Anatomic study of flexor carpi ulnaris and brachioradialis muscles and their implication in reconstructive surgeries

Sushma S. Mandala, Prameela M Dass, Mangala M. Pai, Rajanigandha Vadgaonkar, Rajalakshmi Rai, Murlimanju B.V., Lakshmisha Rao

Department of Anatomy, Kasturba Medical College, Mangalore, Manipal Academy of Higher Education, Manipal, Karnataka, India

SUMMARY

Management of soft tissue loss around the posterior aspect of the elbow region is most challenging for clinicians, as it may require reconstructive methods for the better healing of wounds. One of the options for reconstructive surgery is local muscle rotational flaps by the flexor carpi ulnaris (FCU) and brachioradialis (BR). This study aimed to explore the morphometry and vascular anatomy of FCU and BR. Thirty formalin-embalmed cadaveric upper extremities (16 right and 14 left) were utilized for this study. The average length of the FCU muscle belly was 28.96 ±2.16 cm within a range of 24.3 to 32.5 cm, and the average length of the tendon was 10.05 ± 2.2 cm, with a range of 6.9 to 14.3 cm. The number of vascular pedicles for FCU was one in 5, two in 21, and three and four in 2 specimens respectively. All the pedicles arose from the ulnar artery. The average length of the BR muscle was 28.2 ±3.58 cm, with a range of 22.8 to 36.8 cm, and the average length of its tendon was 8.2 cm, with a range of 5.7 to 13.5 cm. In 90% of specimens, BR had only one vascular pedicle and in 10% there were two pedicles. These pedicles arose from the radial recurrent artery and the radial artery. Detailed morphometric and topographic anatomy of the vascular pedicles of FCU and BR are provided in this study, which can be considered the morphological database for the South Indian population.

Key words: Elbow – Musculocutaneous flap – Morphometry – Tendon transfer – Ulnar artery

INTRODUCTION

The posterior aspect of the elbow region is prone to soft tissue loss. Tissue loss is usually due to injury, wound infection, burns, tumor excision, etc. (Ooi et al., 2016). Management of tissue loss around the posterior elbow region is more challenging for the clinicians, especially if infections, exposure of bones or nerves complicate it. This may require reconstructive methods for the better healing of wounds (Sharpe et al., 2014). Improper correction of the tissue loss may restrict the function of elbow movement and impair the function of the upper limb (Kelly et al., 2015).

Corresponding author:
Dr Prameela M Dass, MD. Department of Anatomy, Kasturba Medical College, Mangalore, Manipal Academy of Higher Education, Manipal, 576 104, India. E-mail: prameela.md@manipal.edu

Submitted: June 16, 2023. **Accepted:** September 19, 2023

https://doi.org/10.52083/LEXE5555

There are several choices available for coverage of soft tissue loss around the elbow. Local muscle rotational flaps by flexor carpi ulnaris (FCU) and brachioradialis (BR) are one such option for tissue reconstruction (Sharpe et al., 2014). A distal FCU flap is useful in the correction of defects around the wrist and hand areas, including the lower part of the forearm (Yang et al., 2019). A few studies have recently showed that FCU flap was used to improve vascular supply and soft tissue coverage at non-union sites (Meals, 1989). The use of FCU as transplant material for loss or paralysis of extensor carpi radialis longus and brevis muscle was reported by several authors (Green et al., 1962; Wenner et al., 1988). Zambelli et al. (2019) have used BR muscle flap for soft tissue repair at the posterior elbow region with good results. BR can be used as graft material in patients with lower brachial plexus injury (C7-T1), causing paralysis of the flexor muscles of the forearm (Shrikanth et al., 2018). FCU is the superficial muscle of the forearm present on the medial aspect (Strandring, 2008). Its origin is from the humerus and ulna and a tendinous arch connecting them. It takes origin in the medial epicondyle of the humerus, the medial margin of the olecranon process and the upper part of subcutaneous posterior border of the ulna. It gets inserts into the pisiform bone mainly, through the pisohamate and pisometacarpal ligament to the hamate and fifth metacarpal bone. Its actions are flexion at the wrist and adduction of the hand. The BR is the superficial muscle along the lateral aspect of the forearm, and it forms the lateral boundary of the cubital fossa. It arises from the lateral intermuscular septa and the upper part of the lateral supracondylar ridge of the humerus and gets inserted into the radius proximal to its styloid process. It is a flexor of the elbow in the mid-prone position. It is supplied by the radial or radial recurrent artery.

Several studies have described the morphometry and vascular pedicles of FCU with variable results (Sharpe et al., 2014; Payne et al., 2011; Wysocki, 2008). Reports on the morphometry of BR (Hospatna et al., 2020; Rohrich et al., 1995) and the vascular anatomy of BR (Rohrich et al., 1995; Sanger et al., 1994; Gilbert et al., 1980; Shen et al., 2008) are available in different studies. Data related to the morphometry and vascular anatomy of FCU and BR in the Indian population are rarely available in the literature.

The objective of the present research is to explore the morphometry and vascular anatomy of both the FCU and BR in a South Indian population.

