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Care of Acute Myocardial Infarction by Noninvasive and Invasive Cardiologists: Procedure Use, Cost and Outcome

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Objectives. **This study sought to determine how noninvasive and invasive cardiologists may differ in the hospital care of patients with acute myocardial infarction.**

Background. **Scant information exists regarding the effect of noninvasive and invasive cardiology subspecialization on invasive cardiac procedural use, cost and outcome in the care of patients with acute myocardial infarction.**

Methods. **This study analyzed a prospective cohort of 292 patients admitted to an urban tertiary care hospital from the emergency room under the care of noninvasive or invasive cardiologists. Clinical characteristics; hospital course, including management, utilization of diagnostic coronary angiography and percutaneous transluminal coronary angioplasty; direct hospital costs; length of hospital stay; and post-hospital discharge follow-up data were collected by a prospective data base instrument.**

Results. **Despite similar clinical characteristics, extent and severity of coronary artery disease and utilization of diagnostic coronary angiography in the two groups of patients, those under the care of an invasive cardiologist were significantly more likely to undergo coronary angioplasty than those under the care of a noninvasive cardiologist. The direct hospital costs and length of stay of the noninvasive and invasive group patients who underwent coronary angioplasty were similar, although overall the direct hospital costs and length of stay were higher for the invasive than for the noninvasive group patients.**

Conclusions. **Noninvasive and invasive cardiologists differ in their rate of utilization of coronary angioplasty in similar patients with acute myocardial infarction.**

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Over 400,000 percutaneous transluminal coronary angioplasty procedures were performed in the United States in 1993 (1). The high initial success rate, superior relief of angina compared with medical therapy and initially lower cost of coronary angioplasty compared with coronary artery bypass graft surgery have resulted in ever-widening indications for angioplasty (2). Recent controlled trials support the efficacy of angioplasty in symptomatic single-vessel (3,4) and multivessel coronary artery disease (5–8) and acute myocardial infarction (9). In retrospective studies, timely angioplasty is efficacious in cardiogenic shock complicating myocardial infarction (10). However, the role of angioplasty remains undefined in several common clinical settings, including the subacute phase of myocardial infarction in patients with one- or two-vessel coronary artery disease (2).

The growth of coronary angioplasty has been accompanied by a parallel growth in the number of invasive cardiology subspecialists who perform angioplasty as part of routine clinical practice. Scant information exists regarding the effect of invasive cardiology subspecialization itself on invasive cardiac procedural use, cost and outcome. The purpose of the present study was to examine the effects of noninvasive versus invasive cardiology subspecialization on the rate of utilization of cardiac procedures, cost and outcome of care of patients with acute myocardial infarction.

Methods

Study group. The study included 292 patients with acute myocardial infarction admitted from the emergency room to the Massachusetts General Hospital between July 1, 1991 and December 31, 1992. Of the 292 patients, 213 (73%) were admitted under the care of one of the 32 hospital staff noninvasive cardiologists, and 79 (27%) were admitted under the care of one of the 13 hospital staff invasive cardiologists. For the purpose of the present study, an *invasive cardiologist* was defined as a staff cardiologist who performed interventional and diagnostic cardiac catheterization (n = 7), diagnostic catheterization alone (n = 2) or invasive electrophysiologic testing (n = 4). All other staff cardiologists were designated as *noninvasive cardiologists*. There were no direct financial incentives for invasive cardiologists to perform diagnostic coronary

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angiography or coronary angioplasty because all staff invasive cardiologists received a fixed annual salary for their cardiac catheterization practices, and procedure-related professional fees were collected by the hospital. Similarly, there were no direct financial incentives for noninvasive cardiologists not to refer patients for catheterization or angioplasty.

All 292 patients were identified prospectively by daily rounds and enrolled in a myocardial infarction registry after giving written informed consent. Enrollment in the registry and the study was approved by the Subcommittee on Human Studies at the Massachusetts General Hospital. The patient's attending staff cardiologist was unaware of the patient's enrollment in the registry or the purpose of the study.

