VARIATION AMONG HOSPITALS IN CORONARY-ANGIOGRAPHY PRACTICES AND OUTCOMES AFTER MYOCARDIAL INFARCTION IN A LARGE HEALTH MAINTENANCE ORGANIZATION

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ABSTRACT

Background Wide geographic variation in the use of coronary angiography after myocardial infarction has been documented internationally and within the United States. An associated variation in clinical outcomes has not been consistently demonstrated.

Methods We assessed the risk of death from heart disease and of any heart disease event (death, reinfarction, or rehospitalization) over a follow-up period of one to four years in 6851 patients hospitalized with acute myocardial infarction at 16 Kaiser Permanente hospitals from 1990 through 1992. The percentage of patients who underwent angiography within three months after infarction ranged from 30 to 77 percent. We selected a subcohort of 1109 patients from three hospitals with higher rates of angiography and four with lower rates for a record review to assess the severity of infarction, the number of coexisting conditions, treatments received, and the appropriateness and necessity of angiography, using established criteria.

Results The rates of angiography were inversely related to the risk of death from heart disease ($P = 0.03$) and the risk of heart disease events ($P < 0.001$) among the 16 hospitals after adjustment for age, sex, race, coexisting conditions, and the location of the infarction (subendocardial vs. transmural). In the subcohort, 440 patients met criteria indicating that angiography was necessary and 669 did not. Among the former, patients treated at hospitals with higher rates of angiography had a lower risk of death and of any heart disease event than those treated at hospitals with lower rates (hazard ratios, 0.67 and 0.72, respectively). Among the latter, the apparent benefits of being treated at hospitals with higher angiography rates were smaller (hazard ratios, 0.85 to 0.90 for death and any heart disease event, respectively).

Conclusions During the one to four years after myocardial infarction, patients treated at hospitals with higher rates of angiography had more favorable outcomes than those treated at hospitals with lower rates. This association was stronger among patients for whom published criteria indicated that angiography was necessary. (N Engl J Med 1996;335: 1888-96.)

THERE is considerable geographic variation in the use of coronary angiography and revascularization within the United States and internationally, both in general populations[1-3] and among patients who have had myocardial infarctions.[4-8] It is less clear whether this variation leads to differences in patient outcomes.[4-7]

Geographic variation may indicate overuse of a procedure (inappropriate use in persons not expected to benefit from the procedure) or underuse (failure to perform the procedure in persons who need it). Outcomes are more likely to differ when variation is due at least in part to the underuse of effective procedures.

Panels of experts have developed criteria for the appropriateness and necessity of coronary angiography and revascularization.[9-13] To date, these criteria have been applied primarily to persons who undergo these procedures.[14-20] The frequency of inappropriate use of procedures has been relatively low and is insufficient to explain geographic variation in procedure rates.[14,20] These findings suggest that underuse may contribute to geographic variation, but this possibility has not been examined directly.

We studied whether variation in the rates of coronary angiography after myocardial infarction among 16 hospitals of a large health maintenance organization (HMO) was associated with differences in patient outcomes. We examined differences in the use of angiography rather than revascularization, because decisions regarding angiography involved more physicians and greater variation in practice patterns. Once referred for angiography, patients come under the care of a relatively small group of invasive cardiologists.

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METHODS

Study Setting and Patient Cohort

We conducted a retrospective, cohort study of 6851 patients 25 years of age or older who were discharged from hospitals of the Kaiser Permanente Medical Care Program, Northern California Region, with principal diagnoses of acute myocardial infarction (*International Classification of Diseases, 9th Revision, Clinical Modification* [ICD-9-CM] code 410) between January 1, 1990, and December 31, 1992. This group-model HMO served 2.4 million enrollees during this period through 15 program-owned hospitals and 1 contract community hospital. Three program-owned hospitals and the community hospital had coronary-angiography suites, but only one performed revascularization. Sixty-three percent of coronary angiographies and 15 percent of revascularizations were performed at these hospitals. The remainder were performed at seven community hospitals, often by Kaiser Permanente cardiologists.

Each patient's follow-up began with the first infarction during the study period. The first Kaiser hospital to which the patient was admitted was designated the index hospital for the attribution of outcomes. The index hospitalization also covered the time spent at another acute care hospital for angiography or revascularization for patients who were directly transferred. Not included were 611 patients admitted from home and discharged within less than five days afterward because their infarctions may have been subacute rather than acute.

