B-mode and Color Doppler Ultrasound of the Forearm Arteries in the Preoperative Screening Prior to Coronary Artery Bypass Grafting

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A B S T R A C T

The objective of this paper was to establish the normal findings of B-mode and color Doppler ultrasound of the forearm arteries in candidates for coronary artery bypass grafting with radial artery graft. Examination of radial and ulnar arteries was performed in 127 patients. The vessel diameters and peak systolic velocities were measured and the presence of atherosclerotic changes, calcifications and anatomical variants was assessed. Radial artery proved to be dominant forearm artery with non-significant side-to-side asymmetry. The luminal changes were present in 30% of the patients. Ulnar arteries were more prone to these changes than radial arteries (28.4% vs. 24.4%). The anatomical variants found included ulnar artery hypoplasia in 3.9% of patients and high brachial artery bifurcation in 2.4% of patients. No cases of high-grade stenosis or occlusion were found. The results of the present study indicate that B-mode and color Doppler are valuable methods for preoperative screening as they enable morphological and functional evaluation of the forearm circulation.

Key words: *ultrasound, color Doppler, radial artery, ulnar artery, coronary artery bypass grafting*

Introduction

The radial artery (RA) is becoming more and more popular as a conduit for coronary bypass grafting (CABG). The method was first introduced by Carpentier

in 1973, but soon abandoned due to the high rate of failure[1,2]. Acar et al. reintroduced it in 1992 when they discovered that the patency rates of radial artery grafts are superior to those of vein grafts and approach those of the internal thoracic artery graft. These results were confirmed by several cardiac centers in Europe and North America[3–7]. Today the RA is for many surgeons the first graft choice after internal mammary artery, particularly as a part of the »all arterial shunting« strategy. Several features favor the use of the radial artery as a conduit: its caliber is similar to that of major coronary arteries; it has adequate thickness and resistance of arterial wall and sufficient length to allow complete myocardial revascularization[8]. In preoperative screening clinicians relied mainly on clinical examination and simple, functional tests, such as Allen's test, with purpose to assess the capacity of collateral ulnar artery blood supply in order to avoid ischemic complications in the hand. Several authors reported the shortcomings of such an approach and described postoperative complications in spite of the normal preoperative findings[9–11]. None of these tests was able to give information about morphological appearance of the vessels.

With time the color Doppler was introduced as a possible screening method because it is non-invasive, accurate and it allows morphological as well as functional evaluation of the forearm circulation[8,12].

The aim of our study was to describe the appearance of radial and ulnar arteries by means of B-mode and color Doppler ultrasound and to provide the standard values for diameters and blood flow velocities; to determine the possible dominancy of radial versus ulnar artery and side-to-side asymmetry as well as to assess the incidence of anatomical variations and luminal changes (atherosclerotic changes and calcifications) in patients with coronary artery disease who were candidates for CABG.

Patients and Methods

Between November 2002 and August 2003 127 patients who needed coronary revascularization were included in the study, regardless of their condition or medication they were taking. Patient demographic data is presented in Table 1. The examinations were performed within two days prior to the surgery, in the supine patient position and after 10 minutes of bed rest with hands only slightly flexed and relaxed. All examinations were performed using Logiq 9 ultrasound scanner (General Electric Medical Systems, Milwaukee, WI, USA) with 9–14 MHz multifrequency matrix linear transducer. All patients had given the informed consent. B-mode ultrasound of the artery was performed first to assess the vessel size and the degree of luminal changes. Both radial and ulnar arteries were visualized from brachial artery branching to the level of the carpal canal. The inner diameter (intima-intima) was measured on transverse sections approximately 5 cm proximally from the carpal canal. Atherosclerotic changes and calcifications were noted, if present. Vessel calcifications were defined as multiple echogenic foci with posterior acoustic shadowing and athe-

TABLE 1
PATIENT DEMOGRAPHIC DATA

Total number of patients	127
Mean age	63.83 ± 8.45
Age range	42–78
Male/female ratio	101/26
Hypertension	72 (57%)
Hypercholesterolemia	32 (25%)
Tobacco use	35 (28%)
Diabetes	38 (30%)
(treated by insulin)	(18 (47%))

rosclerotic changes as plaques that narrow the vessel lumen, with or without posterior acoustic shadowing. The diffuse vessel wall thickening was noted as well. The hypoplasia was defined as the mean diameter of the vessel lesser than 2 mm. The color duplex Doppler was used to visualize the flow and with spectral analysis the flow velocities were measured. The degree of stenosis was determined on the basis of an increase in peak systolic velocity from pre-stenotic segment to the site of stenosis, the doubling of the velocity indicating a significant stenosis of over 50%. The lowest pulse repetition frequencies that did not produce aliasing were used. Measurements were performed with existing software capabilities of the scanner.

The data were presented as mean values and standard deviations. Mean values for diameters and peak systolic velocities were calculated for radial and ulnar arteries on both sides and compared by Student-t and paired samples Student-t test. The frequency of atherosclerotic changes, calcifications and anatomical variations, including vessel hypoplasia was assessed.

