Impact of Cardiac Service Availability on Case-Selection for Angiography and Survival Associated with Angiography

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Objective. To examine whether availability of cardiac services at the admitting hospital affects case-selection for angiography and one-year survival following angiography, within groups of patients who have similar clinical need for angiography according to published criteria.

Study Setting. Elderly Medicare beneficiaries (37,788) discharged with a diagnosis of acute myocardial infarction (AMI) from hospitals in seven U.S. states between February 1994 and July 1995. We focused on patients who were eligible to receive angiography 12 or more hours after symptom onset.

Data Collection. Data were abstracted from patient's medical records, Medicare National Claims Standard Analytic Files, Health Care Financing Administration (HCFA) Provider of Service File and Health Insurance Master File.

Methods. Admitting hospitals were classified as offering no cardiac services, angiography only, or revascularization. Case-selection differences across these three types of hospitals were examined by comparing relative risk of receiving angiography for various patient and hospital characteristics. Relative differences in one-year survival rate, comparing patients who received angiography to those who did not, were estimated within each hospital type and clinical need category (necessary, appropriate, or uncertain) after matching on propensity to receive angiography.

Principal Findings. Compared to patients for whom angiography was deemed necessary, the relative risk of receiving angiography among those for whom it was deemed of uncertain benefit was 0.58, 0.79, and 0.92 (p -value of homogeneity test < 0.001) at hospitals offering no cardiac services, angiography only, and revascularization, respectively. There was no significant difference in survival following angiography across hospital types, overall as well as within clinical need categories.

Conclusions. Despite increased case selection at hospitals with on-site cardiac services, there was no evidence of increase in the survival rate associated with angiography use at these hospitals.

Key Words. Coronary angiography, practice guidelines, classification trees, survival

Several studies have found that availability of angiography or revascularization facilities at the admitting hospital substantially increases the likelihood of

a patient receiving angiography following an acute myocardial infarction (AMI) (Every et al. 1993; Leape et al. 1999; Llevadot et al. 2001). Angiography is a diagnostic procedure used to identify candidates for revascularization and is not directly associated with survival. However, the decision to undergo revascularization following angiography is affected by the availability of cardiac procedures at the admitting hospital. Thus it is plausible that patients who need revascularization have a better likelihood of survival when admitted to a hospital with on-site facilities. There is also evidence that perceptions of appropriateness among physicians are affected by hospital availability of cardiac services, suggesting that there could be differences in case-selection criteria across hospitals (Ayanian et al. 1998).

However, the increased rate of angiography use at hospitals with on-site capability has not been associated with better outcomes following angiography, including survival (McClellan, McNeil, and Newhouse 1994; Llevadot et al. 2001; Every et al. 1997). For example, in the study by Every and colleagues (Every et al. 1997), 67.1 percent of patients admitted to hospitals with on-site catheterization labs received angiography compared to 39.3 percent of patients admitted to hospitals without on-site facilities. However, there was no effect on long-term mortality because of admission to a hospital with on-site facilities, after adjusting for patient's age and concurrent or previous heart disease (hazard ratio from multivariate regression model [95 percent CI] was 1.0 [0.93, 1.1] comparing hospitals with on-site catheterization to those without).

Studies comparing hospitals within a subgroup of patients who are most likely to benefit from being admitted to a hospital with on-site facilities have given conflicting results. Selby et al. (1996) compared hospitals with high and low rates of angiography belonging to the same health care provider, within classes determined by the RAND appropriateness criteria. Among 508

This research was supported by Grant R01-HS08071 from the Agency for Healthcare Research and Quality, Rockville, MD.

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patients for whom angiography was deemed necessary, those at hospitals with higher angiography rates had lower risk of heart disease events (hazard ratio = 0.72, p -value = 0.02), after adjusting for patient's demographic and clinical characteristics. However, there was no clear evidence of reduction in risk of death from heart disease (hazard ratio = 0.67, p -value = 0.13). This study was limited by a small sample size but suggests a benefit of on-site facilities for at least a subgroup of patients following AMI.

