

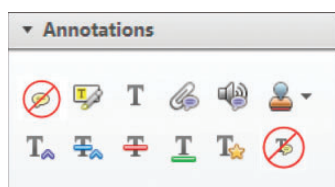
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# Vascular Complications Following Transradial and Transulnar Coronary Angiography in 1600 Consecutive Patients

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## Abstract

**Background:** Major, noncoronary complications are rarely encountered following transradial coronary procedures. **Methods and Results:** Among 1600 prospectively studied patients with complete follow-up, 7 patients experienced major complications following coronary forearm procedures corresponding to an incidence of 0.44%. We found inadvertent symptomatic intramyocardial contrast medium injection, 2 cases with compartment syndrome of which 1 was managed surgically, exertional hand ischemia due to radial artery occlusion, a large ulnar artery pseudoaneurysm, an ulnar arteriovenous fistula, and 1 critical hand ischemia due to late occlusion of the distal brachial artery. **Conclusions:** Although infrequent, surveillance for major complications should be encouraged after forearm coronary procedures.

## Keywords

radial artery, ulnar artery, complications, coronary procedures, hand ischemia

Transradial coronary interventions as compared with the transfemoral route are increasingly used because of low rates of access site complication and patient acceptance.<sup>1,2</sup> Despite some potential merits, the transulnar approach is only exceptionally selected as a default strategy for coronary angiographies. The aim of this study was to prospectively identify any rare, nonhemorrhagic complication with systematic vascular follow-up in patients undergoing coronary angiography and percutaneous coronary intervention (PCI) from the forearm arteries. We present herein 7 complications which we encountered in 1600 consecutive patients between 2010 and 2013 by virtue of the transradial and transulnar approach. The ulnar artery was selected in the context of a randomized trial aiming to assess the feasibility and safety of the ulnar as opposed to the radial access site.<sup>3</sup> All 7 patients received a 5F or a 6F sheath, 5000 units (U) of unfractionated heparin or 100 U per kilogram (U/kg) for coronary angiography and PCIs, respectively, as well as a patent hemostasis after termination of the procedure. A summary of clinical characteristics of these patients is given in Table 1.

## Case 1

A 66-year-old man with suspected coronary artery disease underwent coronary angiography from the right radial artery

with the Tiger diagnostic catheter (Terumo Corporation, Tokyo, Japan; Figure 1). Following opacification of the left coronary system, the right coronary artery was engaged. During contrast medium injection, however, a persisting staining of the left ventricular myocardium was evident as a result of slippage of the diagnostic catheter into the left ventricular cavity. The patient complained immediately about chest pain, whereas ST-elevation in the precordial electrocardiographic (ECG) leads and runs of nonsustained ventricular tachycardia indicated acute myocardial injury. Echocardiography showed absence of pericardial effusion. After delineation of the right coronary artery and despite normal coronary angiogram, the patient was monitored for possible life-threatening complications but no specific therapy was initiated. Subsequently,

