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Vascular Communications of the Hand in Patients Being Considered for Transradial Coronary Angiography

Is the Allen's Test Accurate?

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OBJECTIVES The purpose of this study was to assess the accuracy of the Allen's test (AT) in predicting hand ischemia in patients undergoing transradial coronary angiography.

BACKGROUND Patients with poor vascular communications between the radial artery (RA) and ulnar artery (UA), as indicated by an abnormal AT, are usually excluded from transradial coronary angiography to avoid ischemic hand complications.

METHODS Over a four-month period, patients undergoing coronary angiography were screened for AT time. Circulation in the RA, UA, principal artery of the thumb (PAT), and thumb capillary lactate were measured before and after 30 min of RA occlusion.

RESULTS Fifty-five patients were studied (20 normal, 15 intermediate, 20 abnormal). Three patients with an abnormal AT were excluded, owing to absence of detectible flow in the distal UA. Patients with an abnormal AT were all men, had a larger RA (3.4 vs. 2.8 mm; $p < 0.001$), and smaller UA (1.9 vs. 2.5 mm; $p < 0.001$), compared with patients with a normal AT. After 30 min of RA occlusion in patients with abnormal AT, blood flow to the PAT improved (3.2 to 7.7 cm/s; $p < 0.001$) yet remained reduced relative to patients with normal AT (7.7 vs. 21.4 cm/s; $p < 0.001$. Thumb capillary lactate was elevated in patients with an abnormal AT (2.0 vs. 1.5 mmol/l; $p = 0.019$).

CONCLUSIONS After 30 min of RA occlusion, patients with an abnormal AT showed significantly reduced blood flow to the thumb and increased thumb capillary lactate (compared with patients with a normal AT) suggestive of ischemia. Transradial cardiac catheterization should not be performed in patients with an abnormal AT. (J Am Coll Cardiol 2005;46:2013–7) © 2005 by the American College of Cardiology Foundation

Radial artery (RA) cannulation carries a risk of RA occlusion with an incidence of 4.8% to 19% (1–7). This is usually of no consequence, because the hand receives blood from both the radial and ulnar arteries with extensive collateral channels; however, some patients have incomplete palmar arches and might not have adequate communications between the ulnar and radial arteries (8–10). In these patients, there is a potential risk of hand ischemia in the event of RA occlusion.

A simple bedside test to check for communications between the ulnar and radial arteries is the modified Allen's test (AT). Patients with an abnormal test will usually have their cardiac catheterization performed via the femoral artery, thus denying them the potential advantages of transradial cardiac catheterization. In patients undergoing coronary angiography, the incidence of an abnormal AT ranges from 6.4% to 27% (11,12).

Whether the AT can predict ischemic complications after RA cannulation is controversial, and some centers no longer exclude patients with an abnormal AT.

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METHODS

Over a period of four months, patients undergoing cardiac catheterization at The Royal Jubilee Hospital were screened with the AT. On the basis of the AT, patients were categorized as normal (0 to 5 s, group A), intermediate (6 to 10 s, group B), or abnormal (>10 s, group C). Patients were enrolled consecutively until we reached a pre-specified number of subjects in each group.

Patients were excluded if they had symptomatic peripheral vascular disease, history of Raynaud's phenomenon, severe aortic stenosis, atrial fibrillation, bleeding disorder, or were not taking antiplatelet therapy. All patients gave informed consent.

Perfusion of the hand was assessed with:

1. Doppler ultrasound (SonoSite [Bothell, Washington] with 10-MHz hockey stick vascular probe). Blood flow was recorded at: 1) RA, at level of radial head; 2) distal radial artery, from dorsum of hand at base of first metacarpal; 3) ulnar artery (UA), and 4) principle artery of the thumb (PAT), from palmar surface of hand at most distal point before branching.
2. Pulse oximetry of thumb (Good = signal strength >50%; weak = signal strength <50%; absent = no waveform or saturation reading).

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Abbreviations and Acronyms

ANOVA = analysis of variance
AT = Allen's test
PAT = principle artery of the thumb
RA = radial artery
UA = ulnar artery

3. Thumb capillary lactate concentration (Accutrend Lactate Analyzer, Boehringer Mannheim, Mannheim, Germany), a single drop of blood from the distal thumb was collected for analysis.

