READMISSION AFTER CARDIAC OPERATIONS: PREVALENCE, PATTERNS, AND PREDISPOSING FACTORS

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Objectives: This study was undertaken (1) to determine the prevalence of hospital readmission within 1 month of discharge after cardiac operations, (2) to categorize diagnoses responsible for readmission, and (3) to examine predischarge patient factors that influenced readmission. **Methods:** Data at 1 month after discharge were obtained for 1665 (98.4%) of 1692 patients who underwent cardiac operations between January 1996 and July 1998. **Results:** Two hundred twenty-five patients (13.5%) were readmitted to a hospital within a 1-month period after discharge. Forty-eight percent of readmissions were to other hospitals. The most common readmission problems were congestive heart failure (15.6%), atrial fibrillation (12.9%), chest pain (12.0%), wound problems (10.2%), and gastrointestinal problems (8.0%). Hospital discharge on or before the fifth postoperative day was associated with a lower prevalence of subsequent readmission. The independent predictors of a readmission for congestive heart failure were postoperative stay longer than 5 days, diabetes, New York Heart Association functional class IV, preoperative congestive heart failure, total blood product use, the need for postoperative inotropes, body mass index greater than 28 kg/m², and reoperation for bleeding. **Conclusions:** The prevalence of rehospitalization during the first month after discharge is not trivial. Other than postoperative atrial fibrillation, readmission is probably the single most likely adverse event to befall a patient in the early postoperative period. Patients who are discharged early do not appear to be at increased risk. Patterns in readmission diagnoses suggest opportunities for preventive strategies. (*J Thorac Cardiovasc Surg* 1999;118:823-32)

Cardiac surgical procedures, particularly coronary artery bypass grafting (CABG), are among the most intensively investigated of all patient treatments. Mortality, morbidity, and long-term outcomes are well established. However, there is surprisingly little information regarding postoperative problems that precipitate hospital readmission during the early period after surgical discharge. The current emphasis on cost reduc-

tion has spurred efforts to boost efficiency and to reduce hospital expenditures and postoperative length of stay. Readmissions negatively affect such efforts and are disruptive to patients and their families. From a global perspective of cost and quality of care, early hospital readmission could offset any putative gains achieved by early or "fast track" discharge. In this study we reviewed our experience with hospital readmission in the 1-month postdischarge period after cardiac surgical procedures. We investigated the prevalence of and reasons for readmission and attempted to determine patient characteristics that increased the chances of readmission.

Methods

Patients. Preoperative, intraoperative, and postoperative clinical data in The Society of Thoracic Surgeons National Database format (but including additional variables) were prospectively collected and entered into a computerized database for all patients undergoing cardiovascular operations at the Lahey Clinic Medical Center in Burlington, Mass,

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between January 1, 1996, and July 31, 1998. One thousand eight hundred ninety-one consecutive patients underwent operation by 1 of 4 surgeons. The operations performed included CABG; valve replacement or repair; combined valve and CABG operations; surgical intervention for ascending aortic/arch, descending aortic, and thoracoabdominal aortic pathology; repair of atrial septal and ventricular septal defects; and resection of cardiac tumors. To create a relatively homogeneous population of patients for analysis, this study group was confined to the subset of 1732 consecutive patients who underwent CABG, valve operations, or combined CABG and valve operations and excluded patients with thoracic aortic, congenital, and postinfarction ventriculoseptal defects. We did include 17 patients who underwent concomitant carotid endarterectomy, 10 patients who underwent repair of an incidental patent foramen ovale or atrial septal defect, and 4 patients who underwent CABG and left ventricular aneurysmectomy. Also included were 35 patients who underwent beating-heart CABG through either a thoracotomy or a sternotomy and 47 patients who underwent aortic valve procedures, mitral valve procedures, or both through a minimal access incision.