In a validation study of expert-panel derived appropriateness criteria (Landrum and Normand 1999), members of our group showed that the relative survival rate difference, comparing angiography recipients to nonrecipients, was greatest among the subgroup of patients for whom the procedure was deemed "necessary" or "appropriate, but not necessary," and least in the group for whom it was deemed of "uncertain" benefit (Normand et al. 2001). In this study we examine (1) whether differences in the likelihood of receiving angiography across hospitals persist within groups of patients with similar clinical need, and (2) whether the lack of differences in outcomes across hospitals is because of differences in case-selection according to clinical need. We focus on patients who were eligible to receive the procedure 12 or more hours after symptom onset, using data from the Cooperative Cardiovascular Project (CCP) database (Marciniak et al. 1998).

METHODS

Data Sources

Data used for this study were collected as part of the CCP (Marciniak et al. 1998) and have been described elsewhere (Normand et al. 2001). Medical record data were centrally abstracted and included information on comorbid disease, AMI severity, medications, and diagnostic tests. Sociodemographic characteristics and Medicare eligibility were obtained using Medicare National Claims Standard Analytic Files. The Health Care Financing Administration (HCFA) Provider of Service file and American Hospital Association databases were used to obtain information on teaching affiliation and number of beds. We also collected information through a telephone survey on the availability and types of technology for cardiac services in the hospitals caring for patients in this study. We grouped hospitals into "Angiography Only" hospitals if they had cardiac catheterization facilities only, "Revascularization" hospitals if they performed CABG/PTCA (coronary artery bypass graft/percutaneous transluminal coronary angioplasty) in

addition to cardiac catheterization, and “Basic Services” hospitals if they had none of these facilities. Data on patient survival were obtained from the Health Insurance Master File.

Study Population

The original study sample, as previously described (Normand et al. 2001), consisted of 61,140 Medicare beneficiaries aged 65–89 years (both included) who were discharged with a diagnosis of acute myocardial infarction (AMI) (*International Classification of Diseases, 9th Revision, Clinical Modification* [ICD-9-CM] code 410) from hospitals in California, Florida, Massachusetts, New York, Ohio, Pennsylvania, and Texas, between February 1994 and July 1995. These states were selected because of their diverse geographical locations and because of documented variation in angiography use. We excluded 26,352 patients due to one or more of the following reasons: 1,595 due to possible incorrect coding of AMI (discharged alive with a length of stay less than four days); 3,011 with incomplete data (resided outside the United States; survival not obtained; medical records not available; transferred more than once); 10,121 with missing information on variables needed to determine the appropriateness of angiography (duration of symptom onset, ejection fraction, and stress test results); 3,126 who were not candidates for catheterization in the time frame of interest; and 12,796 with low likelihood of long-term survival (patients with terminal illness, global brain damage, hepatic failure, metastatic cancer, and “do not resuscitate” orders; patients who died within one day of hospital admission). After applying the exclusion criteria, 37,788 patients were eligible for our study.

Clinical Criteria for Use of Angiography

The clinical criteria were developed based on updating UCLA/RAND methodology for constructing recommendations. We identified 28 unique clinical groups when considering the use of angiography more than 12 hours after symptom onset. Characteristics describing the clinical groups were age, prior use of thrombolytic therapy, contraindications to such therapy and complications of the infarction due to shock, persistent chest pain, persistent pulmonary edema, left ventricular ejection fraction <35 percent, stress-induced ischemia, and recurrent ventricular tachycardia or fibrillation 24 hours after the infarction. By definition, patients with the same indication had a similar expected benefit from diagnostic angiography and subsequent treatments (Bernstein et al. 1992). Each indication was assigned one of three

appropriateness ratings indicating the level of clinical need: “necessary” (procedure is the best option available to the patient), “appropriate, but not necessary” (benefits greatly exceed risks), and “uncertain” (benefits and risks about equal).

Statistical Analysis

Comparing Case-Selection across Hospital Types. To study the variation in case-selection across hospital types defined by availability of cardiac services, we compared the unadjusted relative-risk of receiving angiography associated with individual patient and hospital characteristics (described below) using a test of homogeneity (DerSimonian and Laird 1986). Because this test is known to have a low power, results were considered statistically significant if the p -value was less than 0.10.

