Stress cardiac single-photon emission computed tomographic imaging late after coronary artery bypass surgery for risk stratification and estimation of time to cardiac events

Wanda Acampa, MD, PhD,^{a,b} Mario Petretta, MD,^c Laura Evangelista, MD,^d Gianantonio Nappi, MD,^e Luca Luongo, MD,^b Maria Piera Petretta, MD,^c and Alberto Cuocolo, MD^{a,b,d}

Objective: We assessed predictors and temporal characteristics of cardiac risk in patients undergoing stress single-photon emission computed tomography after coronary artery bypass grafting.

Methods: Stress cardiac tomography was performed in 362 patients 5 years after coronary artery bypass grafting. Cardiac death and myocardial infarction were considered as events. Cox proportional hazards analysis was used to identify predictors of events and parametric survival analysis to predict time to events.

Results: During a median follow-up of 27 months, 22 cardiac events occurred (6.1% cumulative event rate). At multivariable Cox analysis, ischemia at cardiac tomography (hazards ratio 3.7, 95% confidence interval 1.5–9.1; $P = .004$), and diabetes (hazards ratio 3.6, 95% confidence interval 1.5–8.5; $P = .006$) resulted in independent predictors of events. Event-free survival was 96% in patients with normal cardiac tomography, 86% in those with abnormal tomography without ischemia, and 70% in those with (log-rank 10.6, P for trend = .008). The parametric survival model revealed that the cardiac risk was greater for all time intervals and accelerated more over time in patients with ischemia than in those without (χ^2 21.4, $P < .0001$). Patients without diabetes and normal cardiac tomography remained below a defined risk level (5%) for the entire follow-up period.

Conclusion: Stress cardiac tomography performed 5 years after coronary artery bypass grafting is useful to characterize the risk of cardiac events and its temporal variation. Parametric survival model estimates the predicted time to risk and the level of risk at specific time intervals after coronary artery bypass grafting.

From the Institute of Biostructures and Bioimages,^a National Council of Research; the Departments of Biomorphological and Functional Sciences^b and of Internal Medicine,^c Cardiovascular and Immunological Sciences, University Federico II; SDN Foundation,^d Institute of Diagnostic and Nuclear Development; and Department of Cardiothoracic Surgery,^e Second University, Naples, Italy.

Stress cardiac tomography performed 5 years after CABG is useful to characterize the risk of cardiac events and its temporal variation. A parametric survival model estimates the predicted time to risk and the level of risk at specific time intervals after CABG.

Received for publication July 18, 2007; revisions received Sept 10, 2007; accepted for publication Oct 4, 2007.

Address for reprints: Alberto Cuocolo, MD, Department of Biomorphological and Functional Sciences, University Federico II, Via Pansini 5, 80131 Naples, Italy (E-mail: cuocolo@unina.it).

J Thorac Cardiovasc Surg 2008;136:46-51
0022-5223/\$34.00

Copyright © 2008 by The American Association for Thoracic Surgery

doi:10.1016/j.jtcvs.2007.10.011

Myocardial perfusion imaging with single-photon emission computed tomography (SPECT) has been demonstrated to be effective to risk stratify patients with known coronary artery disease and guide for referral catheterization.¹⁻³ The American College of Cardiology/American Heart Association guidelines for exercise testing do not take a position regarding the utility of routine stress testing after coronary artery bypass grafting (CABG).⁴ Risk stratification in this substantial coronary artery disease population may have clinical significance because repeating revascularization procedures reduces events at follow-up in high-risk patients.⁵ SPECT studies might be useful not only to guide in the therapeutic decision but also to determine the timing to retest patients during follow-up.⁶ Previous observation suggests that symptomatic and asymptomatic patients more than 5 years after CABG may benefit from testing.² The aim of this study was to assess the predictors and the temporal characteristics of cardiac risk in patients undergoing stress SPECT imaging 5 years after CABG.

