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Anatomical variations of the superficial and deep palmar arches

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The use of radial arteries as an arterial bypass conduit is an invasive procedure which is becoming popular among various medical centres. The greatest risk associated with harvesting the radial artery is ischaemia of the soft tissues of the hand. In this study we dissected 200 hands derived from 100 formalin-fixed cadavers in order to identify arterial patterns that will allow safe removal of the radial artery for use in bypass procedures. A complete superficial palmar arch (SPA) was found in 90% of the cases and divided into 5 types, while the remaining 10% possessed an incomplete palmar arch. Types of SPA are designated by the letter S. In type S-I (40%), the SPA is formed by anastomosis of the superficial volar branch of the radial artery to the ulnar artery. Type S-II (35%) is formed entirely of the ulnar artery. Type S-III (15%) is formed by anastomosis of the ulnar and median arteries. Type S-IV (6%) is formed by anastomosis of the ulnar, radial, and median arteries and Type S-V (4%) is formed by a branch of the deep palmar arch (DPA) communicating with the SPA.DPA was identified in all specimens and classified into three types, all designated by the letter D. Type D-I (60%) is formed by anastomosis of the deep volar branch of the radial artery and the inferior deep branch of the ulnar branch. Type D-II (30%) is formed by anastomosis of the deep volar branch of the radial artery and the superior deep branch of the ulnar artery. Type D-III (10%) is formed by anastomosis of the deep volar branch of the radial artery with both deep branches of the ulnar artery. This data could provide an important source of information for vascular surgeons harvesting radial arteries.

Key words: deep palmar arch, superficial palmar arch, cardiac surgery, vascular surgery, radial artery, ulnar artery

INTRODUCTION

In recent years extensive research has been performed to determine which arterial or venous grafts used in cardiac bypass surgery are most effective. Specific factors weigh heavily in the overall decision of which type of graft to use. These factors include, but are not limited to, location of the donating vessel, ease of harvest, the effect of the removal of the vessel on the surrounding tissue, suitability for coronary circulation and resistance to post-graft atherosclerotic plaque formation [8]. These are all significant factors in the process of selecting an artery for the coronary artery bypass graft (CABG) procedure.

The latest reports on CABG favour the use of an arterial graft, in particular the radial artery, and show benefits over the use of some other frequently

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selected vessels such as the saphenous vein [8]. The greatest risk associated with the harvesting of the radial artery is the possibility of ischaemia to the hand. The radial artery contributes greatly to the circulation of the hand but in many cases can be removed as a non-essential vessel, with adequate circulation being provided by the remaining ulnar and, in some cases, persistent median artery [4, 12, 13, 20].

The radial artery originates in the proximal forearm from the division of the brachial artery. The ulnar is large and provides several important contributing smaller arteries to the forearm, while the radial is often considered expendable from its origin to the wrist because of its lack of vitally important supplying branches between the cubital fossa and the wrist. The radial recurrent artery joins the brachial artery proximal to the elbow and can safely be ligated without the blood flow being significantly compromised. For these reasons the radial artery can be removed with a working length of up to 24 cm for use as an arterial bypass conduit [4]. Most often the DPA is formed by anastomosis of the deep palmar branch of the ulnar artery to the dorsal radial artery, which branches off the radial artery near the wrist and passes dorsally on the hand before passing through the first or second metacarpal space [1, 6, 11, 14–16]. The SPA is more variable, with multifarious contributions from the ulnar, radial and even persistent median arteries [3, 5–7, 9, 15, 19, 21, 23].

Our research goal was to outline the observed types of DPAs and SPAs that would allow for adequate blood supply to the hand once radial circulation is removed. Additionally, we would like to propose a different view of the existing classification of circulation most commonly found in the hand in order to facilitate better documentation and communication amongst medical professionals in the field.

MATERIAL AND METHODS

We examined 120 adult human hands during the "Human Body" course at Harvard Medical School throughout the academic semesters of 2001, 2002, 2003 and 80 adult human hands during the anatomy course at the American University of the Caribbean through the academic semesters of 2003 (fall, winter and summer semesters). The cadavers came from female and male subjects (female 20/male 80), with an age range of 56 to 80 years and a mean age of 73 years. All the cadavers were fixed in a standard formalin/phenol/alcohol solution and routinely dissected by first-year medical students.