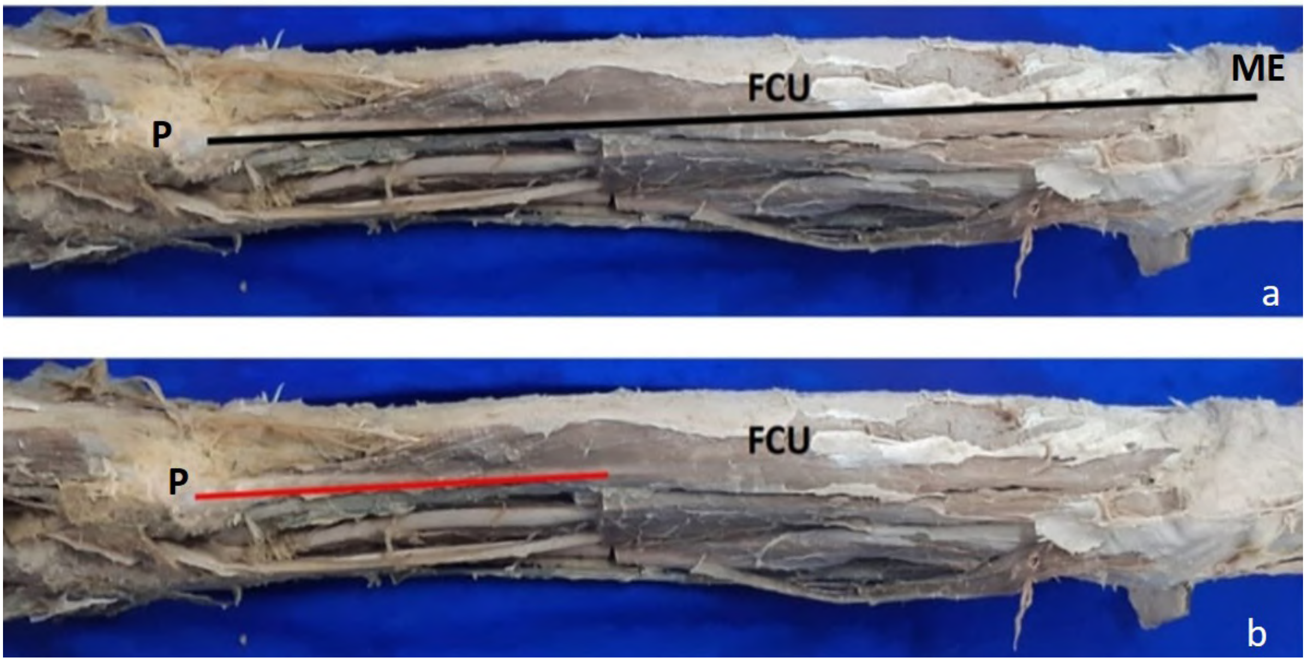

Fig. 1.- Dissected upper limb specimen depicting measurement of length of Flexor carpi ulnaris (FCU). **a)** Black line represents the length of the FCU from the medial epicondyle (ME) to the pisiform bone (P). **b)** Red line represents the length of the tendon from the musculocutaneous junction until the insertion on pisiform bone.

MATERIALS AND METHODS

Thirty formalin embalmed cadaveric upper extremities (16 right and 14 left sides) were utilized for this study. Approval from Institutional Ethics Committee, Kasturba Medical College, Mangalore was obtained for this study. The skin of the forearm was incised and the superficial and deep fascia were reflected. The forearm region was meticulously dissected to look for the FCU and BR muscles. FCU was reflected medially, and BR was reflected laterally to observe the pattern of its blood supply. The following parameters were measured using a measuring tape and a digital Vernier caliper (Aerospace Digital Vernier Caliper, 6”- 150 mm, China. Resolution: 0.01 mm):

1. Length of the FCU muscle was measured from the medial epicondyle of the humerus to the pisiform bone (Fig. 1).
2. Length of the FCU tendon from the myotendinous junction until the insertion in the pisiform bone (Fig. 1b).
3. The total number of proximal vascular pedicles of FCU and the source of origin of these vessels.
4. Distance of the vascular pedicles of FCU from the tip of the medial epicondyle of humerus.
5. Distance of the distal vascular pedicle of FCU from the ulnar styloid process.
6. Length of BR from its origin from the lateral supracondylar ridge to its insertion above the radial styloid process (Fig. 2).
7. The total number of vascular pedicles of BR and the source of origin of these vessels.
8. Distance of the vascular pedicle of BR from tip of lateral epicondyle (LE) of the humerus and the tip of the olecranon process (OP) of the ulna.

RESULTS

Flexor carpi ulnaris

The average length of FCU was 28.9 6 ± 2.16 cm with a range of 24.3 to 32.5 cm. The average length of its tendon was 10.05 ± 2.2 cm, with a range of 6.9 to 14.3 cm (Table 1). The number of vascular pedicles for FCU was one in 5, two in 21, and three and four in 2 specimens respectively (Fig. 3 a, b, c). All the pedicles of FCU arose from the ulnar artery. The distance of the vascular pedicles of FCU from medial epicondyle and the distal-most pedicle from the ulnar styloid process is depicted in Table 1.

Brachioradialis

The average length of the BR muscle was 28.2 ± 3.58 cm with a range of 22.8 cm to 36.8 cm. The average length of the BR tendon was 8.2 cm with the range of 5.7 cm to 13.5 cm. In the majority of specimens, 27 (90%), BR had only one vascular pedicle. However, in three specimens there were two pedicles (10%). In 17 specimens (56.66%) the arterial pedicles arose from the radial recurrent artery (RRA), whereas in 13 specimens (43.33%) they arose from the radial artery (RA) (Fig. 4a and 4b).