Data sources. Postdischarge follow-up data were obtained in 1 or more of the following ways: (1) from the patient at the time of the 3- to 4-week postoperative office visit, (2) from the patient by written or telephone questionnaire, (3) by review of the clinic record, and (4) by review of data from other hospitals and referring physicians' offices. The patient was the primary source of information regarding whether a readmission took place. When patients or their families were uncertain about whether or why a readmission occurred, information was obtained from the Lahey Clinic medical record or from the referring physician, treating hospitals, or both. For patients who underwent operation in 1996, follow-up data were obtained retrospectively, initially by written questionnaire within 6 to 12 months after the operation and then with further inquiry as necessary. Data were collected prospectively for patients operated on since January 1997.

Outcomes assessed. Patients were categorized as readmitted or not readmitted. Admitting diagnoses were recorded for each readmitted patient. For patients with multiple problems the most proximate or dominant condition resulting in readmission was recorded as the reason for readmission. If a patient had more than 1 readmission to the hospital within the 1-month period only the first readmission was recorded. The hospital of readmission was recorded as Lahey Clinic or other institution.

Patient care protocols. Surgical techniques were similar among all 4 surgeons. Operations conducted with cardiopulmonary bypass were performed with a centrifugal pump, moderate hypothermia (28°C-30°C) and cold blood cardioplegia. Anesthetic management was conducted to allow for extubation within 12 hours of operation. No concerted effort was made to extubate patients in the operating room at the conclusion of the procedure. Furthermore, no concerted effort was made to "fast track" patient discharge. During the time frame of this study, our service used a relatively conservative clinical pathway with an ideal hospital discharge of 5 days

after the operation. Most patients were discharged home, but 23% of patients were discharged to an extended care (rehabilitation) facility for a short period, usually because of inadequate family support at home. A readmission was recorded for an extended care facility patient if that patient required transfer to an acute care hospital.

The statistical methods are presented in the appendix.

Results

One thousand seven hundred thirty-two patients underwent CABG, valve, or combined CABG and valve operations. Thirty-one patients (1.8%) died while still hospitalized at Lahey Clinic and 5 patients (0.3%) died after transfer to another acute care hospital, for a total in-hospital mortality rate of 2.1%. These patients, as well as 4 patients continuously hospitalized at another acute care facility 30 days after transfer from our hospital, were excluded from the readmission analysis group. A total of 1692 patients were discharged from the hospital. Six (0.4%) of these discharged patients died within 1 month (total in-hospital plus 30-day mortality rate of 2.4%). Four of these 6 deceased patients were readmitted to a hospital before death, and all 6 of these patients were included in the readmission analysis group. Postoperative in-hospital complications for all 1732 patients were as follows: 34 (2.0%) reoperations for bleeding, tamponade, or both; 32 (1.8%) perioperative myocardial infarctions; 44 (2.5%) strokes or transient ischemic attacks; 5 (0.3%) sternal wound infections; and 9 (0.5%) instances of the need for dialysis.

One month follow-up data were available for 1665 (98.4%) of the 1692 discharged patients, and these 1665 patients comprise the study group. Of these 1665 patients, 1363, 147, and 155 patients underwent CABG, valve, and CABG plus valve procedures, respectively. The mean postoperative length of stay was 6.51 ± 4.16 days. Ninety percent of patients were discharged within 9 days, and the median day of discharge was 5.0.

A total of 225 patients (13.5%) were readmitted to a hospital within 1 month of discharge after the operation. Selected clinical characteristics of all discharged patients, differentiated according to readmission status, are shown in Tables I and II. Patients who were readmitted were more likely to be older, although octogenarians were at no greater risk for readmission. Readmitted patients had a lower ejection fraction, congestive heart failure, a higher New York Heart Association functional class, peripheral vascular disease, and a history of stroke. They also showed greater blood product use and intra-aortic balloon pump use. Also associated with readmission were reoperation for bleeding, postoperative atrial fibrillation, use of digox-

Table I. Preoperative clinical characteristics of the 1665 study patients grouped by readmission status