Estimating Propensity to Receive Angiography. We compared patients who received angiography to those who did not, after matching for propensity to receive angiography. Matching patients with similar propensity, based on a set of confounding variables, ensures a similar distribution of each of these variables in the groups being compared (Rubin 1997). This method of risk adjustment is particularly advantageous when several confounding variables need to be considered, as is the case here. The propensity score, or propensity of an individual patient to receive angiography, was estimated as a function of patient and hospital predictors of angiography using a classification and regression tree (CART) model. The dependent variable was the binary variable indicating use of in-hospital angiography. The advantage of using a CART model is that, unlike in a standard regression model, it is unnecessary to specify the exact functional form of each confounding variable in the model or the interrelations among variables, which could be complex with a large number of predictor variables. The CART model classified patients into mutually exclusive subgroups such that patients in the same group had a similar propensity of receiving angiography. The proportion of patients who received angiography within each subgroup was then used as an estimate of the propensity score for all patients within that subgroup.

Patient Characteristics. Patient predictors included characteristics used by the updated RAND guidelines, in addition to others. Patient characteristics fell into three broad categories—demographic characteristics, comorbid conditions, and measures of severity of AMI—and were obtained from either the record of the initial hospitalization or a contiguous transfer. Demographic characteristics were age, gender, race, and body mass index. Comorbid

disease was measured using patient's history of cancer, dementia, diabetes, chronic obstructive pulmonary disease, congestive heart failure (CHF), myocardial infarction, cerebral vascular accident, peripheral vascular disease, prior use of CABG/PTCA, and stroke, among other variables. Measures of severity of AMI were admission variables (patient mobility, respiration rate, mean arterial pressure, CHF, cardiac arrest, stroke, angina, hemodynamic instability, myocardial ischemia), laboratory measurements (creatinine level), results from diagnostic tests (conduction disturbance, cardiomegaly, stress, S₃ gallop rhythm), use of thrombolytics, and complications of the MI (shock, ejection fraction, persistent chest pain). Continuous variables were converted into ordinal variables using clinically meaningful cut-points.

Hospital Characteristics. Hospitals were classified as urban if they were located within a metropolitan statistical area (as defined by the Census Bureau), and as rural otherwise. We also determined the academic affiliation of the hospital, classifying it as a teaching hospital if the hospital offered a postgraduate residency program. Lastly, we categorized hospitals as small if they had fewer than 100 beds, medium if they had from 100 to 500 beds, and large if they had more than 500 beds.

Matching on Propensity Scores. The matching process involved the following steps: (a) patients were classified into nine groups defined on the basis of the availability of cardiac services at the admitting hospital and clinical need for angiography; (b) within each group, patients who received angiography were randomly ordered; (c) within each group, each patient who received angiography was matched to a randomly selected patient who did not receive angiography such that $|\text{prop}_A - \text{prop}_{NA}| \geq 0.6s_P$, where prop_A and prop_{NA} denote the propensity score of the patient who did and did not receive angiography, respectively, and s_P is the standard deviation of the propensity score for the entire sample in that group; (d) if a successful match was located in (c), it was eliminated from the pool of subjects who did not receive angiography. If a successful match was not found in (c), the patient who received angiography was eliminated from the analysis. The criterion of matching within $0.6s_P$ was selected because it has been shown to result in a reduction of the bias between the groups being compared of almost 90 percent (Gu and Rosenbaum 1993).

Comparison of Survival Associated with Angiography across Hospital Types. The relative difference in one-year survival rates (and 95 percent confidence intervals) between patients who did or did not undergo angiography was used as the measure of survival benefit associated with angiography. To compare the survival rate differences across hospitals we

used a test of homogeneity that was considered significant if the p -value was less than 0.10.

