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Assessment of the Radial Artery and Hand Circulation by Computed Tomography Angiography: A Pilot Study

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ABSTRACT

Objectives: The radial artery (RA) is increasingly being used as a coronary bypass graft. Results of a previous study using Doppler ultrasound and histopathologic examinations indicated that the RA has a higher incidence of preexisting intimal hyperplasia, medial calcification, and atherosclerosis than the internal thoracic artery. The aims of this study were to evaluate the use of computed tomographic angiography (CTA) to display hand collateral circulation, to define the criteria for an abnormal CTA test result, and to demonstrate usefulness of CTA as an alternative to conventional angiography for evaluation of the radial artery.

Materials and Methods: Sixteen patients scheduled for coronary artery bypass grafting entered this study. We performed 32 examinations of forearm and hand arterial anatomy in these patients. CTA was performed in patients with a normal Allen test result, except 1 patient who had a persistent median artery. Soft tissue density forehand roentgenography was performed in all patients before the CTA evaluation. There was no selection of patients in relation to patient characteristics. As a risk factor for radial artery calcification, 6 of the patients had diabetes mellitus, 6 had aortofemoral occlusive disease, and 4 had a history of smoking.

Results: Bilateral forearm arteries were visualized in all patients. Severe RA calcification was found in 1 patient, and distal occlusion was found in another patient. Focal RA calcification was noted in 2 patients. In the remaining patients no radial artery calcification or occlusion was noted. Anatomic variation of the upper limb arteries was shown in 2 patients; these variations were persistent median artery with absence of the radial and ulnar arteries and high bifurcation of the radial artery from the brachial artery.

Conclusion: CTA is useful and safe for detection of radial artery calcific disease and assessment of the forehand circulation and its anatomic variations. Preoperative imaging of the RA is a means to avoid unnecessary forearm exploration or inadvertent use of a diseased conduit in coronary artery bypass candidates with multiple risk factors such as diabetes mellitus.

INTRODUCTION

A previous study using Doppler ultrasound (US) and histopathologic examinations indicated that the radial artery (RA) has a higher incidence of preexisting intimal hyperplasia, medial calcification, and atherosclerosis than the internal thoracic artery [Kaufer 1997]. The radial artery is frequently used by cardiovascular surgeons as a free conduit for coronary artery bypass grafting, especially in full arterial revascularization, and has shown promising midterm graft patency rates [Acar 1998, Possanti 1998]. A severely calcified radial artery is a risk factor, and the long-term patency of such a conduit is questionable. Studies of the prevalence of preexisting disease in this vessel have used Doppler US [Pola 1996, Ruengsakulrach 2001, Nicholosi 2002] or histological analysis [Kaufer 1997].

Multidetector computed tomographic (CT) angiography has emerged as a noninvasive diagnostic modality that is an alternative to conventional angiography [Ofer 2003]. Sensitivity and specificity of CT angiography compared to conventional angiography for diagnosing lower extremity arterial stenoses have been reported to vary from 90% to 98% and 92% to 97%, respectively [Carpentier 1973, da Costa 1996].

In this study, we used CT angiography in coronary artery bypass candidates to examine the entire length of the RA for plaques and calcification, forearm arterial anatomy, and hand circulation. In all but 1 patient, RA calcific disease was investigated by means of x-ray examination, the Allen test, and the modified Allen test.

PATIENT POPULATION

Sixteen patients scheduled for coronary artery bypass grafting entered this study in the preoperative period. Patient characteristics, summarized in the Table, were not used as criteria for patient selection. All patients signed informed consent for evaluation by CT angiography of RA calcification. Patient age ranged from 49 to 70 years (mean, 60.28 years, SD ± 6.56 years). Five patients were women and 11 patients were men. CT angiography was performed in all patients who had normal Allen and modified Allen test results except 1 patient, who had a persistent median artery.

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Patient Characteristics*

Patient No.	Age	Sex	Smoking	Hypercholesterolemia	CAD	ASO	DM	RACD	AV
1	52	F	No	No	+	No	No	No	
2	64	M	+	+	+	No	+ (idDM)	+	
3	60	M	No	No	+	+	No	No	
4	56	M	+	+	+	+	No	No	
5	49	M	No	No	+	No	No	No	
6	55	F	No	No	+	No	+	No	
7	68	F	No	No	+	+	+	No	
8	62	M	No	No	+	No	No	No	
9	59	F	+	No	+	No	No	No	
10	65	M	No	+	+	+	+	No	
11	70	M	+	+	+	No	No	No	
12	62	M	No	+	+	+	+ (idDM)	+	
13	64	F	No	No	+	No	No	No	Yes
14	53	M	No	No	+	No	+	No	Yes
15	70	M	No	No	+	No	+	+	
16	65	M	No	No	+	+	No	No	Yes

*CAD indicates coronary artery disease; ASO, atherosclerosis obliterans; DM, diabetes mellitus; RACD, radial artery calcific disease; idDM, insulin-dependent DM; AV, anatomic variation.