Assessing Determinants of Angiography and Outcomes in the Full Cohort

Cardiac procedures (angiography, percutaneous transluminal coronary angioplasty, and coronary-artery bypass grafting) performed during follow-up were identified from hospital-discharge abstracts and from referrals and claims files from non-Kaiser hospitals. When procedures were performed more than once, the earliest postinfarction procedure was selected. Automated data sources were validated by comparison with a medical-record review in a subcohort of 1210 patients. For 1035 procedures, automated sources recorded 98.1 percent of angiographies, 91.5 percent of angioplasties, and 93.4 percent of bypass procedures.

Follow-up for outcomes extended from the date of the index admission to December 31, 1993, or to the date of death or disenrollment from Kaiser Permanente if it occurred earlier. Two outcomes were assessed: death from heart disease and any heart disease event (including death, reinfarction, and nonelective rehospitalization for other heart disease diagnoses). Deaths were identified from computerized death records of the State of California and classified as due to heart disease if the underlying cause of death was listed as an ICD-9-CM code of 410 to 429.

Reinfarctions were identified from subsequent hospitalizations with principal discharge diagnoses of myocardial infarction and from death certificates listing the principal cause of death as infarction or sudden cardiac death (ICD-9-CM code 798). Other heart disease events included hospitalizations with principal discharge diagnoses of ischemic heart disease (ICD-9-CM codes 411 to 414), arrhythmias (ICD-9-CM code 427), or congestive heart failure (ICD-9-CM code 428).

Coexisting conditions were identified on the basis of secondary discharge diagnoses during the index admission and all other hospitalizations in the previous five years. A Charlson comorbidity score,[21] adapted for derivation from administrative data,[22] was calculated for each patient given these diagnoses. The socioeconomic status of cohort members was estimated with proxy measures obtained by linking the patient's home address during the index hospitalization to 1990 U.S. Census block-group data for two measures: the percentage of block-group households below the poverty level and the percentage of adult residents with less than a high-school education. These measures are associated with health and the use of health services in our population.[23-25]

Measuring Appropriateness and Outcomes in a Subcohort

To measure the severity of the infarction, the degree of comorbidity, and the appropriateness of angiography in greater detail, a subcohort was randomly selected from among patients at three hospitals with the highest rates of angiography after myocardial infarction and four hospitals with the lowest rates from 1990 through 1991. This sampling approach was intended to maximize the power to detect any differences in outcomes with a relatively small sample. Hospitals were selected before the 1992 angiography rates were known. Therefore, the hospitals selected are not those with the three highest or four lowest rates for the entire study period (1990 through 1992). Of 1210 patients selected for the subcohort, 45 were excluded for the following reasons: a clinical diagnosis of infarction that was not confirmed by chart review (n = 25), cocaine-induced infarction (n = 5), or transferral from non-Kaiser hospitals with insufficient records available (n = 15). Subsequently, we excluded 51 additional patients who died within 48 hours after admission and 5 who died of noncardiac causes within three months after this admission, since many of these patients may not have been considered candidates for angiography. This left 1109 patients with confirmed acute infarction.

The severity of the infarction was assessed on the basis of the presence or absence of new Q waves, the location of the infarct (anterior vs. other), and the presence or severity of congestive heart failure (scored on a four-point scale in which a score of 0 indicated no mention of heart failure; a score of 1, mention of heart failure; a score of 2, mention of class IV or "intractable" failure; and a score of 3, mention of symptomatic hypotension or cardiogenic shock). Also abstracted was information on preexisting conditions needed to calculate the Charlson comorbidity index[21] and on medical treatments (the administration and timing of thrombolytic agents, and in-hospital and post-discharge use of aspirin, beta-blockers, and angiotensin-converting–enzyme inhibitors).

RAND appropriateness scores for angiography[9] were calculated for all subcohort members with RAND data-collection instruments. Scores were assigned for three intervals during hospitalization (the first 6 hours after the onset of chest pain, 6 to 12 hours after the onset, and from 12 hours after the onset to the time of discharge) and for the 12-week interval immediately after discharge. Patients who underwent angiography within three months after infarction were classified on the basis of the most recent appropriateness score before angiography. Patients who did not undergo angiography during this period were classified on the basis of their postdischarge score (if they survived after discharge) or their score for the last in-hospital interval if they died in the hospital. Analyses presented in this paper were repeated with the latter score for all subjects, with essentially identical results.

RAND appropriateness scores range from 1 to 9: angiography that is considered appropriate is given a score of 7 to 9, angiography whose appropriateness is uncertain is given a score of 4 to 6, and angiography that is considered inappropriate is given a score of 1 to 3. Patients who were judged to be appropriate candidates for angiography (n = 556) were further subdivided according to whether angiography was considered necessary or crucial (n = 440) or not necessary (n = 116).