RESULTS

Patient Characteristics

The distributions of patient and hospital characteristics within hospital types defined by availability of cardiac services are reported in Table 1. At all hospitals patients were mostly white males younger than 85 years of age. Patients initially admitted to hospitals offering revascularization were more likely to be younger, nonwhite, and male, compared to patients at hospitals that did not offer these procedures. There was a similar distribution of comorbidity and severity variables at the three types of hospitals. The most commonly reported comorbid diseases in this cohort were diabetes and myocardial infarction. The most commonly reported problems indicative of severity of AMI included angina, myocardial ischemia, hemodynamic instability, and congestive heart failure. Prior revascularization was more likely to be reported with increasing availability of on-site procedures. Patients admitted to revascularization hospitals were more likely to be classified as “necessary,” and less likely to be classified as “appropriate,” compared to other hospitals. The one-year survival rate was 78 percent at basic service hospitals, 79 percent at angiography only hospitals, and 82 percent at revascularization hospitals (chi-square p -value < 0.001).

Hospital Characteristics

In the entire study sample, approximately 36 percent of the cohort were admitted to teaching hospitals, 11 percent were admitted to rural hospitals, and 69 percent were admitted to medium-sized hospitals.

There was a strong association between hospital availability of cardiac services and other hospital characteristics. Increasing availability of cardiac services was associated with increasing likelihood of being admitted to a teaching hospital located in an urban area with more than 500 beds.

Differences in Case-Selection for Angiography across Hospitals

As expected, the probability of receiving angiography was lowest at basic service hospitals (25 percent), intermediate at hospitals offering angiography only (41 percent), and highest at those offering revascularization (63 percent) (Table 1). These differences across hospital types persisted in subgroups

Table 1: Distribution of Patient Characteristics According to Cardiac Service Availability

Characteristic	Cardiac Service Availability			
	Basic Services (Total = 11,205) %	Angiography Only (Total = 9,849) %	Revascularization (Total = 16,734) %	
Demographic Variables				
Age (years)	65–69	20	20	25
	70–74	24	25	28
	75–79	23	23	23
	80–84	21	20	16
	85–89	12	12	9
Sex	Male	51	52	56
	Race	White	91	93
Body mass index	Black	4	4	6
	Other	5	3	6
	<20	7	7	6
	20–24.9	30	31	31
	25–29.9	31	33	36
	>30	17	17	17
	Missing	15	12	10
Comorbidity Variables				
History of cancer	1	1	1	
	5	4	4	
History of dementia	33	32	31	
	24	22	20	
Chronic obstructive pulmonary disease (COPD)	22	22	19	
History of congestive heart	29	32	30	
History of myocardial infarction (MI)	13	13	12	
Cerebral vascular accident	11	13	12	
Peripheral vascular disease				

Prior bypass surgery	11	13	16
Prior angioplasty	5	7	9
Severity Variables			
Shock	3	3	4
Ejection fraction			
<35%	15	17	14
>= 35%	51	54	42
Not tested	32	27	41
Missing	2	2	3
Persistent chest pain	24	24	23
Mobility	83	83	84
Independent	14	14	13
Walks with help	2	2	2
Unable to walk	1	1	1
Not	25	26	33
<20	74	73	66
>= 20	1	1	1
Missing	74	74	76
Mean arterial pressure	25	25	23
(log-scale)	1	1	1
Congestive heart failure	46	46	41
Cardiac arrest six hours prior to or at admission	1	1	1
Stroke on arrival	0.9	0.8	0.6
Angina 2-48 hours after arrival	34	37	32
Angina > 48 hours after arrival	46	48	52
Hemodynamic instability	31	33	31
Yes	67	66	67
No	2	1	2
Missing	35	36	38
Myocardial ischemia	65	64	62
Yes	0.1	0.2	0.1
No	22	22	19
Missing			
Conduction disturbances			

continued

defined by other hospital characteristics and patient characteristics, including clinical need. For example, among “necessary” patients, the percentage who received angiography was 36 percent, 55 percent, and 73 percent, as availability of cardiac services increased at the admitting hospital. Among “uncertain” patients it was 23 percent, 44 percent, and 67 percent. Table 2 lists the relative risk of receiving angiography corresponding to different patient characteristics at each type of hospital. Differences in risk ratios across the hospitals are indicative of differences in case-selection criteria. The most likely candidates to receive angiography at all hospitals were patients aged less than 75, those who had undergone angioplasty previously, had a respiratory rate <20 breaths/minute, had received thrombolytics, and those classified as “necessary.” The relative risk of receiving angiography with increasing age decreased more rapidly at basic service hospitals than those with on-site capability.