Myocardial infarction was defined by elevation of the serum creatine kinase (CK), MB fraction (≥3% of total CK) on at least one occasion in addition to either 1) a history compatible with myocardial infarction; or 2) supportive ECG abnormalities defined as a) evolution of new pathologic Q waves (≥0.04 s) or b) ≥0.1-mV ST segment elevation in contiguous leads or c) ≥0.1-mV ST segment depression or definite T wave inversion. Myocardial infarction that occurred as a complication of cardiac catheterization, coronary angioplasty, coronary artery bypass graft surgery or any other surgical procedure were excluded from the study.

Significant coronary artery stenosis was defined as stenosis >70% of the lumen diameter of either the left anterior descending, circumflex or right coronary artery at diagnostic coronary angiography. *Significant left main coronary artery stenosis* was defined as stenosis >50% of the lumen diameter of the left main coronary artery. All coronary angiograms were read by one of two staff cardiac radiologists. Stenoses were measured by the use of hand-held calipers in multiple views and quantified in comparison to the closest nonstenotic arterial segment.

Data collection. Data regarding *hospital course and outcome* were collected by investigators with no knowledge of the hypotheses being tested. Detailed information concerning clinical presentation of acute myocardial infarction, previous cardiac and medical history, previous cardiac procedures, management and clinical course of myocardial infarction was collected for each patient. Outcomes during the hospital period included death, recurrent myocardial infarction, coronary angioplasty, coronary artery bypass surgery, total length of hospital stay (in days), total number of intensive care unit days and direct hospital costs.

Hospital charge and cost data were obtained from the Massachusetts General Hospital Department of Fiscal Affairs. Direct hospital costs were calculated as follows: 1) itemized hospital charges for the entire hospital admission were summed into a single figure, total hospital charges; 2) a single diagnosis-related group (DRG) was assigned for the entire admission according to the principal discharge diagnosis; 3) the total hospital charges were multipled by a DRG-specific cost/charge ratio to yield the direct hospital cost. The DRG-specific cost/charge ratios were derived by the Department of Fiscal Affairs for use in hospital accounting of direct hospital costs and are based on direct hospital marginal costs and hospital overhead. Physician professional fees were not included in the itemized charge accounting.

For *data abstracted from medical records*, data quality control was maintained by rechecking a random 10% sample of medical records to ensure >90% interrater reliability. After data entry, similar random checks and range checks were performed to ensure data accuracy. The records of all patients with hospital charges <$10,000 or >$55,000 (~65 records) were re-reviewed to ensure suitability for inclusion in the study.

Post-hospital discharge follow-up data included death and recurrent myocardial infarction. Postdischarge follow-up data were obtained by telephone interview with patients or responsible physicians (85% of cases) or by review of available medical records for those patients and physicians unreachable by telephone (11% of cases). At the time of analysis, follow-up information was available for 96% of the study group.

Statistical analysis. The distribution of the continuous variables was examined for normality. Nonnormal continuous variables were log transformed for valid parametric analysis (total length of hospital stay, direct hospital costs). In univariate analyses, chi-square tests of general association were used to compare categoric variables; the Fisher exact test was used when appropriate. A two-sample Student t test with assumption of unequal variances was used to compare independent means of continuous variables. In multivariate linear and logistic regression analyses, only variables with a univariate relation to the outcome variable significant at ≤0.10 were entered as candidate variables. For logistic regression analyses, a forward-stepping selection algorithm was used (BMDP program LR); for linear regression analyses, a best possible all-subsets algorithm (BMDP program 9S) was used. Life-table analysis by the method of Kaplan-Meier was used to estimate group survival, and the generalized Savage log-rank test was used to compare group survival distributions.

Results

Demographics and clinical characteristics. Of 292 study patients (mean [±SD] age 66 ± 12.5 years, 213 [71%] male), most had one or more risk factors for coronary artery disease (hypertension 56%, cigarette smoking 54%, positive family history of coronary artery disease 37%, diabetes mellitus 25%, and hypercholesterolemia 37%). Only a minority of patients had previous angina (39%), myocardial infarction (37%), heart failure (18%), cardiac catheterization (23%), coronary artery bypass surgery (14%) or coronary angioplasty (8%).

