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Radial Artery Occlusion and Hand Strength After Percutaneous Coronary Procedures: Results of the HANGAR Study

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Objectives: The aim of this prospective study was to evaluate muscle force of the hand, thumb, and forefinger in patients with prolonged radial occlusion after transradial percutaneous coronary procedures. Background: There are no data on hand strength and function in patients with prolonged radial occlusion after percutaneous coronary procedures. Methods: Elective patients with chronic stable angina undergoing percutaneous coronary procedures were evaluated the day before the procedure for radial artery patency, Allen test, hand grip, and thumb and forefinger pinch tests. The same measures were performed the day after the procedure and at follow-up. At follow-up, patients were divided in two groups according to the radial patency (group 1) or occlusion (group 2). Results: Of the 99 patients included in the study, 90 patients had a patent radial artery (group 1), and nine (9.1%) patients had an occluded artery (group 2). At baseline, there were no significant differences in hand grip test between the two groups (42 ± 11 kg in group 1 and 41 ± 17 kg in group 2, $P = 0.74$). In both groups, after the procedure, the hand grip test values was significantly reduced compared with baseline values (40 ± 11 kg in group 1, $P < 0.0001$ and 37 ± 17 kg in group 2, $P = 0.007$). Finally, at follow-up, in both groups, the hand grip test values returned to baseline values. Thumb and forefinger pinch tests did not show significant differences after the procedure and at follow-up, compared with baseline. Conclusions: Radial artery occlusion after percutaneous coronary procedures was not associated with a reduction in hand and finger strength.

Key words: transradial approach; radial occlusion; hand grip; coronary angiography; Allen test

INTRODUCTION

In the last decade, the use of transradial approach for percutaneous coronary procedures has gained popularity [1] because of a reduced risk of vascular complications [2] and a better comfort for the patient [3]. However, the most frequent complication of transradial approach is the radial artery occlusion (RAO), which is observed in a wide range, from 3% to 30%, of procedures using 6-F catheters [4–8]. Although the radial occlusion is considered a "benign" complication following percutaneous transradial procedures, some previous reports showed that RAO may not be a trivial side effect [9]. Moreover, in a previous study [10], patients with abnormal Allen test after 30 min of radial occlusion showed an increased thumb capillary lactate, suggestive of ischemia, and sometimes patients with radial occlusion become symptomatic [7] with a possible consequent limitation of arm function. At this time, there are no data on hand strength and function in patients with prolonged radial occlusion after percutaneous coronary procedures. Moreover, it is not clear whether transient or prolonged asymptomatic hand ischemia might affect the acute and long-term hand or finger functionality.

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Conflict of interest: Nothing to report.

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Hand grip strength can be easily and quantitatively measured using a hand dynamometer, and the Jamar hand dynamometer is accepted as the gold standard for these measurements [11]. The Jamar hand dynamometer actually is routinely used to evaluate neurological, muscular, and/or skeletal illness and evaluate functional recovery after adequate hand rehabilitation. In a previous study [12], the hand dynamometer has also been employed in patients who underwent transradial percutaneous coronary procedures, to compare the hand grip strength according to different baseline Allen test results. No studies evaluated thumb and forefinger pinch after transradial percutaneous coronary procedures.

The aim of this prospective study was to evaluate muscle force of the hand, thumb, and forefinger in patients with prolonged radial occlusion after transradial percutaneous coronary procedures.

MATERIALS AND METHODS

Study Design and Population

The HANGAR (HANd Grip test After tRansradial percutaneous coronary procedures) study (Clinical Trial Registration: NCT01853943) is a single-center prospective study designed to evaluate hand and finger strength after transradial percutaneous coronary procedures according to the postprocedural patency or occlusion of the radial artery.

Elective patients with chronic stable angina undergoing percutaneous coronary procedures were evaluated the day before the procedure for radial artery patency, Allen test, hand grip, and thumb and forefinger pinch tests. The same measures were performed the day after the transradial procedure and after at least 30 days follow-up. At follow-up, patients were divided in two groups according to the radial patency or occlusion, and the results were compared. RAO was documented in all patients the day after the procedure and at follow-up by ultrasound examination using a ultrasound machine with a multifrequency linear probe (Sonos 5500, Philips, The Netherlands).

According to previous studies [13], the modified Allen test has been performed on both hands, with the patient in supine position as follows: after vigorous compression of both radial and ulnar arteries, the patient is asked to forcefully clench one hand several times. The hand is then opened before release of the ulnar artery compression. The amount of time to achieve maximal palmar blush is measured after compression release of the ulnar artery with continuing occlusive pressure of the radial artery. The Allen test was considered to be ischemic if time to maximal palmar blush was $\geq$10 sec.

