. Regarding the bifurcation of the pronator pedicle, the mean was 7.5 (1.9 SD) cm from the pronator quadratus and 13.72 (2.1 SD) cm from the wrist crease (► Fig. 2).

It was observed that the artery and nerve run in proximity, with the nerve generally positioned radially to the vessels. However, a bifurcation of the pedicle was found at 7.5 cm (SD 1.9) from the proximal border of the pronator quadratus and 13.7 cm (SD 2.1) from the wrist flexion crease (► Fig. 3) (See ► Table 2).

Discussion

Hand injuries often result in musculocutaneous defects in up to 37% of cases and amputations in approximately 24%.¹³

Table 1 Flap component dimensions

	Age	Sex	Pronator quadratus muscle			Anterior Interosseous Artery		Concomitant Veins		Anterior Interosseous Nerve		
			Pronator width (cm)	Pronator Length (cm)	Pronator thickness (cm)	Artery Length (cm)	Proximal	Distal	Diameter (mm)	One	Two	Nerve Length (cm)
Forearm 1	62	M	4.3	4.6	1.0	12.5	1.7	2.5	0.9	-	12.0	1.0
Forearm 2	55	M	4.5	4.2	0.9	-	-	-	1.0	-	-	-
Forearm 3	68	M	4.5	5.5	1.2	11.0	3.0	3.0	1.0	-	11.5	1.0
Forearm 4	70	M	4.5	4.5	1.2	11.3	1.7	2.3	0.8	0.8	11.2	1.0
Forearm 5	56	F	4.3	6.0	1.2	11.0	1.3	2.0	0.6	-	12.2	1.0
Forearm 6	67	F	4.5	5.0	1.1	14.0	1.7	3.0	1.0	1.0	10.0	1.0
Forearm 7	71	F	4.3	4.8	0.9	12.7	2.0	1.8	1.0	1.0	13.5	1.0
Forearm 8	58	M	5.0	5.0	0.8	16.5	1.0	2.2	0.8	0.8	14.3	0.7
Forearm 9	57	M	3.2	4.3	0.7	12.0	0.8	1.5	1.0	-	14.0	1.2
Forearm 10	67	M	4.0	4.3	0.5	12.0	1.5	2.3	1.0	1.0	11.5	1.0
Mean (Median)			4.31 (4.38)	4.82 (4.70)	0.95 (0.96)	12.55 (12.16)	1.63 (1.60)	2.28 (2.26)	0.91 (0.94)	0.92 (0.92)	12.24 (12.00)	0.97 (0.97)
SD (p25 - p75)			0.46 (4.15 - 4.60)	0.57 (4.36 - 5.16)	0.23 (0.8 - 1.15)	1.75 (11.25 - 13.02)	0.63 (1.22 - 1.88)	0.50 (1.95 - 2.58)	0.13 (0.83)	0.1 (0.82)	1.42 (11.35 - 13.62)	0.13 (0.85 - 1.10)
95% confidence interval for the mean			3.97 - 4.64	4.40 - 5.23	0.78 - 1.11	11.20 - 13.90	1.14 - 2.12	1.90 - 2.67	0.81 - 1.00	-	11.15 - 13.33	0.87 - 1.06