Of the 292 patients, 213 (73%) were admitted from the emergency room under the care of a noninvasive cardiologist, and 79 (27%) were admitted under the care of an invasive cardiologist. The noninvasive and invasive patient groups were comparable with respect to age, gender, prevalence of cardiac risk factors (except for an increased prevalence of hypertension in the invasive group) and history of angina, myocardial infarction or previous invasive cardiac procedures, including

Table 1. Patient Characteristics, Presentation, Location and Initial Therapy of Acute Myocardial Infarction: All Patients

	Noninvasive Group (n = 213)	Invasive Group (n = 79)	p Value
Pt characteristic			
Age (yr)	66 ± 12	66 ± 13	0.82
Male	69	71	0.71
Htn	53	68	0.02*
Cigs	54	54	1.00
FHx	37	38	0.89
DM	25	27	0.76
Chol	35	43	0.27
Prior angina	39	35	0.57
Prior MI	34	44	0.13
Prior angio	19	30	0.06
Prior PTCA	6	10	0.20
Prior CABG	14	14	1.00
Prior CHF	16	22	0.27
MI			
CP	81	82	0.95
Arrest	5	4	0.90
Cardiogenic shock	4	8	0.19
CHF	22	24	0.75
Q wave MI	34	44	0.16
Non-Q wave MI	66	56	0.19
Ant MI	33	39	0.41
Inf MI	31	17	0.04*
Thrombolysis	23	25	0.76

*$p < 0.05$. Data presented are mean value ± SD or percent of patients. angio = diagnostic coronary angiography; Ant = anterior; Arrest = cardiopulmonary arrest; CABG = coronary artery bypass grafting; CHF = congestive heart failure; Chol = history of hypercholesterolemia; Cigs = cigarettes; CP = chest pain; DM = diabetes mellitus; FHx = positive family history of coronary artery disease; Htn = hypertension; Inf = inferior; MI = myocardial infarction; Pt = patient; PTCA = percutaneous transluminal coronary angioplasty.

cardiac catheterization, coronary angioplasty and coronary artery bypass surgery (Table 1). There was a trend in the invasive group patients toward a higher incidence of previous myocardial infarction, diagnostic coronary angiography and angioplasty and presentation with Q wave myocardial infarction and shock.

Presentation and initial therapy of myocardial infarction: all patients. The majority of the 292 patients reported chest pain on presentation (81.5%) (Table 1). Most of the resultant myocardial infarctions were non-Q wave (64%) with a mean peak serum CK level of 1,150 ± 1,496 U/liter. A minority of patients (24%) were treated with intravenous thrombolytic agents. The clinical features and initial therapy of myocardial infarction in the invasive and noninvasive patient groups were comparable (Table 1). There were no significant differences in frequency or duration of self-reported chest pain or presence of new pathologic Q waves on the initial surface ECG. Noninvasive group patients were more likely to have inferior than anterior myocardial infarction. A similar proportion of patients in each group received thrombolytic therapy within 6 h of symptom onset.

Table 2. Hospital Course of Myocardial Infarction, Diagnostic Coronary Angiography and Myocardial Revascularization: All Patients

	Noninvasive Group (n = 213)	Invasive Group (n = 79)	p Value
Course			
Peak total CK (IU)	1,119 ± 404	1,203 ± 178	0.67
Peak CK-MB (IU)	123 ± 13	132 ± 18	0.72
Peak CK-MB index (%)	12 ± 0.62	13 ± 0.8	0.65
PA catheter	26	34	0.19
Mechanical ventilation	20	28	0.20
IABP	20	28	0.20
Post-MI angina	40	47	0.35
Post-MI angina equivalent	4	1	0.29
Post-MI VT	21	22	0.87
Post-MI VF	5	6	0.57
Heart block	2	2	1.00
Pulmonary edema	26	25	0.88
Cardiogenic shock	4	9	0.15
ETT-Tl	45	35	0.18
Reversible defects	24	26	0.79
Diagnostic coronary angiography			
Cath	59	68	0.23
Median days after MI	4.5	4.5	1.00
3-VD	20	25	0.31
2-VD	26	19	0.31
1-VD	43	47	0.62
LMCA	11	7	0.59
Myocardial revascularization			
CABG (%)	12	13	0.84
PTCA			
All pts	19	33	0.024*
All pts with cath	32	50	0.019
3-VD	17	40	0.43
2-VD	31	50	0.45
1-VD	43	64	0.14
1- or 2-VD	39	60	0.034*