Telephone interviews were conducted with 757 of 856 long-term survivors in the subcohort an average of 2.8 years (range, 1.3 to 4.8) after infarction. Forty-five patients (5.3 percent) declined to be interviewed, 45 could not be located, 7 were too sick to be interviewed, and 2 did not speak English. Current symptoms of chest pain and dyspnea were assessed on five-point scales ranging from no symptoms to symptoms at rest. Physical functioning was assessed with the Duke Activity Status Index.[26]

Statistical Analysis

Variables associated with the likelihood of angiography in the full cohort were studied with logistic regression. Cox proportional-hazards models were used to examine predictors of death from

heart disease and of any heart disease event. The variables included age, sex, race, socioeconomic status, Charlson comorbidity score, location of the infarction (anterior or other), and type of infarction (subendocardial or transmural). To assess the effects of the hospital on patient outcomes, the patient's hospital was included in regression models first as a categorical variable (16 indicator variables were coded to compare each hospital to the regional mean[27]) and then as a continuous variable substituting each hospital's rate of angiography within three months after myocardial infarction.

Subcohort analyses compared outcomes in patients hospitalized at centers with higher rates of angiography and those hospitalized at centers with lower rates, after adjustment for demographic characteristics, the severity of infarction, and coexisting conditions. The type of hospital (higher vs. lower rate) was included in models as a dichotomous variable. Analyses were conducted in the entire subcohort and separately in the stratum in which angiography was deemed necessary (n=440) and the stratum in which angiography was not deemed necessary (n=669). A time-dependent indicator for the receipt of angiography was then added to determine whether angiography explained the apparent benefits of being hospitalized at a hospital with a higher rate of angiography.

TABLE 1. DISTRIBUTIONS OF DEMOGRAPHIC AND CLINICAL VARIABLES AMONG 16 KAISER PERMANENTE HOSPITALS FOR 6851 PATIENTS HOSPITALIZED WITH ACUTE MYOCARDIAL INFARCTION, 1990–1992.

CHARACTERISTIC	OVERALL STUDY POPULATION	SD	RANGE
Mean age (yr)	64	2.0	59–68
Female sex (%)	31.2	3.6	21.8–36.0
Race or ethnic group (%)*			
White	80.6	11.9	50.4–96.6
Black	7.4	9.6	1.3–36.7
Asian	5.8	3.9	0.4–14.6
Hispanic	5.8	3.3	0.4–3.9
Mean Charlson comorbidity score	1.6	0.2	1.2–1.9
Diagnosis of subendocardial infarction (%)	31.3	8.3	15.2–48.4

*The race or ethnic group was unknown for 32 patients.

RESULTS

Determinants of Angiography and Outcomes in the Full Cohort

There was substantial variation among the 16 hospitals in the distributions of demographic and clinical variables (Table 1). Forty-eight percent of the cohort underwent angiography within three months after myocardial infarction, but the rates ranged from 30 to 77 percent among the 16 hospitals (Fig. 1). Three of the five hospitals with the highest rates of angiography, but none of the five hospitals with the lowest rates, had on-site angiography services. Hospital 5 was closely affiliated with a nearby community hospital that provided angiography services. The variation in the rates of angiography within three months after myocardial infarction changed very little after adjustment for age, sex, race, socioeconomic status, and the Charlson comorbidity score.

In proportional-hazards models, two hospitals with low three-month rates of angiography had adjusted risks of death from heart disease that were significantly above the regional average (Fig. 2A) and