All patients were coronary artery bypass candidates; patient risk factors for RA calcification were as follows: 7 patients had diabetes mellitus (DM) (insulin dependent or non–insulin dependent), 6 had aortofemoral occlusive disease, and 4 had a history of smoking. Also, 5 patients had hypercholesterolemia. The remaining 2 patients had no risk factors for RA calcific disease other than coronary artery disease.

CT ANGIOGRAPHIC EXAMINATION

Four-channel multidetector CT angiography was performed in all patients who had negative Allen test results and for whom soft tissue density x-ray examination results documented no significant RA calcific disease. All CT angiography studies were completed in less than 10 minutes. Multidetector CT angiography studies were performed using a 4-channel multidetector CT (Volume Zoom scanner; Siemens Medical Systems, Iselin, NJ, USA) after administration of 120 mL nonionic iodinated intravenous contrast (300 mg/mL) at a rate of 4 mL/s via 18-gauge angiocath by a power injector. Technical parameters were: detector collimation, 1 mm; slice thickness, 1.25 mm; reconstruction index, 1 mm; pitch, 1.75; gantry rotation time, 0.5 seconds; table speed, 14 mm/s. Axial images were transferred to a workstation, and 3-dimensional images were obtained using volume rendering and maximum intensity projections.

The entire length of the RA was examined for calcification, soft plaques, and stenosis. Hyperdense foci in the arterial wall were recorded as local calcification; occlusion was defined as a distal cut-off or the inability to visualize the distal part of the artery.

RESULTS

Bilateral radial arteries and proximal hand circulation were visualized in all patients. The technical success rate of forearm CT angiography was 100%.

Five patients had 3 risk factors for RA calcification. Focal calcification leading to mild stenosis, occlusion, and diffuse calcification of the distal RA were detected by CT angiography in 3 of the 16 patients (patients 2, 12, and 15) (Figures 1, 2, and 3). All 3 of these patients were men aged older than 60 years, and 2 of these patients had insulin-dependent DM. X-ray test results were negative in all but 1 patient, who had severe RA calcification on soft tissue density roentgenogram (Figure 4). Three patients had a variation of the forearm arterial anatomy (patients 13, 14, and 16). High bifurcation of the radial artery from the brachial artery was noted in patient 13 (Figure 5). The other patient had persistent median artery with absent radial and ulnar arteries (Figure 6). This patient also had aortofemoral occlusive disease. Hypoplastic median artery was found in the other patient. The RA was not used as a conduit for coronary bypass grafting in patients with RA calcific disease or anatomic anomaly.

DISCUSSION

A previous study using Doppler US and histopathologic examinations indicated that the RA has a higher incidence of preexisting intimal hyperplasia, medial calcification, and atherosclerosis than the internal thoracic artery [Kaufer 1997]. The results of this study suggested that predictors of intimal disease of the RA were age, peripheral vascular disease, and DM. Focal calcification was found in our 3 patients who had DM.

A severely calcified RA is a risk factor because the long-term patency of such a conduit is questionable. A few studies have examined the prevalence of preexisting disease in this vessel, using Doppler US [Pola 1996, Ruengsakulrach 2001, Nicholosi 2002] or histologically [Kaufer 1997].

Carpentier et al first used and proposed the RA as a conduit in a coronary bypass patient in 1971 [Carpentier 1973]. They reported an approximately 30% occlusion rate of RA grafts, and therefore the RA graft was abandoned.

Figure 1. Forearm computed tomographic angiography, anterior projection shows eccentric focal calcification (arrow) at distal radial artery, causing mild stenosis.

