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ORIGINAL ARTICLE

Study of Anatomical Variations of 1,2 Intercompartmental Supraretinacular Artery-Based Vascularized Bone Graft in Cadavers

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Abstract

Background The aim of this study is to describe the anatomy of the 1,2 intercompartmental supraretinacular artery (1,2 ICSRA), including the location of the perforators, number of perforators, and proximal and distal origins of the artery.

Materials and Methods The study was done by dissecting both wrists of 11 fresh-frozen cadavers. In each specimen, skin incision and dissections were done in the forearm by the Henry approach. Radial artery was identified and cannulated and dye was injected. The dye consisted of the mixture of polyvinyl chloride and acetone in the ratio of 1:4, to which red-colored resin was added. The artery of interest 1,2 ICSRA was dissected and its anatomical characteristics such as distal origin, proximal origin, number of perforators, and largest perforator were measured.

Results Of the 22 wrists dissected, only in 19 wrists we were able to recognize the perforators. Average number of perforators seen was 3.05 (range 1–5). Average distance of the largest perforator from the radial styloid was 11.79 mm (range 6–19 mm). The average distance of the distal origin of 1,2 ICSRA from the radial styloid was 6.71 mm distal to radial styloid. It ranged from 16 mm distal to styloid process to 6 mm proximal to the styloid process. The average distance of proximal origin of 1,2 ICSRA from the radial styloid was 40.52 mm proximal to the radial styloid (range 25–66 mm). The maximum density of perforators of 2.84 was noticed to be in the region of 6–18 mm from the distal articular margin.

Conclusion The distal origin of 1,2 ICSRA in our study was much more distal in comparison to the western population. The detailed anatomy of the 1,2 ICSRA presented in this study may guide in planning and dissection to maximize the vascularity of a pedicled bone graft based on this vessel for the management of scaphoid nonunions and other carpal pathologies.

Keywords 1,2 intercompartmental supraretinacular artery · polyvinyl chloride-based dye · vascularized bone graft

Introduction

Vascularized bone grafts around the wrist are of tremendous importance as carpal bones are predisposed to fracture nonunion and avascular necrosis (AVN). The scaphoid is the most commonly fractured carpal bone, representing 60%–70% of fractures of the carpal bones. Common complications of scaphoid fractures include delayed union, nonunion, and AVN of the proximal pole. Vascularized bone grafting has recently gained popularity due to higher success rate in treatment of these complications [1]. Open reduction and internal fixation with bone grafting is the treatment of choice for nonunion scaphoid [2–7]. However, in cases with AVN of proximal fragment of the scaphoid, conventional bone grafting is insufficient and leads to suboptimal results.

Pedicled vascularized bone grafts help facilitate bone healing and revascularize bone without creeping substitution and thus accelerate fracture healing. A meta-analysis found that vascularized bone grafts have 88% union rate versus 47% union rates of conventional bone grafting in scaphoid nonunions with AVN of proximal pole [8]. Most commonly and successfully used vascularized bone graft for this purpose is harvested from the dorso-radial aspect of radius. It was described by Zaidemberg [9] and is based on the distal origin of 1,2 intercompartmental supraretinacular artery (1,2 ICSRA) which was defined by Sheetz and Bishop [10]. It is an ascending irrigating branch of the radial artery which

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traverses from the distal to the proximal direction in between the first and second dorsal extensor compartments.

Despite its success, localization and dissection of thin and fragile 1,2 ICSRA and its perforators intraoperatively remain a herculean task. Precise knowledge of anatomy and variations of 1,2 ICSRA is vital for increasing the surgical precision, decreasing operative time, and improvement of overall results of the surgery. The purpose of this cadaveric study is to describe the anatomy of 1,2 ICSRA, its proximal and distal origins, and perforator number and location. None of the previous studies have described the surgical anatomy of 1,2 ICSRA in the Indian population.

Materials and Methods

Twenty-one wrists from 11 cadavers (9 male and 2 female) with an average age of 43.2 years were dissected in the study. The study was conducted by the department of orthopedics in collaboration with the department of forensic medicine and the department of anatomy, after obtaining clearance from the institutional ethics committee. Our study was a descriptive study.

