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Changes in hand grip strength and associated factors after transradial coronary intervention: A longitudinal study

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ABSTRACT

Objectives: This study aims to evaluate hand grip strength following transradial coronary procedures and to identify main factors influencing these changes.

Patients and methods: Between December 2023 and March 2024, a total of 123 patients (92 males, 31 females; mean age: 63.0±9.2 years; range, 39 to 84 years) with stable angina pectoris who were scheduled for elective percutaneous transradial coronary intervention were included. Hand grip measurements were repeated one day after the transradial procedure and six months later. At six months of follow-up, the patients were divided into two groups based on the change in hand grip strength: those whose hand grip strength remained unchanged (n=84, Group 1) and those whose hand grip strength decreased (n=39, Group 2). The results were compared between the groups.

Results: At the end of the follow-up, 31.7% of the 123 patients had reduced hand grip strength. Radial artery occlusion (RAO) occurred in 8.9% of patients and was significantly associated with reduced grip strength at six months (p=0.013). Active smokers also showed a persistent reduction in hand grip strength at six months (p=0.003). Independent predictors of reduced grip strength included RAO (p=0.038), current smoking (p<0.001), and prolonged hemostasis band removal time (p=0.008).

Conclusion: Radial artery occlusion, current smoking, and prolonged hemostasis band removal time were identified as significant factors associated with the reduction in hand grip strength following the transradial approach. Recognizing these risk factors may help clinicians develop strategies to prevent hand function loss and support recovery more effectively.

Keywords: Hand function, hand grip strength, radial artery occlusion, transradial coronary intervention.

In recent years, the use of the transradial approach for percutaneous coronary procedures has been recommended due to the reduced risk of vascular complications and increased patient comfort.[1] However, the most common complication of the transradial approach is radial artery occlusion (RAO), with incidence rates ranging from 5 to 38%.[2-5] Although RAO is often considered a reversible complication following percutaneous transradial procedures, several previous reports have indicated that RAO may not be a minor side effect.[6] In addition, some patients with radial occlusion developed symptoms,[7] which can potentially lead to restricted hand function.

Hand grip strength can be easily and quantitatively measured using a hand dynamometer, with the Jamar hand dynamometer considered the gold standard for such assessments.[8,9] It is routinely used to assess neurological, muscular and skeletal disorders and to evaluate functional recovery following hand rehabilitation. While a previous study used hand dynamometry to assess short-term changes in hand grip strength in patients undergoing transradial percutaneous coronary procedures, focusing on post-procedural RAO-positive (+) and RAO-negative (–) groups,[10] no study has evaluated other factors that influence changes in hand grip strength yet.

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In the present study, we aimed to evaluate the factors which could influence changes in hand grip strength following transradial percutaneous coronary procedures.

PATIENTS AND METHODS

This single-center, longitudinal study was conducted at Bülent Ecevit University, Faculty of Medicine, Department of Cardiology between December 2023 and March 2024. We evaluated patients diagnosed with stable angina pectoris who were scheduled for elective percutaneous transradial coronary intervention. Exclusion criteria were as follows: hemodynamic instability, acute coronary syndromes, hemodialysis, or arteriovenous fistula, a sheath size other than 6-F, uncontrolled hypertension or diabetes, severe left ventricular dysfunction, contrast allergy, previous radial artery interventions, or musculoskeletal/neurological disorders that could potentially affect hand grip strength measurements. Of 140 patients who were initially found to be eligible, 123 (92 males, 31 females; mean age: 63.0±9.2 years; range, 39 to 84 years) who met the inclusion criteria were recruited. A written informed consent was obtained from each patient. The study protocol was approved by the Bülent Ecevit University Faculty of Medicine Ethics Committee (date: 04.09.2024, no: 2024/15). The study was conducted in accordance with the principles of the Declaration of Helsinki.