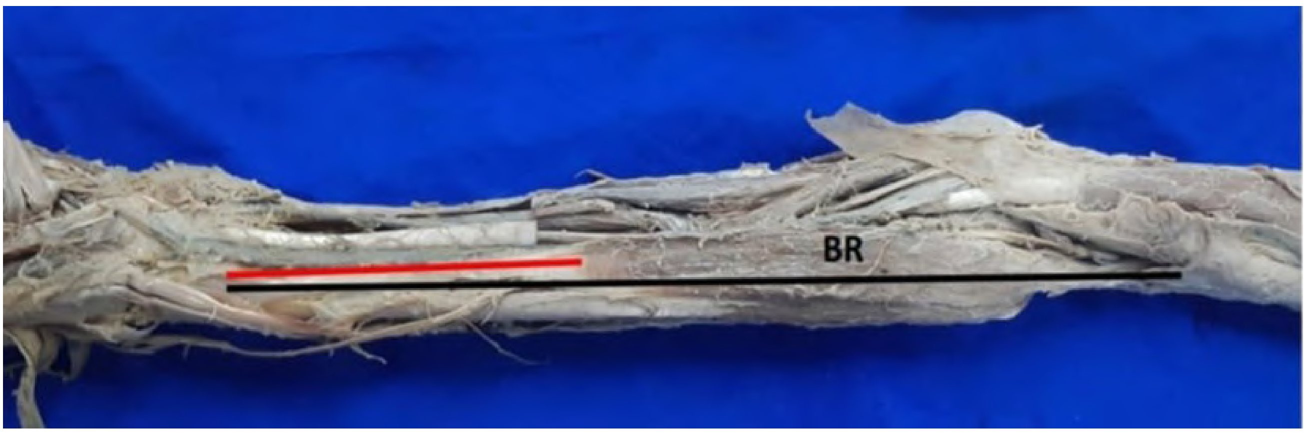

Fig. 2.- Dissected upper limb depicting measurement of length of brachioradialis (BR). The black line represents the length of the brachioradialis muscle from the lateral supracondylar ridge to its insertion above the radial styloid process, and the red line represents the length of the tendon from the musculotendinous junction to its insertion.

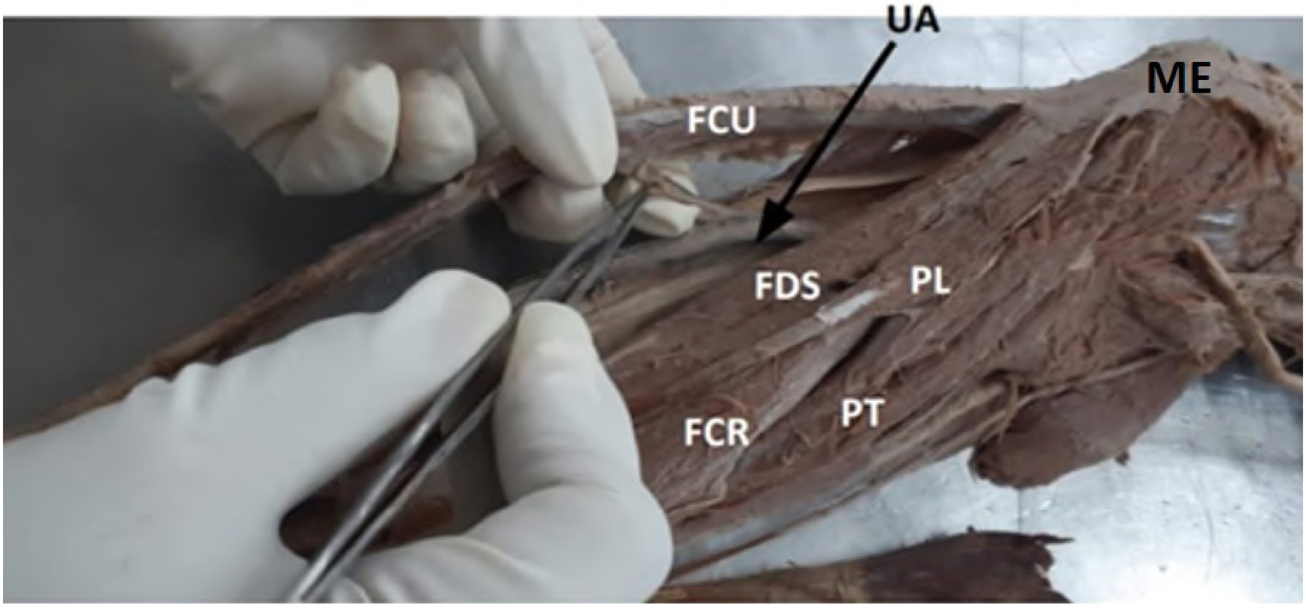

Fig. 3a.- Left upper limb showing flexor carpi ulnaris with one proximal vascular pedicle (black arrow) arising from ulnar artery. FCU- Flexor carpi ulnaris, UA- Ulnar artery, FDS- Flexor digitorum superficialis, FCR- Flexor carpi radialis, PL- Palmaris longus, PT- Pronator teres, ME- medial epicondyle.