Both forearms of each cadaver were used in the study. Radial artery in each forearm was approached by the Henry approach and was cannulated with the 18G cannula. Ligature with silk no. 1 was put around the artery to secure cannula inside it and hence to minimize extravasation. Through a dorso-radial incision, the radial artery in the anatomical snuff box was dissected and ligated.

We used poly vinyl chlorpide [11] (PVC) as a casting material, which is a simple thermoplastic polymer with 57% chlorine and 43% carbon widely used in industry. It has the properties of an ideal casting medium. It is easily available and economical. It was mixed with acetone and the colored resin. It acted as a casting medium for the artery of our interest. PVC of 5 g was measured with electronic weighing scale and transferred to a glass beaker. Acetone of 20 g was added to the same beaker and stirred well to ensure even distribution of PVC in acetone. Few drops of red-colored resin were added to the mixture to give color to it. The mixture was loaded into the syringes and injected into cannulated radial arteries. We waited for 10 min to allow PVC to solidify in the artery. After solidification of PVC, the artery became rigid and microvessels were less pliable during the dissection. The radial artery was then traced in between brachioradialis and flexor carpi radialis. The arterial branches arising from the lateral aspect of the radial artery were dissected carefully. The brachioradialis was elevated from its insertion, proximal to distally. The 1,2 ICSRA was found coursing up dorsally from the radial artery to lie superficially on the surface of the extensor retinaculum between the first and the second compartments. Tendons of the muscles of the first extensor compartment (i.e., abductor pollicis longus and extensor pollicis brevis) were cut and retracted [Figures 1–3]. The 1,2 ICSRA was found to course up dorsally from the radial artery forming an arch where it gave nutrient branches to the distal radius and joined back to the radial artery usually distal to the radial styloid. The artery was carefully dissected out under operating microscope with magnification ×10–15, and nutrient vessels to the distal radius arising from the 1,2 ICSRA were identified and counted.

Measurements

1. The distance of proximal and distal origins of the 1,2 ICSRA from the radial artery to the radial styloid tip was measured. The radial styloid was taken as point zero. If the distal origin was distal to the radial styloid, it was given a positive value and if the distal origin was proximal to the radial styloid, it was given a negative value. Similarly, proximal origin was also measured from the radial styloid
2. The number of perforating branches of 1,2 ICSRA to the dorsum of distal radius was counted
3. The distance of each perforator from the dorsal lip of the distal articular margin of radius was measured. The point where the tendon of extensor carpi radialis longus

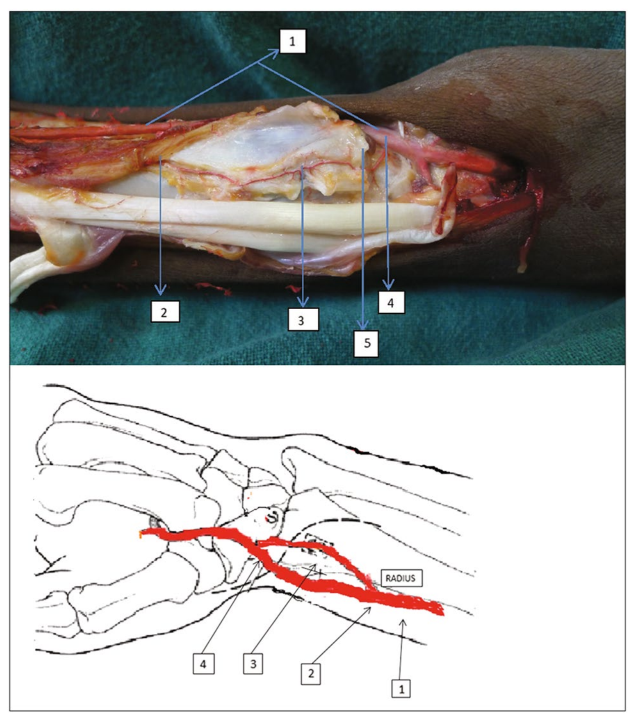

Fig. 1 The 1,2 intercompartmental supraretinacular artery courses between the first and second extensor compartments overlying the dorsal surface of extensor retinaculum. (1- Radial artery, 2- Proximal pedicle of 1,2 ICSRA, 3- Perforator branches of 1,2 ICSRA entering distal radius, 4- Distal origin of 1,2 ICSRA, 5- Radial styloid.)