Results

The normal ultrasound appearance of radial and ulnar arteries is characterized by the thin, homogenous wall and smooth inner luminal surface (Figure 1). The vessel lumen is completely and homogeneously filled with color when examined by color Doppler and normal spectral analysis shows triphasic spectra, typical for the peripheral vessels (Figure 2). In some cases due to vasodilatation biphasic spectra can occur and it can be regarded as a normal finding.

The mean vessel diameters and peak systolic velocities (PSV) measured are shown in Table 2. We found that radial artery is the dominant forearm artery. It
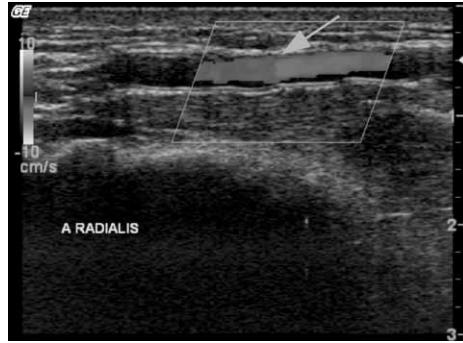

Fig. 1. Normal US appearance of radial artery with thin, homogenous wall and smooth inner luminal surface.
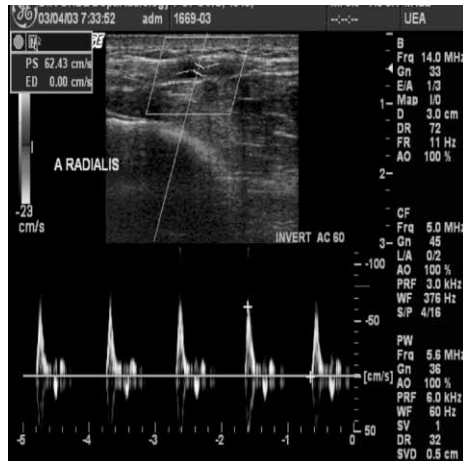

Fig. 2. Spectral analysis with triphasic arterial flow in the normal radial artery.

was wider than ulnar artery on both sides (p<0.01). Radial artery on the right side was slightly wider when compared to the left side, but with no significant statistical difference (p=0.07). No significant difference was found between diameters of right and left ulnar arteries. In 10% (13/127) of the patients the ulnar artery was the dominant forearm artery and it was wider than the radial artery on both arms.

When comparing the vessel diameters measured in females and males, presen-

TABLE 2

DIAMETERS AND PEAK SYSTOLIC VELOCITIES (PSV) MEASURED IN RADIAL AND ULNAR ARTERIES

| | Radial artery | |
	Right	Left
Diameter (mm)	3.28 ± 0.66	3.19 ± 0.59
PSV (cm/s)	69 ± 19	66 ± 18
	Ulnar artery	
	Right	Left
Diameter (mm)	2.86 ± 0.58	2.93 ± 0.54
PSV (cm/s)	65 ± 20	63 ± 20

Fig. 3. B-mode imaging of the calcified ulnar artery with irregular inner luminal border and atherosclerotic changes.

ted in Table 3, both the radial and the ulnar artery proved to be wider in males on both sides, with significant difference in radial arteries (p<0.01) but not in ulnar arteries (p=0.03 and 0.09).

The observed differences in vessel dominancy were not pronounced in female population and it could be explained by either the small number of female patients included in the study, or it could be presumed that in females the radial and ulnar artery might be of more similar importance and caliber than in males.

The calcified artery is characterized by irregular inner luminal surface, possible vessel narrowing and acoustic shadowing (Figure 3).

The multiple calcifications with nonsignificant level of stenosis were present in 25% (32/127) of the patients. The noncalcified atherosclerotic plaques or diffuse vessel wall thickness were noted in further 5.5% (7/127). When the changes

were present usually both arteries and both sides were affected but ulnar arteries seem to be somewhat more prone to atherosclerotic changes (Table 4). The changes were often more prominent in distal thirds of the forearm, which is the finding that we could not explain. No cases of high-grade stenosis (higher than 50%) or vessel occlusion were found.

The hypoplasia of the ulnar artery was found in 5 patients (3.9%) and 6 ulnar arteries were hypoplastic (4 right and 2 left ulnar artery). In one patient the hypoplasia was present bilaterally. Three patients had the unusually high brachial artery bifurcation in the middle upper arm and in one patient the subclavian steal syndrome with pathological post-stenotic spectra in both right radial and ulnar artery was found.

