Surgical implications of variations in hand collateral circulation: Anatomy revisited

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Objectives: One of the risks associated with harvesting the radial artery is hand ischemia. Accordingly, this study investigated the variations of the hand collateral circulation.

Methods: Fifty hands of cadavers were examined. Variations of the palmar arches were recorded. A classic superficial palmar arch was defined as direct continuity between the ulnar artery and the superficial palmar branch of the radial artery. A classic complete deep palmar arch was defined as direct continuity between the radial artery and the deep branch of the ulnar artery.

Results: A classic superficial palmar arch was found in 10% (5/50) of hands, and a classic complete deep palmar arch was found in 90% (45/50) of hands. The superficial palmar branch of the ulnar artery supplied blood to all fingers in 66% (33/50) of hands. Although the superficial palmar branch of the ulnar artery was continuous with the radial artery in only 34% (17/50) of hands (including the classic type of superficial palmar arch), every hand had at least one major branch connecting the radial and ulnar arteries.

Conclusions: Variations in the terminations of the radial and ulnar arteries are common. Although the classic type of superficial palmar arch occurs relatively infrequently, there is always a significant anastomosis between the radial and the ulnar artery in the hand. This anatomic study confirms the presence of a collateral supply in the hand. In the absence of vascular disease, harvesting the radial artery should be regarded as a safe procedure.

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Harvesting radial arteries (RAs) for use as arterial bypass conduits is an invasive procedure with potential risks, as suggested by sporadic reports of hand ischemia after RA removal.¹ If we are to fully assess the feasibility of the RA as a bypass graft, an examination of the possible risks associated with harvesting the artery is needed.

The RA and ulnar artery (UA) provide most of the blood supply of the hand. Additional circulation may come from the median artery or the interosseous arterial system. The RA and UA form 4 circuits in the hand, the anterior and posterior carpal arch at the level of the carpal bones and the superficial and deep palmar arch at the midpalmar level. These arches form 3 circuits on the palmar side and 1 circuit on the dorsal side of the hand. The superficial and deep palmar arches are the most important of the circuits because they provide the blood supply to all of the fingers.

Figure 1. Variations of the hand collateral circulation, palmar aspect of left hand. The *black line* represents the superficial palmar arch, the *gray line* represents the deep palmar arch, and the *dotted line* represents the dorsal artery. **A**, Classic (and complete) superficial palmar arch: the superficial palmar arch from the UA supplies the index finger and thumb and anastomoses with the superficial palmar branch of the RA. **B**, Complete superficial palmar arch: the superficial palmar arch from the UA supplies the thumb. Complete deep palmar arch: the distal end of the deep palmar arch anastomoses with the deep palmar branch of the UA. **C**, Incomplete superficial palmar arch: the superficial palmar arch does not provide a metacarpal branch to supply the thumb. **D**, Incomplete deep palmar arch: no continuity is found between the deep palmar branch of the UA and the RA. **E**, Median artery. *SPA*, Superficial palmar arch; *DPA*, deep palmar arch.

Standard anatomy textbooks lack information about crucial variations in the arterial supply of the hand. Several studies have described the variations of the complex anatomy of the hand and forearm. However, these studies are limited by the fact that none of them look specifically for variations of the collateral circulation that might affect the decision to remove the RA, such as the presence of both an incomplete superficial palmar arch and an incomplete deep palmar arch in the same hand. Such information is very important when considering RA harvesting.

Accordingly, the aim of this study was to provide a comprehensive assessment of the anatomic variations of the arterial anastomoses in the hand, focusing in particular on the arterial connections between the superficial and deep palmar arches.

Methods

This study was carried out on 50 randomly selected hands from cadavers in the dissecting room of the Department of Anatomy and Cell Biology at the University of Melbourne. All of the cadavers had been embalmed soon after death. The dissection focused on the hands and sought to identify the communications between the RA and the UA. Sketches and photographs were used to document the dissected specimens.

Results

Radial Artery

The terminal branches of the RA at the wrist were the superficial palmar branch of the RA and the dorsal RA. The superficial palmar branch of the RA connected with the superficial palmar branch of the UA to form the superficial

Figure 2. The origin of the deep palmar arch in which the RA passes to the palmar side through the second interosseous space. **A,** Dorsolateral aspect of the left wrist showing the origin of the deep palmar arch. **B,** Palmar aspect of the left wrist and hand.