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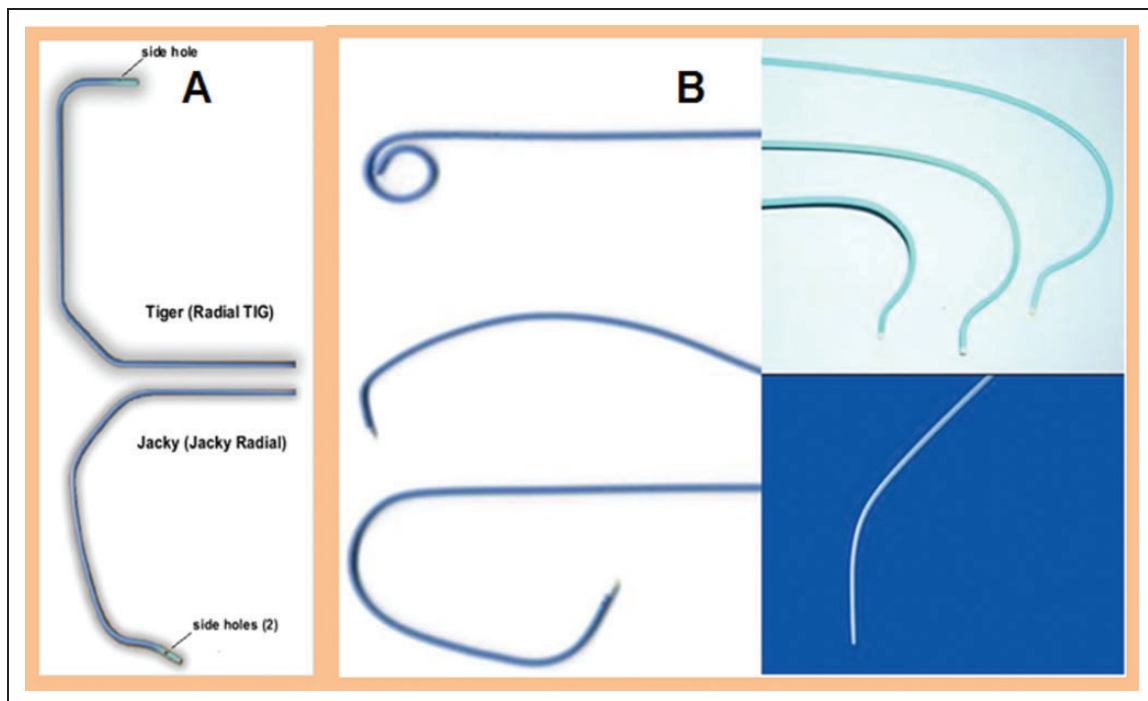
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**Table 1.** Characteristics of the 7 Study Patients.

#	Patient	Gender	Age	Coronary Procedure	Sheath Size	Dose of UFH	Complication	Treatment and Outcome
1	KA (Figure 1)	M	66	Coronary angiography	5F	5000 units	Left ventricular myocardial staining with contrast medium	Short-lasting symptoms; malignant tachyarrhythmias; spontaneous resolution
2	CL (Figure 2A)	M	65	Coronary angiography	5F	5000 units	Compartment syndrome surgically corrected	Fasciotomy; patent radial artery; no sequelae
3	KG (Figure 2B)	M	75	PCI for NSTEMI	6F	100 units/kg	Compartment syndrome conservatively managed	Gradual resolution of clinical picture; patent radial artery; uneventful course
4	PG (Figure 3)	F	72	Coronary angiography	5F	5000 units	Persisting moderate stress-induced hand ischemia after occlusion of the radial artery	Remaining mild residual symptoms of the right hand
5	GK (Figure 4)	F	81	Coronary angiography	5F	5000 units	Ulnar artery pseudoaneurysm	Surgical closure of the aneurysm; patent ulnar artery; no sequelae
6	AI (Figure 5)	M	60	PCI for NSTEMI	6F	100 units/kg	Ulnar AV fistula	Spontaneous resolution of the AV communication; patent ulnar artery
7	ME (Figure 6)	M	81	PCI for NSTEMI	6F	100 units/kg	Critical hand ischemia due to distal brachial artery occlusion presumably of embolic origin	Surgical resection of the embolus established patency of the forearm arteries; no sequelae

Abbreviations AV, arteriovenous; PCI, percutaneous coronary intervention; NSTEMI, non-ST-elevation myocardial infarction.



**Figure 1.** Patient with myocardial staining due to inadvertent left ventricular contrast medium injection through the Tiger diagnostic catheter (patient #1). Optitorque catheters for transradial coronary angiography from Terumo Interventional systems (A) in comparative view with conventional diagnostic catheters (B).

angina and ECG abnormalities resolved and the patient was discharged the next day.

## Case 2

A 65-year-old man presented with a painful progressive swelling of the forearm 8 days after an uncomplicated coronary angiography from the right radial artery. Physical examination revealed a significant hematoma, hand hypesthesia with some motor disturbances, and palpable forearm pulses. Ultrasonography confirmed arterial patency. A bleeding site in proximity to that previously cannulated was evident on computed tomographic angiography. Under the diagnosis of compartment syndrome, the patient underwent fasciotomy and closure of a small radial artery leak which was found on surgical inspection (Figure 2A).