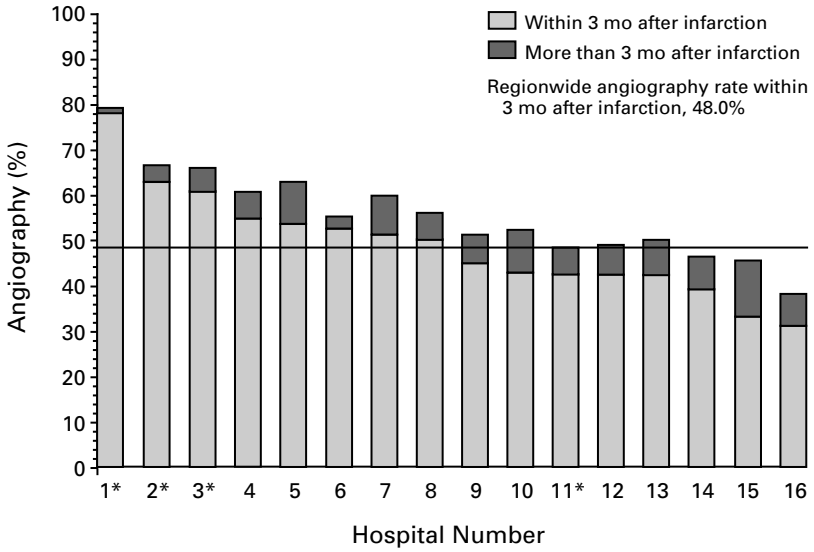

Figure 1. Unadjusted Proportions of Patients Who Underwent Coronary Angiography within Three Months or More Than Three Months after the Index Myocardial Infarction, in 16 Kaiser Permanente Hospitals, 1990–1992.

Asterisks indicate the hospitals with angiography services.

one hospital with a high rate of angiography had a risk that was significantly below average. Overall, we found a weak inverse association between a hospital's three-month angiography rate and the risk of death from heart disease after adjustment for age, sex, race, the Charlson comorbidity score, and the type of infarction (subendocardial vs. transmural) (hazard ratio, 0.88 for a 20 percent increase in the angiography rate; $P = 0.03$).

There was a clearer trend toward fewer heart disease events at hospitals with higher rates of angiography (Fig. 2B). The linear association between three-month angiography rates and this outcome was significant (hazard ratio, 0.82 for a 20 percent increase in the angiography rate; $P<0.001$). The patients' sex and race were unrelated to outcomes. The rates of revascularization within three months after infarction correlated very highly with the three-month rates of angiography ($r = 0.93$) and were more strongly associated with both mortality and any heart disease event (hazard ratios, 0.78 and 0.74, respectively; $P<0.01$ for each comparison).

Appropriateness of Angiography and Outcomes in the Subcohort

Among the 1109 eligible subcohort members, the rates of angiography within three months after infarction averaged 68 percent at three hospitals with higher rates of angiography and 38 percent at four hospitals with lower rates. Patients treated at hospitals with lower rates of angiography were slightly older and significantly more likely to be female and nonwhite (Table 2). Scores on the Charlson comorbidity index did not differ between patients treated at hospitals with higher rates of angiography and those treated at hospitals with lower rates. After adjustment for age, sex, and race, patients treated at hospitals with higher rates of angiography were substantially more likely to undergo revascularization, but the use of thrombolysis and recommended discharge medications did not differ significantly between the two groups. The rates of death from heart disease in the hospital and after discharge were lower at hospitals with higher rates of angiography.

Appropriateness of Angiography

Of 1109 subcohort patients, 440 (39.7 percent) met the RAND necessity criteria for angiography. The rates of angiography within three months after myocardial infarction were highest (77.5 percent) among these patients, intermediate (51.0 percent) among the 116 patients who met the criteria for appropriateness but not for necessity and the 227 patients for whom the appropriateness of angiography was uncertain, and lowest (14.4 percent) among the 326 patients for whom angiography was deemed inappropriate (Fig. 3). However, there were wide variations in the patterns of practice for patients who met the necessity criteria, with 89.2 percent of these patients undergoing angiography at hospitals with higher rates and 66.4 percent undergoing the procedure at hospitals with lower rates ($P<0.001$). More angiographies were performed more than three months after myocardial infarction at hospitals with lower rates of angiography (Fig. 3). Differences in the use of angiography between hospitals with higher rates of angiography and those with lower rates were even greater among patients for whom the appropriateness of angiography was deemed uncertain. Angiography rates were much lower among patients for whom angiography was judged inappropriate, although two hospitals with higher rates performed angiography in more than 20 percent of these patients.