TABLE 1. Summary of prevalence of incomplete and complete superficial and deep palmar arches

	Superficial palmar arch		Deep palmar arch	
	Incomplete	Complete	Incomplete	Complete
Coleman and Anson, 1961 ²	21.5%	78.5%	3%	97%
Ikeda et al, 1988 ⁶	3.6%	96.4%	23.1%	76.9%
Mezzogiorno et al, 1994 ⁷			33.3%	66.7%
Ruengsakulrach et al, 2001	34%	66%	10%	90%

palmar arch in 10% (5/50) of hands (Figure 1, A). In the remaining 90% of cases, the superficial palmar branch of the RA was absent or small (Figure 1, B-E) and only supplied a minor part of the thenar muscles. The main RA passed to the dorsal side of the hand under the abductor pollicis longus and extensor pollicis brevis tendons. It then pierced the first interosseous space and formed the deep palmar arch with the deep palmar branch of the UA in 94% (47/50) of hands (Figure 1, A-C and E). In 3 hands there were anatomic variations of the origin of the deep palmar arch. In these cases the RA formed the deep arch by passing through the second interosseous space (Figure 2, A and B).

Deep Palmar Arch

Two types of deep palmar arches were found.

Complete deep palmar arch. In this variation the terminal portion of the deep palmar branch of the RA had a connection with the deep palmar branch of the UA. This type of arch was found in 90% (45/50) of hands (Figure 1, A-C and E).

Incomplete deep palmar arch. In this variation the deep

palmar branch of the RA did not have any connection with the UA at the deep palmar level. This was found in 10% (5/50) of hands (Figure 1, D).

Ulnar Artery

In all of the hands, the UA terminated by dividing into superficial palmar and deep palmar branches. The UA made no visible contribution to the dorsal side of the hand at the level of the wrist.

Superficial Palmar Arch

Two types of superficial palmar arch were found.

Complete superficial palmar arch. The superficial palmar arch was defined as complete when it supplied all the fingers and the ulnar side of the thumb. This variation was found in 66% (33/50) of hands (Figure 1, A, B, D, and E).

Incomplete superficial palmar arch. The arch was defined as incomplete when it only supplied the little, ring, and middle fingers. This variation occurred in 34% (17/50) of hands (Figure 1, C).

Superficial Palmar Branch of the UA

The distal end of the superficial palmar arch of the UA communicated with the RA in only 34% (17/50) of hands. There were 4 types of this communication between the superficial palmar branch of the UA and the RA at the level of the arches (Figure 3): (1) through the superficial palmar branch of the RA (the classic superficial palmar arch) in 10% (Figure 3, A); (2) through the digital branch of the dorsal RA in 18% (Figure 3, B); (3) through the deep palmar arch of the RA in 4% (Figure 3, C); and (4) through the median artery and digital branch of the dorsal RA in 2% (Figure 3, D).

Median Artery

A median artery was found in 3 (6%) cadavers. One terminated at the wrist, and one anastomosed with the superficial palmar arch (Figure 1, E). The third median artery terminated by giving off branches to the index finger and thumb at the palmar side without anastomosing with the RA or UA.

Combined Contributions of the UA and RA

Even though the superficial palmar branch of the UA did not supply the thumb in about 34% of hands, a deep palmar branch of the UA anastomosed with the deep palmar branch of the RA in all cases. Similarly, even though an incomplete deep palmar arch was found in 10% of hands, all of these cases had a complete superficial palmar arch.

Discussion

Our study found that the collateral blood supply of the hand is complex and often marked by variations. A number of variations of the superficial palmar arch of the UA were detected, with the most common type found in this study being the complete superficial palmar arch (66%) and the complete deep palmar arch (90%). As noted, even though the superficial palmar branch of the UA did not supply the thumb in about 34% of hands, a complete deep palmar arch was present in all of these hands, thereby enabling the RA to be safely harvested.

Our study confirmed the findings from a larger series reported by Coleman and Anson² in 1961. Of 650 hands examined, they found a complete superficial palmar arch in 78.5% of hands. In this series a complete superficial palmar arch was recorded when the superficial palmar branches of the RA and UA anastomosed or when the UA reached the thumb and index finger. The classic type of superficial palmar arch (as typically demonstrated in anatomy textbooks),³⁻⁵ in which the superficial branch of the RA joins the superficial palmar arch of the UA, was found in 34.5% of hands. In our series this classic type of arch occurred more rarely, being found in only 10% of hands.

In contrast, in 1988, Ikeda and associates⁶ reported a high prevalence of complete superficial palmar arches using the same definition (96.4% of 220 hands from cadavers).

Figure 3. Four types of communication between the superficial palmar arch of the UA and the RA in the hand: *a*, through superficial palmar branch of RA (10%); *b*, through deep palmar arch (4%); *c*, through digital branch of the dorsal RA (18%); and *d*, through median artery and digital branch of the dorsal RA (2%). SPA, Superficial palmar arch; DPA, deep palmar arch.