All patients were assessed on the morning of the procedure for radial and ulnar artery patency using the reverse Barbeau test (RBT), hand grip strength, thumb, and forefinger pinch strength. Hand grip measurements were repeated one day after the transradial procedure and six months later. At six months of follow-up, the patients were divided into two groups based on the change in hand grip strength: those whose hand grip strength remained unchanged (n=84, Group 1) and those whose hand grip strength decreased (n=39, Group 2). The results were compared between the groups.

Reverse Barbeau test

The RBT uses a pulse oximeter to display the plethysmographic waveform through a sensor placed on the thumb of the tested hand. Initially, both the radial and ulnar arteries are compressed simultaneously until the plethysmographic waveform disappears. The pressure on the radial artery is, then, released and the waveform is assessed. Four waveform patterns are identified: (A) no change in shape or amplitude (indicating no dumping), (B) slight dumping, (C) temporary loss of the waveform followed by its return within 2 min, and (D) permanent loss of the waveform. Type A, B and C waveforms are indicative of radial artery patency, D pattern demonstrates occlusion.[11]

Assessment of radial artery occlusion

The RAO was initially assessed in all patients using the RBT. In those presenting with pattern D, RAO was further confirmed by Doppler ultrasound with a multifrequency linear probe (L12-3, Philips, The Netherlands) performed the day after the transradial procedure and at six months of follow-up.

Transradial coronary catheterization procedure

Radial artery access was obtained using a 6-F radial sheath (Radifocus™, Terumo Europe N.V., Leuven, Belgium) following local anesthesia with 0.5 mL of 2% xylocaine under the routine procedure. Right or left radial access was left to the operator's discretion. For diagnostic angiography, 5,000 IU of heparin was administered, while a total dose of 100 IU/kg for percutaneous coronary intervention was used. Activated clotting time (ACT) was not measured during diagnostic coronary angiographies, but ACT values were tested in all patients undergoing percutaneous coronary interventions. In all radial procedures, 100 µg of glyceryl trinitrate were administered intra-arterially at the start of the procedure as an antispasmodic agent. After the procedures, the radial sheaths were immediately removed, and a compression device (TR Band™, Terumo Europe N.V., Leuven, Belgium) was applied with minimal compression necessary to prevent bleeding. Deflation of the compression device was initiated 15 min after removing the radial sheath and placing the compression device. Hemostasis time was defined as the time from TR Band™ application to device removal.

Hand grip strength assessment

Hand grip strength was measured using a Jamar hand dynamometer (Sammons Preston, Bolingbrook, IL, USA) following the well-established Southampton protocol based on the recommendations of the American Society of Hand Therapists (ASHT).[12] All measurements were performed on the radial procedure arm by a physical medicine and rehabilitation specialist, starting prior to the radial

Figure 1. Position of the patient during the hand grip test.

procedure. The patient was seated comfortably in a standardized chair with fixed legs, back support, and armrests. The forearm rested on the chair's armrest with the wrist in a neutral position and the thumb facing upwards. The patient was instructed to squeeze the dynamometer as long and tightly as possible while the examiner encouraged maximum effort (Figure 1). Three attempts were made in each session, and the highest score was used for statistical analysis. The same procedure was repeated one day after the procedure and again at six months of follow-up.

The primary endpoint of the study was the change in hand grip strength from baseline (pre-procedure) to six months post-procedure, measured with a hand dynamometer. The secondary endpoint was the detection of RAO during follow-up.

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 26.0 software (IBM Corp., Armonk, NY, USA). Continuous data were expressed in mean ± standard deviation (SD) or median and interquartile range (IQR), while categorical data were expressed in number and frequency. The normality of the distribution of parameters was assessed using the Kolmogorov-Smirnov test. The Pearson chi-square test or Fisher exact test was used to analyze categorical variables. Comparisons were made using Student t-test or Mann-Whitney U-test. Baseline, post-procedural, and follow-up hand grip strength values were analyzed according to RAO and smoking status using the Wilcoxon test (Figure 2). Univariate and multivariate logistic regression analyses were conducted to identify