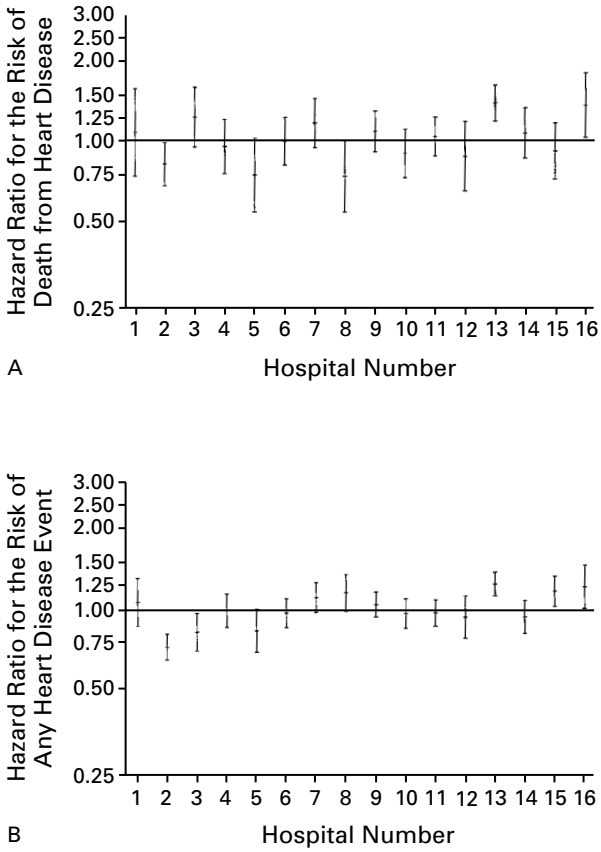

Figure 2. Hospital-Specific Hazard Ratios and 95 Percent Confidence Intervals for the Risk of Death from Ischemic Heart Disease (Panel A) and the Risk of Any Heart Disease Event (Panel B). The 16 hospitals are arranged in descending order of the rates of angiography within three months after myocardial infarction. The reference group is all patients in the cohort. Models are adjusted for age, sex, race, Charlson comorbidity score, and type of infarction (subendocardial vs. transmural).

Outcomes

For the entire subcohort, being hospitalized at a hospital with a higher rate of angiography was asso-

ciated with a 25 percent lower risk of death from heart disease (P = 0.06) and a 15 percent lower risk of any heart disease event (P = 0.08) after adjustment for age, sex, race, Charlson comorbidity score, congestive-heart-failure score, and history of prior infarction (Tables 3 and 4). Given that the rates of angiography differed by 30 percent between hospitals with higher rates of angiography and those with lower rates, these effect sizes are very similar to those observed for the full cohort. The location of infarction and the presence of new Q waves were not related to outcomes after adjustment for the congestive-heart-failure score.

The benefits of being hospitalized at a hospital with a higher rate of angiography appeared greater for both outcomes in patients who needed angiography. The adjusted hazard ratios for mortality (hospitals with higher rates vs. those with lower rates) were 0.67 for patients who met the criteria for the necessity of angiography and 0.85 for patients who did not (Table 3); for any heart disease event, the respective hazard ratios were 0.72 and 0.90 (Table 4). Tests for an interaction between necessity and the type of hospital (higher rates of angiography vs. lower rates) were not statistically significant (P = 0.30 for mortality and P = 0.32 for any heart disease event).

Inclusion of the variable for undergoing angiography markedly attenuated the apparent benefits of being hospitalized at a hospital with a higher rate of angiography for both outcomes among patients who met the necessity criteria, but not among the remaining patients (Table 5). Moreover, the hazard ratios for the angiography variable suggested greater efficacy in patients judged to need the procedure. The interaction between necessity and angiography was nearly significant for mortality (P = 0.09) and was significant for any heart disease event (P<0.001).

Measures of angina, shortness of breath, and physical functioning did not differ significantly between survivors treated at hospitals with higher rates of angiography and those treated at hospitals with lower rates in either subgroup before or after adjustment for covariates.

DISCUSSION

This study examined whether outcomes after myocardial infarction differed between hospitals with

TABLE 2. DISTRIBUTIONS OF THE CLINICAL, DEMOGRAPHIC, AND TREATMENT CHARACTERISTICS AND OUTCOMES AMONG THE SEVEN HOSPITALS IN THE SUBCOHORT STUDY, ACCORDING TO THE VOLUME OF ANGIOGRAPHY.

VARIABLE	HOSPITALS WITH HIGHER RATES OF ANGIOGRAPHY*			HOSPITALS WITH LOWER RATES OF ANGIOGRAPHY*				P VALUE†
	1 (N=149)	2 (N=181)	5 (N=172)	12 (N=173)	13 (N=154)	14 (N=175)	16 (N=161)	
Mean age (yr)	62	64	65	64	65	65	66	0.10
Female sex (%)	27.5	33.7	25.0	34.1	33.8	38.9	36.0	0.01
Nonwhite race (%)	16.2	15.5	4.7	15.0	21.7	56.3	38.8	0.001
Mean Charlson comorbidity score	1.2	1.3	1.0	1.1	1.2	1.4	1.3	0.54‡
Angiography (%)								
Within 3 mo after infarction	76.5	60.8	59.9	40.5	34.4	38.3	28.6	<0.01‡
Any time after infarction	78.5	64.1	64.0	48.6	46.1	46.9	37.3	<0.01‡
Revascularization (%)	54.4	42.5	42.4	27.8	25.3	32.0	20.5	<0.01‡
In-hospital mortality (%)	7.4	9.4	7.6	8.7	14.3	10.3	11.8	0.13‡
Death from heart disease after discharge (%)	11.0	9.2	9.7	11.5	18.9	16.6	19.2	0.01‡
Thrombolysis (%)	33.6	21.0	40.7	30.1	24.7	15.4	27.3	0.15‡
Medical treatments at discharge (%)§								
Aspirin	67.4	85.4	84.3	67.7	77.3	80.3	77.5	0.13‡
Beta-blockers	37.7	34.8	44.7	39.9	50.8	27.4	30.5	0.95‡
ACE inhibitors¶	12.3	12.8	9.4	10.8	10.6	11.5	7.0	0.27‡