Abbreviations and Acronyms

CABG = coronary artery bypass grafting
 CI = confidence intervals
 SPECT = single-photon emission computed tomography

Patients and Methods**Patient Population**

We studied 390 consecutive patients referred for stress cardiac SPECT imaging after CABG. For the purpose of the present investigation, we selected patients referred for SPECT imaging 5 years after CABG (range 60–66 months). Patients ($n = 20$) who underwent early (<60 days after SPECT) revascularization procedures (percutaneous coronary intervention or repeated CABG) were excluded. Although after CABG symptomatic patients are usually referred for exercise testing, including radio-nuclide imaging, there is no consensus for the evaluation of symptom-free patients. Therefore, for asymptomatic patients, referral for exercise perfusion imaging was at the discretion of individual cardiologists. Eight patients were lost to follow-up. Thus, the final population comprised 362 patients. All patients had off-pump CABG. Of these patients, 258 (71%) underwent physical exercise and 104 (29%), dipyridamole SPECT imaging. At the time of SPECT, 267 patients were asymptomatic and 95 had angina symptoms. The prevalence of diabetes mellitus was 30% (31% in asymptomatic and 27% in symptomatic patients; $P = .52$). The ethics committee of our institution approved the protocol and all patients provided written informed consent.

Study Protocol

Beta-blocking medications and calcium antagonists were withheld for 48 hours and long-acting nitrates for 12 hours before testing. For patients undergoing exercise test, symptom-limited treadmill standardized protocols were performed, with monitoring of heart rate and rhythm, blood pressure, and electrocardiography. Test end points were physical exhaustion, horizontal or downsloping ST-segment depression greater than 2 mm, ST-segment elevation greater than 1 mm, moderate-to-severe angina, systolic blood pressure decrease greater than 20 mm Hg, blood pressure greater than 230/120 mm Hg, dizziness, or clinically important cardiac arrhythmia. For dipyridamole stress test, patients were instructed not to consume products containing caffeine for 24 hours before the test. Dipyridamole was infused at a dose of $0.56 \text{ mg} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ intravenous over 4 minutes. A dose of 100 mg of aminophylline was administered intravenously in the event of chest pain or other symptoms or after significant ST depression. At peak exercise, or 4 minutes after completion of dipyridamole infusion, a bolus of 370 MBq of technetium-99m sestamibi was intravenously injected. Patients continued the exercise for an additional 60 seconds after tracer injection. For both types of stress, heart rate, blood pressure, and 12-lead electrocardiographic data were recorded at rest, at the end of each stress stage, at peak stress, and in the delay phases at rest. Maximal degree of ST-segment change at 80 ms after the J-point of the electrocardiogram was measured and assessed as horizontal, downsloping, or upsloping. Four hours after the conclusion of the stress test, 1110 MBq of technetium-99m sestamibi was injected at rest.⁷

SPECT was performed 60 minutes after tracer injection for both stress and rest studies.

SPECT Imaging

Gated SPECT acquisitions were performed with a dual-head rotating gamma camera (E.CAM, Siemens Medical Systems, Hoffman Estates, Ill) equipped with a low-energy, high-resolution collimator and connected with a dedicated computer system. No attenuation or scatter correction was used. After filtered back-projection, short-axis, vertical, and horizontal long-axis tomograms were generated. A quantitative analysis of relative perfusion distribution in 17 myocardial segments was performed.³ Each segment was scored on a 5-point scoring system (0 = normal, 1 = mild, 2 = moderate, 3 = severe reduction, and 4 = apparent absence of detectable tracer uptake). A commercially available software program (Cedars-Sinai Medical Center, Los Angeles, Calif) was used to automatically calculate left ventricular ejection fraction and the variables incorporating both the extent and severity of perfusion defects: summed stress score, summed rest score, and summed difference score.^{2,3} Stress SPECT was considered abnormal with summed stress score of 3 or greater. Patients with abnormal SPECT were considered to have no ischemia with a summed difference score less than 2, mild-to-moderate ischemia with a summed difference score of 2 to 6, and severe ischemia with a summed difference score of 7 or more.⁸

Follow-up

Data were obtained by scripted telephone interviews by a researcher blinded to the patient's test results. Cardiac events were defined as cardiac death and nonfatal myocardial infarction. Patients who underwent late revascularization ($n = 32$) were censored at the time of the procedures. Cardiac death was confirmed by review of death certificate, hospital chart, or physician's records. Cardiac enzyme and electrocardiographic changes documented nonfatal myocardial infarction. All patients were followed up for at least 1 year for the outcome end points, and the median follow-up time was 27 months (range interquartile 18–34 months).