They also found a higher proportion of classic superficial palmar arches (55.9%). However, in this classic type the contribution of the RA was small in 34.6% of hands and was equal in size in only 21.3% of hands.

In our study we found the deep palmar arch to be variable in size. The size of the superficial palmar arch was inversely proportional to that of the deep palmar arch. Coleman and Anson² found a complete deep palmar arch in which the deep branch of the RA anastomosed with the deep branch of the UA in 97% of hands. Ikeda and associates⁶ found a complete deep palmar arch in 76.9% of hands. In our series we found this type of arch in 90% of hands. In contrast, in 1994, Mezzogiorno and colleagues⁷ found that the deep palmar arch was formed by the RA and UA in only 66.7% of 60 hands. In 21.7% of hands, the deep palmar arch was formed by the RA, and an anastomotic branch formed a digital artery. The deep palmar arch was formed solely by the RA or the UA in 8.3% and 3.3% of cases, respectively.

In the case of the incomplete deep palmar arch (found in 10% of the hands in our study), all these hands had complete superficial palmar arches. This implies that the thumb received its blood supply from the UA at the ulnar side and that the RA could be removed without endangering the circulation of the hand. Table 1 summarizes the prevalence of incomplete and complete superficial and deep palmar arches.

In 1978, Parks and colleagues⁸ published a study of the variations of the arterial supply of the thumb in 50 hands

from cadavers. They found that, in 80% of hands, the arterial supply of the thumb usually came from the first palmar metacarpal artery (the first branch of the deep palmar arch of the RA). In 5% of hands, a branch of the second palmar metacarpal artery formed the main artery of the thumb. The first dorsal metacarpal artery, which is a branch of the RA at the dorsal side, was the main artery to the thumb in 15% of hands. This latter result was consistent with our finding that 18% of hands had a digital branch of the dorsal RA, which supplied the thumb and anastomosed with the superficial palmar arch.

In 1999, Olave and Prates⁹ reported the findings of an anatomic study of both hands in 30 cadavers. In 13.3% of the hands, the deep palmar arch was formed by the RA passing through the second interosseous space, a variation we found in 6% of cases in our series. However, the significance of this variation in RA harvesting is minimal because the RA and UA both contribute blood supply to the arch.

Our study is unique in that the anastomoses between the RA and UA have been documented and correlated in individual hands. The major finding from the series of 50 hands examined was that there were no cases of an incomplete superficial and deep palmar arch being present in the same hand. From an anatomic perspective, this study confirms that it is safe to remove the RA from its origin proximally to the level of the wrist distally. However, in patients with coronary artery disease, vascular disease affecting the upper extremities may be present. In 1999, Rauch and colleagues¹⁰ reviewed 66 upper extremities from 60 patients who underwent angiography before skin-muscle transplantation (63.6% of hands), creation of a hemodialysis fistula (6.1%), or evaluation of vascular diseases (30.3%). Classic superficial palmar arches and deep palmar arches were detected in 31.8% and 84.8% of the patients, respectively. These findings suggest that patients with coronary artery disease should be screened before RA harvesting to confirm the presence of a viable collateral circulation. Currently, the methods of assessing hand circulation include the modified Allen test, Doppler ultrasonography, photoplethysmography, and oximetric techniques.¹¹⁻¹⁴ The modified Allen test is easily performed by the bedside and requires no special equipment; we use this technique as a primary screening test and use the Doppler ultrasound examination when the modified Allen test is abnormal or inconclusive.¹⁵

Although our results suggest the overall safety of RA harvesting, it must be noted that our study suffers from 2 limitations. First, we studied the anastomoses between the RA and UA only at the level of the palmar arches. Therefore, although we may have designated an arch as incomplete, it may have possessed anastomotic connections at the level of the digital circulation. Second, even though there is always an anatomic connection between the 2 arterial systems, such as that between the deep palmar arch of the RA and the

superficial palmar arch of the UA, it is possible that these anastomoses may be insufficient. Thus, despite the presence of an anatomic collateral circulation, the blood supply may still be compromised when an RA is removed.

Our study indicates that anastomoses between the superficial and the deep palmar arch are complex and varied. However, in all of the hands we dissected, there was some degree of collateral circulation between the RA and the UA. This suggests that, at least from an anatomic perspective, it is safe to sacrifice one of these arteries. Such arterial interventions include RA cannulation, radial forearm flap, and particularly RA or UA harvesting for coronary artery bypass grafting. We still recommend testing the hand (by using the modified Allen test, Doppler ultrasonography, photoplethysmography, or oximetric techniques) before performing an arterial intervention to identify the occasional case in which collateral circulation is compromised by the presence of arterial disease.

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