

Myocardial Perfusion in Patients With a Totally Occluded Left Anterior Descending Coronary Artery Reinjecting by a Normal Right Coronary Artery: The Role of Collateral Circulation

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In this article, myocardial perfusion in patients with a totally occluded left anterior descending artery re-injected by a normal right coronary artery is assessed using stress single photon emission computed tomography (SPECT). In all, 20 patients, with a totally occluded left anterior descending artery re-injected by normal right coronary artery, underwent myocardial single photon emission computed tomography imaging within 60 days of angiography. All patients had abnormal perfusion single photon emission computed tomography results and 70% had reversible defects. Perfusion defects at rest were present in 75% of patients, with perinecrotic residual ischemia

in 45% of patients whereas for 30% of patients, no viable myocardium was detected in the collateral-dependent segments. In all, 25% of patients had no resting perfusion defects but all are presented with stress-induced ischemia. Collaterals are not protective against stress-induced ischemia, but they can preserve myocardial viability. This conclusion is highly supported by the presence of residual ischemia in the collateral-dependent segments.

Keywords: collateral circulation; myocardial perfusion; SPECT; total LAD occlusion

Coronary collaterals mature and develop in response to the presence of severe coronary stenosis as an adaptation to ischemia.¹ The essential value of collaterals is clearly shown in patients with a completely preserved left ventricular function, despite a totally occluded coronary artery.² However, despite decades of study, the functional role of the coronary collateral circulation remains controversial.²⁻⁴

The results of previous studies assessing the relationship between myocardial perfusion scintigraphy and coronary collateral vessels remain inconclusive.⁵

Only a few studies have reported stress single photon emission computed tomography (SPECT) results in patients with chronic total occlusions of a single coronary artery with collateral circulation.^{2,5}

The aim of our study is to assess the degree of ischemia in patients with a totally occluded left anterior descending coronary artery (LAD) re-injected by a normal right coronary artery (RCA) using stress SPECT.

Patients and Methods

Study Population

The patients were selected from the departments of cardiology and nuclear medicine in our institution between 1997 and 2002. We included 20 consecutive patients who had coronary angiography results that showed a total occlusion of the LAD with

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collateral circulation from a normal RCA and who had stress myocardial SPECT within 60 days of angiography. These patients were subjected to SPECT imaging after coronarography results for the evaluation of any viability or residual ischemia in the segments supplied by the totally occluded LAD, which were totally collateral dependent. We excluded all patients, who had previous coronary artery bypass surgery, previous coronary angioplasty, and those patients with more than 60 days time interval between coronarography and SPECT imaging.

Stress Protocol

All patients had an exercise stress test using a modified Bruce protocol. Heart rate, systolic and diastolic blood pressures, and 12-lead electrocardiogram (ECG) were recorded before and during exercise. We increased the power during exercise by 30 W for every 3 minutes until reaching the maximum predicted heart rate for age ($220 - \text{age}$), having a positive stress test for ischemia (electrical or clinical signs of ischemia), vertigo, pallor, cyanosis, serious arrhythmia, dyspnea, or drop in systolic blood pressure below control.

Resting Echocardiography

Resting echocardiography was obtained for all patients by a single operator using an Acuson Sequoia C256 (Acuson Corporation, Mountain View, Calif) with a probe 3.5 MHz with second harmonic imaging. The recommendations of the American Society of Echocardiography (ASE) concerning wall motion abnormalities of the collateral-dependent segments and ejection fraction (EF) measurements were applied.

Myocardial SPECT Imaging

Myocardial SPECT imaging was obtained by a Sopha single head tomography (Sopha, Buc, France). A solution of Tc-99m tetrofosmin was used. A dose of 7 mCi was injected at peak exercise, and stress imaging was started 30 minutes after completion of the exercise stress testing. After 4 hours, a second dose of 20 mCi was injected, followed by rest imaging 1 hour later. The results were analyzed by 2 operators according to the recommendations of the American Society of Nuclear Cardiology (ASNC).

Coronary Angiography

Selective coronary angiographies were performed and interpreted by 2 experienced angiographers in

multiple views by the Judkins technique, using a Philips angiographic system (Philips, Eindhoven, Netherlands). Total LAD occlusion and the presence of collateral circulation were noted. Further attempt was not made to subclassify the degree of collateral vessels by angiography. The mean delay between angiography and SPECT imaging was 20 days (5-42 days).