Statistical Analysis

Continuous variables were expressed as a mean $\pm$ standard deviation and categorical data as percentage. Differences between groups were assessed by unpaired t test and by χ^2 test with Yates correction, as appropriate. The end point was the time from the index nuclear testing to cardiac event, whichever occurred first. Effect of variables on event-free survival was evaluated by stepwise multivariable Cox proportional hazards model and hazards ratio, and 95% confidence intervals (CI) were calculated^{9,10} (SPSS Inc, Advanced Models 13.0, Chicago, Ill). The variables considered were age, gender, hypertension, smoking, hypercholesterolemia, diabetes, symptoms, number of diseased vessels, and gated SPECT results. The entry probability in the model was set at .05 and the P value used as the cutoff for retention in the model was $<.1$. The proportional hazard assumption of the Cox model was checked separately for each covariate before the regression analysis was performed. Such checking was done by a graphical and analytical method. The graphs of $\log_e [-\log_e \hat{S}(t)]$ versus $\log_e(t)$ for each dichotomous covariate were obtained to check that the curves were roughly parallel. Additionally, for each covariate a time-dependent covariate (covariate $\times t$) was obtained and checked whether the coefficient of the latter

significantly differed from 0. The proportional hazard assumption was not rejected for any one of the covariates included in the Cox model, except for stress type, which was treated as stratification variable. Survival curves were constructed by the Kaplan–Meier method to account for censored survival times and were compared with the log–rank test (SPSS Inc, Advanced Models 13.0, Chicago, Ill). A parametric survival model was used to identify which variables influenced time to event and to estimate risk-adjusted event rates at 6-month intervals during the follow-up and the length of time to specific risk thresholds (JMP by SAS Institute, Inc, Cary, NC). For these purposes, the estimated probability of failure, defined as $1 - \text{estimated event-free survival probability}$, was calculated. On the basis of the distribution of survival times in our cohort, a Weibull distribution was selected for parametric survival and a good fit was found with STATA version 9 for Windows (StataCorp LP, College Station, Tex).^{11,12}

Results

SPECT Results and Outcome Events

Stress SPECT imaging was normal in 156 (43%) patients and abnormal in 206 (57%). Of these latter patients, 144 (70%) had evidence of ischemia and 62 (30%) did not. Ischemic patients had a higher prevalence of male gender (96% vs 89%; $P = .020$), previous myocardial infarction (75% vs 49%; $P < .001$), and hypertension (49% vs 35%; $P = .012$) than did patients without ischemia. Angina symptoms were present in 36% of patients with ischemia and in 20% of those without ($P < .001$) and nitrate treatment was more frequent in ischemic patients ($P = .044$). In the 144 patients with ischemia, the mean summed difference score was 5.1 ± 2 . Among the 108 ischemic patients with previous myocardial infarction, ischemia was infarct-related in 36 and non infarct-related in 40, whereas 32 patients had both infarct- and noninfarct-related ischemia.

During the follow-up, 22 cardiac events occurred (6.1% cumulative event rate). The events were cardiac death in 10 patients and nonfatal myocardial infarction in 12 patients. Characteristics of patients with and without cardiac events are reported in Table 1. A higher prevalence of diabetes was observed in patients with events. SPECT results in patients with and without events are reported in Table 2. Patients with events showed a higher incidence of abnormal SPECT and a higher summed difference score than did patients without events. In particular, among the 18 patients with events and abnormal SPECT imaging, 14 had myocardial ischemia.

A separate analysis was performed in asymptomatic patients with and without diabetes. The prevalence of ischemia was comparable in patients with and without diabetes (30% vs 36%; $P = .27$). Cardiac events occurred in 2 ischemic patients with and in 4 ischemic patients without diabetes ($P = .73$).

At multivariable Cox analysis, evidence of ischemia at SPECT (χ^2 9.9, hazards ratio 3.7, 95% CI 1.5–9.1; $P = .004$) and diabetes (χ^2 9.6, hazards ratio 3.6, 95% CI 1.5–8.5; $P = .006$) resulted in independent predictors of events,

TABLE 1. Characteristics of patients with and without cardiac events

	Events (n = 22)	No events (n = 340)	P value
Age (y)	61 $\pm$ 8	63 $\pm$ 8	.4
Male gender	91	90	.1
Prior myocardial infarction	54	59	.6
Grafts (n)	2.5 $\pm$ 0.4	2.3 $\pm$ 0.6	.1
Arterial grafts (n)	1.6 $\pm$ 0.3	1.5 $\pm$ 0.4	.2
Incomplete revascularization	9	13	.5
Hypertension*	36	41	.7
Smoking	9	10	.9
Hypercholesterolemia†	36	42	.6
Diabetes	54	29	.01
Symptoms	9	29	.06
Three-vessel disease	54	61	.6
Medications			
Beta-blockers	36	32	.6
Nitroglycerin	36	35	.9
Calcium channel blocker	45	41	.6

Categorical variables are presented as column percentages and continuous variables as mean $\pm$ standard deviation. *Defined as blood pressure $\geq 140/90$ mm Hg or chronic antihypertensive treatment. †Defined by history or recent cholesterol level ≥ 90 th percentile for age and sex.

whereas the extent and severity of ischemia did not. The event-free survival curves of patients according to SPECT results are showed in Figure 1. At the end of the follow-up, cumulative probability of event-free survival was 96% in patients with normal SPECT, 86% in those with abnormal SPECT without ischemia, and 70% in those with ischemia (log–rank test 10.6; P for trend = .008).