The hand grip strength was measured with the Jamar Plus dynamometer (Sammons Preston, Bolingbrook, IL) using a well-established protocol (the Southampton protocol), which is based on the American Society of Hand Therapist recommendations [10]. Briefly, the patient was sitting comfortably in a standard chair with legs, back support, and fixed arms. For every measurement, the same chair has been used. The patient was asked to rest their forearms on the arm of the chair with the wrist just over the end of the arm of the chair and positioning the wrist in a neutral position with the thumb facing upward. The observer encouraged the participant to squeeze as long and as tightly as possible starting with the right hand (Fig. 1). Subsequently, the measurements were performed in the left hand, and further measurements were performed for each hand alternating sides to give three readings in total for each side. The highest score and the mean value of the three measurements were used in statistical analysis.

An electronic pinch gauge (Jamar Plus, Sammons Preston) was used to assess the key pinch for thumb and forefinger. The patient was asked to press as tightly as possible the dynamometer starting with the right hand (Fig. 1). Subsequently, the measurement was performed in the left hand, and further measurements were performed for each hand alternating sides to give three readings in total for each side. The highest score and the mean value of the three measurements were used in statistical analysis.

Exclusion criteria were hemodynamic instability, acute coronary syndromes, hemodialysis patients with an arteriovenous fistula, sheath diameter different from 6 F, and age $<$ 18 years.

The primary end-point of the study was the variation in had grip strength after the procedure (the day after and at follow-up) compared with baseline in the two groups. Secondary end-points were thumb and forefinger pinch after the procedure (the day after and at follow-up) compared with baseline in the two groups.

The Institutional Ethics Committee approved the protocol, and all patients enrolled signed a written informed consent.

Transradial Coronary Catheterization

Radial artery access was obtained using a 6-F sheath (Radifocus, Terumo, Leuven, Belgium) 7 or 16 cm length after local anesthesia with xylocaine 2%. The radial site access (right or left) was left to operator choice. A dose of at least 4,000 IU of heparin was administered for diagnostic angiography, whereas a total dose of 100 IU/kg was given in case of percutaneous coronary interventions. During diagnostic coronary procedures, the activated clotting time was not measured, whereas during percutaneous coronary interventions the activated clotting time values were tested in