## Case 3

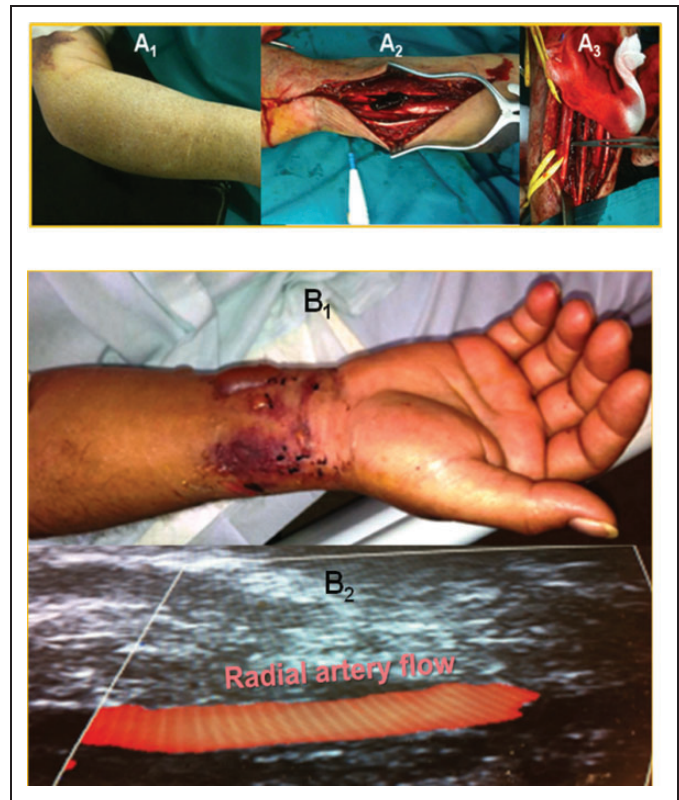
A 72-year-old male patient underwent PCI of the left circumflex artery due to non-ST-elevation myocardial infarction (NSTEMI) 1 day before. After removal of the hemostatic device, the patient developed increasing forearm discomfort, palmar paresthesias, and motor disturbances as well as progressive forearm and hand swelling (Figure 2B). Blood pressure was found to be within normal limits. Administration of analgetics and anticoagulation reversal did not improve the clinical picture. Three hours after symptom onset, a sphygmomanometer with subsystolic pressures was applied for 15 minutes twice in 1 hour. Symptoms and signs of the ongoing compartment syndrome stabilized and receded 24 hours later without need for surgical intervention.

## Case 4

A 72-year female patient underwent a routine follow-up vascular examination 16 days after a successful right radial coronary angiography with initially normal Allen test. She developed paresthesias along the radial side of her right hand that were unrelated to exertion. Palpation and ultrasonography demonstrated an occluded radial artery. On exertion, the patient complained of mild hand pain and the palmar side of the right hand blanched prematurely indicating stress-induced hand ischemia. Both symptoms and physical findings remained unchanged 6 months later (Figure 3).

## Case 5

An 81-year-old woman with nonpalpable right radial artery but normal Allen/reverse Allen tests underwent an uncomplicated coronary arteriography from the right ulnar artery. One week later, she presented with a tender pulsatile mass in her right forearm and reported pain in the ulnar forearm during the active flexion of the little finger. The ulnar artery was palpable proximal and distal to the mass; however, the ipsilateral radial artery pulse remained absent. Functional tests of the palmar circulation could not be repeated. Color Doppler ultrasonography



**Figure 2.** A and B, Two patients with compartment syndrome managed surgically (A, patient #2) and conservatively (B, patient #3). Arm swelling with hematoma (A<sub>1</sub>), surgical view (A<sub>2</sub> and A<sub>3</sub>). Arm swelling with forearm hematoma and contact dermatitis (B<sub>1</sub>), patent right radial artery (B<sub>2</sub>).

revealed a 10 × 20 mm pseudoaneurysm arising from the ulnar artery with small mural thrombi and a typical laminar flow entering and exiting the neck of the pseudoaneurysm (Figure 4). Additionally, a severe stenosis of the radial artery was found immediately after the bifurcation of the brachial artery in the cubital fossa. The cause of this radial narrowing remained elusive. Treatment with thrombin injection was not considered safe and a successful surgical excision of the ulnar pseudoaneurysm was performed. The patient had a good pulsating ulnar artery on follow-up.