Clinical variable	No readmission (n = 1440)		Readmission (n = 225)		Significance†	Odds ratio*	
	No.	%	No.	%		Calculated	95% CI
Age (y)							
Mean ± SD	65.1 ± 10.8		66.7 ± 10.3		P = .05	F = 3.92	
>55	1152	80	193	86	P = .04	1.51	1.01-2.24
>65	770	54	128	57	P = .4	1.07	0.92-1.26
>75	255	18	50	22	P = .12	1.32	0.94-1.86
>80	70	5	16	7	P = .16	1.57	0.86-2.66
Male	1013	71	155	69	P = .6	0.93	0.68-1.25
Currently married	940	72	153	73	P = .8	1.05	0.90-1.08
Elective admission	271	19	45	20	P = .7	1.08	0.26-1.53
Interhospital transfer	415	29	80	36	P = .05	1.36	1.01-1.83
Body mass index (kg/m ² , mean ± SD)	28.1 ± 5.2		27.9 ± 5.6		P = .5	F = 0.423	
Hypertension	849	59	142	63	P = .3	1.19	0.89-1.58
Diabetes	403	28	71	32	P = .3	1.18	0.87-1.60
Tobacco use	896	62	147	65	P = .4	1.14	0.84-1.53
Peripheral vascular disease	284	20	60	27	P = .02	1.48	1.07-2.04
Preoperative cerebrovascular accident or transient ischemic attack	127	8	31	14	P = .03	1.65	1.08-2.51
New York Heart Association functional class IV	450	31	92	41	P = .006	1.52	1.14- 2.70
Left ventricular ejection fraction (% , mean ± SD)	50.3 ± 13.4		47.8 ± 13.9		P = .01	F = 6.67	
Chronic atrial fibrillation	53	4	11	5	P = .4	1.34	0.69- 2.61
Renal insufficiency	77	5	19	8	P = .09	1.63	0.97- 2.75
Preoperative congestive heart failure	112	8	29	13	P = .01	1.75	1.13-2.70
Preoperative medications							
Intravenous nitroglycerin	384	27	73	32	P = .08	1.32	0.97-1.78
Intravenous heparin	645	45	13	50	P = .2	1.24	0.94-1.64
Digoxin	140	10	26	12	P = .4	1.21	0.78-1.90
Diuretic	324	23	57	25	P = .3	1.17	0.84-1.61
β-Blocker	989	69	142	63	P = .09	0.78	0.58-1.04

All data are in number and percentage of patients unless otherwise stated. CI, Confidence interval.

*F value for continuous data.

†Two-tailed P value.

in at discharge, and a longer postoperative stay. Although they comprised fewer than half of total discharges, patients with postoperative stays longer than 5 days were more likely to be readmitted and comprised a greater proportion of total readmissions relative to total discharges ($P = .003$; Fig 1). The mean time to readmission for those 175 patients for whom we had an exact date of readmission was 11.7 ± 8.7 days. A histogram depicting the number of days until readmission is shown in Fig 2. Most readmissions took place in the early period after discharge, with a continuously decreasing number of readmissions occurring across time. Of some importance, we found that only 52% of readmissions (116/225) were to Lahey Clinic directly; the remainder were to other institutions.

The primary problems that prompted readmission were varied (Table III). The 2 most common single reasons for readmission were congestive heart failure and arrhythmias, most notably atrial fibrillation. A diagnosis of congestive heart failure was based on clinical or radiographic evidence of pulmonary edema or dyspnea in the setting of fluid overload. Every effort was made to differentiate these patients from those with dyspnea related to isolated pleural effusions or anemia. Most patients readmitted because of chest pain were ultimately found to have pain of noncardiac origin. One third of patients with gastrointestinal problems were admitted because of hemorrhage. There were 7 patients readmitted for vascular surgical problems (3 patients with pseudoaneurysm at the catheterization site and 4

Table II. Operative and postoperative in-hospital clinical characteristics of the 1665 study patients grouped by readmission status