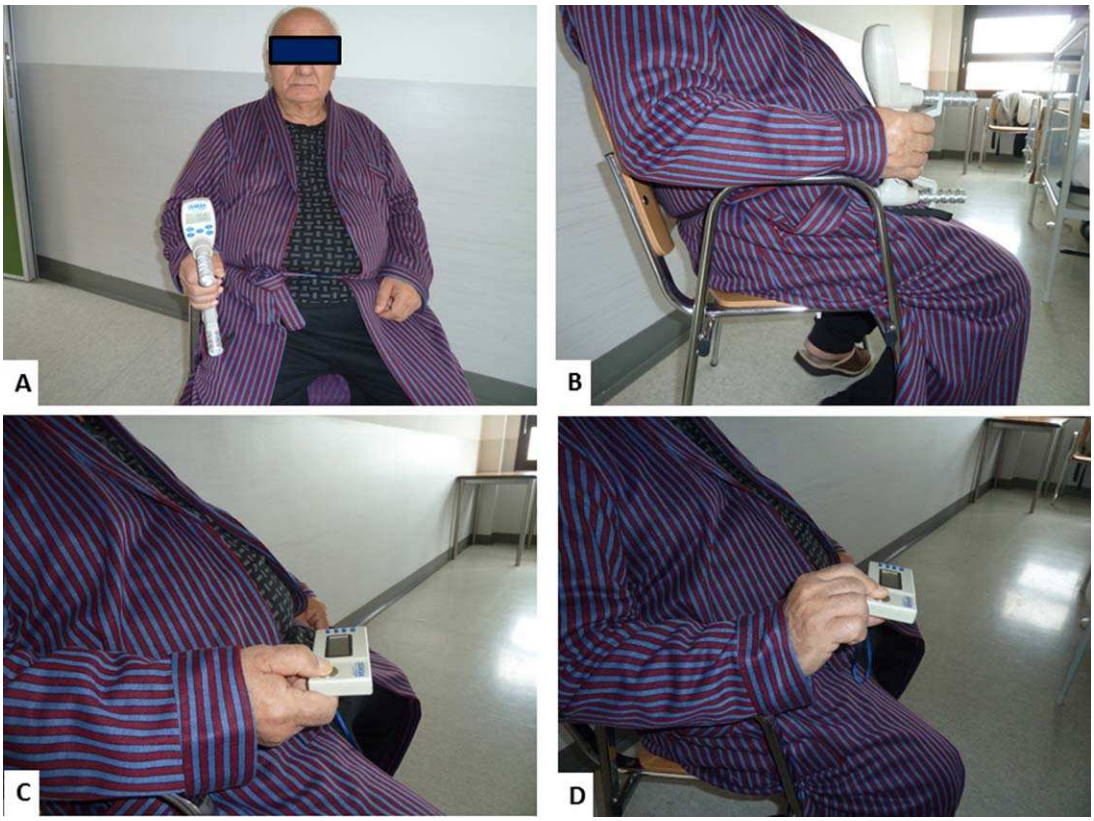

Fig. 1. Position taken by the patient while performing the hand grip test (panels A and B), the thumb pinch test (panel C), and the forefinger pinch test (panel D). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

all patients. An intra-arterial bolus of 2.5 mg verapamil was administered with short sheath use, whereas no spasmolytic drugs were used with long sheaths. After the procedures, radial sheaths were removed immediately, and a compression device (TR-Band, Terumo) was applied using the lowest compression sufficient to avoid bleeding. Hemostasis time was defined from the application of TR band to device removal, but the deflation of the device stared 1 hr after the procedure.

Statistical Analysis

Continuous variables for each of the two groups are reported as mean and standard deviation for variables normally distributed and as median with interquartile range (IQR) for those not normally distributed and were compared using Student's *t*-test or Mann–Whitney *U*-test as appropriate. Handgrip, thumb, and forefinger values at baseline, after procedure, and follow-up were analyzed by one-way repeated-measures analysis of variance. *Post hoc* comparisons were performed according to Bonferroni correction. Categorical variables are indicated as the absolute number and percentage and were compared by Pearson's χ^2 test or if the number expected of patients was less than 5, with the Fisher's exact test. A two-tailed *P*-value of ≤ 0.05 was considered statistically significant. All analyses were performed with SPSS 21.0 software (SPSS, Chicago, IL).

RESULTS

From a total of 108 patients enrolled, nine patients who could not complete the follow-up were excluded, thus obtaining a sample size of 99 patients. The reasons for exclusion before completion of follow-up were death (one case), procedural switch to femoral access (one case), and indication to coronary artery bypass surgery (seven cases). Of the 99 patients included in the analysis, 89 patients had a patent radial artery after the procedure, but at follow-up 90 patients had a patent radial artery (group 1) and nine (9.1%) patients had a persistent occluded radial artery (group 2). The rate of radial artery recanalization was 10%. The median time of follow-up was, respectively, 81 days (IQR, 60–110 days) and 86 days (IQR, 82–105 days, $P = 0.18$).

Clinical and procedural characteristics of the two populations are presented in Tables I and II. Compared with group 1, group 2 patients were significantly shorter, more frequently had a family history of

TABLE I. Clinical Characteristics

	Radial artery patent ($n=90$)	Radial artery occluded ($n=9$)	P-value
Age (years)	66 ± 11	64 ± 14	0.51
Male sex, *n* (%)	67 (74)	5 (56)	0.25
Height	167 ± 8	162 ± 8	0.04
Weight	79 ± 14	73 ± 9	0.17
BMI	28 ± 5	28 ± 4	0.85
Systolic blood pressure	136 ± 18	142 ± 32	0.44
Diastolic blood pressure	77 ± 10	77 ± 17	0.89
Heart rate	68 ± 12	69 ± 12	0.90
Current smoker, *n* (%)	16 (18)	4 (44)	0.08
Hypertension, *n* (%)	61 (68)	7 (78)	0.81
Diabetes, *n* (%)	32 (36)	1 (11)	0.26
Family history of CAD, *n* (%)	20 (22)	5 (56)	0.04
Dyslipidemia, *n* (%)	39 (43)	5 (56)	0.51
Peripheral vascular disease, *n* (%)	13 (14)	2 (22)	0.62
Previous MI, *n* (%)	17 (19)	3 (33)	0.38
Previous PCI, *n* (%)	17 (19)	3 (33)	0.38
Previous CABG, *n* (%)	3 (3)	0 (0)	0.75
Ischemic Allen test, *n* (%)	26 (29)	2 (22)	0.97

Results are expressed as mean ± standard deviation.
BMI: body mass index; CABG: coronary artery bypass grafting; CAD: coronary artery disease; MI: myocardial infarction; PCI: percutaneous coronary intervention.