*$p < 0.05$. Data presented are mean value ± SE or percent of patients, unless otherwise indicated. Cath = catheterization; CK = creatine kinase; ETT-Tl = exercise treadmill test with thallium (Tl) perfusion imaging; IABP = intraaortic balloon pump device; LMCA = left main coronary artery; PA = pulmonary artery; pts = patients; Reversible defects = reversible defects on thallium scintigraphy; VF = ventricular fibrillation; VT = ventricular tachycardia; 1-, 2-, 3-VD = one-, two-, three-vessel coronary artery disease, respectively; other abbreviations as in Table 1.

Hospital course of myocardial infarction: all patients. Overall, 122 patients (42%) experienced postinfarction angina pectoris, 60 (21%) had ventricular tachycardia (≥3 consecutive ventricular beats), and 75 (26%) had pulmonary edema (Table 2). During the hospital course, 81 patients (28%) underwent invasive hemodynamic monitoring with a thermodilution pulmonary artery catheter, 64 (22%) underwent endotracheal intubation and mechanical ventilation, and 43 patients (15%) underwent insertion of an intraaortic balloon pump. One hundred twenty-two patients (42%) underwent exercise or dipyridamole thallium scintigraphy; there was no difference in the proportion of noninvasive versus invasive group patients

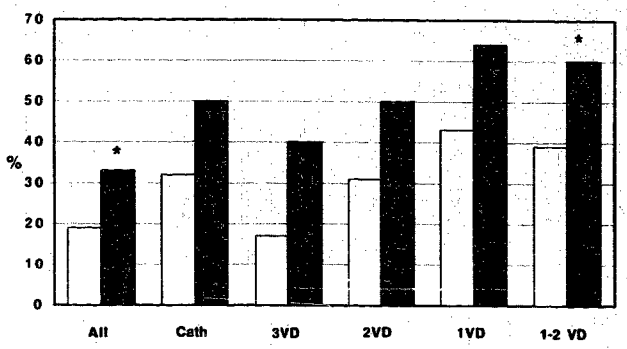

Figure 1. Comparison of percent of noninvasive (**open bars**) and invasive group patients (**solid bars**) undergoing angioplasty. Cath = diagnostic coronary angiography; VD = vessel disease. *p < 0.05 between groups.

who underwent exercise or dipyridamole thallium scintigraphy (45 vs. 35%, p = NS).

Overall, 179 patients (61%) underwent diagnostic coronary angiography at a median of 4.5 days after hospital admission. A similar proportion of noninvasive and invasive group patients underwent diagnostic coronary angiography (59% vs. 68%, p = 0.23). Univariate predictors of diagnostic coronary angiography for all 292 patients included postinfarction angina pectoris, insertion of an intraaortic balloon pump, older age, higher peak serum CK levels, appearance of a new ECG Q wave, previous diagnostic coronary angiography, anterior myocardial infarction, development of congestive heart failure during admission and previous coronary angioplasty. By multivariate logistic regression, only postinfarction angina pectoris, older age, insertion of an intraaortic balloon pump, previous diagnostic coronary angiography and anterior myocardial infarction were significant independent predictors of diagnostic coronary angiography in all patients.

At diagnostic coronary angiography, 38 patients (21%) had significant three-vessel coronary artery disease, 45 (25%) had significant two-vessel disease, 79 (44%) had significant one-vessel disease, and 17 (9%) had no significant coronary artery disease. Seventeen patients (9%) had significant left main coronary artery disease. There was no difference between noninvasive and invasive group patients in angiographic extent or severity of coronary artery disease (Table 2).