The above measurements were compared at baseline, immediately after RA occlusion (except capillary lactate), and after 30 min of RA occlusion with an RA compression device (Fig. 1). This device placed focal pressure over the RA at the wrist without affecting UA flow. Obstruction of RA flow was confirmed with Doppler. The hand was kept warm before and between measurements. Heparin 70 IU/kg (to a maximum of 5,000 IU) was given before RA compression if the patient was not already heparinized.

Patients were studied either before angiography (majority) or after their procedure if they were heparinized and the RA had not been cannulated.

Statistical analysis. Several methods of statistical analysis were used to analyze the data. Differences between Allen's groups for baseline characteristics were analyzed with analysis of variance (ANOVA) for continuous variables and chi-square tests for categorical variables. The normality assumptions for ANOVA were assessed with the following tests available in Proc Univariate of SAS 9.1 (SAS Institute, Cary, North Carolina): Shapiro-Wilk, Kolmogorov-Smirnov, Anderson-Darling, and Cramer-von Mises. If the normality assumption was violated, the Kruskal-Wallis non-parametric test was used instead. Paired *t* tests were used to compare blood flow at different times for a given Allen's group. Correlations in the data were investigated with the Pearson product-moment correlation. All analyses were done with SAS 9.1 (SAS Institute).

RESULTS

Over a four-month period, 55 patients were studied—20 normal, 20 abnormal, and 15 intermediate AT. Three patients with an abnormal AT were excluded because of absent ulnar flow at baseline. The baseline characteristics are summarized in Table 1.

Results are summarized in Table 2. The diameter of the RA became larger (group A = 2.8 mm, group B = 3.2 mm, group C = 3.4 mm; p = 0.0016) and the UA smaller (group A = 2.5 mm, group B = 2.2 mm, group C = 1.9 mm; p = 0.0002) as the AT time increased.

Blood flow to the PAT was significantly reduced immediately after RA occlusion in all groups, but more marked in patients with an abnormal AT (group A: 29.7 to 16.1 cm/s; group B: 26.3 to 7.8 cm/s; group C: 29.4 to 3.2 cm/s). After 30 min of RA occlusion, flow improved significantly (group A: 16.1 to 21.4 cm/s; group B: 7.8 to 14.6 cm/s; group C: 3.2 to 7.7 cm/s).

Capillary blood lactate levels after 30 min of RA occlusion increased as AT time increased (group A = 1.46 mmol/l; group B = 1.87 mmol/l; group C = 2.1 mmol/l; p = 0.007). The degree of lactate elevation correlated with blood flow in the PAT (r = −0.4; p = 0.004).

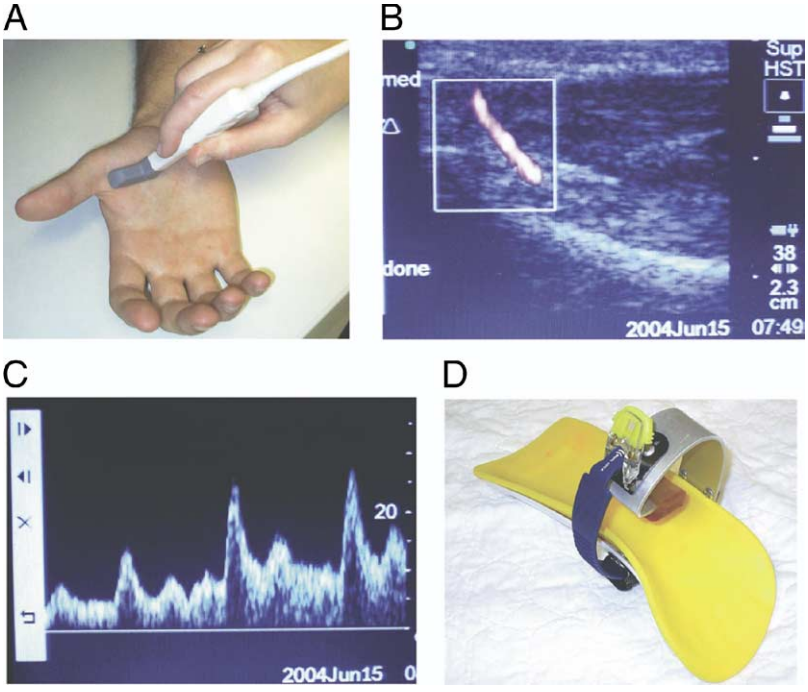

Figure 1. **(A and B)** Visualizing the principal artery of the thumb (PAT) with color Doppler. **(C)** Pulsed-wave Doppler of the PAT as the clamp is removed from the radial artery. **(D)** Clamping device used to occlude the radial artery.