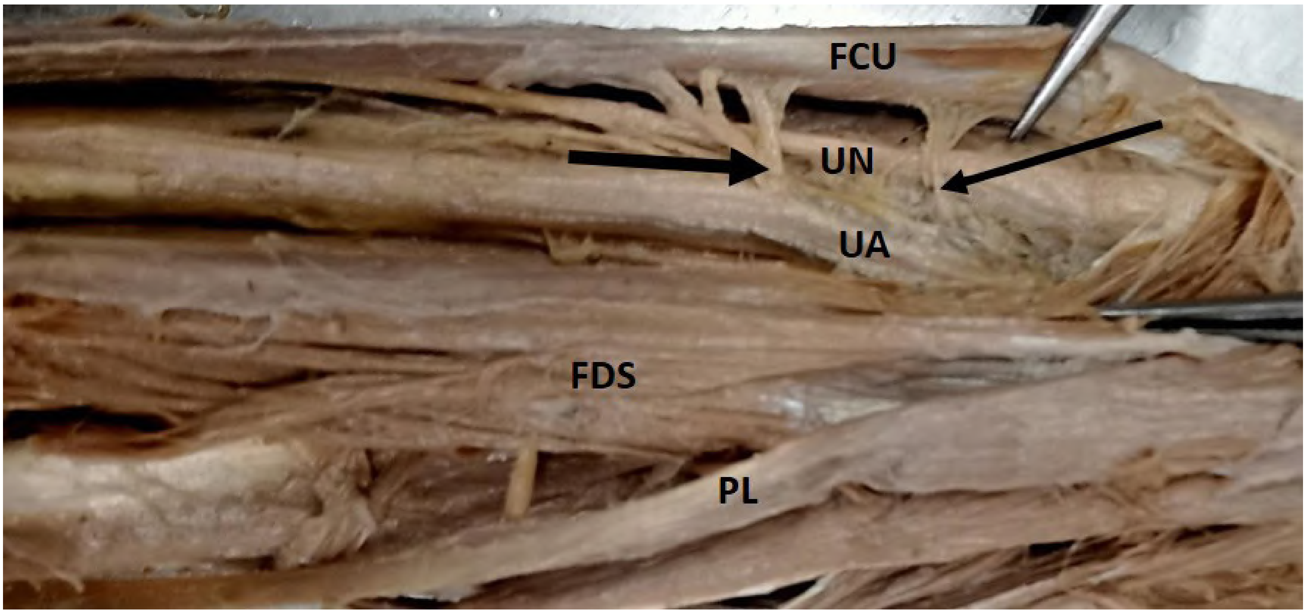

Fig. 3b.- Flexor carpi ulnaris with two proximal vascular pedicles indicated by black arrows. FCU- Flexor carpi ulnaris, UN- Ulnar nerve, UA- Ulnar artery, FDS- Flexor digitorum superficialis, PL- Palmaris longus.

Table 1. Morphometric data and vascular pedicles of Flexor carpi ulnaris. ME: Medial epicondyle.

Parameters	Min	Max	Mean	SD
Length of FCU (cm)	24.3	32.5	28.96	2.16
Length of FCU tendon (cm)	6.9	14.3	10.05	2.2
Distance of first vascular pedicle from ME (cm)	5.2	14.5	9.74	2.34
Distance of second vascular pedicle from ME (cm)	9.6	22.9	13.45	3.06
Distance of third vascular pedicle from ME (cm)	12.6	21.7	16.87	4.41
Distance of fourth vascular pedicle from ME (cm)	23	23	23.3	0.21
Distance of distal most vascular pedicle from the ulnar styloid process (cm)	3.7	18.6	11.91	5.13

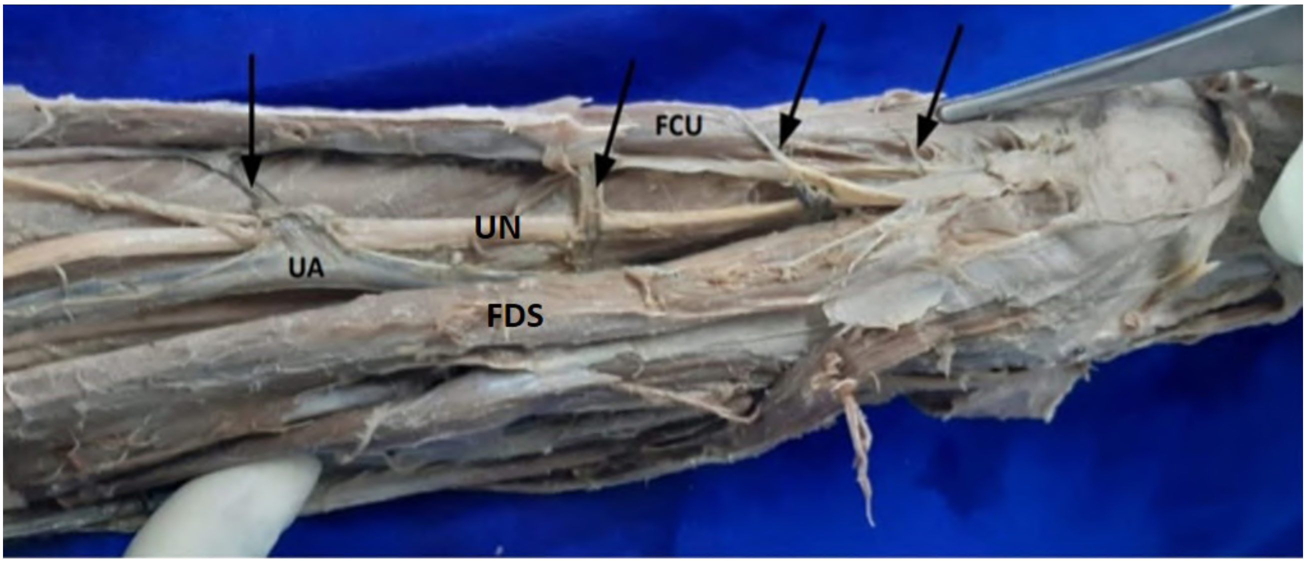

Fig. 3c.- Left upper limb showing flexor carpi ulnaris with four proximal vascular pedicles indicated by black arrows. FCU- Flexor carpi ulnaris, UN- Ulnar nerve, UA- Ulnar artery, FDS- Flexor digitorum superficialis.