Percutaneous transluminal coronary angioplasty: all patients. After diagnostic coronary angiography, 67 patients (37% of those undergoing diagnostic coronary angiography) underwent coronary angioplasty (Fig. 1). Despite similar baseline characteristics, clinical course of myocardial infarction and angiographic severity of coronary artery disease, a significantly larger proportion of invasive versus noninvasive group patients overall (33% vs. 19%, p = 0.024) and invasive versus noninvasive group patients who underwent diagnostic coronary angiography (50% vs. 32%, p = 0.019) subsequently underwent angioplasty (Table 2). Invasive patients with one- or two-vessel coronary artery disease were also significantly more likely to undergo angioplasty (60% vs. 39%, p = 0.034).

Predictors of coronary angioplasty: all patients. Univariate predictors of coronary angioplasty for the 179 patients who underwent diagnostic coronary angiography included the angiographic extent of coronary artery disease, history of previous angioplasty, new Q wave myocardial infarction, a reversible perfusion defect on thallium-201 myocardial scintigraphy and absence of left main coronary artery stenosis (Table 3). In addition, invasive cardiology subspecialization was associated with a higher utilization rate of angioplasty overall compared with noninvasive subspecialization (47 vs. 32%, p = 0.050). By multivariate logistic regression analysis controlling for the presence of one-, two- or three-vessel coronary artery disease, independent predictors of angioplasty included previous angioplasty, invasive cardiology subspecialization, one- or two-vessel coronary artery disease and new Q wave myocardial infarction (Table 3).

Predictors of coronary angioplasty: patients with one- or two-vessel coronary artery disease. There were no significant differences in the baseline patient clinical characteristics or presentation or clinical course of myocardial infarction in noninvasive versus invasive group patients with one- or two-vessel coronary artery disease (Table 4). In patients with one- or two-vessel coronary artery disease, significant univariate

Table 3. Predictors of Coronary Angioplasty in 179 Patients Undergoing Diagnostic Coronary Angiography

Variable	Coeff	SE or Coeff	p Value
Univariate analysis			
No. of vessels with CAD			<0.001
Prev PTCA			0.004
New Q waves			0.01
Revisable defects			0.02
LMCA			0.035
Invasive cardiologist			0.05
Multivariate analysis			
New Q waves	1.85	0.63	0.006
2-VD CAD	2.43	1.05	0.011
Prev PTCA	2.46	1.24	0.023
1-VD CAD	2.64	0.93	0.029
Invasive cardiologist	2.14	0.86	0.036

CAD = coronary artery disease (>70% lumen diameter narrowing); Coeff = variable logistic regression coefficient; other abbreviations as in Tables 1 and 2.

Table 4. Clinical Characteristics and Predictors of Coronary Angioplasty: Patients With One- or Two-Vessel Coronary Artery Disease

	Noninvasive Group (n = 83)	Invasive Group (n = 35)	p Value
Clinical characteristic			
Mean (±SD) age (yr)	63 ± 11	62 ± 11	0.71
Q wave	43	57	0.84
Cardiogenic shock	2	0	1.0
CHF	18	14	0.79
Prev MI	27	29	0.90
Prev CABG	5	6	0.99
Prev PTCA	9	14	0.51
DM	28	17	0.25
Mean (±SEM) peak CK (IU)	1,518 ± 203	1,521 ± 296	0.70
Pulmonary edema	25	20	0.64
ETT-Tl done	50	40	0.83
IABP	22	23	1.0
Ant MI	56	43	0.54
Inf MI	31	23	0.50
Post-MI angina	52	63	0.32
LMCA	6	3	0.67
LAD	47	57	0.33
RCA	61	43	0.07
Predictors of PTCA			
Univariate analysis			
Q wave MI			0.005
Prev PTCA			0.011
Prev angio			0.021
Invasive cardiologist			0.034
Reversible defects			0.045
Multivariate analysis			
	Coeff	SE or Coeff	
Prev PTCA	2.32	0.83	0.011
Q wave MI	1.23	0.42	0.021
Invasive cardiologist	0.94	0.45	0.045

Unless otherwise indicated, data presented are percent of patients. LAD = left anterior coronary artery; RCA = right coronary artery; other abbreviations as in Tables 1 to 3.

predictors of angioplasty included previous cardiac catheterization, previous angioplasty, invasive cardiologist subspecialization, reversible defect on thallium scintigraphy and new Q waves on the ECG. By multivariate logistic regression analysis, independent predictors of angioplasty included previous angioplasty, new Q waves on the ECG and invasive cardiology subspecialization (Table 4).