*Hospital numbers refer to the rank among the 16 hospitals for the rates of angiography within three months after infarction (see Fig. 1).

†The hospitals with higher rates of angiography were compared with those with lower rates.

‡P values were obtained from generalized linear models (for continuous variables) and logistic-regression models (for proportions) that adjusted for patients' age, sex, and race.

§The analysis excludes 115 patients who died before discharge.

¶ACE denotes angiotensin-converting enzyme.

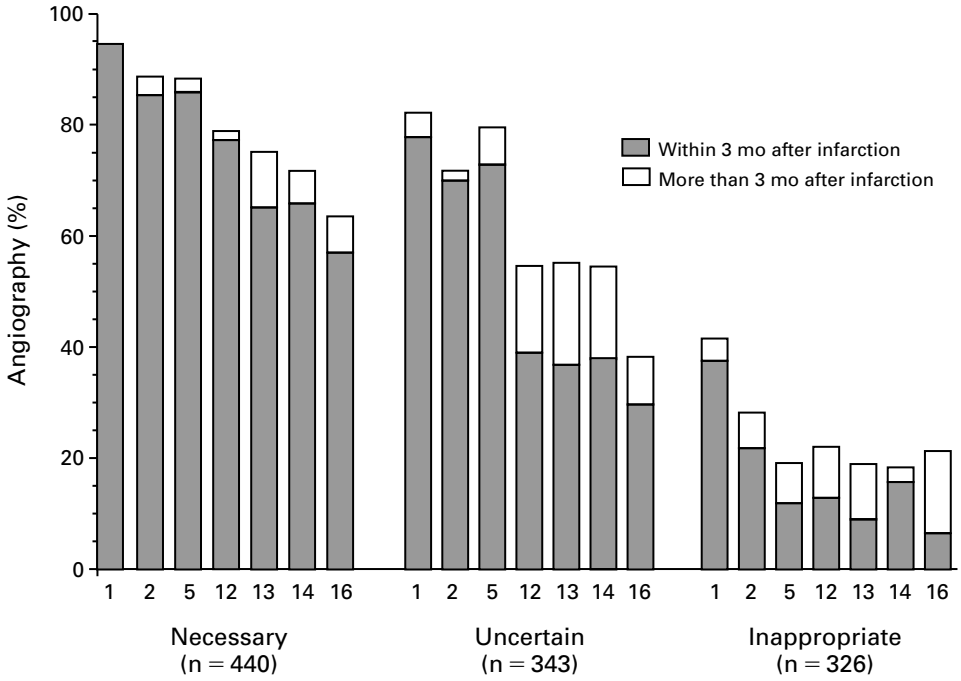

Figure 3. Proportions of Patients Who Underwent Coronary Angiography within Three Months or More Than Three Months after the Index Myocardial Infarction, According to the RAND Scores for the Appropriateness and Necessity of Angiography.

The uncertain category includes 227 patients with uncertain appropriateness criteria and 116 patients who met appropriateness criteria but not necessity criteria. The hospital numbers are shown below the bars.

higher rates of coronary angiography and those with lower rates. The use of coronary angiography after myocardial infarction in this HMO was similar to that of other community-hospital settings during the same period[28,29] but varied widely among the hospitals that are part of the HMO. Variation was not explained by demographic or clinical differences between hospital populations, but it was related to the availability of on-site angiography services, as in other settings.[29,30]

Patients from hospitals with lower rates of angiography were not more likely to undergo revascularization after angiography. Thus, these hospitals were not successfully identifying a smaller group of patients with a greater need for revascularization. To determine whether these hospitals may have missed some patients who needed angiography, we applied the RAND criteria for the appropriateness and necessity of angiography[9] in the subcohort, regardless of whether the patient underwent angiography. Kravitz et al.[31] used a similar approach, applying appropriateness criteria for revascularization to a cohort of patients after angiography. Among patients in the subcohort who met the criteria for the necessity of angiography, we found sizable differences among hospitals in the proportion who received it.