crosses the articular margin was considered as a referral point

4. The largest among these perforators was also identified and its distance was measured from the reference point.

Grading of dye entry

Dye entry into the artery was graded on the basis of extent of its penetration into the artery 1,2 ICSRA.

- Grade 1: Dye was present in the radial artery, but dye cannot be visualized in 1,2 ICSRA
- Grade 2: Dye was present in the radial artery and has even entered 1,2 ICSRA, but the extent of its entry is not complete, and the dye cannot be traced till perforators
- Grade 3: Dye in the 1,2 ICSRA can be traced till the perforators.

1,2 ICSRA was considered absent, if the dye was present in the radial artery and midcarpal artery but not in 1,2 ICSRA.

Results

Median distance of the distal origin of 1,2 ICSRA from the radial styloid was 8 mm distal to the radial styloid (Q_1–Q_3 = 5–10 mm). The mode was 8 mm. The distance ranged from − 6 to 11 mm (i.e., 6 mm proximal to 16 mm distal to the radial styloid). Standard deviation was 5.23.

The median distance of the proximal origin of 1,2 ICSRA was 38 mm proximal to the tip of radial styloid. The mode was 38 mm. The distance ranged from 25 to 66 mm. Standard deviation was 8.41.

Of the 21 wrists dissected, only in 19 wrists we were able to recognize the perforators. Median number of perforators seen was 3 (Q_1–Q_3 = 2.5–4). Mode of the perforators was 3. Ranges of the number of perforators were 1–5. Standard deviation of the number of perforators was 1.02.

The median distance of the largest perforator from the reference point was 12 mm (Q_1–Q_3 = 10–13 mm). The mode was 10 mm. The distance ranged from 6 to 19 mm, and the standard deviation was 2.72 [Table 1].

Perforator density of the graft determines the extent of vascularity of the graft. Perforator density was measured in 10 mm length of bone graft taken from the dorsal radius in variable distances from the articular margin of the radial styloid. The highest perforator density of 2.84 was present in the bone, which was 6–16 mm and 8–18 mm proximal to the dorsal distal articular margin [Table 2].

Among 21 wrists which were dissected, dye entry of Grade 1 was seen in two wrists. Dye entry of Grade 2 was seen in six wrists. In the remaining 13 wrists, dye entry of Grade 3 was seen [Table 3].

Discussion

The skeleton of the hand and wrist has a complex anatomy to accommodate the precise movements. Exclusive size, shape and vascular anatomy of the carpals predisposes them to AVN (e.g., the proximal scaphoid after fracture and the lunate in Kienböck's disease) and nonunion (# scaphoid). 1,2 ICSRA-based vascularized bone graft has been used successfully in many of these conditions. 1,2 ICSRA-based vascularized bone grafts, in theory, seem to be having good results, but in practice, identification, dissection, and transposition of the pedicled bone graft is an uphill task. Sound knowledge of the anatomy of the artery, delicate fine dissection, and expertise in microsurgery is a must to expect optimal surgical results. Our study was intended to describe the detailed anatomy of the 1,2 ICSRA, including its point of origin from the radial artery and the distribution and consistency of its perforating vessels penetrating the distal radius for successful harvesting of a vascularized graft.

The distal origin of 1,2 ICSRA was in and around the styloid process of the radius. The vessel could be exceedingly difficult to visualize near its origin, and knowledge of the proximity of this critical branch point to the radial styloid provides a reliable landmark for cautious mobilization of the pedicle. After its origin, it continues between the first and second extensor compartments overlying the dorsal surface of the extensor retinaculum.