Hospital outcomes: length of stay, direct cost, reinfarction and mortality. For the entire study group, the median length of hospital stay was 11 days. Invasive group patients had significantly longer mean total hospital stays and days in intensive care unit (Table 5). Overall, direct total hospital costs were higher for invasive group patients, especially for those who did not undergo diagnostic coronary angiography. However, direct hospital costs were similar among noninvasive and invasive group patients who underwent diagnostic coronary angiography or coronary angioplasty. The cost difference between noninvasive and invasive group patients who did not undergo cardiac catheterization was most likely related to greater baseline comorbidity and severity of illness in the invasive group patients. Compared with noninvasive group patients (n = 85), invasive group patients (n = 26) tended to have an increased prevalence of previous congestive heart failure (46% vs. 27%), more total hospital days (2.51 ± 0.81 vs. 2.43 ± 0.62 log days, p = 0.041), more intensive care unit days (1.11 ± 0.11 vs. 0.81 ± 0.85 log days, p = 0.015), a higher incidence of pulmonary artery catheterization (35% vs. 20%) and intubation (35% vs. 21%) and increased in-hospital mortality (31% vs. 12%, p = 0.032).

For all 292 patients, significantly higher direct total hospital costs were associated with diabetes mellitus, higher peak serum CK levels, insertion of a pulmonary artery catheter or intraaortic balloon pump, intubation, postinfarction angina pectoris, development of pulmonary edema or cardiogenic shock, diagnostic coronary angiography, coronary angioplasty, coronary artery bypass surgery, invasive physician subspecialization and number of both total hospital and total days in intensive care unit. Multivariate predictors of total direct hospital cost in all patients included performance of coronary artery bypass surgery, number of total hospital days, number of days in intensive care unit and insertion of an intraaortic balloon pump. Performance of diagnostic coronary angiography, angioplasty and cardiology subspecialization were not independent multivariate predictors of total direct hospital cost in all patients. When patients undergoing coronary artery bypass surgery were excluded from cost analysis, univariate predictors of direct total hospital costs included therapy with a thrombolytic agent, Q wave or anterior myocardial infarction, higher peak CK levels, shock, insertion of a pulmonary artery catheter or intraaortic balloon pump, postinfarction angina pectoris, performance of diagnostic coronary angiography or angioplasty, invasive physician subspecialization and number of both total hospital days and days in intensive care unit. Multivariate predictors of total direct hospital costs in those patients not undergoing coronary artery bypass surgery included number of total hospital days, number of days in intensive care unit, performance of diagnostic coronary angiography and endotracheal intubation.

Follow-up. Overall mean follow-up was 13 months (range 1 to 39). There was no difference between noninvasive and invasive group patients in the incidence of recurrent myocardial infarction or all-cause mortality rate (Table 5).

Discussion

The major finding of this study is that patients with acute myocardial infarction admitted to the hospital under the care of invasive cardiologists were more likely to undergo coronary angioplasty during their hospital stay than were similar patients with acute myocardial infarction admitted under the care of noninvasive cardiologists. Care by an invasive cardiologist was an independent predictor of angioplasty in the 292 study patients overall, in the 179 who underwent diagnostic coronary angiography and the 119 found to have one- or two-vessel

Table 5. Outcomes: Hospital Length of Stay, Cost, Mortality Rate and Recurrent Myocardial Infarction