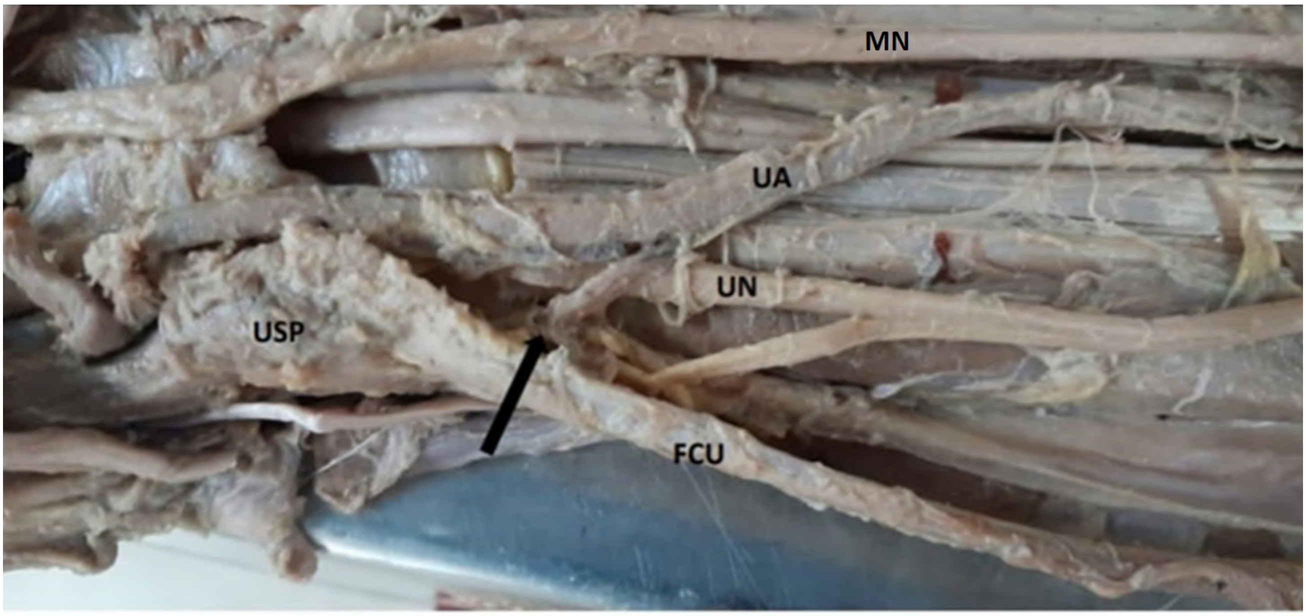

Fig. 3d.- Dissected lower part of front of forearm showing distal vascular pedicle of Flexor carpi ulnaris arising from the ulnar artery (arrow). FCU- Flexor carpi ulnaris, UN- Ulnar nerve, UA- Ulnar artery, MN- Median nerve, ME- medial epicondyle, USP- ulnar styloid process.

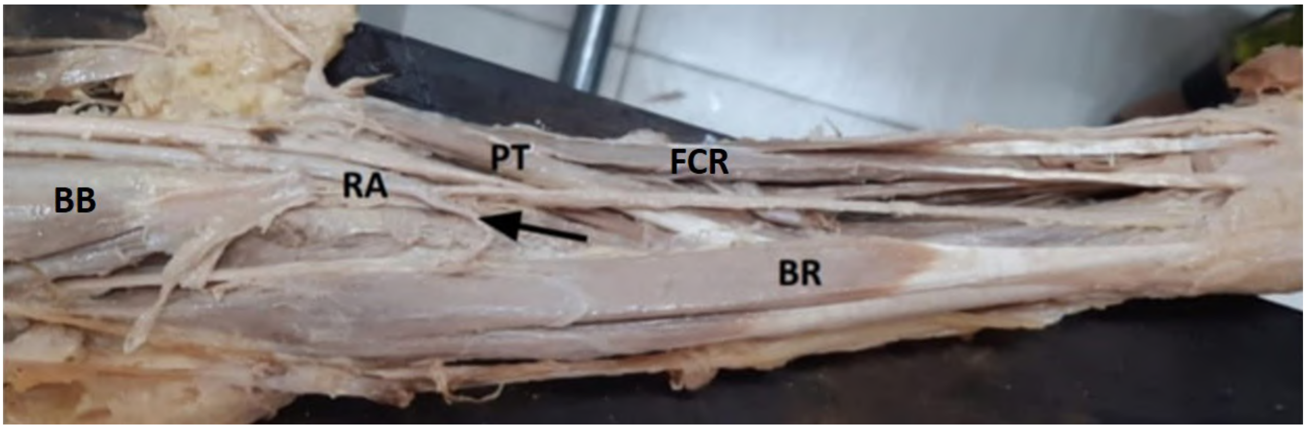

Fig. 4a.- Dissected right upper limb showing brachioradialis with vascular pedicle (black arrow) arising from radial artery. BR- Brachioradialis, RA- Radial artery, PT- Pronator teres, BB- Biceps brachii muscle, FCR- Flexor carpi radialis.