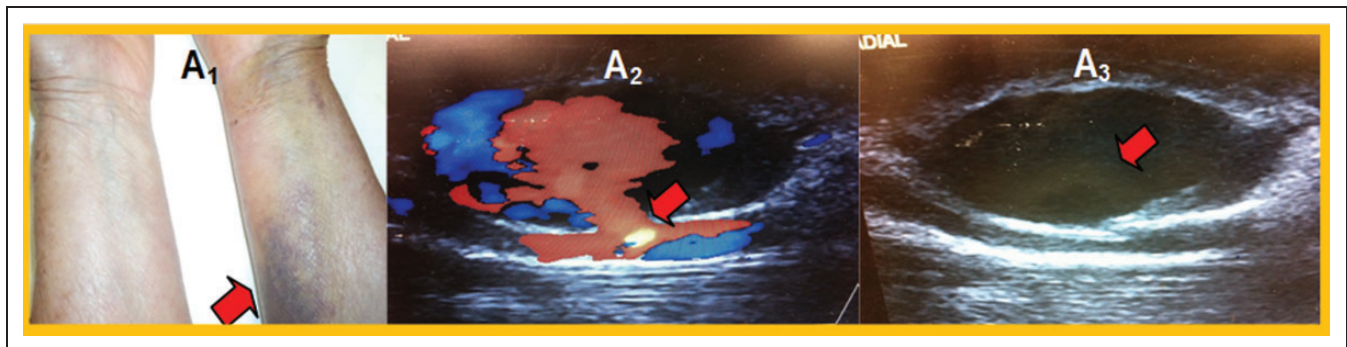
## Case 6

A 60-year-old male patient underwent transulnar PCI with stenting of the left anterior descending artery for NSTEMI 1 day previously. He was discharged 1 day later with a moderate forearm hematoma. One week after the procedure, the patient presented in the outpatient clinic for a scheduled postprocedural follow-up. He complained of mild pain in the distal forearm. On palpation, the ulnar artery appeared patent and some thrill was evident whereas a low-intensity continuous murmur was audible. Ultrasonography confirmed the suspicion of ulnar arteriovenous (AV) fistula (Figure 5). The patient was managed

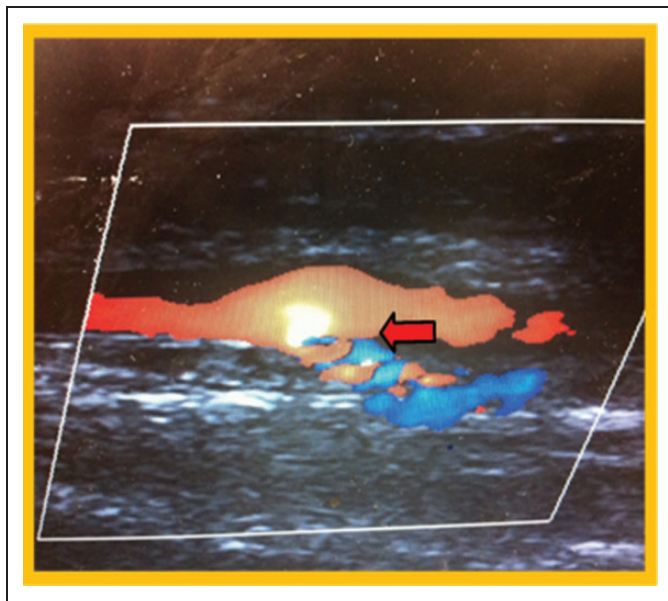




**Figure 3.** Exertional ischemia of the right hand (patient #4). Patient with chronic occlusion of the right radial artery and normal Allen test before coronary angiography: ischemic right hand on exertion at 16 days ( $A_1$ ) and 6 months ( $A_2$ ) after the procedure (red arrows).