Change in Risk with Time

The parametric model for prediction of time to events identified SPECT results and diabetes as significant variables (χ^2 14.4 and 10.6, respectively; both $P < .001$). The survival

TABLE 2. SPECT results in patients with and without cardiac events

	Events (n = 22)	No events (n = 340)	P value
Left ventricular ejection fraction (%)	43 $\pm$ 11	46 $\pm$ 14	.3
Abnormal SPECT	82	55	.01
Summed stress score	8.1 $\pm$ 5	7.5 $\pm$ 8	.6
Summed rest score	4.5 $\pm$ 5	5.2 $\pm$ 6	.4
Summed difference score	3.4 $\pm$ 3	2.0 $\pm$ 2	.03

Categorical variables are presented as column percentages and continuous variables as mean $\pm$ standard deviation.

Figure 1. Event-free survival curves by Kaplan–Meier analysis according to SPECT imaging results. Stress SPECT studies were considered normal with summed scores less than 3 and abnormal with summed scores of 3 or more. In abnormal studies, myocardial ischemia was defined by the presence of a summed difference score of 2 or more.

model including both variables (χ^2 21.4; $P < .0001$) revealed that for both nondiabetic and diabetic patients, the cardiac risk was greater for all time intervals and accelerated more over time in patients with ischemia at SPECT than in those without (Figure 2). Finally, the time to reach a defined risk level ($>5\%$) in patients with or without diabetes according to SPECT results is depicted in Figure 3. Noteworthy, patients without diabetes and with normal SPECT remained below 5% estimated risk for the entire follow-up period.

Discussion

The results of the present study show that, in post-CABG patients, myocardial ischemia by SPECT imaging and the presence of diabetes independently influence the patient's outcome as well as the temporal characteristic of the patient's risk at long-term follow-up.

Risk assessment by nuclear cardiology is important for patient management and to guide therapeutic decision-making in subjects with suspected or known coronary artery disease.¹³ Patients with previous CABG represent a substantial coronary artery disease population.¹⁴ Risk stratification for subsequent major cardiac events in these patients has clinical importance, because repeated CABG could reduce the risk of death in high-risk patients. It has been recently shown that patients with ischemic cardiomyopathy, undergoing repeated CABG according to scintigraphic results, benefit from revascularization as regards midterm outcome.⁵ Even though repeated CABG is still associated with increased cardiac risk compared with first CABG, this risk seems to be related to patient selection.^{15,16} In particular, a high risk of repeated CABG has been observed in patients with left ventricular dysfunction.^{15,17} The results of the present investigation confirm that, after CABG, stress SPECT imaging results provide

Figure 2. Estimated probability of failure by 6-month intervals in patients without (A) or with diabetes (B) according to SPECT imaging results (circles = normal, squares = abnormal without ischemia, and triangles = abnormal with ischemia).

prognostic information useful to identify patients at high risk of major cardiac events. Similarly, previous studies showed the prognostic value of SPECT imaging in the evaluation of post-CABG patients.^{2,13,18} In particular, it has been demonstrated that myocardial perfusion defects by SPECT imaging, performed 7 years after CABG, were independent predictors of subsequent cardiac death or myocardial infarction.¹⁸ It has also been reported that nuclear variables, such as infarct size and myocardial ischemia, were predictors of cardiac death in patients more than 5 years after CABG.² In agreement with these previous studies, our findings show

Figure 3. Estimated time from index test to reach the selected risk level (5%) of cardiac events, in patients with or without diabetes according to SPECT imaging results.

a high predictive value of myocardial ischemia by SPECT imaging in such patients. Moreover, even though diabetes was a predictor of unfavorable outcome, the presence of myocardial ischemia at SPECT had the greatest prognostic power. In our patient population, the infarct size did not prove to be a univariate predictor of major cardiac events. However, the combination of infarct size with the presence of myocardial ischemia determined a decrease in patient survival, more evident after the third year of follow-up (as shown in Figure 1).