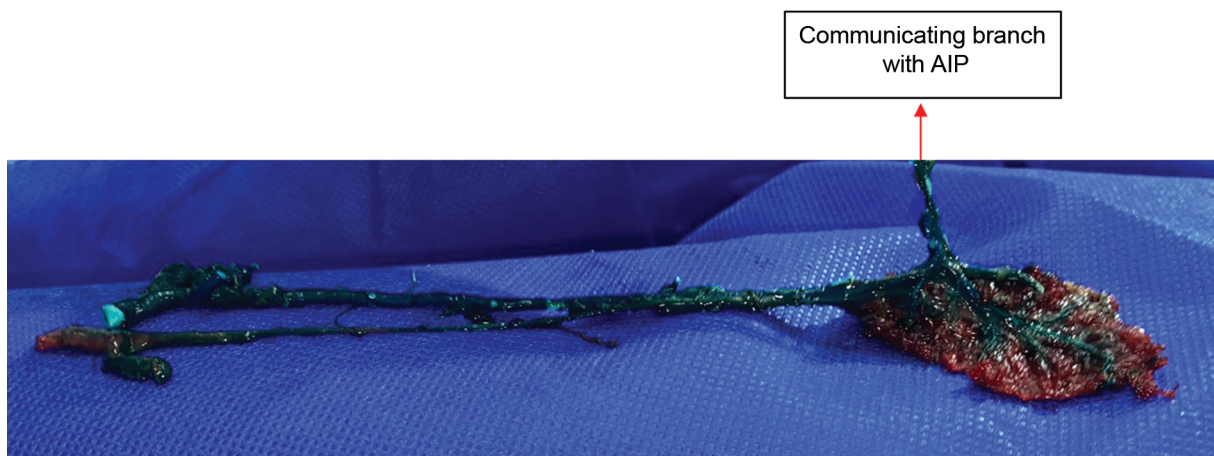


Fig. 2 Communicating branch of the anterior interosseous artery with the posterior interosseous artery. PIA: Posterior interosseous artery.

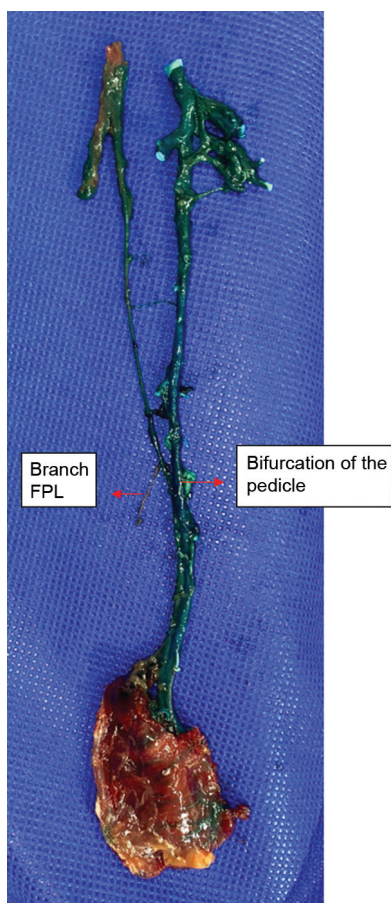


Fig. 3 Pronator quadratus with neurovascular pedicle, with its bifurcation and branch of the Flexor pollicis longus. FPL: Flexor pollicis longus.

Understanding the neurovascular anatomy of muscles is crucial to performing muscle transfers. An ideal muscle must have the appropriate size, constant anatomy, and be dispensable, characteristics that make the pronator quadratus a favorable option.¹²

The versatility of the pronator quadratus has been evident in the literature, being used on the face and upper limb for the correction of blepharoptosis and opponentoplasties^{14,15}

indicating the spectrum of possibilities. In this sense, an exhaustive description of the dimensions and characteristics inherent to the PQ flap and its adjacent structures is imperative.

There are fundamental anatomical parameters for the dissection of the pronator quadratus flap that must be considered to reduce morbidity in the donor area. One of the most relevant and in which significant variability is seen in previously published studies is the distance that the AIN travels from the branch of the FPL to the proximal edge of the pronator quadratus, and the bifurcation that exists between nerve and artery, not previously described. Additionally, the establishment of measurements already described, in relation to surface anatomy such as the wrist crease, is considered of great relevance to achieve the most precise identification of relevant anatomical points after incision and dissection of the flap.

As previously mentioned, there is variability in some parameters, predominantly of the nerve, however, consistency with the literature was observed in relation to the muscle and artery. Evaluating what has been described to date, following a sequence of muscle, artery, veins, and nerve, we can see that regarding the PQ, Hinds et al¹⁶ described the dimensions of the muscle in 25 fresh corpses, establishing an average width of 3.8 cm, length of 4.6 cm and a thickness of 0.6 cm; Carlson et al,³ describe an average width of 3.6 cm and an average length of 4.5 cm; The study by Idge et al,¹⁴ describes the morphological measurements of the PQ as 4.1 cm wide, 5.7 cm long, and 0.78 cm thick. Our cadaveric study found similar dimensions for the Colombian population, showing an average of 4.3 cm wide, 4.8 cm long, and 0.9 cm thick, thus confirming its constant anatomy.