Statistical Analysis

All continuous variables are reported as mean \pm standard deviation. An unpaired *t* test was used to compare the means of 2 independent groups for the purpose of determining the statistical significance (*P* value) of the observed findings. A chi-square test was used for comparing 2 or more independent proportions within 2 or more groups. A *P* value $< .05$ was considered to be statistically significant.

Results

Demographic Data

The demographic results are summarized in Table 1. Data are presented as mean \pm standard deviation or number (%).

In all, 15 patients were men (75%) and 5 patients were women (25%); their mean age was 63.45 years with a standard deviation of 7.55 years. The youngest patient was a 46-year-old and the oldest one was a 75-year-old. Most of the patients (80%) had at least 2 cardiovascular risk factors.

Resting ECG Results

The resting ECG was abnormal in 75% of the patients. In all, 9 patients (45%) presented Q waves on resting ECG, 4 patients (20%) presented inverted T waves in anterior leads, 1 patient (5%) had atrial fibrillation, 1 patient had a left bundle branch block, and the remaining 5 patients (25%) had a normal resting ECG.

Echocardiographic Results

Wall motion abnormalities of collateral-dependent myocardial segments in total LAD occlusion with collateral circulation and the corresponding EF measurements by echocardiography are summarized in Table 2.

Resting echocardiography was normal in 20% of patients and abnormal in 80% of patients. The mean EF was $48 \pm 11\%$.

Table 1. Demographic Data

Characteristics	Data
No of patients	20 (100)
Men	15 (75)
Women	5 (25)
Age, y	63.45 ± 7.55
Age (min-max)	46-75
Risk factors	
Smoking	13 (65)
Hypercholesterolemia	11 (55)
Family history	7 (35)
Hypertension	7 (35)
Diabetes mellitus	7 (35)
Abnormal resting ECG	15 (75)

NOTE: ECG = electrocardiogram.

Table 2. Echocardiography Results

Wall Motion Abnormalities	No of patients, %	EF
Akinesia (severe dysfunction)	11 (55)	40.64 ± 10.56
Hypokinesia (mild dysfunction)	5 (25)	53.75 ± 3.03
Normal (normal function)	4 (20)	61.75 ± 3.03

NOTE: EF = ejection fraction.

Stress Testing Results

Patients reached $81.6\% \pm 8.38\%$ of their maximum predicted heart rate and a power of 116.5 ± 37.87 W. Stress testing was positive for ischemia either clinically or electrically in 13 patients (65%) and negative for ischemia in 7 patients (35%).

Angiographic Results

According to selection criteria, all patients had a total LAD occlusion reinjected by collateral circulation from a normal RCA.

SPECT Results

All patients had abnormal perfusion SPECT imaging results (20 patients) with 14 patients (70%) having reversible perfusion defects. Perfusion defects at rest were present in 15 patients (75%). These infarcts were surrounded by perinecrotic residual ischemia in 9 patients (45%), and for the remaining 6 patients (30%), no viable myocardium in the collateral-dependent segments was detected. In all, 5 patients (25%) had no evidence of resting perfusion defects but all of them presented stress-induced ischemia (Table 3).

Table 3. SPECT Results

SPECT Results	No of Patients, %
Abnormal SPECT	20 (100%)
Reversible perfusion defects	14 (70%)
Perfusion defects at rest	15 (75%)
Infarct with perinecrotic residual ischemia	9 (45%)
Infarct without perinecrotic residual ischemia	6 (30%)
Normal resting SPECT with stress-induced ischemia	5 (25%)

NOTE: SPECT = single photon emission computed tomography.

Discussion

There are several important observations in our study.

- The frequency of myocardial perfusion abnormalities in patients with a total LAD occlusion with collateral circulation was 100%.
- Most of the perfusion defects (70%) were reversible, suggesting preserved myocardial viability in the collateral-dependent segments.
- Collateral circulation did not prevent stress-induced ischemia.

Our results are in concordance with previous studies reporting stress SPECT results.^{3,5} The demonstration of residual ischemia in patients with a totally occluded LAD reinjected by a normal RCA can provide unique information on the management of these patients.