**Figure 4.** Ulnar artery pseudoaneurysm (patient #5). Patient with large ulnar pseudoaneurysm and ipsilateral radial artery stenosis: extensive hematoma of the right forearm ( $A_1$ , red arrow), large pseudoaneurysm communicating with a patent right ulnar artery on echocardiography ( $A_2$  and  $A_3$ ).



**Figure 5.** Ulnar arteriovenous (AV) fistula (patient #6). This AV communication (red arrow) resolved spontaneously without specific treatment.

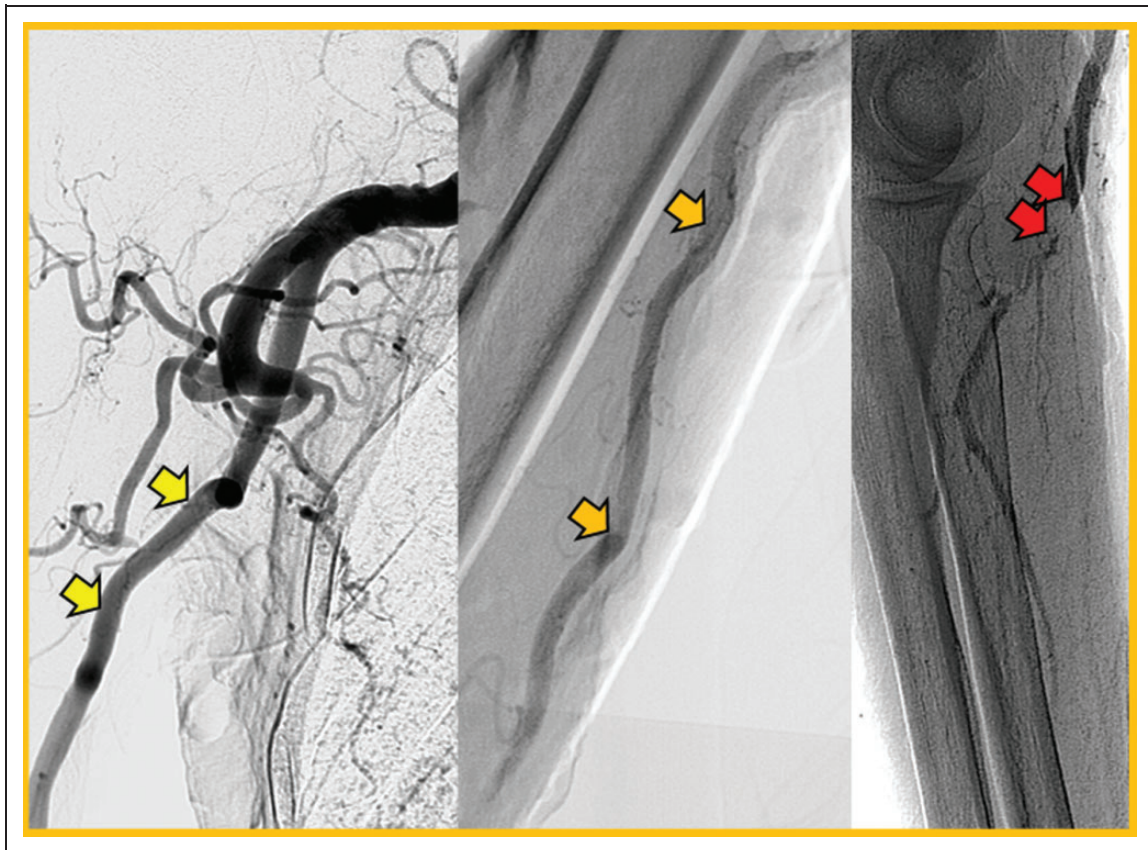
conservatively. One week later, the AV communication was no longer detectable.

