

SHORT REPORT

# Association Between Preoperative Palmar Arch Velocity on Duplex Ultrasonography and Ischemic Hand Symptoms After Radial Artery Harvest



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## ABSTRACT

**BACKGROUND** Duplex ultrasonography is often used to assess radial artery suitability for coronary artery bypass grafting, but clear guidelines for its usage are lacking. This study investigates the association between preoperative arterial velocity characteristics and postoperative ischemic hand symptoms after endoscopic radial artery harvest.

**METHODS** We performed a retrospective review of 584 patients who underwent coronary artery bypass grafting with a radial artery graft from 2016 to 2023. Using preoperative duplex ultrasonography, patients were categorized based on their palmar arch reversal velocity during radial artery occlusion: normal (>20 cm/s), marginal (10–20 cm/s), or low (<10 cm/s). The primary outcome was any report of ischemic hand symptoms (pain, weakness, or sensation loss) at the 30-day postoperative follow-up.

**RESULTS** Of the 584 patients, 421 (72.1%) had normal flow, 139 (23.8%) had marginal flow, and 24 (4.1%) had low flow. The overall incidence of ischemic hand symptoms at 30 days was low at 5.8% (34 patients). There was no significant association between preoperative palmar arch reversal velocity and postoperative symptoms (odds ratio, 1.56 for combined marginal/low flow vs normal; 95% CI, 0.84–2.85). No ischemic events requiring intervention occurred. On multivariable analysis, only diabetes was associated with an increased risk of symptoms (odds ratio, 1.98; 95% CI, 1.11–3.59).

**CONCLUSIONS** Low palmar arch reversal velocity on preoperative duplex ultrasonography was not associated with an increased risk of hand ischemia after radial artery harvest. These findings suggest that harvesting the radial artery is safe in patients with marginal or even low flow, provided ulnar collateral circulation is adequate.

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The radial artery is a class I indication during coronary artery bypass grafting (CABG) due to its higher patency, greater endurance, and better short- and long-term outcomes compared with the saphenous vein.<sup>1-3</sup> However, one concern with the use of the radial artery is the possibility of patients developing ischemia or ischemic symptoms in the hand of

their harvested radial CABG if their ipsilateral ulnar artery cannot adequately compensate. Though severe hand ischemia after radial artery

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harvest has been infrequently reported in the literature, symptoms associated with inadequate hand perfusion have been documented. In various studies examining postoperative complications after radial artery harvest, around 10% of patients developed mild hand ischemia, 3% of patients developed paresthesia, and between 6.5% and 21.3% of patients had hand pain and numbness at 3 months postoperation.<sup>4-6</sup>

The Allen test is a commonly used preoperative screening method to assess the suitability of the radial artery for harvest. Due its high false-positive rates,<sup>6</sup> some institutions utilize duplex ultrasonography for radial artery assessment, which can be a more precise preoperative technique to identify palmar arch flow and anatomical abnormalities.<sup>6,7</sup> However, there are currently no clear guidelines for the use of duplex ultrasonography to determine a radial artery's suitability for CABG. Furthermore, no study has been published to determine whether these measurements can predict potential postoperative ischemic hand symptoms. As such, we sought to determine the association between preoperative arterial flow duplex ultrasonography measurements and postoperative ischemic hand events.

## PATIENTS AND METHODS

We performed a retrospective cohort study of patients who underwent a CABG with endoscopic radial artery harvest at 2 hospitals in the same academic medical system from January 2016 through June 2023. Patient data were obtained from the institutional Society of Thoracic Surgeon registry data and patient medical records.

Ischemic symptoms were obtained from review of each patient's medical record. We defined an ischemic symptom as a report of weakness, sensation loss, or pain in the ipsilateral hand from which the radial artery was harvested. We did not record pain at the incision as an ischemic event. Also, a report of these symptoms in both hands simultaneously or on the contralateral hand were not considered reasonably attributable to the radial artery harvest. Patient records were reviewed for reports of ischemic symptoms at both their postoperative in-hospital summary and at their 30-day follow up visit.