	All Pts	Noninvasive Group	Invasive Group	p Value
Log total days	2.44 ± 0.69	2.43 ± 0.62	2.51 ± 0.81	0.041
Log ICU days	0.88 ± 0.92	0.81 ± 0.85	1.1' ± 0.11	0.015
Median cost (dollars)				
All pts	14,006	13,321	16,707	0.16
No angio (n = 113)	10,059	8,801	16,302	0.053
Angio (n = 179)	16,971	17,317	16,886	0.89
PTCA (n = 66)	15,834	16,624	15,721	0.80
2-VD (n = 118)	15,835	15,852	15,201	0.85
2-VD + PTCA	14,534	14,935	14,189	0.84
Mean log total cost (dollars)				
All pts	9.65 ± 0.76	9.60 ± 0.73	9.81 ± 0.81	0.041*
No angio (n = 113)	9.29 ± 0.75	9.16 ± 0.66	9.75 ± 0.88	0.006*
Angio (n = 179)	9.87 ± 0.68	9.89 ± 0.63	9.83 ± 0.78	0.60
PTCA (n = 66)	9.83 ± 0.65	9.83 ± 0.80	9.80 ± 0.80	0.93
2-VD (n = 118)	9.81 ± 0.64	9.84 ± 0.57	9.74 ± 0.70	0.20
2-VD + PTCA	9.73 ± 0.56	9.66 ± 0.64	9.73 ± 0.56	0.56
In-hospital mortality (%)				
All pts	10	9	13	0.31
No angio	16	12	31	0.03*
Angio	6	6	4	0.73
PTCA	6	5	8	0.63
Follow-up				
Recurrent MI (%)				
All pts	14	15	10	0.49
No angio	20	19	27	0.48
Angio	10	13	5	0.22
PTCA	9	11	5	0.64
Mortality (%)				
All pts	11	11	11	1.00
No angio	17	16	19	0.73
Angio	7	7	8	0.91
PTCA	3	5	0	0.51

Unless otherwise indicated, data are mean value ± SD. ICU = intensive care unit; Log = logarithm; other abbreviations as in Tables 1 to 3

coronary artery disease. Compared with patients cared for by noninvasive cardiologists, patients cared for by invasive cardiologists did not differ with respect to presentation, size or clinical course of myocardial infarction, performance or results of exercise or dipyridamole thallium scintigraphic stress testing or the angiographic extent of coronary artery disease. Patients who were cared for by either a noninvasive or invasive cardiologist and who underwent diagnostic coronary angiography or angioplasty had similar total direct hospital costs and length of hospital stay. There were no differences in in-hospital reinfarction or mortality rates or postdischarge reinfarction or mortality rates between noninvasive and invasive group patients overall during a mean 13-month follow-up period. The difference in utilization of angioplasty was found in the absence of a direct financial incentive to invasive cardiologists for performance of diagnostic coronary angiography or angioplasty, because fee-for-service invasive cardiology practice was not permissible.

Role of coronary angioplasty in myocardial infarction. The role of coronary angioplasty in the management of the acute and subacute phase of myocardial infarction is evolving. Direct angioplasty may be comparable if not superior to thrombolytic therapy in selected centers, with a higher short-term infarct-related vessel patency rate and fewer in-hospital adverse events, especially in high risk patients (9,11,12). Routine early or delayed angioplasty after thrombolytic therapy has not been shown to improve the survival rate or left ventricular function or to decrease postinfarction angina (13,14). The initial success rate of coronary angioplasty is lower for unstable angina and non–Q wave myocardial infarction than for stable angina, and the risk of abrupt occlusion and long-term restenosis is increased (15). As a result, angioplasty at present is usually reserved for the postinfarction patient who experiences either recurrent angina or demonstrable myocardial ischemia on exercise testing (2,15). The finding in the present study that a minority of patients undergoing angioplasty had stress testing before angioplasty is consistent with previous reports: Despite the publication of angioplasty guidelines recommending stress testing before angioplasty in patients with stable angina after myocardial infarction, only 9% of patients nationwide undergo

exercise testing after myocardial infarction before angioplasty (16).

The role of coronary angioplasty in chronic coronary artery disease is similarly evolving. In carefully selected patients, the efficacy of angioplasty is similar to coronary artery bypass grafting in multivessel coronary artery disease (5–8,17). In one- or two-vessel coronary artery disease the role of angioplasty is unclear; in such patients, even bypass surgery appears to have no advantage over medical therapy with respect to survival (17). In patients with single-vessel coronary artery disease and stable exertional angina pectoris, angioplasty may increase exercise performance, necessitate fewer antianginal medications and decrease the frequency and severity of angina (3). Angioplasty may be comparable in efficacy to left internal mammary grafting for isolated left anterior descending coronary artery stenosis (4). Despite these encouraging results, the long-term outcome and cost-effectiveness of angioplasty are not yet established.