### Case 7

A 81-year-old male patient underwent PCI and stenting of the proximal left anterior descending coronary artery due to NSTEMI 2 days before. The right radial artery was used, and the Allen test was normal. The intervention was uneventful and the patient was discharged on the next day. Three weeks later, the patient developed acute, critical ischemia of the right forearm with nonpalpable radial and ulnar pulsation. The right arm angiography showed complete occlusion of the distal brachial artery (Figure 6). The patients underwent thereafter emergent surgery resulting in removal of occlusive thromboembolic material from the distal brachial artery and establishing a normal forearm flow in otherwise smooth arteries.

### Discussion

We observed a 0.44% incidence of nonhemorrhagic, entry and nonentry site complications following forearm coronary



**Figure 6.** Right arm arteriography depicting occlusion of the distal brachial artery in a patient presenting with critical hand ischemia (patient #7). The proximal and midportions of the brachial artery appear patent and smooth (yellow and brown arrows, respectively). The distal portion of the brachial is abruptly occluded indicating an embolic rather than a thrombotic event (red arrows). Faint collaterals allow for some forearm perfusion. Surgical removal of the embolus established complete patency of both forearm arteries.

procedures. Although infrequent, such adverse events may prolong hospitalization, be life-threatening, and require treatment. A previous and a recent meta-analysis found up to 1.0% rate of radial entry site complications including major hemorrhages and a 65% to 80% rate reduction over the transfemoral route.<sup>1,2</sup> In the radial versus femoral access for coronary angiography and intervention in patients with acute coronary syndromes (RIVAL) trial, the sole, major nonhemorrhagic complication among the patients who underwent transradial procedures was pseudoaneurysm necessitating closure with a 0.2% incidence. Similarly to the current series, a large single-center report found radial-related vascular complications in 0.41% of the patients, one-fourth of which were major and uncorrelated to either diagnostic or interventional procedure or to the experience level of the radialist.<sup>4</sup> Our results imply that both operators' awareness and careful surveillance are needed after forearm coronary procedures whether diagnostic angiography or PCI; otherwise some unusual complications may be missed, left untreated, or underreported. All coronary angiographic complications occurred with a 5F sheath, suggesting that low profile catheters do not necessarily afford vascular protection.

The first case report of this series illustrates that the "all-purpose," radial Tiger catheter with 2 sharp tip curvatures may slip in the left ventricular cavity and cause myocardial trauma

during forceful contrast injection in an unstable engaged arterial ostium of a low-originating right coronary artery.

Compartment syndrome of the forearm following transradial coronary interventions has been associated with intense anticoagulation and disability if not treated in a timely fashion.<sup>5,6</sup> It occurs as a result of tissue pressure increase within a nonexpandable space. The etiologic factors are diverse and not confined to transradial procedures only.<sup>6</sup> Its incidence was 0.125% in our series but variable rates between 0% in the RIVAL<sup>2</sup> and several other trials (as summarized by Burzotta et al<sup>4</sup>), 0.02%<sup>4</sup> and 0.004%<sup>6</sup> have been reported so far, accounting for less than 10 cases in total.<sup>4-6</sup> Careful anticoagulation and application of short-lasting, subsystolic cuff inflation at the site of arm swelling, pulse-oxymetric monitoring of the fingers, analgetics, blood pressure control, and surgical consultation are necessary steps in management and minimizing the rates of this complication.<sup>6</sup> This approach prevented a surgical intervention in our case 3 patient. Our case 2 patient developed this adverse event insidiously over several days after the coronary procedure, indicating that excessive physical exertion of the arm may be etiologically involved and should therefore be avoided early after discharge.

Exertional hand ischemia was found in 1 of 170 occluded forearm arteries (incidence 0.6%). This finding was observed despite normal Allen test at baseline and remained stable



overtime. Search for stress-induced ischemia among patients with occluded forearm arteries after coronary interventions has not been proposed so far, although it may be helpful in unmasking ischemic forearm symptoms. We recommend a hand exertion stress test in all patients with an occluded forearm artery as well as careful clinical follow-up of those patients with stress-induced ischemia. This case illustrates again that the Allen test delivers a rough only functional information on the palmar circulation being thereby unable to predict hand ischemia related to ulnar artery patency status.<sup>3,7,8</sup>