Preoperative radial, ulnar, and palmar arch arterial diameters and flow characteristics were obtained from preoperative duplex ultrasonography reports. All duplex ultrasonography

## IN SHORT

- The incidence of ischemic hand symptoms after endoscopic radial artery harvest for coronary artery bypass grafting is very low. In a cohort of 584 patients, only 5.8% experienced minor symptoms, and no severe ischemic events requiring intervention occurred.
- Preoperative palmar arch flow reversal velocity, as measured by duplex ultrasonography, does not predict postoperative ischemic symptoms. Therefore, low or marginal flow rates should not be considered an absolute contraindication to radial artery harvest when adequate ulnar collateral circulation is present.

measurements were obtained by vascular technicians. Patients with missing duplex ultrasonography reports were excluded. Because our institution does not utilize the Allen test to assess radial artery suitability, the Allen test could not be evaluated in comparison to duplex ultrasonography.

Patients were categorized as normal flow if their palmar arch velocity after radial artery occlusion was  $>20$  cm/s, as marginal flow if greater than or equal to 10 cm/s and less than or equal to 20 cm/s, and low flow if  $<10$  cm/s. Patients were categorized in this way, because, historically, at our institution surgeons would not harvest the radial artery if flow was  $>20$  cm/s.

Single-factor analysis of variance tests were used to compare continuous cohort characteristics between the 3 comparator groups. Multivariable logistic regression modeling was used to analyze the association of postoperative ischemic symptoms with both flow group and palmar arch velocity after radial artery occlusion and other clinical and flow characteristics. This study was approved by the University of Pennsylvania institutional review board (855836).

## RESULTS

From January 2016 to June 2023, 584 patients underwent CABG with endoscopic radial artery harvest. The primary outcome, ischemic hand symptoms at 30 days post operation, was reported by only 34 patients (5.8%). No instances of severe hand ischemia requiring intervention were recorded.

Of the 584 patients, 422 (72.3%) were classified as normal flow, 139 (23.8%) as marginal flow, and 23 (3.9%) as low flow based on preoperative palmar arch velocity after radial artery occlusion measurements (Supplemental Table 1). Table 1

**TABLE 1 Preoperative Duplex Ultrasonography Flow Characteristics**

Flow Characteristics	Normal (> 20 cm/s)	Marginal (10-20 cm/s)	Low Flow (<10 cm/s)	P Value
Number (%) of patients	422 (72.3)	139 (23.8)	23 (3.9)	
Palmar arch velocity, cm/s	63.3	44.1	35.8	< .001
Reversal palmar arch velocity w/ radial occlusion, cm/s	42.6	15.4	9.2	< .001
Percent change palmar arch velocity w/ radial occlusion	-24.6	-60.0	-68.9	< .001
Ulnar velocity, cm/s	71.5	64.0	54.6	<.001
Ulnar velocity w/ radial occlusion, cm/s	102.5	91.0	73.6	< .001
Percent ulnar velocity augmentation w/ radial occlusion	45.1	43.5	40.4	.7
Radial artery velocity, cm/s	73.4	65.5	57.5	< .001
Proximal radial diameter, cm	0.3	0.3	0.3	.9
Mid radial diameter, cm	0.3	0.3	0.3	.9
Distal radial diameter, cm	0.4	0.3	0.3	.8

shows the flow characteristics for each group. The average reversal of palmar arch velocity with radial artery occlusion for each group was 42.6 for normal flow, 15.4 for marginal flow, and 9.2 for the low flow groups. There was no difference in the diameter for the radial artery between groups. Patients in the low flow group had the largest decrease in reversal of palmar arch velocity with radial artery occlusion of -68.9% as compared with normal flow (-24.6%) and marginal flow patients (-60.0%). Furthermore, we found no statistical difference in ulnar velocity augmentation with radial occlusion between the three patient groups (Table 1).

Among the 584 patients, 59 (10.1%) patients reported ischemic symptoms either during their index hospitalization or at the 30-day postoperative visit and had the following breakdown among flow categories: 39 (9.2%) normal flow patients, 19 (13.7%) marginal flow patients, and 1 (4.4%) low flow (Table 2). Of these, 34 (5.8%) of the patients complained of an ischemic hand symptom at the 30-day postoperative visit. Loss

of sensation was the most common reported ischemic symptom, followed by weakness, and then pain. There were no reports of severe hand ischemia in any patient requiring treatment or intervention.