The risks of death from heart disease and of heart disease events were both lower among patients in hospitals with higher rates of angiography. The subcohort study was not originally planned (nor did it have sufficient power) to test for differences in these associations between subgroups stratified according to the necessity of angiography. However, three aspects of the stratified analyses suggest that these overall associations were due to better outcomes in patients who underwent coronary angiography that was deemed necessary. The associations were consistently stronger for patients in whom angiography was deemed necessary; the variable for undergoing angiography almost entirely explained the benefits of facilities with higher rates of angiography in this stratum; and the estimated efficacy of angiography itself was substantially greater in patients who needed the procedure. These findings also support the validity of the RAND necessity criteria.

Although the use of other recommended therapies did not differ significantly between hospitals with higher rates of angiography and those with lower rates, the use of thrombolysis and treatment with aspirin and angiotensin-converting–enzyme inhibitors after discharge were somewhat more common at hospitals with higher rates. It is possible that their more favorable outcomes may be due in part to these therapies rather than to angiography. How-

TABLE 3. RISK OF DEATH FROM HEART DISEASE IN THE ENTIRE SUBCOHORT AND IN THE SUBGROUPS IN WHICH ANGIOGRAPHY WAS DEEMED NECESSARY OR NOT NECESSARY.*

VARIABLE	ENTIRE SUBCOHORT (1109/209)†		ANGIOGRAPHY NECESSARY (440/68)		ANGIOGRAPHY NOT NECESSARY (669/141)	
	HAZARD RATIO	P VALUE	HAZARD RATIO	P VALUE	HAZARD RATIO	P VALUE
Age (per year of age)	1.05	<0.001	1.03	0.04	1.05	<0.001
Sex (male vs. female)	1.23	0.16	0.82	0.45	1.41	0.06
Race						
Black vs. white	0.93	0.75	0.82	0.67	0.84	0.93
Other vs. white	0.87	0.59	1.28	0.49	2.61	0.19
4-Point congestive-heart-failure score (per point)	1.52	<0.001	1.63	<0.001	1.49	<0.001
Charlson comorbidity score (per point)	1.27	<0.001	1.52	<0.001	1.23	<0.001
Prior infarct (yes vs. no)	1.74	<0.001	2.14	<0.01	1.60	0.01
Hospital with higher rate of angiography (yes vs. no)	0.75	0.06	0.67	0.13	0.85	0.36

*The ratios in parentheses are the total number of patients in each group as compared with the number who died.

†The analysis excludes 51 patients who died of noncardiac causes within 48 hours after the index admission and 5 who died of noncardiac causes within three months after the index admission.

TABLE 4. RISK OF ANY HEART DISEASE EVENT IN THE ENTIRE SUBCOHORT AND IN THE SUBGROUPS IN WHICH ANGIOGRAPHY WAS DEEMED NECESSARY OR NOT NECESSARY.*

VARIABLE	ENTIRE SUBCOHORT (1109/509)†		ANGIOGRAPHY NECESSARY (440/217)		ANGIOGRAPHY NOT NECESSARY (669/292)	
	HAZARD RATIO	P VALUE	HAZARD RATIO	P VALUE	HAZARD RATIO	P VALUE
Age (per year of age)	1.01	0.02	1.00	0.97	1.02	<0.01
Sex (male vs. female)	1.33	<0.01	1.11	0.49	1.49	<0.01
Race						
Black vs. white	0.84	0.23	0.69	0.15	0.94	0.73
Other vs. white	0.80	0.14	0.74	0.18	0.82	0.35
4-Point congestive-heart-failure score (per point)	1.21	<0.001	1.26	<0.001	1.16	<0.01
Charlson comorbidity score (per point)	1.11	<0.001	1.18	<0.01	1.11	<0.01
Prior infarct (yes vs. no)	1.64	<0.001	1.63	<0.01	1.60	<0.001
Hospital with higher rate of angiography (yes vs. no)	0.85	0.08	0.72	0.02	0.90	0.42

*The ratios in parentheses are the total number of patients in each group as compared with the total number of heart disease events.

†The analysis excludes 51 patients who died of noncardiac causes within 48 hours after the index admission and 5 who died of noncardiac causes within three months after the index admission.

ever, the specificity of the benefit of hospitals with higher rates of angiography (and of angiography itself) for patients who needed angiography and the observation that revascularization was even more closely related to outcomes than angiography suggest that angiography and the revascularization that followed it had the larger role in explaining benefits of hospitals with higher rates.