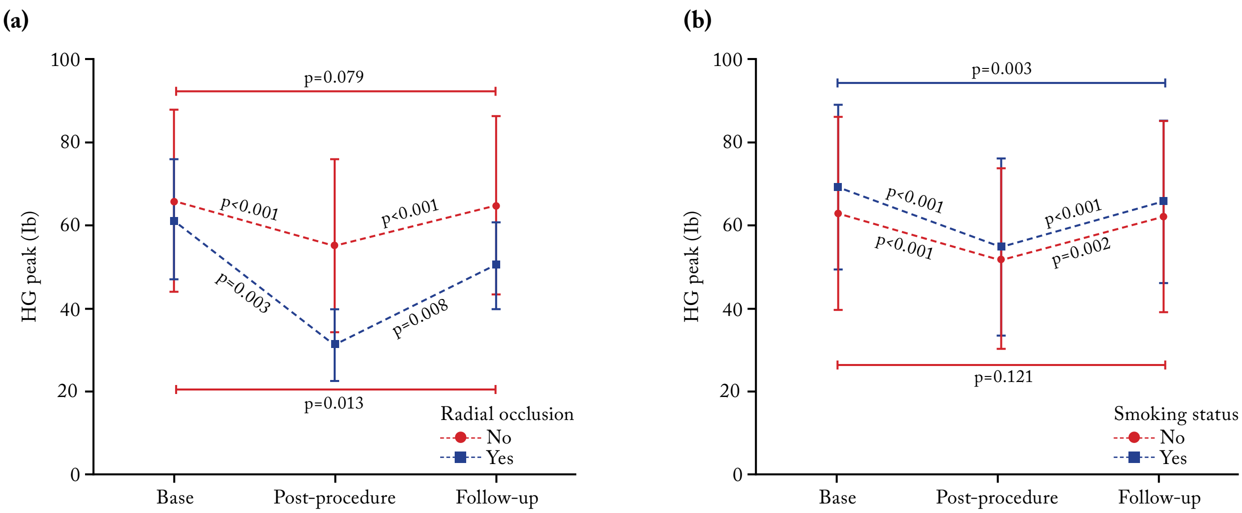

Figure 2. **(a)** Comparison of maximum hand grip strength values at baseline, post-procedure, and six-month follow-up in patients with RAO and those without. **(b)** Comparison of maximum hand grip strength values at baseline, post-procedure, and six-month follow-up in current smoker and non-smoker patient groups.

HG: Hand grip test; lb: Pound-force; RAO: Radial artery occlusion.

predictors of decreased hand grip strength. Variables with a *p* value of <0.1 in the univariate analysis were included in the multivariate model to identify independent predictors. A two-tailed *p* value of <0.05 was considered statistically significant.

RESULTS

Of the 123 patients included in the analysis, 84 (68.3%) showed no change in hand grip strength six months after the procedure compared to baseline (Group 1), while 39 (31.7%) experienced a decrease in hand grip strength (Group 2). The mean follow-up was 187±14.3 days and 184.1±14.7 days, respectively (p=0.310).

Clinical and procedural characteristics of the two groups are shown in Tables 1 and 2. Group 2 patients were predominantly male (89.7%) and had a significantly higher smoking rate (82.1%) compared

Table 1
Baseline characteristics and smoking habits in relation to changes in hand grip strength at 6-month follow-up