Male gender, history of myocardial infarction, prior angioplasty, and measures of severity such as shock, chest pain, angina, conduction disturbances, and cardiomegaly were more strongly associated with receiving angiography as availability decreased across hospitals. Admission to a teaching or rural hospital decreased the likelihood of receiving angiography as availability decreased across hospitals. The relative risk comparing patients with “uncertain” recommendation to those with a “necessary” recommendation was 0.59 at basic service hospitals, 0.80 at hospitals offering angiography only, and 0.92 at CABG/PTCA hospitals (p -value of the homogeneity test <0.001). This indicates patients with an “uncertain” recommendation were much less likely to receive angiography when admitted to a basic service hospital.

Impact of Angiography on Survival

CART Model. All variables listed in Table 1 (excluding availability of cardiac services, recommendations for angiography, and one-year survival) were used in the construction of the CART model. The final CART model classified patients into 37 subgroups based on sixteen predictors: patient’s age, body mass index, prior PTCA, prior congestive heart failure, stress test results, patient mobility, persistent chest pain, episodes of myocardial infarction, respiratory rate, creatinine level, ejection fraction, cardiomegaly, use of thrombolytics, hospital size, hospital location, and hospital teaching status.

We were successful in finding a match for 10,588 angiography patients, based on their propensity score: 2,644 (96 percent of angiography patients

Table 2: Relative Risk of Receiving Angiography According to Cardiac Service Availability

Characteristic	Value	Cardiac Service Availability			P-value of Test of Homogeneity of RR
		Basic Services RR	Angiography Only RR	Revascularization RR	
Demographic Variables					
Age (years)	65–69*	1	1	1	0.13
	70–74	0.87	0.95	0.93	<0.001
	75–79	0.62	0.71	0.82	<0.001
	80–84	0.34	0.41	0.56	<0.001
	85–89	0.12	0.18	0.31	0.01
Sex†	Male	1.28	1.23	1.17	0.01
	White*	1	1	1	
Race	Black	0.77	0.77	0.81	0.73
	Other	0.98	1.05	0.95	0.37
	<20	1	1	1	
	20–24.9	1.92	1.49	1.27	0.001
	25–29.9	2.43	1.84	1.45	<0.001
Body mass index	> 30	2.48	1.93	1.44	<0.001
	Missing	1.94	0.86	0.57	<0.001
Comorbidity Variables					
History of cancer†		1.03	0.66	0.86	0.26
	History of dementia†	0.25	0.28	0.34	0.18
History of diabetes†		0.93	0.87	0.91	0.29
	Chronic obstructive pulmonary disease (COPD)†	0.94	0.83	0.88	0.08
History of congestive heart†		0.60	0.50	0.59	0.002

History of MI [†]	0.99	0.93	0.90	0.03
Cerebral vascular accident [†]	0.71	0.72	0.76	0.50
Peripheral vascular disease [†]	1.16	0.89	0.86	<0.001
Prior bypass surgery [†]	1.04	1.05	0.98	0.18
Prior angioplasty [†]	1.83	1.40	1.22	<0.001
Severity Variables				
Shock [†]	1.29	1.03	1.02	0.03
Ejection fraction				
	1	1	1	1
	<35%*	1.39	1.28	0.05
	>= 35%	1.19	1.47	0.001
	Not tested	1.21	1.56	0.001
	Missing	0.24	1.23	<0.001
Persistent chest pain [†]	1.91	1.49	1.15	<0.001
Mobility	1	1	1	1
	Independent*	0.41	0.61	<0.001
	Walks with help	0.38	0.65	0.009
	Unable to walk	0.43	0.80	0.57
	Undetermined	0.75	1	<0.001
Respiratory rate	<20*	1	0.83	0.08
(breaths/minute)	>= 20	0.73	0.90	0.09
	Missing	0.66	1	0.91
Mean arterial pressure	<2.01 or	1	0.98	0.19
(log-scale)	2.01–2.06	1.01	0.76	0.08
	Missing	0.73	<0.001	0.09
	0.71	0.65	1.08	0.91
Congestive heart failure [†]	1.09	0.74	1.00	0.19
Cardiac arrest 6 hours prior to or at admission [†]	0.24	0.84	0.52	0.08
Stroke on arrival [†]	1.65	0.32	1.10	<0.001
Angina 2–48 hours after arrival [†]		1.36		