In order to obtain a clear field for visualisation of the superficial and deep palmar arches the following structures were removed: skin and palmar aponeurosis, and where necessary, the flexor retinaculum.

Following preliminary examination, images from all the dissected specimens were recorded with a Sony digital camera (model: Sony Cyber-Shot DSC-f717) and studied using a computer-assisted Image Analysis System. The digital camera was connected to an image processor (Nvidia Riva TNT model 64) with linkage to a mainframe computer. Digitised images of the DPAs and SPAs, together with their surrounding structures, were stored in a "tif" format and the measurements analysed with the software program Lucia (Nikon). When possible, we measured the distance from the origin of the SPA and/or DPA to its termination. Statistical analysis was performed using a t-test (Statistica for Windows v. 6.2). Measurements were considered to be significant when $p < 0.05$.

RESULTS

The classification of the observed palmar arch circulation was divided into superficial and deep, with S and D respectively used in the nomenclature.

The SPA was observed to be complete in 90% (180) of specimens. We further divided this group into 5 subtypes (Fig. 1). While small variatiances were observed amongst our specimens, all were easily grouped into the following categories. Superficial Class I (hereafter referred to as S-I) contained complete superficial arches formed from the anastomosis of the ulnar artery and the superficial volar branch of the radial artery, and was observed in 40% (72) of specimens (Fig. 2, 3). Class S-II 35% (63) was formed exclusively from the ulnar artery, without significant contribution from any other vessel. Class S-III 15% (27) was formed from anastomosis between the ulnar and median arteries. Class S-IV 6.1% (11) emerged through anastomosis between the ulnar, median, and radial arteries. Class S-V 3.9% (7) utilises a contribution in blood flow from the DPA in conjunction with the ulnar artery. The SPA was classified as incomplete when there was no visible anastomosis to other contributing arteries, or when the ulnar arch did not extend into the space between the thumb and first digit and could therefore have little or no effect on blood flow to the thumb, making radial artery harvest ill-advised. This situation was observed in 10% (20) of cases.

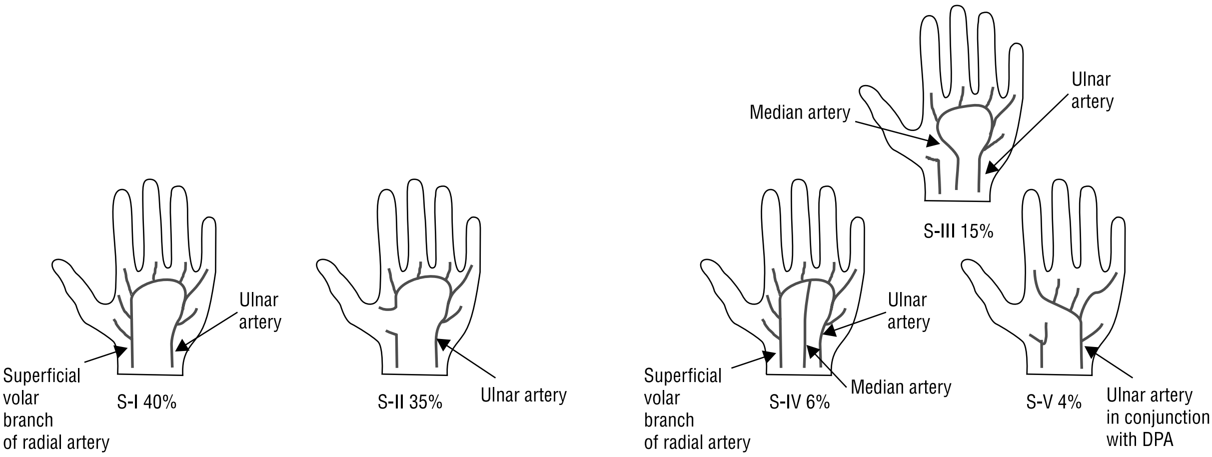

Figure 1. Schematic representation of superficial palmar arch types.