	Group 1 (n=84)			Group 2 (n=39)			
Variables	n	%	Mean±SD	n	%	Mean±SD	*p*
Age (year)			63.4±9.3			62.1±9.0	0.445
Sex							0.009
Male	57	67.9		35	89.7		
Body mass index (kg/m^2)			28.7±4.9			29.0±4.2	0.509
Systolic blood pressure (mmHg)			139.0±19.9			135.7±20.6	0.392
Diastolic blood pressure (mmHg)			83.9±10.3			84.1±11.4	0.895
Heart rate (bpm)			77.7±13.5			74.9±13.2	0.294
Current smoker	28	33.3		32	82.1		<0.001
Diabetes mellitus	44	52.4		17	43.6		0.364
Hypertension	50	59.5		24	61.5		0.832
Chronic kidney disease	16	19.0		3	7.7		0.105
Thyroid disease	10	11.9		3	7.7		0.479
Dyslipidemia	44	52.4		18	46.2		0.520
Peripheral artery disease	8	9.5		5	12.8		0.580
Previous PTCA	17	20.2		12	30.8		0.200
Previous CABG	13	15.5		7	17.9		0.729
Medications							
Acetylsalicylic acid	65	77.4		30	76.9		0.955
P2Y12 inhibitor	19	22.6		11	28.2		0.502
Oral anticoagulant	10	11.9		4	10.3		0.789
ACEi/ARB	43	51.2		25	64.1		0.180
SGLT2i	34	40.5		14	35.9		0.628
Mineralocorticoid receptor antagonist	9	10.7		2	5.1		0.312
Diuretic	38	45.2		12	30.8		0.128
Calcium channel blocker	26	31.0		12	30.8		0.984
Beta blocker	39	46.4		15	38.5		0.407
Oral nitrate	16	19.0		6	15.4		0.622
Statin	38	45.2		13	33.3		0.212

SD: Standard deviation; bpm: Beats per minute; PTCA: Percutaneous transluminal coronary angioplasty; CABG: Coronary artery bypass grafting; ACEi/ARB: Angiotensin-converting enzyme inhibitor/angiotensin receptor blocker; SGLT2i: Sodium-glucose co-transporter 2 inhibitor.

Table 2
Comparison of procedural characteristics between groups with and without changes in hand grip strength

	Group 1 (n=84)					Group 2 (n=39)					
Variables	n	%	Mean±SD	Median	Min-Max	n	%	Mean±SD	Median	Min-Max	*p*
Diagnostic CAG	67	79.8				34	87.2				0.318
PTCA	32	38.1				22	56.4				0.057
Normal coronary arteries	16	19.0				0	0				-
Non-obstructive CAD	36	42.9				14	35.9				0.465
Quantity of opaque material (mL)				75.0	47.0-120.0				98.0	52.0-160.0	0.038
Radial sheath duration (min)				22.0	14.0-37.0				37.0	14.0-55.0	0.027
Fluoroscopy times (min)				17.0	7.6-24.5				21.0	11.0-41.0	0.016
Number of catheters used				2	2-3				3	2-3	0.009
Hemostasis band inflation volume (mL)			15.5±1.3					15.6±1.3			0.875
Hemostasis band removal time (min)			151.5±23.2					171.7±26.6			<0.001
Heparin dose (IU)				5,000	5,000-8,875				9,500	5,000-10,000	0.003
Intra-arterial SBP (mmHg)			126.1±24.8					123.5±22.6			0.567
Intra-arterial DBP (mmHg)			77.5±16.9					76.9±13.3			0.835
Heart rate (bpm)			83.0±14.8					80.5±15.0			0.377
Barbeau test D pattern	2	2.4				9	23.1				<0.001
Radial artery occlusion	2	2.4				9	23.1				<0.001

SD: Standard deviation; CAG: Coronary angiography; PTCA: Percutaneous transluminal coronary angioplasty; CAD: Coronary artery disease; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; bpm: Beats per minute.

to Group 1. There was no significant difference between the two groups in terms of body mass index (BMI), diabetes mellitus, hypertension, peripheral arterial disease or medication use (p>0.05 for all) (Table 1).

Patients with decreased handgrip strength had longer radial sheath duration (p=0.027), a higher number of catheters used (p=0.009), and longer hemostasis band removal time (p<0.001) compared to those without changes in handgrip strength. No significant differences were observed in intraoperative blood pressure or heart rate between the groups (Table 2).

Effect of radial artery occlusion and smoking status on hand grip strength

Radial artery occlusion occurred in 8.9% of patients (n=11) during follow-up. Patients were divided into two groups according to RAO status: RAO (–) and RAO (+). At baseline, hand grip strength was similar between the two groups (Table 3). However, the RAO (+) group experienced a significant decrease in grip strength immediately after the intervention (p=0.003), which persisted at six months of follow-up (p=0.013). In contrast, the RAO(-) group also showed a temporary decrease in hand grip strength after the procedure, but values recovered by the six-month follow-up (p=0.079) (Figure 2).