The muscle's blood supply is primarily provided by the anterior interosseous artery. However, studies by Lee et al¹⁷ and Fontaine et al¹⁸ indicate that branches from the radial and ulnar arteries also contribute to the muscle's vascularization. Specifically, the radial artery supplies five to six branches perpendicular to the muscle's longitudinal axis, though these were not observed in the cadaveric dissection of the 10 specimens in our study. Two key variables related to the artery are its diameter and length from the bifurcation at

Table 2 Relevant anatomical parameters in pedicle dissection

	Length from FPL (cm)		Pedicle bifurcation (cm)	
	Pronator quadratus	Wrist flexion crease	Pronator quadratus	Wrist flexion crease
Forearm 1	9.4	17.0	7.5	13.2
Forearm 2	–	–	–	13.5
Forearm 3	7.0	17.0	3.8	9.5
Forearm 4	9.5	17.3	8.2	14.2
Forearm 5	9.5	16.5	6.0	13.0
Forearm 6	9.5	16.0	7.0	13.0
Forearm 7	10.5	18.5	9.0	16.0
Forearm 8	11.5	18.5	8.2	16.4
Forearm 9	12.5	18.5	11.0	15.5
Forearm 10	9.5	17.0	7.0	12.7
Mean (Median)	9.88 (9.50)	17.37 (17.00)	7.52 (7.50)	13.72 (13-20)
SD (p25 - p75)	1.54	0.92	1.99 (6.50 - 8.60)	2.11 (12.85 - 15.62)
95% confidence interval for the mean	8.69 - 11.06	16.65 - 18.08	5.98 - 9.05	12.09 - 15.35

the interosseous trunk. Based on the most representative studies we reviewed, the average diameter of the artery is reported as 1.8 mm.^{3,18,19} However, these studies do not differentiate between the proximal and distal diameters—defined as immediately after the pedicle bifurcation and at the muscle entry point, respectively. In our study, we found a proximal diameter of 1.6 mm and a distal diameter of 2.2 mm, offering clinically relevant data for pre-surgical planning of recipient vessels and for determining end-to-end or end-to-side anastomoses based on the required pedicle length. Regarding artery length, previous studies report an average length of 118 mm,^{3,14,20} while our study found an average length of 125 mm.

The AIA is constantly accompanied by two veins of sufficient caliber to guarantee the venous return of the flap,¹⁸ their presence is consistent.³ In the work of Fontaine et al¹⁸ and Carlson et al³ an average diameter of 2.4 mm and 2.2 mm respectively are reported. However, Idge et al¹⁴ in two descriptive studies, show an average diameter of 1.11 and 1.02 ± 0.09 mm for each of the accompanying veins¹⁴ and 0.75 mm,²⁰ which is more consistent with what was found in our study, evidencing an average diameter of 0.9 mm in cases with a single and double vein.

The pronator quadratus muscle is innervated by the anterior interosseous nerve, a branch of the median nerve, which provides innervation to the flexor pollicis longus muscle and the radial half of the flexor digitorum profundus muscle. The last muscular branch of the anterior interosseous nerve runs to the flexor pollicis longus muscle and originates approximately 60 mm from the proximal border of the pronator quadratus muscle; this being relevant to pedicle dissection.¹⁸

Regarding the dimensions of the anterior interosseous nerve, significant variability is observed in the average length from the branch of the flexor pollicis longus (FPL) to the proximal border of the pronator quadratus. Previous reports

cite lengths of 48 mm,¹² 125 mm³, and 110 mm¹⁴ compared to an average of 98 mm from the FPL branch and 137 mm from the wrist flexion crease, as documented in our study. This measurement is crucial, as it represents the useful length of the pedicle without significantly compromising function, aligning with Fontaine et al's¹⁸ findings, which indicate a length of 70–80 mm from the point where the nerve reaches the pronator quadratus. As for the nerve diameter, the literature reports an average of 1.6 mm,^{14,16} which is notably larger than the 0.97 mm average observed in our study.

This study has inherent limitations associated with cadaveric research, which can inherently cause anatomical distortion. Although the same measuring instrument was used throughout, the fact that measurements were taken by only one of the authors introduces potential bias. Additionally, the generalization of the findings is limited by the unilateral dissection of the components and the sample size.

Conclusion

This study provides a detailed description of the anatomy of the muscle and vascular nervous pedicle of the pronator quadratus flap, including variables not previously described in the literature. This information complements existing knowledge on the muscle's vascularization,¹⁸ as well as the extra- and intramuscular anatomy of the AIN in the PQ.^{21,22} Additionally, it offers measurements based on surface anatomical landmarks such as the wrist flexion crease and the bifurcation of the pedicle, which have not been evaluated in previous studies. We can conclude that the muscle and vascular-nervous pedicle exhibit consistent anatomy, with a sufficient pedicle length of approximately 8 cm that does not induce functional morbidity. This makes it an important and reliable resource for facial and upper limb reconstruction.

Conflict of Interest

None declared.

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