Clinical variable	No readmission (n = 1440)		Readmission (n = 225)		Significance†	Odds ratio*	
	No.	%	No.	%		Calculated	95% CI
Reoperation	71	5	10	4	<i>P</i> = .7	0.79	0.38-1.68
Type of operation							
CABG	1187	82	176	78	<i>P</i> = .14	0.76	0.54-1.08
Valve operation	122	9	25	11	<i>P</i> = .2	1.36	0.86-2.14
CABG plus valve operation	131	9	24	11	<i>P</i> = .5	1.19	0.75-1.9
Minimally invasive procedure‡	63	4	14	6	<i>P</i> = .2	1.45	0.78-2.63
Emergency operation	61	4	13	6	<i>P</i> = .3	1.40	0.75-2.56
Cardiopulmonary bypass time (min, mean ± SD)	111.9 ± 44.9		115.7 ± 43.4		<i>P</i> = .3	F = 1.31	
Crossclamp time (min, mean ± SD)	80.7 ± 34.8		84.5 ± 35.1		<i>P</i> = .14	F = 2.26	
Intra-aortic balloon pump	80	6	22	10	<i>P</i> = .02	1.84	1.21-3.01
Total blood used (units, mean ± SD)	1.98 ± 2.8		2.53 ± 3.2		<i>P</i> = .007	F = 7.21	
Any platelet or fresh-frozen platelet use	283	19	65	29	<i>P</i> = .05	2.97	1.02-8.64
Postoperative inotropes	174	12	44	20	<i>P</i> = .003	1.73	0.16-2.89
Postoperative complications							
Reoperation for bleeding	19	1.3	11	4.8	<i>P</i> = .001	3.84	1.80-8.17
Myocardial infarction	20	1.4	5	2.2	<i>P</i> = .4	0.89	0.62-1.27
Cerebrovascular accident or transient ischemic attack	29	2	3	1.3	<i>P</i> = .03	2.17	1.08-2.51
Atrial fibrillation	414	29	85	38	<i>P</i> = .008	1.5	1.12-2.01
Respiratory failure	72	5	15	7	<i>P</i> = .3	1.35	0.76-2.41
Renal failure	22	2	1	0.4	<i>P</i> = .09	3.5	0.46-25.4
Discharge medications							
Digoxin	415	29	80	36	<i>P</i> = .05	1.36	1.01-1.83
β-Blocker	1106	77	167	74	<i>P</i> = .4	0.86	0.62-1.19
Diuretic	772	54	119	53	<i>P</i> = .8	1.2	0.84-1.70
Angiotensin-converting enzyme inhibitor	113	8	30	13	<i>P</i> = .01	0.97	0.73-1.28
Postoperative length of stay (d)							
Mean ± SD	6.44 ± 4.3		6.99 ± 3.2		<i>P</i> = .07	F = 3.37	
>5	670	47	130	58	<i>P</i> = .002	1.26	1.10-1.48
Discharged to extended care facility	312	22	70	31	<i>P</i> = .003	1.63	1.20-2.22

All data are in number and percentage of patients unless otherwise stated. *CI*, Confidence interval.

*F value for continuous data.

†Two-tailed *P* value.

‡Minimally invasive procedure was either beating-heart CABG or minimal access valve operation.

with limb ischemia). Included in the miscellaneous category were 12 patients classified as having other reasons (2 patients with dehydration and 1 each with urinary retention, renal failure, spontaneous pneumothorax, ocular migraine, negative results of workup for deep venous thrombosis, seizures, planned readmission for bowel resection, asthma, alcohol withdrawal, and cardiac arrest).

The results of univariable analyses for specific types of readmission problems are shown in Table IV. Several

variables were associated with readmission for congestive heart failure, the most notable being preoperative renal dysfunction, preoperative congestive heart failure, New York Heart Association functional class IV, and perioperative intra-aortic balloon pump use. Of interest, β-blocker use on discharge was associated with a decreased risk of readmission. Fewer variables affected readmission for atrial fibrillation and for wound and gastrointestinal problems. Not surprisingly, postoperative atrial fibrillation was most strongly asso-

Fig 1. Distribution of total discharges (n = 1665) and readmissions (n = 225) by postoperative length of stay. Scheffé test was used for all possible pairwise comparisons. *Solid bars*, Percentage readmission; *open bars*, percentage of total discharges; *dotted bars*, percentage of total readmissions.