TABLE II. Procedural Characteristics

	Radial artery patent ($n=90$)	Radial artery occluded ($n=9$)	P-value
Diagnostic coronarography, *n* (%)	65 (72)	5 (56)	0.51
PCI, *n* (%)	25 (28)	4 (44)	0.51
Procedure duration (min)	30 (20–45)	60 (40–60)	0.002
Fluoroscopy times (min)	4 (2–9)	10 (5–11)	0.044
Heparin dose (IU)	5,567 ± 1,241	6,000 ± 1,392	0.33
Catheters employed (*n*)	2 (2–3)	3 (2–3)	0.56
Hemostasis duration (h)	5.5 (5–6)	6 (5–6)	0.35
Systolic blood pressure	141 ± 24	133 ± 30	0.35
Diastolic blood pressure	77 ± 10	73 ± 9	0.27
Heart rate	69 ± 13	64 ± 9	0.22

Results are expressed as mean ± standard deviation or median with interquartile range.
PCI: percutaneous coronary intervention.

coronary artery disease, and had a trend to a higher rate of smoking habits (Table I).

There were no significant differences in the rate of ischemic Allen test between the two groups ($P=0.97$). According to the procedural characteristics, the occlusion of the radial artery was associated with a significantly longer procedure duration and fluoroscopy times (Table II). No significant differences were observed for heparin dose, the number of catheters used, hemostasis duration, blood pressure, and heart rate. At follow-up, no vascular complications were observed in both groups.

TABLE III. Hand Grip Test and Thumb and Forefinger Pinch Tests

	Radial artery patent ($n=90$)	Radial artery occluded ($n=9$)	P-value
Hand grip (peak values)			
Baseline	42 ± 11	41 ± 17	0.74
After procedure	40 ± 11	37 ± 17	0.51
Follow-up	43 ± 12	42 ± 19	0.94
Hand grip (mean values)			
Baseline	41 ± 11	39 ± 17	0.69
After procedure	39 ± 11	36 ± 16	0.40
Follow-up	41 ± 12	41 ± 19	0.90
Thumb pinch test (peak values)			
Baseline	8.2 ± 2.4	7.6 ± 2.4	0.50
After procedure	8 ± 2.4	7.1 ± 2.6	0.29
Follow-up	8.2 ± 2.5	7.4 ± 2.4	0.32
Thumb pinch test (mean values)			
Baseline	7.8 ± 2.3	7.3 ± 2.4	0.50
After procedure	7.6 ± 2.3	6.6 ± 2.6	0.25
Follow-up	7.8 ± 2.4	7 ± 2.3	0.35
Forefinger pinch test (peak values)			
Baseline	4.7 ± 1.2	4.6 ± 1.7	0.84
After procedure	4.6 ± 1.2	4.1 ± 1.6	0.31
Follow-up	4.7 ± 1.4	4.4 ± 1.6	0.43
Forefinger pinch test (mean values)			
Baseline	4.3 ± 1.1	4 ± 1.6	0.45
After procedure	4.3 ± 1.2	3.7 ± 1.4	0.15
Follow-up	4.4 ± 1.3	3.9 ± 1.5	0.30

Results are expressed in kilograms and as mean ± standard deviation.

Hand Grip Test

At baseline, there were no significant differences in hand grip test between the two groups (Table III). In both groups, the day after the procedure, the hand grip test values was significantly reduced compared with that of baseline (Fig. 2). Finally, at follow-up in both groups, the hand grip test values returned to baseline values (Fig. 2 and Table III). No differences were observed if patients were stratified according to the results of the Allen test.

Thumb and Forefinger Pinch Test

Also for thumb and forefinger pinch tests, there were no significant differences at baseline between the two groups (Table III). For both tests, after the procedure and at follow-up, there were no significant differences in values compared with that of baseline (Fig. 3 and Table III).