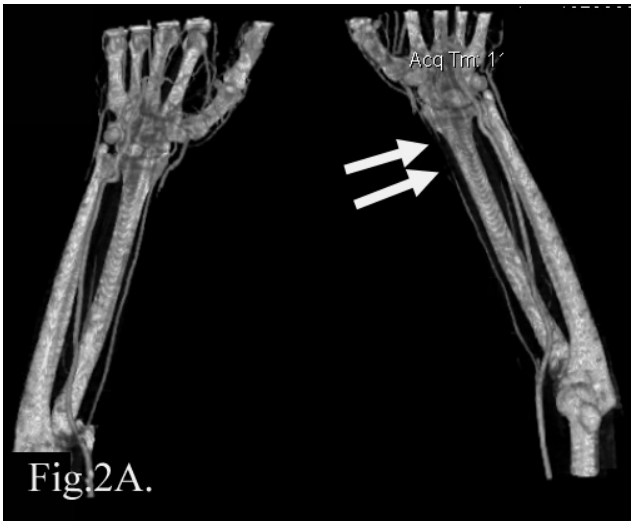
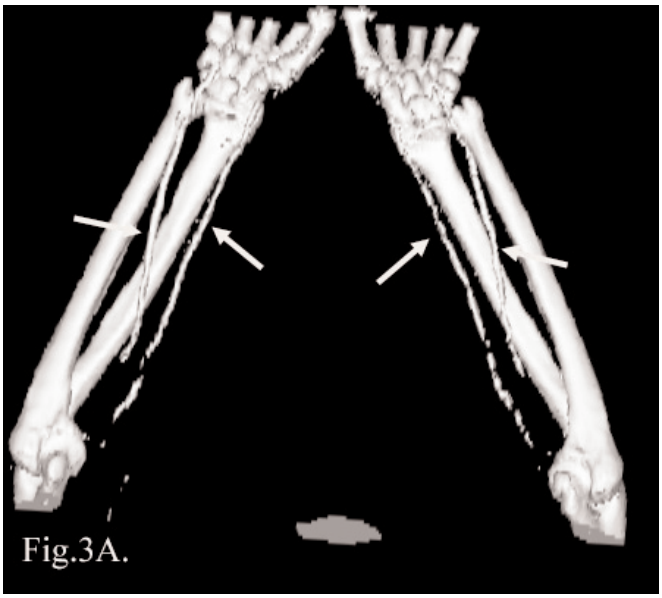


Figure 2. A, Computed tomographic angiography, anterior projection shows occlusion of distal radial artery (arrows). B, Anterior projection at the level of the hand shows reconstitution of the radial artery distal to occlusion (short arrow) via deep palmar arch (arrowheads) through ulnar artery (long arrow) that explains the reason for normal Allen test in this patient.

Since 1990, with developing methods using pharmacologic agents and harvesting techniques to avoid conduit spasm, the RA has became a popular conduit for coronary artery bypass surgery. The RA is frequently used by cardiovascular surgeons as a free conduit for coronary artery bypass grafting, especially in full arterial revascularization, and has shown promising early results.

Multidetector CT angiography has emerged as a noninvasive diagnostic modality that is an alternative to conventional angiography [Martin 2003]. Sensitivity and specificity of CT angiography compared to conventional angiography for diagnosing lower extremity arterial stenoses have been reported to vary between 90% to 98% and 92% to 97%, respectively [Nicolosi 2002, Ofer 2003]. In addition, RA calcific disease was investigated by x-ray examination in a coronary bypass graft patient [Deshpande 2000]. Therefore, we also performed soft tissue density roentgenoram (STDR) in all patients before the CT angiographic examination of the upper extremities. But by the use of STDR we found calcific RA in only 1 patient, who had insulin-dependent DM. The Allen and the modified Allen tests were performed in all patients except 1 patient who had a persistent median artery.

With the resurgence of the use of the RA for coronary artery bypass grafting, tests such as Doppler US and the Allen test have been increasingly used as screening devices for assessing the hand collateral circulation in the most centers. The advantage of the Doppler US technique is that it can be used to examine the vessel, measure the flow velocity, and assess the physiologic adaptation of vessels by observing the direction of the blood flow after RA compression. However, one of the drawbacks of using this test is that there are no established standard criteria to differentiate normal and abnormal Doppler US results [Ruengsakulrach 2001]. Also, ultrasonography is a subjective operator-dependent investigation. On the other hand, the Allen test is a simple and cost-effective test; however, there is some debate about whether it is a valid screening test. In our study, we determined that 3 patients had RA occlusive disease (1 patient had RA calcification with the ulnar artery); however, we could not detect negative Allen test results in these patients. The modified Allen test is a subjective operator/patient-dependent test, and there have been a number of reports of unexpected hand ischemia after RA intervention, including RA harvesting [Nunoo-Mensah 1998].