In the study of Waitayawinyu *et al*., [12] the distal origin of 1,2 ICSRA was found 1.9 mm proximal to the tip of the radial styloid on average, with a range of 6.3 mm proximal to 3.2 mm distal to the radial styloid. In contradiction to the study of Waitayawinyu *et al*., our study showed that the average distance of the distal origin of 1,2 ICSRA from the radial styloid was 6.71 mm distal to the radial styloid. This value is 8.61 mm distal to Waitayawinyu *et al*.'s average. Since the origin of 1,2 ICSRA is much more distal compared to the western population, this may prove advantageous, as it allows a significantly more distal transposition of the vascularized bone graft and can reduce tension in the graft postoperation [Figures 2 and 3].

Detailed anatomy of proximal origin of 1,2 ICSRA was not done in the earlier studies, which is likely to be due to the fact that the vascularized bone graft is solely based on distal pedicle and proximal pedicle is merely divided to facilitate graft mobilization and transposition. However, its anatomical description from our study may help for future comparisons.

The 1,2 ICSRA gives multiple perforating branches in the dorsal aspect of distal radius. Perforating branches from 1,2 ICSRA to the distal radius were identified and their distances were measured from the dorsal lip of articular margin of the distal radius where extensor carpi radialis

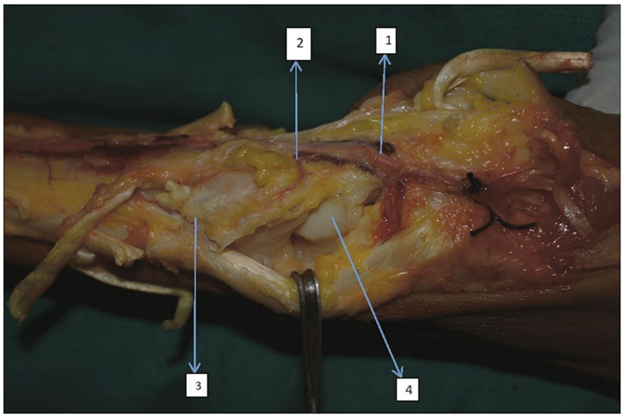

Fig. 2 1,2 intercompartmental supraretinacular artery with its proximity to scaphoid exposed. (1- Radial artery, 2- Distal origin of 1, 2 ICSRA, 3- 1, 2 ICSRA with its perforators, 4- Scaphoid.)

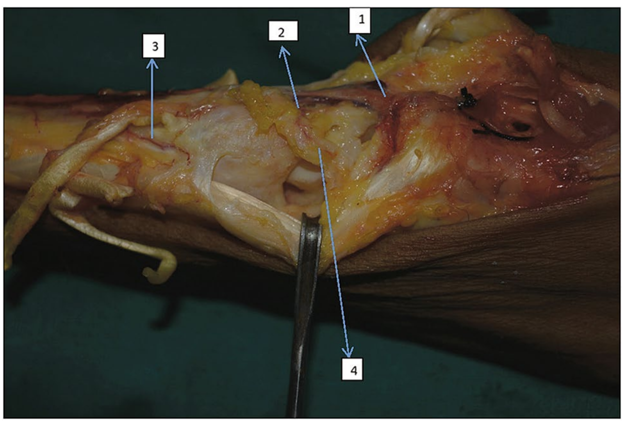

Fig. 3 Distal end-based graft mobilization to the scaphoid. (1-Radial artery,2- distal origin of 1,2 ICSRA, 3- Proximal pedicle of 1,2 ICSRA, 4-Distal origin based 1,2 ICSRA pedicle mobilised on scaphoid.)