Table 1. Baseline Characteristics

	Allen's Test Time			
	0–5 s	6–10 s	>10 s	p Value
Age (yrs)	63.4	63.2	70.5	0.03
Gender (% male)	70%	80%	100%	0.05
Weight (kg)	88.1	75.2	80.0	0.02
Height (cm)	170.7	168.2	172.6	0.31
BSA (m^2)	2.0	1.8	1.9	0.05
Wrist circumference (cm)	18.0	17.3	17.8	0.18
Radial art diameter (mm)	2.8	3.2	3.4	0.02
Ulnar art diameter (mm)	2.5	2.2	1.9	0.02
Urgent case	10%	13%	24%	0.50
Risk factors				
Smoking	15%	20%	12%	0.71
Hypertension	65%	40%	65%	0.26
Diabetes	25%	13%	41%	0.20
Hyperlipidemia	60%	80%	82%	0.24
Family history	60%	47%	71%	0.38
CABG	5%	7%	24%	0.17
Medications				
Beta-blocker	30%	73%	59%	0.03
Calcium channel blocker	15%	7%	18%	0.64
Nitrate	30%	53%	47%	0.34
ACE inhibitor	35%	47%	65%	0.19
Statin	70%	53%	65%	0.59

ACE = angiotensin-converting enzyme; BSA = body surface area; CABG = coronary artery bypass graft surgery.

All patients had a strong pulse oximetry signal at baseline. Immediately after RA occlusion, 100%, 67%, and 0% of patients had a strong signal in groups A, B, and C, respectively. After 30 min of RA occlusion, 100%, 93%, and 64% of patients, respectively, had a strong signal.

One patient, with an abnormal AT and no recordable PAT flow at 30 min, developed numbness of his thumb. Another patient with an abnormal AT complained of mild paresthesia of the thumb. No other symptoms were reported.

DISCUSSION

The vascular anatomy of the hand is complex and highly variable (8). The UA continues into the hand and usually anastomoses with the RA to complete the superficial palmar arch. The RA continues into the hand and usually anastomoses with the UA completing the deep palmar arch. The prevalence of incomplete superficial or deep palmar arches ranges from 3.6% to 34% and 3% to 33.3%, respectively, in cadaver dissections (8,10,13,14); however, a study of 50 hands showed that all specimens had either a complete superficial or deep palmer arch (10). This would suggest that all patients have some anastomosis and that occlusion of the RA should not result in ischemic complications.

The AT is a simple test to assess for adequacy of ulnar collateral circulation before RA cannulation. False normal rates range from 3% to 45.5%, and false abnormal results might be as high as 73%, depending on technique (15–17). Some authors have suggested that the AT should be replaced by more objective and reliable tests such as Doppler ultrasound and plethysmography before the RA is cannulated or harvested

Table 2. Summary of Results (Negative Values Indicate Flow Reversal Compared With Baseline)

	Group A 0–5 s	Group B 6–10 s	Group C >10 s	p Value
RA				
Diameter (mm)	2.8	3.2	3.4	0.0016
Pre-occlusion (cm/s)	61.8	56.4	63.0	
UA				
Diameter (mm)	2.5	2.2	1.9	0.0002
Pre-occlusion (cm/s)	70.6	57.4	34.6	<0.0001
Immediately after occlusion (cm/s)	105.1	92.9	50.2	<0.0001
30 min occlusion (cm/s)	110.1	102.3	59.7	<0.0001
PAT				
Pre-occlusion (cm/s)	29.2	26.3	29.4	0.69
Immediately after occlusion (cm/s)	15.9	7.8	3.2	0.0001
30 min occlusion (cm/s)	21.4	14.6	7.7	0.0001
Distal radial				
Pre-occlusion (cm/s)	45.5	46.6	48.0	0.43
Immdiately after occlusion (cm/s)	−16.9	−11.0	−2.0	0.0003
30 min occlusion (cm/s)	−18.8	−16.5	−6.0	0.0031
Oximetry				
Pre-occlusion	Good 100%	Good 100%	Good 100%	
Immediately after occlusion	Good 100%	Good 67% Weak 20% Absent 13%	Good 0% Weak 24% Absent 76%	
30 min occlusion	Good 100%	Good 93% Weak 7% Absent 0%	Good 64% Weak 18% Absent 18%	
Lactate				
Pre-occlusion	1.7	1.9	1.7	0.62
30 min occlusion	1.5	1.9	2.0	0.007

PAT = principal artery of the thumb; RA = radial artery; UA = ulnar artery.