Fig 2. Distribution of time (in days) to patient readmission (n = 175).

ciated with a readmission for atrial fibrillation. We found no association with the use of postoperative β -blockers. However, we did find that patients who were transferred to our hospital for the operation were less likely to be readmitted subsequently for atrial fibrillation. This may be related to the observation that our interhospital transfer patients were 1.5 times more likely to be treated with β -blockers before the operation than were our nontransfer patients. Sternal and leg wound problems were associated with the presence of diabetes, larger body mass index, peripheral vascular

disease, and the use of insulin. The development of a sternal wound problem but not a leg wound problem during initial hospitalization influenced hospital readmission for wound problems. We believe that this finding was due to the small number of patients involved, but it could also have been due to the evolutionary nature of some sternal wound problems that do not completely manifest themselves during the initial hospital stay. Gastrointestinal readmissions were associated with a longer postoperative stay, reoperation for bleeding, and greater blood product use. Older age was

Table III. Primary or dominant reason for readmission
(*n* = 225)

<i>Diagnosis</i>	<i>No.</i>	<i>Proportion of total readmissions (%)</i>
Congestive heart failure or pulmonary edema	35	15.6
Arrhythmia	37	16.4
Atrial fibrillation	29	
Ventricular arrhythmia	3	
Pacemaker insertion	5	
Chest pain	27	12.0
Recurrent angina	3	
Myocardial infarction	6	
Noncardiac (musculoskeletal)	18	
Infection (nonsurgical)	10	4.4
Pneumonia	6	
Other	4	
Wound problem	23	10.2
Sternal	7	
Leg	16	
Gastrointestinal	18	8.0
Hemorrhage	6	
Nausea or diarrhea with dehydration	4	
Cholecystitis	3	
Hepatitis	1	
Pancreatitis	3	
Bowel obstruction	1	
Vascular problem	7	3.1
Deep venous thrombosis, pulmonary embolus, or both	11	4.9
Cerebrovascular accident or transient ischemic attack	9	4.0
Thoracentesis or complication thereof	10	4.4
Miscellaneous	38	16.9
Symptomatic anemia with transfusion	9	
Adverse medication reaction	6	
Postpericardotomy syndrome	3	
Pericardial effusion or pericardiocentesis	4	
Syncope	4	
Other	12	

of borderline significance. We were intrigued to find an association with preoperative intravenous heparin use, for which we have no ready explanation.

Several logistic regression models were created in an attempt to identify independent predictors for readmission. Because of the large number of parameters in each model relative to fairly low frequencies of many variables for readmitted patients, as well as the highly interrelated nature of the variables, models predicted probabilities across a small range of data. Most explained less than 5% of the total variation in read-

mission. However, when we restricted our multivariable analysis to the single largest category of readmissions—congestive heart failure—the resulting model demonstrated a much better predictive ability and explained 24% of the total variation in readmission rate for congestive heart failure (Table V).

Discussion

The prevalence of and circumstances surrounding readmission in the early postdischarge period after cardiac operations have been a relatively understudied aspect of cardiac surgery. In 1985 Stanton and associates¹ reported a 24% prevalence of readmission within 6 months after the operation for a small prospectively studied group of patients who underwent CABG. Lubitz and colleagues² reviewed 1986 and 1987 Medicare claims data for approximately 54,000 patients who underwent CABG and found a substantial 1-year rehospitalization rate of 629 readmissions/1000 patients. Other studies that were based on Medicare claims data^{3,4} and recent small but single-institution studies⁵⁻⁷ have demonstrated the prevalence of early readmission to be between 8% and 21%. Our finding of a 13.5% prevalence of 1-month readmission is concordant with these reports.