Similarly, current smokers showed a significant reduction in hand grip strength post-procedure (p<0.001), which was still evident at six months (p=0.003). Non-smokers also experienced an initial decrease in grip strength, but their values returned to baseline by the six-month follow-up (p=0.121) (Figure 2).

Independent predictors of decreased hand grip strength

Logistic regression analysis identified RAO, current smoking, and hemostasis band removal time as independent predictors of decreased hand grip strength after transradial intervention (p<0.001; p=0.008; and p=0.038, respectively) (Table 4).

Table 3
Comparison of hand grip strength at baseline, post-procedure and six months by RAO status

	RAO (–) (n=112)		RAO (+) (n=11)		
	Median	Min-Max	Median	Min-Max	*p*
Hand grip test (peak values)					
Baseline	62.5	50.0-80.0	64.0	52.0-75.0	0.756
Post-procedure	54.0	40.0-70.0	30.0	25.0-38.0	<0.001
Six-month follow-up	60.0	50.0-80.0	52.0	44.0-58.5	0.027

RAO: Radial artery occlusion.

Table 4
Predictors of decrease in hand grip test after transradial intervention

	Univariate analysis			Multivariate analysis		
	OR	95% CI	*p*	OR	95% CI	*p*
Age (year)	0.984	0.944-1.025	0.442			
Sex						
Female	4.145	1.337-12.847	0.014			
Current smoker (Ref. no)	9.143	3.589-23.294	<0.001	6.041	2.233-16.342	<0.001
Hemostasis band removal time (min)	1.034	1.016-1.051	<0.001	1.026	1.007-1.045	0.008
Heparin dose (IU)	1.000	1.000-1.002	0.005			
Radial sheath duration	3.094	1.402-6.827	0.005			
RAO (Ref. no)	12.300	2.513-60.209	0.002	5.781	1.003-30.292	0.038

RAO: Radial artery occlusion; Ref: reference; R^2=0.397.

DISCUSSION

In the present study, we evaluated the factors which could influence changes in hand grip strength following transradial percutaneous coronary procedures. The main finding of our study is that RAO, current smoking and prolonged hemostasis band removal time were independent predictors of reduced hand grip strength after transradial coronary interventions. Furthermore, in all patients, regardless of radial artery patency or RAO, the transradial procedure was associated with a significant reduction in hand grip strength on the day after the procedure. However, by the sixth month of follow-up, this decrease disappeared in RAO (–) patients, whereas it remained significant in patients with RAO (+).

Previous studies such as the Hand Grip Test After Transradial Percutaneous Coronary Procedures (HANGAR) and Coronary Arteriography with Radial Access in Coronary Acute Disease and its Relation with Handgrip Strength and Radial Artery Permeability (CARHANG) trials measured the loss of hand grip strength after transradial intervention.[10,13] However, these studies did not identify factors that predict loss of hand grip strength. The Effects of Transradial Percutaneous Coronary Intervention on Upper Extremity Function (ARCUS) interim report, involving a sample of 191 patients, also demonstrated upper extremity dysfunction following transradial intervention, but relied on questionnaire-based scales.[14] In contrast, our study utilized a hand dynamometer to objectively measure hand grip strength and employed the RBT to assess hand ischemia before the procedure, one day after, and at six months of follow-up.

Radial artery occlusion is the most common complication after transradial percutaneous coronary intervention.[3,5,15] Although RAO is asymptomatic in most cases,[15] significant cases of hand ischemia have been reported. To illustrate, Rhyne and Mann[4] described a case requiring radial artery angioplasty to correct hand ischemia, while another report documented acute hand ischemia in a patient with Raynaud's disease complicated by thrombosis.[16] Additionally, a previous study found that patients with an abnormal Allen test after 30 min of radial occlusion exhibited elevated thumb capillary lactate levels, indicating ischemia.[17] Chronic hand ischemia, even in the absence of overt clinical symptoms, cannot be ruled out as a contributing factor to reduced hand grip strength. In line with this, our study suggests that RAO-related ischemia may play a significant role in the observed decrease in hand grip strength after transradial interventions.