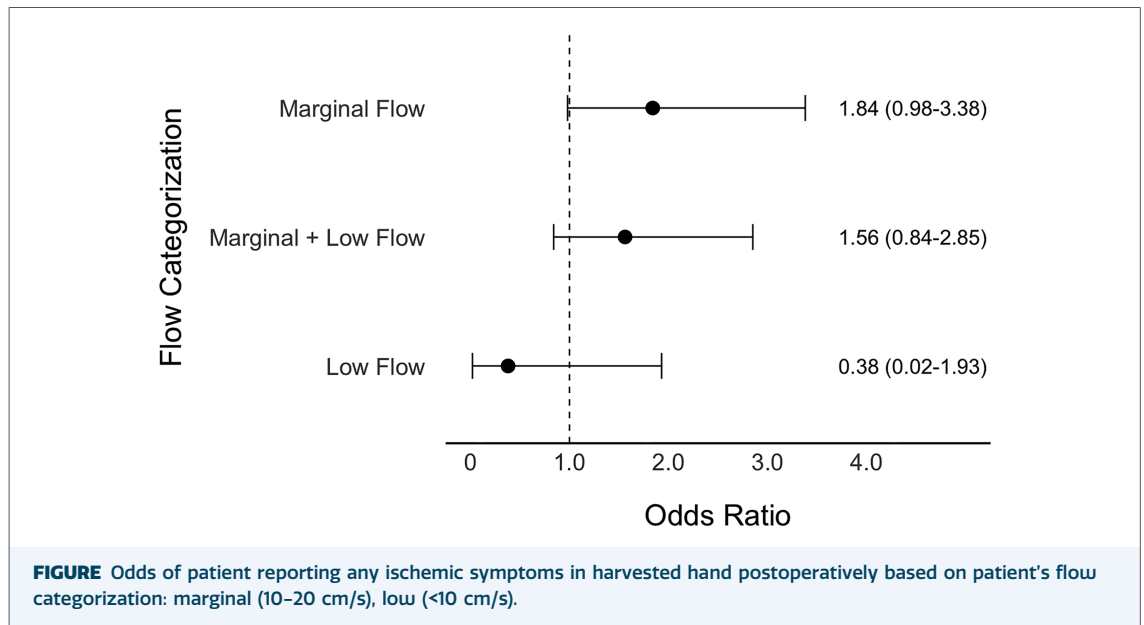
There was no statistically significant association between a patient's flow categorization and the reporting of ischemic symptoms post-operation (Figure). As compared to patients categorized as normal flow, marginal flow patients (odds ratio [OR], 1.84; 95% CI, 0.98-3.38) and marginal flow and low flow patients compositely (OR, 1.56; 95% CI, 0.84-2.85) had no statistical difference in the odds of reporting an ischemic symptom. There was similarly no significant difference between the low flow patients and normal flow patients (OR, 0.38; 95% CI, 0.02-1.93).

Furthermore, in a multivariable logistic regression model that included all patients, preoperative palmar arch reversal velocity after radial artery occlusion was not associated with increased risk of ischemic hand symptoms (OR,

**TABLE 2 Postoperative Ischemic Graft Hand Symptoms Count by Flow Category**

Hand Symptoms	Normal (> 20 cm/s) n = 422	Marginal (10-20 cm/s) n = 139	Low Flow (<10 cm/s) n = 23
<b>Postop in-hospital ischemic symptoms<sup>a</sup></b>	18 (4.3)	8 (5.8)	1 (4.4)
Sensation loss	15 (3.6)	5 (3.6)	1 (4.4)
Weakness	3 (0.7)	3 (2.2)	0
Pain	0	0	0
<b>Postop 30-d ischemic symptoms<sup>a</sup></b>	22 (5.2)	12 (8.6)	0
Sensation loss	19 (4.5)	9 (6.5)	0
Weakness	5 (1.2)	4 (2.9)	0
Pain	2 (0.5)	2 (1.4)	0
<b>Patients with severe hand ischemia</b>	0	0	0
<b>Patients with any event</b>	39 (9.2)	19 (13.6)	1 (4.4)

<sup>a</sup>Multiple ischemic symptoms were only counted once for the composite "ischemic symptoms" count. Values are presented as n (%).



1.02; 95% CI, 1.00-1.03). The only patient variable associated with ischemic hand symptoms was diabetes (OR, 1.98; 95% CI, 1.11-3.59) (Table 3).