In patients with coronary artery disease, cardiac risk is considered to be high with an annual event rate greater than 5%.^{2,19} The time to reach a significant risk is clinically important in post-CABG patients, considering that the risk of a hard event increases with time in the overall population with known coronary artery disease and normal SPECT results.⁶ Accordingly, from our data it emerged that in post-CABG patients a normal stress SPECT is reassuring in the subgroup of subjects without diabetes (Figure 2). On the other hand, in the subgroup of patients with diabetes, the probability of failure seems to be less reassuring. In fact, the risk of a hard event increases with time and is accelerated as compared with patients without diabetes, also in the presence of a normal SPECT. Thus, diabetes is an important determinant in cardiac risk and in its evolution, in both patients with normal and abnormal SPECT results. These findings are consistent with those of a previous investigation.⁶ In interpreting our results, it should be considered that diabetes is associated with lipid, platelet, and coagulation abnormalities, contributing to accelerated atherogenesis and thrombogenesis and diffuseness of coronary atherosclerosis.²⁰⁻²² Moreover, endothelial dysfunction, platelet and coagulation abnormalities, and metabolic disorders associated with diabetes may also contribute to the complex and difficult healing process after arterial wall injury.²³

Considering the acceleration in the cardiac risk in diabetic patients with abnormal SPECT and myocardial ischemia after 12 months (Figures 2 and 3) from the imaging study, a clinical weighed decision should be considered in these subgroups of patients as regards referral for invasive procedures. Differently, the time to reach a risk level characterized by an annual event rate greater than 5% in the nondiabetic population with abnormal SPECT without ischemia is relaxed, and it needs more than 3 years before to require a control study during the follow-up (Figure 3).

Limitations

In this study, the event rate was relatively low, as expected in such a low-risk population (ie, revascularized patients with relatively preserved left ventricular function). Despite the limited power to detect the level of some differences between patients with and without events, the prognostic power of SPECT imaging and diabetes is demonstrated. Finally, follow-up angiography was not performed in this study;

thus, the accuracy of SPECT in distinguishing graft stenosis from disease progression in untreated vessels cannot be investigated.

Conclusions

Stress cardiac tomography performed 5 years after CABG is useful to stratify patients at risk of cardiac events. Parametric survival model estimates time to predefined risk and the level of risk at specific time intervals after CABG.

References

1. Hachamovitch R, Berman DS, Shaw LJ, Kiat H, Cohen I, Cabico JA, et al. Incremental prognostic value of myocardial perfusion single photon emission computed tomography for the prediction of cardiac death: differential stratification for risk of cardiac death and myocardial infarction. *Circulation*. 1998;97:535-43.
2. Zellweger MJ, Lewin HC, Lai S, Dubois EA, Friedman JD, Germano G, et al. When to stress patients after coronary artery bypass surgery? Risk stratification in patients early and late post-CABG using stress myocardial perfusion SPECT: implications of appropriate clinical strategies. *J Am Coll Cardiol*. 2001;37:144-52.
3. Berman DS, Hachamovitch R, Kiat H, Cohen I, Cabico JA, Wang FP, et al. Incremental value of prognostic testing in patients with known or suspected ischemic heart disease: a basis for optimal utilization of exercise technetium-99m sestamibi myocardial perfusion single-photon emission computed tomography. *J Am Coll Cardiol*. 1995;26:639-47.
4. Gibbons RJ, Balady GJ, Bricker JT, Chaitman BR, Fletcher GF, Froelicher VF, et al. American College of Cardiology/American Heart Association Task Force on Practice Guidelines. Committee to Update the 1997 Exercise Testing Guidelines. ACC/AHA 2002 guideline update for exercise testing: summary article. A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee to Update the 1997 Exercise Testing Guidelines). *J Am Coll Cardiol*. 2002;40:1531-40.
5. Rizzello V, Poldermans D, Schinkel AF, Biagini E, Boersma E, Elhendy A, et al. Outcome after redo coronary artery bypass grafting in patients with ischaemic cardiomyopathy and viable myocardium. *Heart*. 2007;93:221-5.
6. Hachamovitch R, Hayes S, Friedman JD, Cohen I, Shaw LJ, Germano G, et al. Determinants of risk and its temporal variation in patients with normal stress myocardial perfusion scans: what is the warranty period of a normal scan? *J Am Coll Cardiol*. 2003;41:1329-40.
7. Acampa W, Petretta M, Florimonte L, Mattered A, Cuocolo A. Prognostic value of exercise cardiac tomography performed late after percutaneous coronary intervention in symptomatic and symptom-free patients. *Am J Cardiol*. 2003;91:259-63.
8. Sharir T, Germano G, Kang X, Lewin HC, Miranda R, Cohen I, et al. Prediction of myocardial infarction versus cardiac death by gated myocardial perfusion SPECT: risk stratification by the amount of stress-induced ischemia and the poststress ejection fraction. *J Nucl Med*. 2001;42:831-7.
9. Cox DR. Regression models and life table. *J R Stat Soc B*. 1972;34:187-220.
10. Harrell FE, Lee KL, Califf RM, Pryor DB, Rosati RA. Regression modelling strategies for improved prognostic prediction. *Stat Med*. 1984;3:143-52.
11. Lawless J. Statistical models and methods for lifetime data. New York: John Wiley; 1982.
12. Harrell FE Jr. Predicting outcomes: applied survival analysis and logistic regression. Charlottesville (VA): University of Virginia; 2000.
13. Shaw LJ, Iskandrian AE. Prognostic value of gated myocardial perfusion SPECT. *J Nucl Cardiol*. 2004;11:171-85.
14. Abramov D, Tamariz MG, Femes SE, Guru V, Borger MA, Christakis GT, et al. Trends in coronary artery bypass surgery results: a recent, 9-year study. *Ann Thorac Surg*. 2000;70:84-90.
15. Shapira I, Isakov A, Heller I, Topilsky M, Pines A. Long-term follow-up after coronary artery bypass grafting reoperation. *Chest*. 1999;115:1593-7.