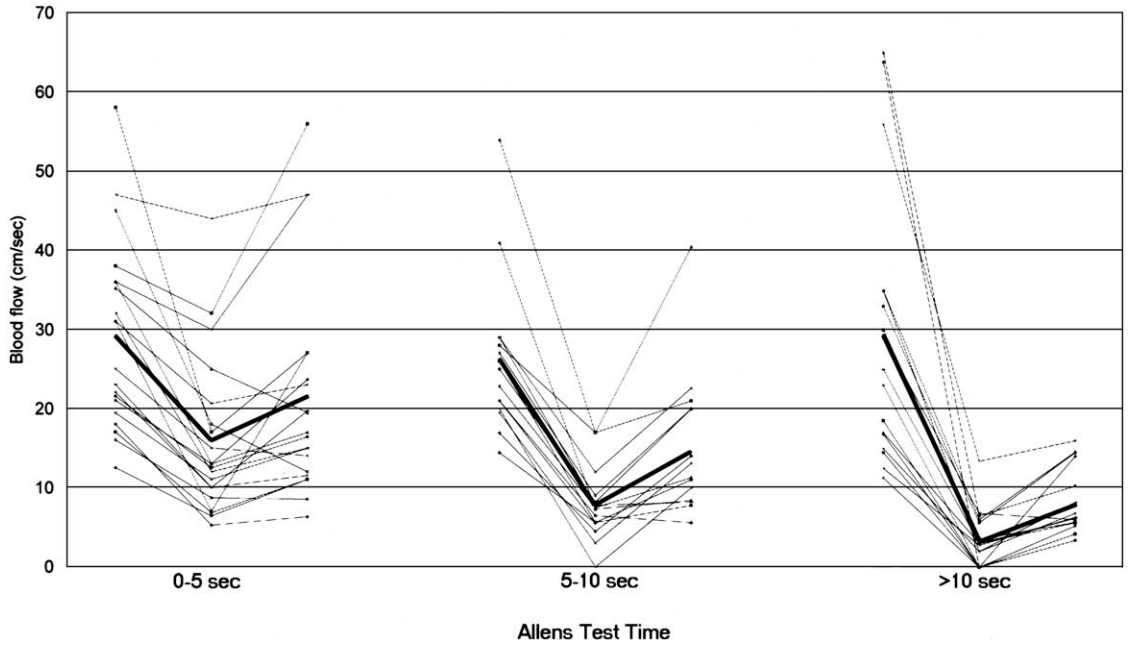

Figure 2. Peak blood flow velocity in the principal artery of the thumb from baseline to immediately after radial artery occlusion to 30 min after radial artery occlusion. **Heavy line** represents the average for the group.

for coronary bypass surgery (11,17–20). Conversely, other authors have suggested that assessment of the ulnar collateral circulation is unnecessary, owing to the absence of complications in their series (which included patients with abnormal AT) and the fact that complications often occurred in patients with a normal AT (21–23).

There are case reports of digital ischemia in patients undergoing RA cannulation in the surgical, intensive care, and perioperative setting, but none after transradial cardiac catheterization (24). These patients don't routinely receive heparin, and the catheters are often left in place for prolonged periods. Other factors such as distal embolization, vasospasm, and distal thrombosis have been proposed (21). Of interest, the majority of these patients were reported to have a normal AT.

Previous studies have used blood flow in the hand immediately after RA occlusion as an end point. This ignores the fact that the circulation in the hand is dynamic and it might take some time for collateral channels to reach their full potential. We occluded the RA for at least 30 min and found a significant improvement in the PAT flow (Fig. 2, Table 3). This improvement appeared to be most marked in the group with an abnormal AT, where flow increased by an average of 240%, compared with 135% in patients with a normal AT. No detectible PAT flow was seen in 35% of patients with an abnormal AT, immediately after RA occlusion. After 30 min, there was detectible flow to the thumb in all but one patient. No patient with an abnormal AT had a good oximetry signal immediately after RA occlusion, compared with 64% after 30 min of RA occlusion.