Coronary Collaterals

Coronary collaterals are anastomotic connections without an intervening capillary bed between portions of the same coronary artery and between the different coronary arteries.⁶ They provide an alternative source of blood supply to myocardium jeopardized by occlusive coronary artery disease, and they can help to preserve myocardial function in the setting of a chronic total coronary occlusion.⁷ The collateral circulation develops in response to recurrent myocardial ischemia with coronary artery disease being a necessary precondition for collateral growth.⁸

In patients with significant coronary disease, the extent of collateral flow to the distal myocardium is best predicted by the degree of coronary stenosis or the duration of antecedent angina, which are both surrogate markers of the ischemic burden.^{9,10}

Myocardial Perfusion Abnormalities in the Presence of Angiographic Collateral Circulation

Several studies have investigated the effects of collateral circulation on myocardial perfusion during stress and at rest, but the results remain inconclusive. Most of these studies have suggested that coronary collaterals are not protective against stress-induced ischemia,^{3,5,11-13} but they may be important in preserving the resting myocardial blood flow to near normal limits.^{5,11-13} However, the collateral vessels have been found to prevent stress-induced ischemia by some investigators.¹⁴⁻¹⁶

Tubau et al¹⁵ in a series of 22 patients with no prior infarction observed that myocardial perfusion defects involved more myocardial segments in patients without collateral circulation than in patients with collateral circulation. The extent of perfusion defects measured by quantitative analysis of planar Tl-201 imaging by Iskandrian et al,¹⁷ in patients with LAD stenosis, was smaller in patients with collateral circulation than in patients without collateral circulation. The extent of perfusion defects in patients with either left circumflex or RCA stenosis was, however, similar for patients with collateral circulation and patients without collateral circulation.

In 2 studies that reported stress SPECT results,^{3,5} the coronary collaterals appear to preserve myocardial perfusion at rest but are not protective against stress-induced ischemia. He et al,³ using SPECT, assessed myocardial perfusion in patients with total occlusion of a single coronary artery with and without collateral circulation. In their study, stress-induced myocardial ischemia was almost always present, irrespective of the presence or the absence of angiographic collaterals. Similarly, Aboul-Enein et al⁵ found that, in the setting of single-vessel chronic total occlusion and no prior myocardial infarction, collaterals appear to protect against resting perfusion defects, but do not appear to protect against stress-induced perfusion defects, regardless of the Rentrop angiographic grading.

Similar results have also been reported by investigators using positron emission tomography.¹²

Myocardial Viability and Collateral Circulation

In patients with prior myocardial infarction, reversible perfusion defects are more common in segments with collateral circulation than in those without collateral circulation.¹⁸

Data from a study by Akutsu et al¹⁹ suggest that the presence of collateral circulation may preserve myocardial viability in the infarct zone.

In the trial in myocardial infarction, infarct size, as determined by serum creatine kinase (CK), was smaller among patients with collateral vessels compared with patients without such vessels (20.6 vs 31.4 CK g Eq, $P = .001$).²⁰ Lee et al²¹ found that in patients with sufficient collaterals, left ventricular recovery after reperfused myocardial infarction is primarily determined by the amount of collateral blood flow and is less dependent upon the time for reperfusion. Also, the presence of significant collateral flow is associated with a higher postinfarction-ejection fraction²² and decreased aneurysmal dilation.

Recovery of functionally impaired myocardium after revascularization can only be expected with a minimum collateral supply to maintain myocardial viability.²³ No viable myocardium will be found in the absence of collaterals.²⁴ However, the collateral may not be sufficient to uphold full nutritional supply, hence the myocardium may remain viable but nonfunctional, that is, hibernating.²

To be noted that collateral development does not depend on the presence of viable myocardium,²⁵ and well-developed collaterals may also be observed with nonviable myocardium.²

Study Limitations

Several limitations of this study should be pointed out.

- Small number of patients.
- Patients with Q and non Q waves were included.
- Viability may be underestimated because of the use of Tc-99m tetroformin and not thallium 201.
- Perfusion defects were not analyzed quantitatively.
- No Rentrop classification of collaterals was obtained.

Conclusion and Clinical Implications

An interesting finding in our study is the demonstration of residual ischemia in patients with a totally occluded LAD reinjected by a normal RCA. All patients with a totally occluded LAD reinjected by a normal RCA present perfusion abnormalities as detected by SPECT imaging. These patients may still be at high risk for future ischemic cardiac events. The evaluation of myocardial perfusion and viability will provide important information on the management of these patients.

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