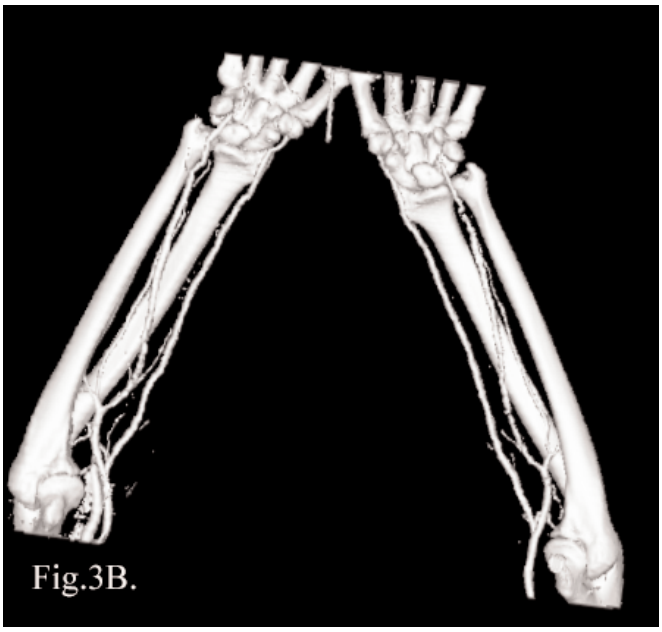


Figure 3. A, Unenhanced computed tomography shows diffuse calcification of bilateral radial and ulnar arteries (arrows). B, Computed tomographic angiography shows patency of proximal ulnar and radial arteries, diffusely calcified segments cannot be evaluated.

Pola et al established criteria for an abnormal Doppler US dynamic test result to determine which RAs could be harvested [Pola 1996]. But we believe that difficulties in evaluation of Doppler ultrasonographic findings and subjectivity of this technique can be overcome by state-of-the-art CT angiography studies. In a study by Nicholosi et al, 5.9% of the patients had abnormal Doppler US dynamic test results [Nicholosi 2002].

Based on these findings, we think that more reliable radiologic methods should be used in preoperative patients to document the anatomy of the hand and forearm and atherosclerotic changes in the arterial system in order to do reliable RA harvesting in patients with a high risk for arterial calcific disease, such as patients with DM or hypercholesterolemia, although these methods are not used routinely in the clinical setting. Multidetector CT angiography can be used as an alternative to Doppler US and the Allen test to document anatomical and atherosclerotic changes.

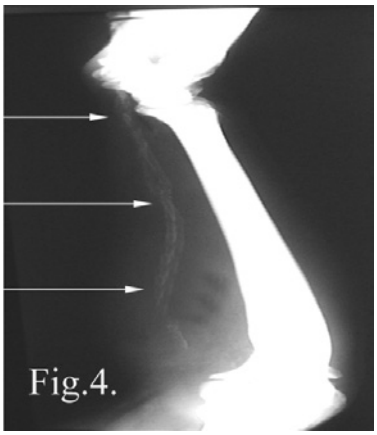


Figure 4. Soft tissue roentgenogram shows diffuse calcification in the forearm indicative of radial and ulnar artery calcifications (arrows).

Conventional angiography is still the gold standard for evaluation of arterial system anatomy and pathologies, but it has several disadvantages including long procedure time, need for sedation and arterial catheterization, and potential complications such as arterial occlusion and dissection. Therefore, routine use of conventional angiography for RA evaluation is not practical. Moreover evaluation of calcification and the vessel wall are not possible by conventional angiography, in contradistinction to CT angiography, which allows noninvasive

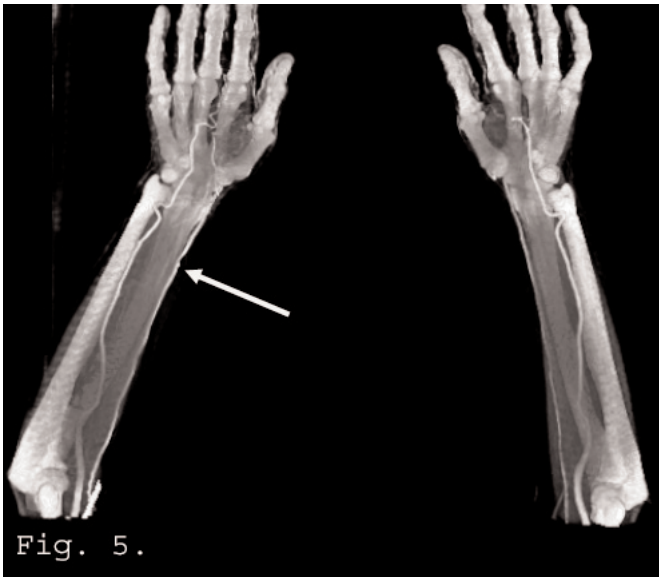


Figure 5. Computed tomographic angiography, anterior projection shows high bifurcation of radial artery above the elbow joint as a normal anatomic variant. The bifurcation is not seen on computed tomographic angiography image due to limited coverage.