In an attempt to demonstrate thumb ischemia, we measured capillary blood lactate levels in the thumb before and after 30 min of RA occlusion. If blood flow to the thumb was inadequate, we would expect to see a gradual rise in lactate concentration as the tissues became dependent on anaerobic metabolism. Patients with an abnormal AT had a significantly higher capillary lactate level after 30 min of RA occlusion. This would suggest inadequate thumb perfusion, which could lead to ischemic complications with prolonged occlusion. The degree of lactate elevation correlated with the measured blood flow in the thumb; however, there was a large amount of scatter (Fig. 3).

Conclusions. Although collateral circulation of the hand is dynamic, with significant improvement of blood flow to the thumb over a 30 min period of RA occlusion (particularly in patients with an abnormal AT), there is still potential for hand ischemia after prolonged RA occlusion. We recommend that, in the presence of an abnormal AT, the RA should not be used for cardiac catheterization unless the risk of using the femoral

Table 3. Comparison of Blood Flow Immediately After Occlusion to 30 Min After Occlusion for Each Allen's Group Separately (Negative Values Indicate Flow Reversal Compared with Baseline)

	Immediately After Occlusion (cm/s)	After 30 min Occlusion (cm/s)	p Value
PAT			
0–5	15.9	21.4	0.005
5–10	7.8	14.6	0.001
>10	3.2	7.7	<0.001
UA			
0–5	105.1	110.1	0.40
5–10	92.9	102.3	0.07
>10	50.2	59.7	0.02
Distal radial			
0–5	−16.9	−18.8	0.40
5–10	−11	−16.5	0.01
>10	−2	−6.0	0.005

Abbreviations as in Table 2.

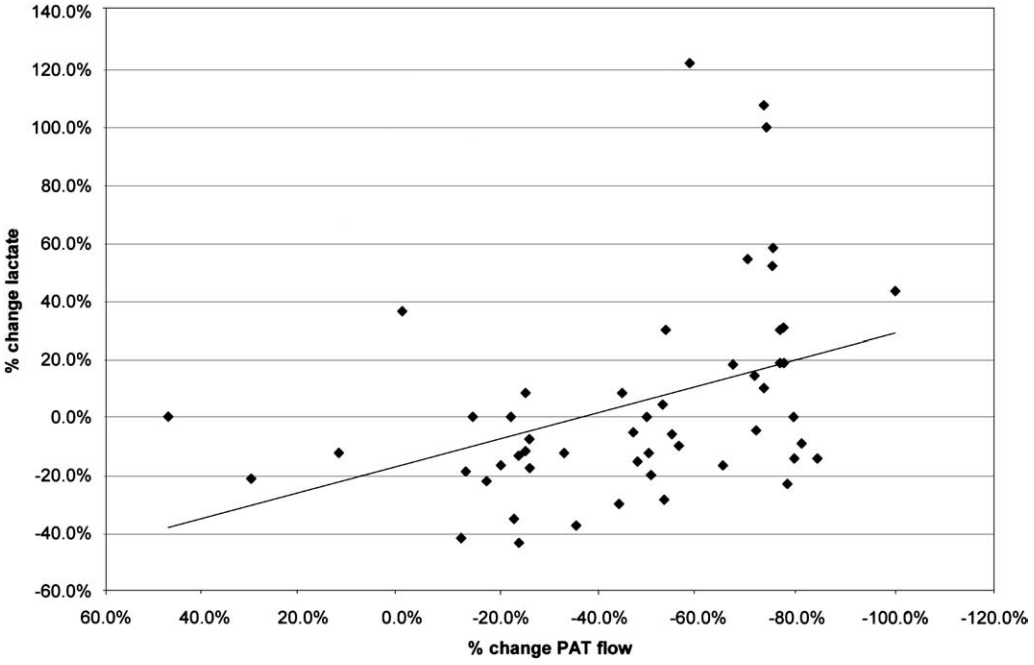

Figure 3. Lactate and principal artery of the thumb (PAT) flow correlation after 30 min of radial artery occlusion.

approach is excessive (e.g., severe peripheral vascular disease, morbid obesity, large abdominal aortic aneurysm).

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