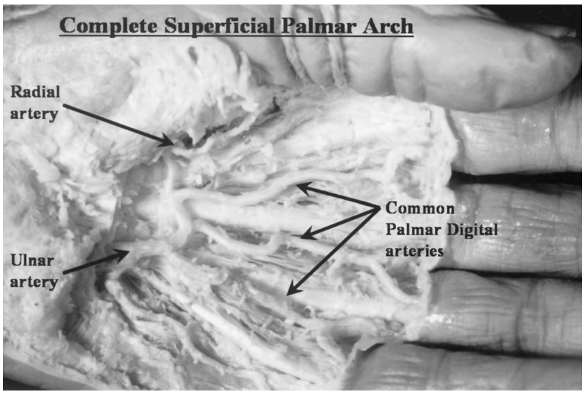

Figure 2. A cadaveric specimen exhibiting a complete superficial palmar arch.

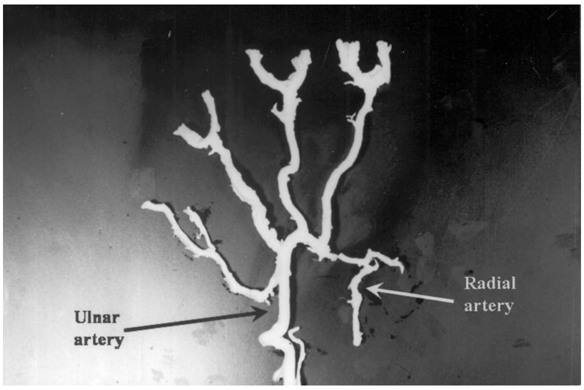

Figure 3. Arterial palmar arch removed en-block from a cadaveric specimen.

The DPA was identified as complete in all 200 specimens (100%). This conclusion was reached by direct visualisation of a major contribution from the radial artery reaching the DPA, formed by the ulnar artery or by the DPA directly contributing to the circulation of the thumb and first digit, including the thenar muscles, making contribution from the radial artery extraneous. We further divided this group into three subtypes (Fig. 4). While small variances were observed amongst our specimens, all were easily grouped into the following categories. Deep Class I (hereafter referred to as D-I) Type D-I (60%) is formed by anastomosis of the deep volar branch of the radial artery and the inferior deep branch of the ulnar branch. Type D-II (30%) is formed by anastomosis of the deep volar branch of the radial artery and the superior deep branch of the ulnar artery. Type D-III

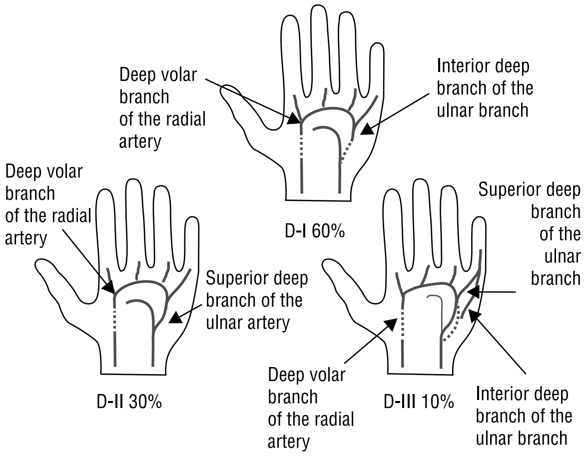

Figure 4. Schematic representation of deep palmar arch types.

Table 1. A synoptic form of all the classes of both superficial and deep palmar arches with percentages and number of specimens for each class

Class	Anastomotic vessels	Percentage (%)	Number of specimens
S-I	Ulnar artery and the superficial volar branch of the radial artery	40	72
S-II	Exclusively the ulnar artery, without significant contribution from any other vessel	35	63
S-III	Ulnar and median arteries	15	27
S-IV	Ulnar, median, and radial arteries	6.1	11
S-V	DPA in conjunction with the ulnar artery	3.9	7
D-I	Deep volar branch of the radial artery and the inferior deep branch of the ulnar branch	60	120
D-II	Deep volar branch of the radial artery and the superior deep branch of the ulnar artery	30	60
D-III	Deep volar branch of the radial artery with both deep branches of the ulnar artery	10	20

(10%) is formed by anastomosis of the deep volar branch of the radial artery with both deep branches of the ulnar artery. Table 1 represents a synoptic form of all classes with results and percentages.

Furthermore, no statistical significant differences were observed between the specimens received from two different schools with respect to race, gender, morphology and percentages.