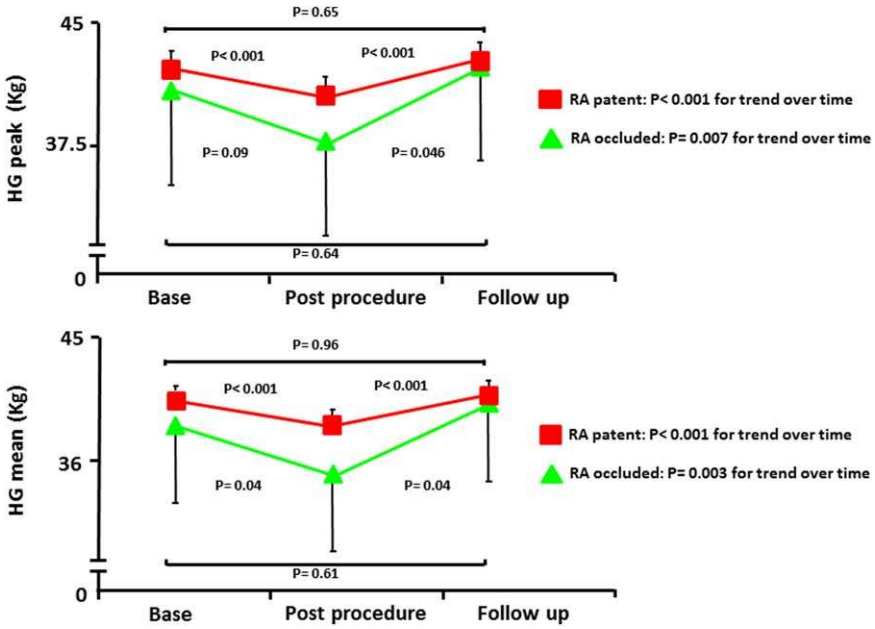

Fig. 2. Peak and mean values for hand grip test at baseline, after procedure, and follow-up in the two groups of patients. Results are expressed as mean ± standard error of mean. HG: hand grip; RA: radial artery. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

DISCUSSION

The main finding of our study is that chronic RAO after percutaneous coronary procedures is not associated with a reduction in hand grip strength or thumb and forefinger pinch. Moreover, in all patients (independently of radial artery patency or RAO), the transradial procedure was associated with a significant reduction in hand grip strength the day after, but this reduction disappeared at follow-up evaluation.

RAO is the most frequent complication after transradial percutaneous coronary procedure with variable incidence, which in some series reach 30% [4–8]. Although in most cases RAO is asymptomatic, there are some reports of major complications and a significant ischemia of the hand has been detected in a previous study [9]. Consequently, we cannot exclude that a chronic ischemia of the hand unnoticed by the patient might reduce the hand strength without evident clinical signs. The results of our study can exclude this possible complication even in the subgroup of patients with ischemic baseline Allen test.

In literature, there is only one study evaluating hand grip strength after transradial coronary procedures [12]. However, differently from our study, the RADAR investigators did not evaluated the hand grip test according to postprocedural occlusion of the radial artery. Moreover, another important difference is the inclusion in the RADAR study of patients with different clinical settings (at least 30% of patients with acute myocardial infarction). Consequently, it is possible that the baseline hand grip evaluation was biased from the clinical status of the patients and might explain the progressive increase over time of the hand grip strength. In our study, to exclude a possible clinical bias, we included only elective patients with chronic stable angina, and we observed a significant postprocedural reduction in hand grip strength in both groups (patent and occluded radial artery). The reason of this reduction in hand strength is probably due to procedural factors: in some patients, there was a local hematoma, and most patients were symptomatic for the recent radial puncture.

The hand grip strength has also been evaluated in patient with radial artery harvested for a coronary artery bypass [14]. According to our data in these patients at 1 year follow-up, there were no significant differences in hand grip strength compared with that of baseline.

In our study, the rate of RAO was 9%, which is in the range of that of previous studies, but higher compared with that of most recent studies. However, in all patients, we evaluated the radial occlusion using ultrasound examination, avoiding the underestimation of radial occlusion documented clinically that might be observed in some studies. Another possible explanation for the relatively high rate of radial occlusion is the moderately long hemostasis time observed in our patients.

Different factors have been identified as independent predictors of RAO, such as the diameter of the sheath