continued

Table 2: Continued

Characteristic	Value	Cardiac Service Availability			P-value of Test of Homogeneity of RR
		Basic Services RR	Angiography Only RR	Revascularization RR	
Angina > 48 hours after arrival [†]	Yes	1.12	1.15	1.09	0.11
Hemodynamic instability	No*	1.11	0.87	0.88	<0.001
	Missing	1	1	1	
Myocardial ischemia	Yes	0.47	0.51	0.74	0.01
	No*	1.77	1.41	1.17	<0.001
	Missing	1	1	1	
Conduction disturbances [†]		1.41	0.70	0.81	0.52
Cardiomegaly [†]		0.68	0.69	0.76	0.007
Stress	Positive	0.63	0.66	0.76	<0.001
	Negative*	1.60	1.51	1.33	0.07
	Not performed	1	1	1	
S ₃ gallop rhythm [†]	Missing	1.52	1.53	1.37	0.10
Creatinine level	< 1.5*	0.58	0.99	1.25	0.31
	1.5-7	0.76	0.72	0.75	0.89
	Missing	1	1	1	
		0.55	0.54	0.67	<0.001
		0.84	0.92	1.03	0.08
In-Hospital Processes of Care					
Thrombolytics [†]		2.09	1.68	1.26	<0.001
Angiography		—	—	—	—

Initial Admitting Hospital			
Teaching ^{††}	0.92	0.94	1.01
Rural ^{†††}	0.80	0.92	0.94
Number of beds	1	1	1
	1.11	0.81	1.34
	0.75	0.99	1.36
Angiography Recommendations			
Necessary [*]	1	1	1
Appropriate	0.44	0.54	0.68
Uncertain	0.58	0.79	0.92
			<0.001
			<0.001

^{*}Reference Category. RR = Relative risk of receiving angiography
[†]For binary risk factors of receiving angiography absence of the indication was treated as the reference category
[†]Female was the reference for Male
^{††}Nonteaching hospital was the reference for teaching hospital
^{†††}Urban hospital was the reference for rural hospital location

admitted to basic service hospitals), 2,988 (74 percent of angiography patients admitted to angiography only hospitals), and 4,956 (47 percent of angiography patients admitted to revascularization hospitals). Tables 3a and 3b list the survival rate differences comparing patients who received angiography to those who did not, after stratification by cardiac service availability and clinical need. Tables 3a and 3b present results prior to and following matching

Table 3a: Unadjusted Comparisons of Hospitals within Clinical Need Groups

		<i>Cardiac Service Availability</i>			<i>P-value of Homogeneity Test</i>
<i>Guideline for Receiving Angiography</i>		<i>Basic Services</i>	<i>Angiography Only</i>	<i>Revascularization</i>	
Number of patients	Necessary	2797	2548	4873	—
	Appropriate	4521	3963	5833	—
	Uncertain	3887	3338	6028	—
Relative difference in survival rate* (95% CI)	Necessary	16 (13, 19)	20 (17, 23)	21 (18, 24)	0.20
	Appropriate	20 (18, 23)	23 (20, 26)	17 (15, 20)	0.19
	Uncertain	8 (6,10)	11 (9, 14)	11 (10, 13)	0.07
	Overall	15 (14, 17)	19 (18, 21)	18 (17, 19)	0.15

*Survival rate among those who received angiography - Survival rate among those who did not receive angiography

Table 3b: Adjusted Comparisons of Hospitals within Clinical Need Groups Following Matching