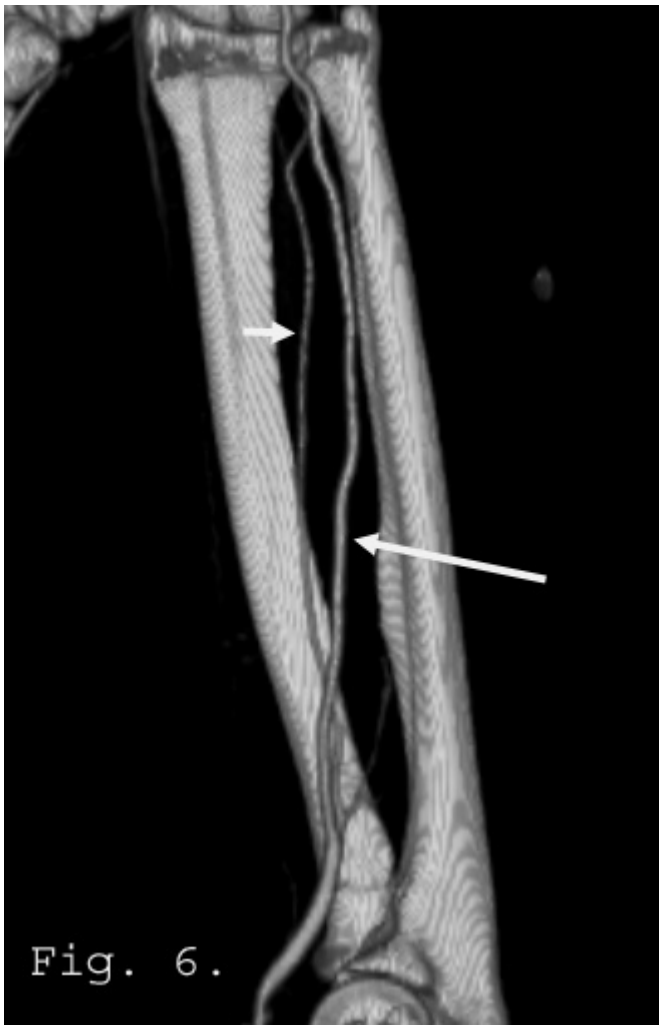


Figure 6. Computed tomographic angiography, anterior projection shows persistent median artery (long arrow). Note absence of radial and ulnar arteries. Interosseal artery (short arrow) originates from persistent median artery.

visualization of the vessel wall and its lumen. However, extremity multidetector CT angiography has disadvantages, which are radiation exposure and iodine contrast-material administration. But compared to conventional angiography, radiation dose, iodinated contrast load, and procedure time are less with CT angiography. Contrast material is administered through a cubital vein in contradistinction to conventional angiography, in which contrast is administered through a catheter located in the arterial system. CT angiography is a cheaper, safer, and noninvasive technique and provides detailed information about the anatomy of the vasculature and arterial pathologies. Moreover, it is quite difficult to evaluate changes in the arterial system with Doppler US.

In our study we first examined the anatomopathologic hand circulation and used CT angiography to document the patency status of the RA and the ulnar artery in the forearm and the wrist. CT angiography is superior to Doppler US because it can document anatomical and pathological details at the same time. The results of CT angiography are more

Figure 7. Computed tomographic angiography, anterior projection shows normal anatomic pattern of forearm arteries. Note bifurcation of brachial artery just below elbow joint.

comprehensible and displayable than those of Doppler US. Three-dimensional volume-rendered CT angiography images provide images of the arteries as well as bony anatomy as a vascular roadmap for preoperative planning. Also, anatomic variants, which are difficult to visualize and map on Doppler US, can be diagnosed by CT angiography. The most important disadvantage of Doppler US is operator dependence and subjectivity of this technique. This technique has been used in adult patients for preoperative evaluation for microsurgical reconstruction of extremities.

In conclusion, objective noninvasive evaluation of the RA and hand circulation is possible with CT angiography. Therefore CT angiography can be used for preoperative evaluation of the RA in coronary bypass candidates, especially patients with risk factors for RA calcification.

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