Cardiologist subspecialization and utilization of coronary angioplasty. The growth of coronary angioplasty as an option for coronary revascularization has paralleled an increase in physician subspecialization within cardiology in the United States. In the United States, 1.5 to 5.0 more angioplasty procedures are performed per capita than in any European country (1). One large survey (18) of U.S. practicing cardiologists found that 43% of respondents performed angioplasty. It is estimated that >8,000 U.S. cardiologists perform angioplasty (1). The effect of such subspecialization on cardiology practice patterns, cost and outcome is unknown.

Physician subspecialization has been reported to influence practice patterns and cost of medical care in diverse clinical settings outside cardiology. The cost and benefit of asthma care are both increased when provided by allergists compared with family practitioners (19,20). Similar observations have been reported for the care of breast cancer (21), acquired immunodeficiency syndrome (AIDS) (22), diabetes (23) and chronic obstructive pulmonary disease (24). Cardiologists are more likely than internists or general practitioners to be aware of key advances in the treatment of myocardial infarction (25). In one study of the ambulatory care of patients with chronic ischemic heart disease, cardiologists were less likely than internists to prescribe systemic drugs but more likely to obtain ECGs (26). Patients of cardiologists have a higher rate of hospital admissions and office visits, a greater number of drugs prescribed and more tests and procedures performed (27) than do similar patients cared for by internists and family practitioners.

Practice pattern differences have been reported among cardiologists as well. Unexplained differences in hospital length of stay for myocardial infarction occur in different geographic regions (28). Regional differences exist in the United States regarding the utilization and associated hospital length of stay for coronary angioplasty without clear improvement in outcome (16). In a study of postinfarction patients from New York State, the availability of angioplasty at a given hospital significantly increased the odds of a patient undergoing the procedure during the period after acute myocardial infarction (29). There exists an inverse relation between the number of angioplasty procedures performed at a given hospital and the rate of subsequent coronary artery bypass graft surgery procedures and short-term mortality (30).

Clinical implications. The implications of possible disproportionate utilization of coronary angioplasty by invasive cardiology subspecialists are not clear at present. In New York State, 38% of angioplasties performed in 1990 were rated as having "uncertain" value on review, and 4% were rated as "inappropriate"; the "uncertain" rate varied significantly by hospital and ranged from 26% to 50% (31). Fourteen percent of patients referred for angioplasty in southwestern Sweden in 1990 had uncertain or inappropriate indications (32). In the state of California, 60% of hospitals in which angioplasty was offered performed fewer than the recommended 200 angioplasties/year (33). Thus, invasive cardiologists may tend to use angioplasty more often than noninvasive cardiologists and be prone to recommend angioplasty in marginal or uncertain clinical circumstances. Alternatively, noninvasive cardiologists tend to use angioplasty less often than invasive cardiologists and be prone to recommend angioplasty only in dire circumstances. The present study suggests that the practice patterns of noninvasive and invasive cardiologists differ and that practice differences with regard to the performance of angioplasty may exist. Direct financial incentives for the performance of diagnostic coronary angiography and angioplasty did not exist in the present study. The differences in utilization of angioplasty where such incentives exist may be even more striking. Previous studies (23) support the notion that financial incentives do influence the physician's decisions and practice styles.

Study limitations. The present study is limited in several respects. It represents the experience of a single tertiary care academic hospital in a competitive urban medical environment. Thus, the results of the study may not be generalizable to different hospitals and medical environments. Physician fees were not included in the cost calculations: only direct hospital costs (based on marginal cost and overhead) were used. However, imputation of Medicaid professional fees to the cost totals did not qualitatively alter the differences in log costs between groups displayed in Table 5. The power of the study to detect differences in mortality over the follow-up period is low. Information concerning long-term patient outcomes was limited. Further multicenter studies are necessary to determine whether these observed practice patterns and possible biases indeed exist and to assess their effect on longer term outcomes and cost.

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