The apparent benefits could also be due in part to remaining case-mix differences between populations. We examined and adjusted for a number of demographic characteristics, the severity of disease, and the Charlson comorbidity score. The RAND appropriateness criteria incorporate additional indicators of disease severity, including the ejection fraction, results of noninvasive tests for ischemia, and the presence of persistent angina. Case-mix differences would be unlikely to explain the differential benefit of hospitals with higher rates of angiography for patients in whom angiography was deemed necessary.

Four previous geographic-variation studies have examined the association of angiography rates with mortality after infarction. In the Global Utilization of Streptokinase and Tissue Plasminogen Activator for Occluded Arteries trial,[5,6] higher rates of angiography in the United States (72 percent) than in Canada (25 percent) were associated with higher survival rates at one year[5]; a smaller variation among various regions of the United States (52 to 81 percent) was unrelated to mortality.[6] Postinfarction angiography rates in the Survival and Ventricular Enlargement trial[4] were 78 percent and 48 percent in U.S. and Canadian hospitals, respectively, with no significant difference in one-year mortality. This trial excluded patients with congestive heart failure and required all patients with angina to undergo angiography. Guadagnoli et al.[7] found no significant difference in the two-year mortality rate between Medicare patients from New York and those from Texas, despite moderate differences in the rates of angiography after infarction (30 percent and 45 percent, respectively). Angiography rates among patients at the highest risk of reinfarction were said to be similar among the states. Thus, the negative studies excluded patients who needed angiography, treated them similarly across comparison groups, or studied smaller rate differences than our study.

Previous studies[4,5] have reported more symptoms and worse functional status due to chest pain and dyspnea in populations with lower rates of angiography. We found no such differences. However, we did not assess functional status until nearly three years after infarction, giving hospitals with lower rates of angiography time to perform angiography in symptomatic patients. The higher survival rate at hospitals with higher rates of angiography could also serve to obscure differences in these outcomes.

TABLE 5. RISK OF DEATH FROM HEART DISEASE AND OF ANY HEART DISEASE EVENT IN RELATION TO THE HOSPITAL ANGIOGRAPHY RATE BEFORE (MODEL I) AND AFTER (MODEL II) ADJUSTMENT FOR UNDERGOING ANGIOGRAPHY IN THE SUBGROUPS IN WHICH ANGIOGRAPHY WAS DEEMED NECESSARY OR NOT NECESSARY.*

OUTCOME	ANGIOGRAPHY NECESSARY		ANGIOGRAPHY NOT NECESSARY	
	MODEL I	MODEL II	MODEL I	MODEL II
	hazard ratio (95% confidence interval)			
Death from heart disease				
Hospital with higher rate of angiography vs. one with lower rate	0.67 (0.40–1.12)	0.91 (0.53–1.55)	0.85 (0.59–1.21)	0.92 (0.64–1.33)
Angiography vs. no angiography	—	0.29 (0.15–0.55)	—	0.55 (0.33–0.92)†
Any heart disease event				
Hospital with higher rate of angiography vs. one with lower rate	0.72 (0.54–0.95)	0.98 (0.73–1.31)	0.90 (0.72–1.17)	0.92 (0.71–1.18)
Angiography vs. no angiography	—	0.36 (0.26–0.49)	—	0.94 (0.70–1.28)‡

*Model I is a proportional-hazards model that includes age, sex, race, Charlson comorbidity score, congestive-heart-failure score, history of prior infarction, and type of hospital (higher rate of angiography vs. lower rate). Model II also includes the time-dependent covariate indicating whether the patient underwent angiography.

†P=0.09 for the comparison of the association of angiography with outcome between subgroups.

‡P<0.001 for the comparison of the association of angiography with outcome between subgroups.

As pointed out by Mant and Hicks,[32] the sensitivity of outcomes analyses to variations in the patterns of practice is diminished if only a portion of a population is eligible for a certain practice. In this study, necessity criteria were helpful in focusing an outcomes comparison on the appropriate patients. Our finding of better outcomes with higher procedure rates cannot be generalized to other settings in the absence of information on the need for the procedure. Indeed, we observed some evidence of overuse, which may explain most or all of the geographic variation in other settings. Within this HMO, our study findings have been shared with hospital chiefs of cardiology since 1994. The rates of angiography within three months after infarction increased from 48 percent to 58 percent regionwide from 1992 to 1995, with a reduction in the variation among facilities.

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