In the current study, hand grip strength decreased in 39 patients, only nine of whom had RAO. Among patients without RAO, current smoking emerged as a potential factor contributing to grip strength reduction. Notably, 82.1% of patients with reduced grip strength were smokers. Smoking, a well-established modifiable risk factor for cardiovascular disease and atherosclerosis, is associated with impaired endothelium-dependent arterial dilation, reflecting endothelial dysfunction.[18-20] Heiss et al.[21] demonstrated that active smokers undergoing transradial coronary catheterization experienced more pronounced endothelial dysfunction due to mechanical irritation from the catheter, along with a slower recovery compared to non-smokers. These findings also align with our results, suggesting that active smoking may impair vascular and functional recovery, thereby contributing to the reduction in hand grip strength observed in patients without RAO.

Sheath removal after transradial catheterization typically involves external compression, achieved through either a simple bandage or specialized hemostatic devices at the insertion site. However, prolonged compression, regardless of the method used, is associated with complications such as deep vein thrombosis or chronic regional pain syndrome and significantly increases the risk of RAO.[22,23] In our study, prolonged hemostasis band removal time was identified as an independent predictor of decreased hand grip strength, suggesting that extended compression durations may adversely affect hand function recovery. While the exact mechanism remains unclear, it is hypothesized to be of vascular origin, with prolonged blood flow interruption potentially leading to stasis and local thrombus formation.[3] There was no significant difference in the inflation volume of the hemostatic band between the groups with and without reduced hand grip strength, likely as the inflation volume was adjusted to achieve bleeding control rather than using a fixed amount. However, radial sheath duration was longer and the number of catheters used was higher in patients with reduced grip strength.

Decreased hand grip strength has been suggested as a potential predictor of future disability, morbidity and mortality, with significant systemic implications.[24] The Prospective Urban Rural Epidemiologic (PURE) study also showed an association between reduced hand grip strength and both cardiovascular and non-cardiovascular mortality, as well as the development of cardiometabolic disease.[25] These findings suggest that it may be useful to identify patients at risk of clinically significant reduction in hand grip strength after transradial coronary angiography. Patients with low baseline hand grip strength, active smoking, or a predisposition to RAO may require closer monitoring. To preserve post-procedural hand function, strategies such as minimizing procedure duration, reducing the number of catheters used, and deflating the hemostasis band as early as possible can be considered.

Nonetheless, this study has several limitations: First, it reflects the experience of a single center with a relatively limited number of patients, which may preclude the generalizability of the findings to broader populations. In addition, the small number of patients with RAO limits our ability to explore whether specific subgroups might have different patterns of hand grip strength recovery. There is potential for selection bias, as we included only elective patients with stable angina, excluding those with more severe coronary conditions or acute presentations. This may have influenced the outcomes, particularly in terms of hand function recovery. Another limitation is the absence of a standardized pain scale, which could have provided valuable insight into the relationship between procedural discomfort, post-procedural upper extremity pain, and recovery of hand function.

In conclusion, our study results highlight the significant impact of RAO, active smoking and procedural characteristics, particularly prolonged hemostasis band removal time, on the reduction of hand grip strength after transradial coronary intervention. Recognizing these risk factors may help clinicians develop strategies to prevent hand function loss and support recovery more effectively. Further well-designed, multi-center, large-scale, long-term studies are needed to draw more definite conclusions on this subject.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Conseptualsation and writing: I.E., N.E.G., U.K., P.A., S.O.C., A.A.; Conceptualisation: I.E., S.O.C., A.A.; Data curation: I.E., N.E.G., H.O., B.H., S.O.C.; Methodology: I.E., P.A., S.O.C, A.A.; Methodology and writing: All authors.

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