Table 1 Measurements indicating location of perforators

	Median	Mode	Q_1–Q_3	Range
Distal origin (mm)	8	8	5-10	−6-16
Proximal origin (mm)	38	38	36.5-43	25-66
Number of perforators (mm)	3	3	2.5-4	1-5
Largest perforator (mm)	12	10	10-13	6-19

longus crosses the articular margin. In the study conducted by Waitayawinyu *et al*., the average number of perforators was 5.5 and ranged from 3 to 7. Hence, the number of average perforators visualized in our study was 44.55% less than the earlier study. This indicates that the number of perforators seen in the Indian population is 44.55% less than the western population. As the number of perforators present in our population is found to be less than the western population, the better knowledge regarding the location of the largest perforator and density of perforator in a given length of graft can improve the results of the graft. In the study conducted by Waitayawinyu *et al*., the location of the largest perforators was not recorded.

Table 2 Variability of number of perforators depending on graft harvest location

Graft location from the articular surface (mm)	Average number of perforators
5-15	2.79
6-16	2.84
7-17	2.79
8-18	2.84
9-19	2.63
10-20	2.68
11-21	2.05
12-22	1.84
13-23	1.47
14-24	1.16
15-25	0.68

Table 3 Grading of dye entry in wrists in our study

Grading of dye entry	Number of wrists
1	2
2	6
3	13

Vascularized bone grafts are taken based on 1,2 ICSRA, from the dorsal radius. The size of this bone graft usually is around 10 mm length and 5 mm breadth. To have better vascularity in the graft, it is essential to take the graft from the area of bone where perforator density is maximum and must include the largest perforator. If we consider all 19 wrists in which we were able to visualize the perforators, the highest perforator density of 2.84 was present in the bone which was 6–16 mm and 8–18 mm proximal to the dorsal distal articular margin. The maximum density of perforators was noticed to be in the region of 6–18 mm from the distal articular margin. Even the largest perforator location is also 10–13 mm (Q_1–Q_3) proximal to the articular margin. In case of study of Waitayawinyu et al., the average number of perforators for a graft length of 1 cm was 2.75. A graft located between 8 and 18 mm from the articular surface incorporated the maximal number of perforators with a frequency of 4. Hence, our data of location of the highest density of perforators are matching with the earlier study.

We used a dye solution indigenously developed by the department of anatomy of our institute. This dye was primarily used for preparation of corrosion casts. However, in our study to facilitate immediate dissection of the artery after injection of dye, the dye solution was calibrated. It was also felt that the flow of dye into the vessel was dependent on its viscosity. Hence, more viscous the dye, less would be the vessel penetration. It was found that the dilution of dye in the ratio of 1:4 using acetone (i.e., PVC: acetone ratio – 1:4) facilitated the maximum dye penetration into the perforators. Dye entry into the artery was graded on the basis of extent of its penetration into the artery 1,2 ICSRA.

Dye entry was found to be correlated with the number of perforators which were visualized. There is a positive correlation between the grade of dye entry and the number of perforators visualized with $r = 0.39$ and $P = 0.09$.

Conclusions

- The first study to describe the anatomy of 1,2 ICSRA-based graft in the Indian population
- The distal origin of 1,2 ICSRA in our study was much more distal in comparison to the western population; this may prove advantageous, as it allows a significantly more distal transposition of the vascularized bone graft
- The vascularity of the 1,2 ICSRA-based vascularized bone graft was found to be less compared to the western population
- Location of the largest perforator was described in our study in view of the poor perforator density in the Indian population. This entity was not at all measured in earlier studies
- The distal articular margin of radius being curved, it is essential to define a point which could be consistently reproducible to minimize interobserver variation. That is why, it has been suggested to consider the point where the tendon of extensor carpi radialis longus crosses the distal dorsal articular margin
- The maximum density of perforators was found in the region 6–18 mm proximal to the dorsal lip of distal articular margin of radius. Hence, in the Indian population, it is recommended to take graft in this site to get graft with the maximum vascularity
- We have used indigenously developed dye which is cheap and available in all places. Dye entry was found to be correlated with the number of perforators which were visualized.

Limitations

- The dye used in our study has never been used in any microsurgical studies and is not standardized for such studies
- Cadavers are not gender matched
- The anatomy described should be validated with surgical success.

Declaration of patient consent The authors certify that they have obtained all appropriate patient consent forms. In the form, the patients have given their consent for their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest There are no conflicts of interest.

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