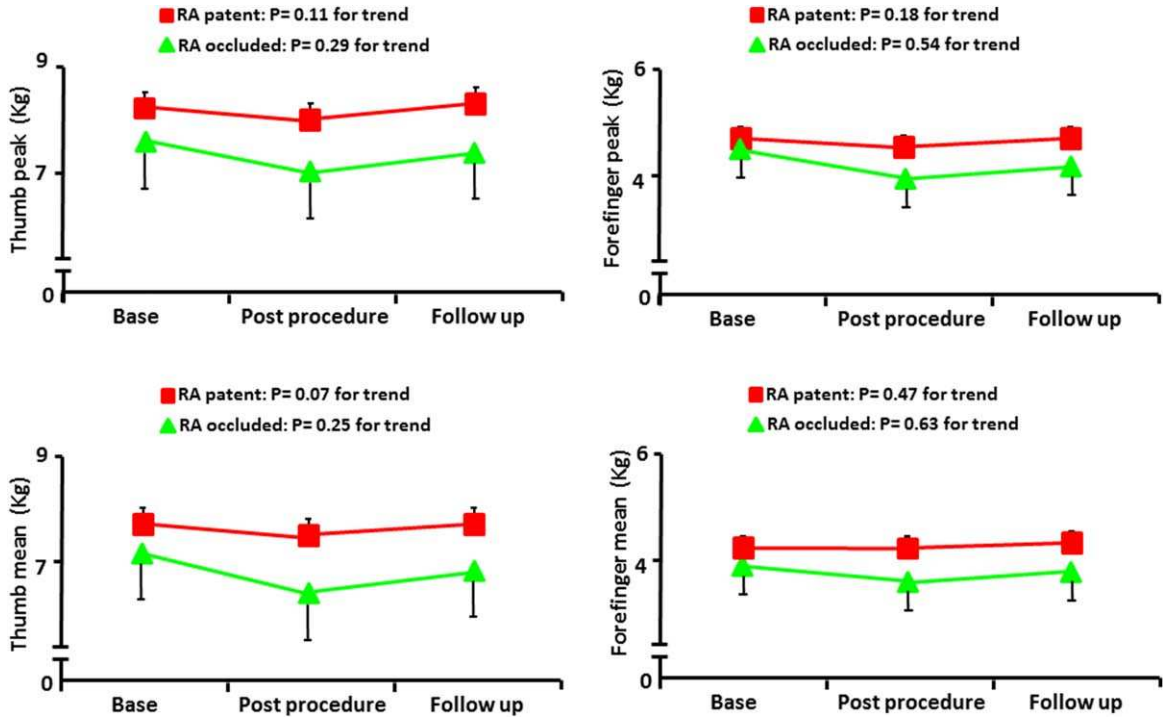

Fig. 3. Peak and mean values for thumb and forefinger pinch tests at baseline, after procedure, and follow-up in the two groups of patients. Results are expressed as mean ± standard error of mean. RA: radial artery. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

and its relationship to the size of the radial artery, the presence of anterograde flow in the artery during hemostasis, postprocedure compression time, female sex, and the use of anticoagulation [9,15–18]. In our study, patients with RAO were shorter, had more frequently history of ischemic heart disease, and the procedural duration was longer compared with that of patients with patent radial artery.

The issue of using or not the Allen test before transradial coronary procedures is an important topic for interventional cardiologists. The reason for the use of this test is based on the potential risk of ischemic complications of the hand due to periprocedural RAO. However, as documented in previous studies [11], in our study too, the results of the Allen test were not a predictor of ischemic complications of the hand in case of RAO. Considering that in our study, as in previous ones, more than 20% of patients had an ischemic test, a great number of patients could be inappropriately precluded from transradial approach. Larger randomized studies should test the validity of this examination in the screening of patients intended to transradial percutaneous coronary procedures.

Despite the absence of clinical sequelae associated with RAO documented in our study, interventional cardiologists should apply all efforts to avoid this complication. Indeed, these efforts should not be due for the fear of ischemic complications to the hands but because RAO may have significant implications for repeated catheterization procedures and for the availability of arterial conduits for surgical revascularization or hemodialysis fistulae. Consequently, minimizing radial injury should be a fundamental component of transradial procedures and can be obtained reducing vessel trauma with smaller catheters and reducing the risk of thrombus formation using adequate anticoagulation and limiting the hemostasis [7,16,18].

Our study has some limitations: first of all, it represents a single center experience with a limited number of patients enrolled, and we cannot exclude that increasing the number of enrolled patients may give different results. Moreover, the low number of patients with RAO excludes the possibility to determine whether specific subgroups of patients (as elderly, female, or diabetic) would have different results. Furthermore, we used a dynamometer that has not been previously validated in this setting of patients. Finally, we used the modified Allen test to stratify our patients, and we cannot exclude that the use of different test as the Barbeau test [13] may obtain different results.

In conclusion, in our study, RAO after percutaneous coronary procedures was not associated with a reduction in hand and finger strength independently to the results of the Allen test. Larger randomized studies

should test the validity of the Allen test in the screening of patients intended for transradial percutaneous coronary procedures.

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