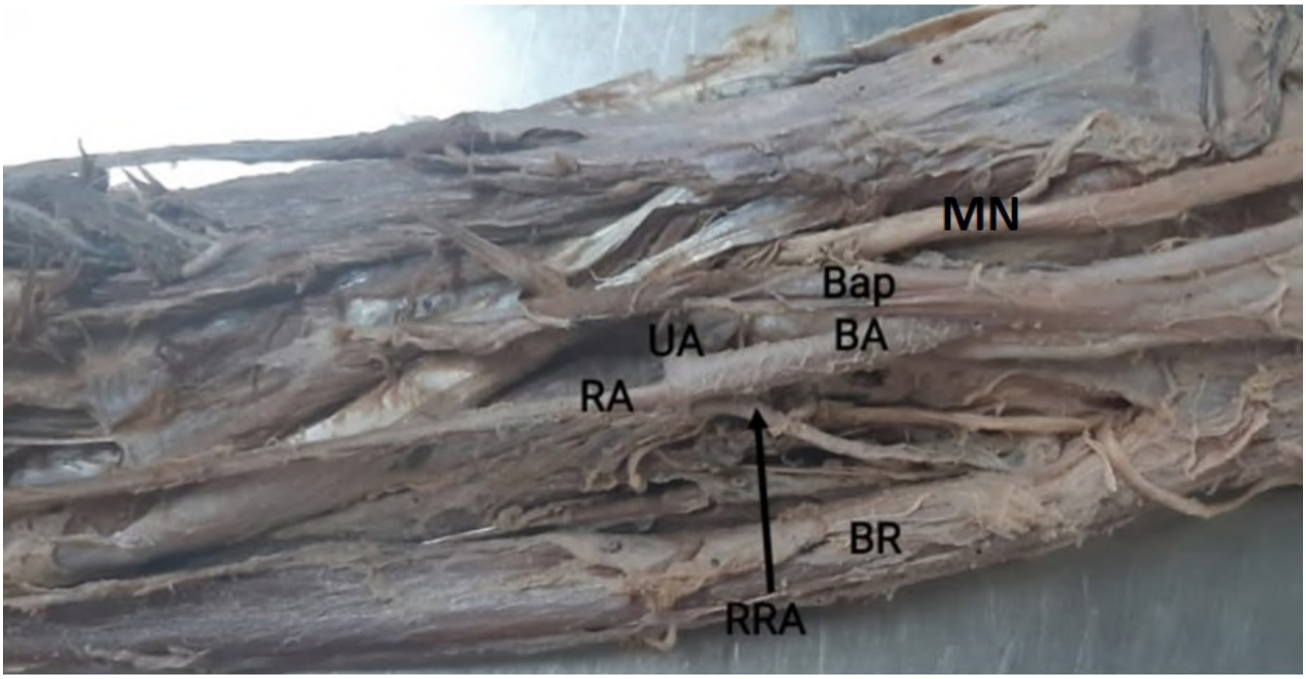

Fig. 4b.- Brachioradialis with vascular pedicle arising from radial recurrent artery (arrow). BR- Brachioradialis, RA- Radial artery, RRA- Radial recurrent artery, BA- Brachial artery, UA- Ulnar artery, Bap- Bicipital aponeurosis, MN- Median nerve.

The average distance of the vascular pedicle of BR from the LE was 6.56 cm with a range of 4 cm to 13 cm, and from the OP was 8.84 cm with a range of 6.2 cm to 14.5 cm.

DISCUSSION

The option available for the corrections of soft tissue loss around the elbow region include local and axial fascio-cutaneous flaps, distant pedicle flap, local muscle flaps by using anconeus, BR and FCU, or distant muscle flaps by using latissimus dorsi, etc. (Sharpe et al., 2014). Results of the previous studies have shown significant benefits in using FCU flap for soft tissue reconstruction around the proximal forearm, elbow and distal arm region (Sharpe et al., 2014; Payne et al., 2011).

The average length of the FCU muscle and its tendons were 28.96 ± 2.16 cm and 10.05 ± 2.2 cm respectively in our study. Sharpe et al. (2014) measured the length of FCU from the medial epicondyle to the pisiform bone, and found its average length as 28.3 cm with a range from 25.2 cm and 32.6 cm. Payne et al. (2011) reported the average length of FCU from the olecranon process to the pisiform bone as 27.4 cm. Wysocki et al. (2008) measured the FCU length from the olecranon process to the ulnar styloid process and reported it as 26.6 cm. These findings correspond to our study. The knowledge of the morphometry of FCU is important because it can be transplanted to improve the wrist function in patients suffering from cerebral palsy. The FCU can be transplanted to the extensor carpi radialis longus and the extensor carpi brevis to improve the hand function (Green et al., 1962; Wenner et al., 1988).

In our study, the average number of vascular pedicles was 2.3 with the range of 1 to 4 and all the pedicles were arising from ulnar artery. The average distance of the first, second, third and fourth vascular pedicles from the medial epicondyle was 9.74 cm, 13.45 cm, 16.87 cm and 23.3 cm, respectively. This finding is different from the study by Sharpe et al. (2014). They have reported that the average number of vascular pedicles of FCU is 3.8, with a range from 2 to 7 and all the pedicles were arising from the ulnar artery. The distance of seven vascular pedicles were 5.6 cm, 8.2 cm, 12.2 cm, 14.6 cm, 20.1 cm, 21.3 cm and 27.5 cm from the medial epicondyle. The average distance of the proximal pedicle from OP was 5.9 cm and 5.0 cm by Payne et al. (2011) and Wysocki et al. (2008), respectively. Shen et al. (2008) in their anatomical study reported that the ulnar artery provided vascular pedicle in 86% and ulnar recurrent artery in 14% of specimens. Andre et al. (2014) reported harvesting FCU musculocutaneous flap is relatively a faster and reliable procedure for tissue loss around the olecranon process, as the proximal pedicle is more constant in position (6 cm from OP), and it does not require microsurgery, because the pedicle can be easily visible. Anatomical knowledge of FCU like the long length of the muscle belly, its rich vascularity and its vicinity to the elbow region, confirms that it is the best suitable graft material for soft tissue loss.

In the present study, the average distance of the distal capsular pedicle from the ulnar styloid process was 11.91 cm with the range between 3.7 cm to 18.6 cm. The distal vascular pedicle is the least reported in the literature. Yang et al. (2019) studied the distance of the distal vascular pedicle from the ulnar styloid process and reported that the average distance was 3 cm, with a range of 2.6 to 3.5 cm. They used a distal FCU flap for the treatment of median nerve neuroma with carpal tunnel syndrome in a patient following a previous median nerve injury repair. Complete recovery from symptoms of carpal tunnel syndrome like cessation of pain and tingling sensation were achieved in the patient within 4 weeks of treatment. They concluded that the distal FCU flap can also be utilized for the soft tissue reconstruction of the distal forearm, wrist and hand region.