		<i>Cardiac Service Availability</i>			<i>P-value of Homogeneity Test</i>
<i>Guideline for Receiving Angiography</i>		<i>Basic Services</i>	<i>Angiography Only</i>	<i>Revascularization</i>	
Number of matched pairs	Necessary	984	883	1240	—
	Appropriate	785	1062	2008	—
	Uncertain	875	1043	1708	—
Relative difference in survival rate* (95% CI)	Necessary	12 (8, 15)	18 (14, 21)	17 (14, 21)	0.37
	Appropriate	18 (14, 22)	18 (15, 22)	14 (12, 17)	0.28
	Uncertain	5 (3, 8)	9 (6, 11)	8 (6, 10)	0.23
	Overall	11 (9, 13)	15 (13, 17)	13 (11, 14)	0.32

*Survival rate among those who received angiography-Survival rate among those who did not receive angiography

on propensity scores, respectively. There was no significant difference in survival benefit associated with angiography according to hospital availability of cardiac services, overall or within any clinical need category.

DISCUSSION

Our results demonstrate a variation in use of angiography across hospitals with varying cardiac service capabilities, but not in survival associated with angiography, overall as well as within categories defined by clinical need. However, the consistent improved survival associated with angiography suggests that admission to a hospital with on-site cardiac facilities is beneficial because it increases the likelihood of receiving angiography.

Our findings are consistent with earlier studies (Every et al. 1997; Selby et al. 1996), though we studied a much larger sample from a more diverse geographic area here. Our results are also consistent with Thiemann and colleagues (Thiemann et al. 1999), who examined 30-day mortality rates for elderly Medicare patients after AMI and found that the availability of technology for angioplasty and bypass surgery was not independently associated with overall mortality after adjusting for hospital volume. McClellan et al. (McClellan, McNeil, and Newhouse 1994) reported a small incremental survival benefit of increasing the angiography rate after AMI that they attributed to correlated beneficial technologies at hospitals with angiography capabilities. However, their results are applicable to the marginal patient rather than the average patient (McClellan and Newhouse 2000).

We found a consistent beneficial effect of angiography within all categories of clinical need, including the uncertain category where, by definition, benefits are equal to risks. Similar results have been observed in a recent study on the appropriateness of angioplasty (Hemmingway et al. 2001)—there was a graded effect of angioplasty, with greater survival benefit in the group deemed necessary compared to those deemed uncertain. However, there was still a clear benefit among those deemed uncertain. This suggests that expert-defined appropriateness criteria may be conservative in identifying patients who would benefit from angiography. However, we cannot completely eliminate the possibility that the improved survival rates observed here might be due to a selection bias. Our results raise the question of whether the high rate of angiography use at hospitals with on-site capabilities among patients for whom the procedure is deemed of uncertain benefit, is justified. Future evaluation of the appropriateness of angiography among this

group should take into account the effect on patient and hospital costs, as well as patient quality of life in addition to survival.

The validity of our results centers on our ability to adequately adjust for confounding variables. Previous studies similar to ours have used multivariate regression models or instrumental variable methods. While the latter method can adjust for unmeasured confounders, results apply only to the marginal patient and cannot be easily generalized. The detailed information available on several independent predictors of the use of angiography permitted us to use a complex risk-adjustment strategy. While stratifying by appropriateness criteria allows comparisons to be made between patients who are equally likely to benefit from angiography, further adjustment is needed for patient and hospital characteristics that are known to affect the likelihood of receiving angiography in practice and may affect survival. While matching on propensity scores has been shown to result in a reduction in bias, it cannot remove the bias completely. The cohort used in this study is representative of elderly patients discharged with AMI in the United States in the mid-1990s, who were eligible for angiography more than 12 hours after symptom onset. While nearly 60 percent of AMI patients receive angiography in this time frame, our results are not applicable to patients who received primary angioplasty. Further, our results do not necessarily generalize to patients under the age of 65 years or to those with characteristics similar to the 30 percent of our patient sample that was excluded.

In conclusion, our results demonstrate a beneficial effect of angiography on one-year survival within all clinical need categories. While availability of cardiac services at the admitting hospital affects case-selection for angiography, it does not modify the average survival benefit following angiography within clinical need categories.

ACKNOWLEDGMENT

We thank two anonymous reviewers whose comments resulted in a much improved version of this paper.

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