16. Di Mauro M, Iacò AL, Contini M, Teodori G, Vitolla G, Pano M, et al. Reoperative coronary artery bypass grafting: analysis of early and late outcomes. *Ann Thorac Surg.* 2005;79:81-7.
17. He GW, Acuff TE, Ryan WH, He YH, Mack MJ. Determinants of operative mortality in reoperative coronary artery bypass grafting. *J Thorac Cardiovasc Surg.* 1995;110:971-8.
18. Lauer MS, Lytle B, Pashkow F, Snader CE, Marwick TH. Prediction of death and myocardial infarction by screening with exercise-thallium testing after coronary-artery-bypass grafting. *Lancet.* 1998;351:615-22.
19. Braunwald E, Mark DB, Jones RH. Unstable angina: diagnosis and management. AHCPR publication 94-0602. *US Department of Health and Human Services.* 1994.
20. Berry C, Tardif JC, Bourassa MG. Coronary heart disease in patients with diabetes. Part I: recent advances in prevention and noninvasive management. *J Am Coll Cardiol.* 2007;49:631-42.
21. Berry C, Tardif JC, Bourassa MG. Coronary heart disease in patients with diabetes. Part II: recent advances in coronary revascularization. *J Am Coll Cardiol.* 2007;49:643-56.
22. Ledru F, Ducimetière P, Battaglia S, Courbon D, Beverelli F, Guize L, et al. New diagnostic criteria for diabetes and coronary artery disease: insights from an angiographic study. *J Am Coll Cardiol.* 2001;37:1543-50.
23. Stadius ML, Alderman EL. Coronary artery revascularization. Critical need for, and consequences of, objective angiographic assessment of lesion severity. *Circulation.* 1990;82:2231-4.

Interactive eLearning Activities

<http://learning.ctsnet.org>

The Joint Council on Thoracic Surgery Education was pleased to introduce a series of unique eLearning activities to CTSNet users at the AATS annual meeting in Philadelphia. Sponsored by several cardiothoracic surgical groups, this exciting new educational tool contains narrated videos of actual surgical procedures followed by a series of questions and an evaluation to earn Continuing Medical Education credit.

- * **Diagnosis and Management of Complications of Mitral Valve Repair**
- * **Off Pump Coronary Artery Bypass**
- * **OPCAB Debriefing**
- * **Pediatric Cardiopulmonary Bypass Emergency Situations**

Experience these new educational tools today and provide us with your feedback. Go to: <http://learning.ctsnet.org>

William E. Baumgartner, Chair
Joint Council on Thoracic Surgery Education

Sponsored By:
American Association for Thoracic Surgery
The Society of Thoracic Surgeons
European Association for Cardio-Thoracic Surgery
Children's Memorial Hospital