TABLE 3

DIAMETERS (MM) OF FOREARM ARTERIES MEASURED IN FEMALES AND MALES

Females (N = 26)		Males (N = 101)	
Right radial artery	2.86±0.43	Right radial artery	3.39±0.67
Left radial artery	2.85±0.50	Left radial artery	3.28±0.59
Right ulnar artery	2.66±0.67	Right ulnar artery	2.92±0.55
Left ulnar artery	2.69±0.47	Left ulnar artery	2.99±0.55

TABLE 4
THE AFFECTION OF RADIAL AND ULNAR ARTERIES WITH LUMINAL CHANGES

	Radial artery	Ulnar artery
Atherosclerotic vessel wall changes	10	14
Calcifications of the vessel wall	52	58
Total	62 (24.4%)	72 (28.4%)

Discussion

As the radial artery is becoming more used as a graft for CABG the optimal pre-operative and postoperative screening technique is needed. The functional tests routinely used (Allen's test) provide the quick and simple information for clinicians and have mainly focused on function of ulnar collateral circulation[10,11]. These functional tests are not able to provide the morphological characteristics of the forearm arteries and thus they could lead to false negative results and allow possible postoperative complications to occur.

In our study we found that the radial artery is the dominant forearm artery, with wider lumen than the ulnar artery. This is in accordance with the previously published results of Haerle and coauthors that performed studies on cadaver extremities and color Doppler studies[13]. Side-to-side asymmetry was not significant even though the right radial artery was little wider than the left one. Males had wider arteries than females.

We demonstrated that the forearm arteries have relatively high rate of mild atherosclerotic changes and calcifications (30% of patients) that could be related to the high incidence of risk factors present in the examined population. These changes were more common and usually more severe in ulnar than in radial arteries (28.4% versus 24.4% of arteries). We were not able to differentiate whether the calcifications were placed in the intimal or medial layer of the vessel and thus with ultrasound we were not able to determine the underlying pathology (atherosclerosis versus Mönckeberg's sclerosis). High-grade stenosis or vessel occlusion was not found. Anatomical variants found included ulnar artery hypoplasia and high brachial artery bifurcation, and were present in 3.9% and 2.4% of patients, respectively.

The latest published studies also report that radial arteries are prone to atherosclerotic changes, intimal hyperplasia and medial calcifications, particularly in the older age group patients with common risk factors such as diabetes mellitus[14,15]. Ruengsakulrach and coauthors reported radial artery calcification in 24.7% patients, and overall incidence of radial artery abnormalities in 31.5%[16]. These results are similar to ours.

We found no literature data describing the morphological appearance of ulnar arteries, which in our opinion are also important, as the complete hand blood supply after the extraction of radial artery is dependant on ulnar artery, and it could become severely disturbed if the ulnar artery has severe luminal changes with stenosis, is hypoplastic, or occluded.

From our cohort of patients radial artery was harvested in 74 patients (58%). The hypoplastic vessels and vessels with pronounced atherosclerotic changes were not harvested. To all patients calcium channel blockers were recommended in the therapy to prevent vasospasm. Considering the local complications in one patient acute brachial artery thrombosis oc-

curred on the first postoperative day and was successfully treated with selective fibrinolysis. In all other patients only transient and mild symptoms with numbness and paresthesias in the hand were postoperatively present with no ischemic injury during the 6-month follow-up period.

As a conclusion, ultrasound proved to be very valuable in visualization of forearm arteries prior to CABG. It allows detection of luminal changes as well as anatomical variations. This information can help surgeons to make decision whether to use a radial artery and which side to use, as well as to help avoid unnecessary vessel exploration and prevent local ischemic postoperative complications. Whether the mild changes observed could have implication on long-term graft patency is uncertain and thus postoperative follow-up is necessary.

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B-MOD I KOLOR DOPLER ULTRAZVUK ARTERIJA PODLAKTICE U PREOPERATIVNOM PROBIRU BOLESNIKA S PREMOSNICAMA KORONARNIH ARTERIJA

S A Ž E T A K

Cilj ovog rada bio je utvrditi raspon fizioloških nalaza B-mod i kolor dopler ultrazvuka arterija podlaktice kod bolesnika u kojih je planiran za zahvat ugradnje koronarne premosnice radijalnom arterijom. Pregled radijalnih i ulnarnih arterija izvršen je kod 127 bolesnika. Mjereni su promjeri krvnih žila i brzine protoka u sistoli te je evaluirana prisutnost aterosklerotskih promjena, kalcifikacija stjenke i anatomskih varijacija. Radijalna arterija dominantna je arterija podlaktice bez statistički značajne razlike lijevo-desno. Promjene stjenki krvnih žila prisutne su u oko 30% bolesnika. Ulnarne arterije sklonije su nastanku promjena stjenke nego radijalne (28,4% prema 24,4%). Anatomske varijante uključuju hipoplaziju ulnarne arterije kod 3,9% bolesnika te visoko račvište brahijalne arterije kod 2,4% bolesnika. Nije nađeno slučajeva stenoze visokog stupnja ili okluzije. Rezultati ovog istraživanja pokazuju da su B-mod i kolor dopler korisne metode u preoperativnom probiru bolesnika zbog toga što omogućuju morfološku i funkcijsku analizu krvnih žila podlaktice.