The average length of the BR muscle in our study was 28.2 cm and its tendon was 8.2 cm. In a study by Hospatna et al. (2020), the average length of the muscle belly and tendon of the BR were 21.22 cm and 12.7 cm respectively. Rohrich et al. (1995) reported the mean length of the BR tendon as 6.9 cm. BR can be used as a graft material in cases of lower part of brachial plexus injury (C7-T1), causing paralysis of flexor muscles of the forearm, as BR is commonly spared in these injuries because of its innervation by C5, C6 (Srikanth et al., 2018). BR can also be used as graft for flexor pollicis longus to improve lateral pinch in tetraplegic patients (Waters et al., 1985).

Rohrich et al. (1995) found vascular pedicle to BR arising from RRA in 58%, BA in 24% and RA in 17% of the study sample. Sanger et al. (1994) reported the vascular pedicles from RA in 39.4%, RRA in 33.3% and BA in 27.3%. The report from Shen et al. (2008) stated that the pedicles wearosere arising from RA in 38%, RRA in 33.3% and BA in 27.3% of cases. Gilbert et al. (1980) found pedicles from RRA (10%), RA (78%) and BA (12%). In our study, we found that the arterial pedicles of the BR from RRA in 56.66% and RA in 43.33% (Fig. 4) of cases. We did not find vascular pedicles from BA. The comparison of the vascular pedicle to BR between our study and others in depicted in the Fig. 5.

Average distance of the vascular pedicle of from LE was 6.4 cm in our study with the range of 4 cm to 13 cm. The average distance of the pedicle from

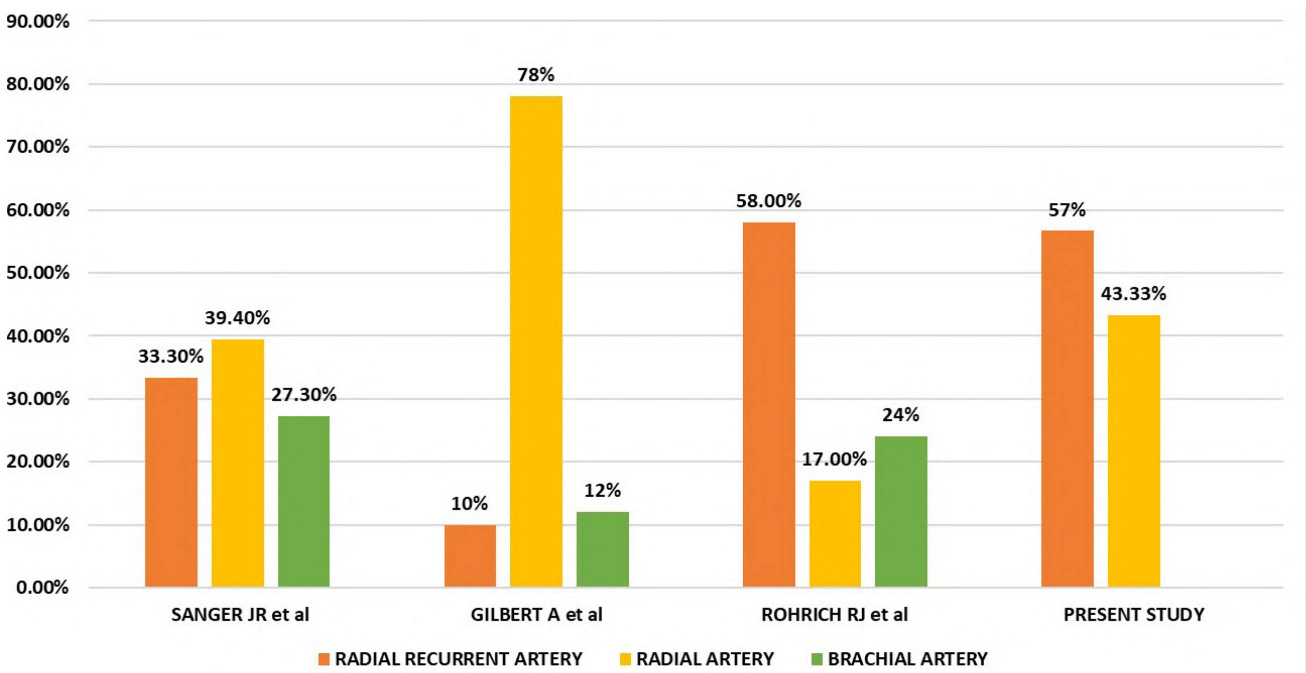

Fig. 5.- Comparison data of origin of vascular pedicles of brachioradialis.

OP was 8.84 cm with the range of 6.2 cm to 14.5 cm. Sanger et al. (1994) reported that the proximal perforator of the BR was at the middle third of the muscle in a majority of the specimens. However, in literature review we did not find the distance of the vascular pedicles from any bony landmarks. Therefore, result of this study may benefit the clinicians and researchers to know the level of vascular pedicle from the LE and OP and where to pivot the flap. Zampeli et al. (2019) have used BR muscle flap for soft tissue defect around elbow due to arthroplasty, postoperative infection or neuropathic arthropathy causing elbow arthrodesis. They have reported that all their patients had viable and functional soft tissue coverage after flap surgery.

Increase in the knowledge of the anatomy of the muscle, its blood supply, and level of perforators is important in plastic and reconstructive surgeries. Muscle flaps by anconeus, BR and FCU are the preferred choice for significant defects in the posterior elbow region, especially when it is associated with infection, because they provide bulkier tissue than the other type of flap (Patel et al., 2013).