Ulnar pseudoaneurysm following coronary angiography has been previously reported in 3 patients only<sup>9</sup> but it is not a surprising complication. In fact, the ulnar artery appears either smaller than or as large as the radial artery at the wrist level<sup>3</sup> and requires more attempts for successful cannulation compared with the transradial route.<sup>3</sup> Radial artery pseudoaneurysm appeared with an incidence of 0.625% in our total cohort of patients is found in the literature with a rate of 0% to 0.5%.<sup>4</sup> In the largest series to date, a frequency of 0.04% has been reported for this kind of complication.<sup>4</sup>

Ulnar AV fistula is a rare and benign complication.<sup>11</sup> Our patient represents the second known case in the literature. Radial AV fistula has been reported in 0% to 2% and in the largest series, 0.04%.<sup>4</sup> In the current study, ulnar AV fistula had an incidence of 0.06% of the total forearm procedures.

Critical hand ischemia after transradial coronary procedures is a rare complication which occurred in our patient despite normal Allen test and was the result of late, distal brachial artery occlusion, presumably of embolic origin. This kind of complication has not been described previously and indicates the diverse etiology beyond radial artery occlusion underlying postprocedural critical hand ischemia.<sup>3,8</sup>

In summary, in this prospectively studied consecutive 1600 patients, we found 7 uncommon complications following forearm coronary procedures. Three patients underwent surgical intervention, and additional 3 had to be closely monitored. Clinical course was thereafter uneventful. Mild residual disability was further noticed in another patient as a result of stress-related hand ischemia. Systematic vascular follow-up is mandatory to detect such potentially deleterious adverse events after a seemingly uncomplicated coronary procedure even with small-sized coronary catheters.

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## Declaration of Conflicting Interests

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## References

1. Agostoni P, Biondi-Zoccai GG, De Benedictis ML, et al. Radial versus femoral approach for percutaneous coronary diagnostic and interventional procedures: Systematic overview and meta-analysis of randomized trials. *J Am Coll Cardiol*. 2004;44(2):349-356.
2. Jolly SS, Yusuf S, Cairns J, et al. Radial versus femoral access for coronary angiography and intervention in patients with acute coronary syndromes (RIVAL): a randomised, parallel group, multicentre trial. *Lancet*. 2011;377(9775):1409-1420.
3. Hahalis G, Tsigkas G, Xanthopoulou I, et al. Transulnar compared with transradial artery approach as a default strategy for coronary procedures: a randomized trial. The Transulnar or Transradial Instead of Coronary Transfemoral Angiographies Study (the AURA of ARTEMIS Study). *Circ Cardiovasc Interv*. 2013;6(3):252-261.
4. Burzotta F, Trani C, Mazzari MA, et al. Vascular complications and access crossover in 10,676 transradial percutaneous coronary procedures. *Am Heart J*. 2012;163(2):230-238.
5. Lin YJ, Chu CC, Tsai CW. Acute compartment syndrome after transradial coronary angioplasty. *Int J Cardiol*. 2004;97(2):311.
6. Tizón-Marcos H, Barbeau GR. Incidence of compartment syndrome of the arm in a large series of transradial approach for coronary procedures. *J Interv Cardiol*. 2008;21(5):380-384.
7. Ghuran AV, Dixon G, Holmberg S, de Belder A, Hildick-Smith D. Transradial coronary intervention without pre-screening for a dual palmar blood supply. *Int J Cardiol*. 2007;121(3):320-322.
8. Brzezinski M, Luisetti T, London MJ. Radial artery cannulation: a comprehensive review of recent anatomic and physiologic investigations. *Anesth Analg*. 2009;109(6):1763-1781.
9. Roberts EB, Palmer N, Perry RA. Transulnar access for coronary angiography and intervention: an early review to guide research and clinical practice. *J Invasive Cardiol*. 2007;19(2):83-87.
10. Aptekar E, Pernes JM, Chabane-Chaouch M, et al. Transulnar versus transradial artery approach for coronary angioplasty: the PCVICUBA. Study. *Cathet Cardiovasc Interv*. 2006;67(5):711-720.

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