DISCUSSION

The literature is replete with descriptive information about the SPA. The "traditional classification" consists of linkage between the superficial palmar branches of the radial and ulnar arteries. It is interesting to note that this is not always the most commonly observed variation. The "traditional classification" has been reported to be evident in as many as 55.9% of specimens in the research of Ikeda et al. [9] or as few as 10% of specimens according to Ruengsakulrach et al. [20]. Our data indicate that this "traditional classification", which we refer to as S-I, was found in 40% of specimens. In addition, in these specimens the radial contribution to the SPA is of a debatable clinical significance as it is often found to be of negligible diameter in comparison to the ulnar artery [9]. Ikeda et al. [9] demonstrated this phenomenon when they further subdivided this group into ulnar-dominant (33.2%), radial-dominant (1.4%), and equal types (21.3%). While our research did not differentiate between ulnar and radial dominance of the SPA, it is obvious that in cases of ulnar or equal dominance the blood supply would not be significantly affected by removal of the radial artery. Furthermore, the radial dominant type of SPA was specified by Ikeda as one in which the contribution of the radial artery was larger than the contribution of the ulnar artery in its calibre and blood supply to the fingers. However, Ikeda's description has major limitations regarding the degree of anastomosis between ulnar and radial arteries and the contribution of the radial dominant type to the DPA [9].

Our results for groups S-I, S-II, and S-V show them to be similar in incidence to those found by Coleman and Anson, with respective incidences of 34.5%, 37% and 2% [3].

While the median artery normally ceases to exist during early embryological development, it has been reported in the literature to be present as the persistent median artery [3, 9, 17, 20]. The persistent median artery's contribution to the SPA is reported in some studies to be present in up to 5% [3, 5, 9], while our data showed a much higher incidence of median persistence (21%) distributed amongst groups S-III (ulnar-median) and S-IV (ulnar-median-radial). Our results were in an agreement with the results of Ruengsakulrach et al. [20], who reported median arterial persistence of this magnitude.

While the origin of superficial and deep palmar arches is significant, it is the determination of radial contribution to the thenar muscles and digits that is of greatest importance to the harvesting of the radial artery. Parks et al. [17] illustrated a number of clinical cases involving variations in blood supply to the thumb and index finger, several of which are of interest in this respect. These authors caution that 1 to 10% of patients could exhibit varying levels of vascular compromise in the area of the thumb following damage to or removal of the radial artery. Obviously, pre-operative screening is necessary for patients undergoing radial arterial harvest for CABG.

The extent of radial and ulnar contribution to the blood supply of the hand can be determined through a variety of invasive and non-invasive methods, including angiography, ultrasonography [18] and the standard Allen test. In fact a combination of the standard Allen test and ultrasonography has been reported to be very successful [10, 18–20, 22]. Ruengsakulrach et al. [20] have suggested the use of a modified Allen test (Allen-LEC) to determine whether variations exist such as a radial version of the persistent median artery and a type of high-take off the superficial dorsal radial artery exist. Either of these exceptional situations might yield misleading information during a standard Allen test (without confirmatory angiography or ultrasonography) that could potentially result in serious ischaemia following radial artery harvest such as that described by Parks et al. [17]. The findings of Bianchi and Leiro support our assertion that in most cases a complete SPA is usually sufficient to provide adequate blood flow to the thumb in conjunction with a complete DPA [2]. We found that these requirements were fulfilled in 90% of our cases.

With the recent advances in the field of endoscopic surgical removal of the radial artery reported by Connelly et al. [4] and their promising results, it is apparent that the use of the radial artery as a CABG is being met with some degree of approval. Connelly et al. [4] reported the use of the radial artery in 60% of coronary bypass cases. They reported a reduction in infection rate, discomfort, scarring and possible neurological deficiency, even in patients with such complicating factors as diabetes or peripheral vascular disease. The removal of the radial artery endoscopically can be performed by a properly trained physician's assistant in as little as 15 min. The reported poor long-term performance of saphenous vein grafts [8] allows one to remain cautiously optimistic regarding the use of this novel technique in the future.

It is interesting to note that many authors [3, 5–7, 9, 15, 19, 21, 23] have tried to explore the anatomy and morphology of the superficial and deep palmar arches and very few have reported similar results and percentages. Ethnic and gender differences, sample size and different classification interpretation could be some of the reasons that the results are not uniform. However, it is important to note that this study is representative of a small subset of the human population, and only serves to illustrate the many variations in the anatomy of the palmar arch. We hope that our findings will help to promote more positive outcomes in surgical procedures requiring the use of radial arterial grafts.

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