#### COMMENT

More evidenced-based standards are necessary to ensure that surgeons are properly evaluating radial artery suitability to minimize potential postoperative hand complications. The results of our study support existing literature that demonstrate radial artery harvesting leads to a low event rate of ischemic symptoms postoperatively.<sup>4-6</sup> Furthermore, there was no significant evidence that decreased palmar arch reversal velocity with radial artery occlusion is associated with ischemic symptoms postoperatively.

In our cohort, patients categorized as low or marginal flow were not associated with increased odds of reporting ischemic symptoms in their graft hand, which suggests that low baseline preoperative flow may not be a risk factor itself. Though our analysis did not identify an association between ulnar augmentation and postoperative ischemic symptoms, past studies have found that an ulnar augmentation lower than 20% is associated with ill-suited radial candidates and disappearance of superficial palmar arch velocity.<sup>8,9</sup> In our study, there was no significant difference in ulnar arterial velocity augmentation among the 3 flow categories. Based on this study and previous literature, we recommend that the ulnar augmentation is at least 20% with radial

artery occlusion. However, further studies specifically assessing patients with lower ulnar velocity augmentation and its association with postoperative ischemic hand are necessary to empirically identify a benchmark for future guidelines.

**LIMITATIONS.** Ischemic hand symptoms are not a common discussion point during CABG follow-up,

**TABLE 3 Association of Risk Factors With Reporting Unilateral Ischemic Symptoms in Grafting Hand 3 (N = 576<sup>a</sup>)**

Risk Factor	Odds Ratio	95% CI	P Value
Age	1.00	0.96-1.05	.89
Female sex	0.433	0.10-1.27	.18
Hypertension	0.74	0.37-1.56	.40
Prior MI	0.76	0.41-1.38	.38
Heart failure	0.99	0.49-1.90	.98
Peripheral artery disease	0.148	0.01-0.72	.06
Chronic obstructive pulmonary disease	0.59	0.16-1.63	.35
Diabetes	1.98	1.11-3.59	.02
Current smoker	1.86	0.68-4.80	.21
Palmar arch velocity w/ radial occlusion <sup>b</sup>	1.02	1.00-1.03	.06
Ulnar velocity w/ radial occlusion <sup>b</sup>	1.00	0.99-1.01	.41
Ulnar velocity augmentation w/ radial occlusion <sup>b</sup>	1.00	0.99-1.01	.62

<sup>a</sup>Eight observations dropped due to incomplete duplex ultrasonography studies; <sup>b</sup>Describes the odds per standard deviation decrease in these preoperative flow measurements. MI, myocardial infarction.

likely leading to underreporting. Similarly, our study did not use an objective measurement of hand function. A future clinical study measuring objective metrics of hand function, such as grip strength, after radial harvested CABG could augment our findings. Lastly, the relatively small number of patients categorized as low flow (n = 23) may have limited our ability to determine significant differences with this group.

**CONCLUSIONS.** We found no evidence that low or marginal palmar arch flow on preoperative duplex ultrasonography is associated with an increased risk of postoperative hand ischemia after endoscopic radial artery harvest. The overall incidence of ischemic symptoms was low, and no

severe events occurred. These results suggest that these patients can safely undergo a radial artery harvest during their CABG procedure without increased risk of ischemic complications or symptoms when ulnar augmentation is adequate.

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#### DISCLOSURES

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## Duplex Assessment for Radial Artery Harvest



### INVITED COMMENTARY:

The radial artery (RA) is an excellent second arterial conduit for coronary artery bypass grafting (CABG), with superior long-term patency compared with the saphenous vein and a consistent, albeit gradual, increase in adoption.<sup>1,2</sup> Although true ischemic complications after RA harvesting are rare, even transient paresthesia, weakness, or pain may interfere with daily activities and affect postoperative quality of life. Although many surgeons still rely on the Allen

test, its limitations, including imprecision and a high false-positive rate, are well recognized. Duplex ultrasonography provides an objective evaluation of palmar arch flow and arterial anatomy, but its use remains inconsistent, and clearly defined thresholds for RA suitability are lacking.

In this issue of *The Annals of Thoracic Surgery*, Szeto and colleagues<sup>3</sup> report an analysis of 584 patients who underwent preoperative duplex ultrasonography before RA harvesting, without the use of the Allen test, at a center with high RA adoption and exclusively endoscopic harvesting. Patients were categorized by palmar arch reversal velocity into normal-flow (>20 cm/s),