We have presented the comprehensive data of the morphometry and vascular anatomy of FCU and BR in a South Indian population. We have also provided the data related to the level of vascular pedicles of BR, which is scarcely available in the literature. However, the age and gender differences of these morphometric data were not determined in this study. These are the limitations of this research.

CONCLUSION

The present study reports the morphometric and vascular anatomy of FCU and BR. The detailed data about the topographic anatomy of the vascular pedicle are provided, which can be considered the morphological database for the South Indian population. These data are beneficial to the surgeons for tendon transplants and muscle flap surgery to cover the soft tissue loss around the elbow and wrist region.

ACKNOWLEDGEMENTS

The authors sincerely thank those who donated their bodies to science so that anatomical research and teaching could be performed. Results from such research can potentially increase scientific knowledge and can improve patient care. Therefore, these donors and their families deserve our highest respect.

REFERENCES

ANDRE A, BONNEVIALLE N, GROLLEAU JL, MANSAT P (2014) Soft-tissue coverage of olecranon with musculocutaneous flexor carpi ulnaris flap. *Orthop Traumatol Surg Res,* 100(8): 963-966.

GILBERT A, RESTREPO J (1980) Le long supinateur: anatomie et utilisation comme lambeau de rotation musculaire [The brachioradial muscle: anatomy and use as a muscular rotation flap]. *Ann Chirurgie Plastique*, 25(1): 72-75.

GREEN WT, BANKS HH (1962) Flexor carpi ulnaris transplant and its use in cerebral palsy. *J Bone Joint Surg Am,* 44-A: 1343-1430.

HOSAPATNA M, SOUZA AD, RAO M, HARI ANKOLEKAR V (2020) Morphology and innervation of brachioradialis and flexor carpi radialis and their utility in tendon transfer surgeries: A cadaveric study. *Morphologie: Bull l'Assoc Anat*, 104(345): 91-96.

KELLY BP, CHUNG KC (2015) Soft-tissue coverage for elbow trauma. *Hand Clinics*, 31(4): 693-703.

MEALS RA (1989) The use of a flexor carpi ulnaris muscle flap in the treatment of an infected non-union of the proximal ulna. A case report. *Clin Orthop Relat Res*, (240):168-172.

OOI A, NG J, CHUI C, GOH T, TAN BK (2016) Maximizing outcomes while minimizing morbidity: an illustrated case review of elbow soft tissue reconstruction. *Plast Surg Int,* 2016: 2841816.

PATEL KM, HIGGINS JP (2013) Posterior elbow wounds: soft tissue coverage options and techniques. *Orthop Clin North Am*, 44(3): 409-417.

PAYNE DE, KAUFMAN AM, WYSOCKI RW, RICHARD MJ, RUCH DS, LEVERSEDGE FJ (2011) Vascular perfusion of a flexor carpi ulnaris muscle turnover pedicle flap for posterior elbow soft tissue reconstruction: a cadaveric study. *J Hand Surg Am,* 36(2): 246-251.

ROHRICH RJ, INGRAM AE JR (1995) Brachioradialis muscle flap: clinical anatomy and use in soft-tissue reconstruction of the elbow. *Ann Plast Surg,* 35(1): 70-76.

SANGER JR, YE Z, YOUSIF NJ, MATLOUB HS (1994) The brachioradialis forearm flap: anatomy and clinical application. *Plast Reconstr Surg*, 94(5): 667-674.

SHARPE F, BARRY P, LIN SD, STEVANOVIC M (2014) Anatomic study of the flexor carpi ulnaris muscle and its application to soft tissue coverage of the elbow with clinical correlation. *J Shoulder Elbow Surg,* 23(1): 82-90.

SHEN S, PANG J, SENEVIRATNE S, ASHTON MW, CORLETT RJ, TAYLOR GI (2008) A comparative anatomical study of brachioradialis and flexor carpi ulnaris muscles: implications for total tongue reconstruction. *Plast Reconstr Surg*, 121(3): 816-829.

SRIKANTH R, RAYIDI KR, KAKUMANU S (2018) Brachioradialis to flexor digitorum profundus tendon transfer to restore finger flexion. *Indian J Plast Surg,* 51(2): 123-130.

STANDRING S (2008) Gray's Anatomy. The Anatomical Basis of Clinical Practice. 40th ed. Churchill-Livingstone, London, pp 847-849.

WATERS R, MOORE KR, GRABOFF SR, PARIS K (1985) Brachioradialis to flexor pollicis longus tendon transfer for active lateral pinch in the tetraplegic. *J Hand Surg Am*, 10(3): 385-391.

WENNER SM, JOHNSON KA (1988) Transfer of the flexor carpi ulnaris to the radial wrist extensors in cerebral palsy. *J Hand Surg Am*, 13(2): 231-233.

WYSOCKI RW, GRAY RL, FERNANDEZ JJ, COHEN MS (2008) Posterior elbow coverage using whole and split flexor carpi ulnaris flaps: a cadaveric study. *J Hand Surg Am*, 33(10): 1807-1812.

YANG K, RIVEDAL D, BOEHM L, YAN JG, SANGER J, MATLOUB H (2019) Distally based pedicled flexor carpi ulnaris muscle flap: an anatomical study and clinical application. *Hand (NY),* 14(1): 121-126.

ZAMPELI F, SPYRIDONOS S, FANDRIDIS E (2019) Brachioradialis muscle flap for posterior elbow defects: a simple and effective solution for the upper limb surgeon. *J Shoulder Elbow Surg,* 28(8): 1476-1483.