An accurate accounting of the prevalence and reasons for early readmission after cardiac operations has both quality of care and financial implications that will assume greater importance as hospitals move further toward fully capitated systems of reimbursement. Toward this end the Medicare claims database offers a vast repository of relevant information. However, data are restricted to patients older than 65 years, are potentially subject to coding errors, and cannot readily yield information to control for the individual patient characteristics necessary for constructing risk models. The Society of Thoracic Surgeons National Database does record many essential clinical variables. Interestingly, however, the prevalence of 30-day readmission was only about 6% for the 1997 group of patients, which raises the specter of incomplete capture of these readmission events. As a practical matter, readmissions are difficult to track. Our data, as well as those of Lahey and colleagues,⁷ show that nearly half of all readmissions take place at hospitals other than that where the operation was performed. This pattern may not be true of cardiac surgical hospitals in geographically isolated communities but is probably representative of the experience in major metropolitan areas, and it underscores the need for vigilance and completeness when tracking such events.

To the best of our knowledge this study involves the largest number of patients from a single institution

Table IV. Univariable predictors of specific rehospitalization problems (reasons for readmission)

Variable	Congestive heart failure		Atrial fibrillation		Wound problem		Gastrointestinal	
	Significance	Odds ratio*	Significance	Odds ratio*	Significance	Odds ratio*	Significance	Odds ratio*
Age							<i>P</i> = .05	3.75*
Age >55 y			<i>P</i> = .04	6.28				
Hospital transfer			<i>P</i> = .03	0.29				
Body mass index					<i>P</i> = .007	7.43*		
Body mass index <28 kg/m ²	<i>P</i> = .03	0.44			<i>P</i> = .04	2.38		
Diabetes	<i>P</i> = .02	2.15			<i>P</i> = .003	3.33		
Peripheral vascular disease					<i>P</i> = .001	3.58		
Renal dysfunction	<i>P</i> < .001	4.32						
New York Heart Association functional class IV	<i>P</i> < .001	3.61						
Congestive heart failure	<i>P</i> < .001	6.91						
Preoperative medications								
Intravenous heparin							<i>P</i> = .006	4.25
Intravenous nitroglycerin	<i>P</i> = .01	2.27						
Inotropes	<i>P</i> = .05	3.21						
Digoxin	<i>P</i> = .002	3.22						
Diuretic	<i>P</i> = .02	2.29	<i>P</i> = .03	2.35				
Intra-aortic balloon pump	<i>P</i> < .001	4.84						
Left ventricular ejection fraction	<i>P</i> = .001	11.4*						
Cardiopulmonary bypass time >120 min			<i>P</i> = .04	2.22				
Internal thoracic artery used								
Total units of blood used	<i>P</i> = .002	10.0*					<i>P</i> = .06	3.64*
Blood used >2 units							<i>P</i> = .02	2.85
Fresh-frozen plasma or platelet use	<i>P</i> < .001	3.89						
Reoperation for bleeding	<i>P</i> = .003	5.36					<i>P</i> = .004	6.97
Respiratory complication	<i>P</i> = .02	3.15						
Sternal wound complication					<i>P</i> < .001	54.9		
Any complication	<i>P</i> = .009	2.69						
Postoperative atrial fibrillation			<i>P</i> < .001	29.67				
Discharge medications								
β-Blocker	<i>P</i> = .002	0.35						
Digoxin	<i>P</i> = .01	2.26	<i>P</i> = .003	8.66				
Insulin	<i>P</i> = .006	2.97			<i>P</i> = .001	4.38		
Diuretic	<i>P</i> = .03	2.20						
Postoperative length of stay	<i>P</i> = .02	5.69*						
Postoperative length of stay >5 d	<i>P</i> < .001	5.40						
Postoperative length of stay >8 d							<i>P</i> = .02	3.04
Discharge to extended care	<i>P</i> = .02	2.28						

*F value for continuous variables.

studied to date with 98.4% completeness of follow-up and for whom relevant predischARGE clinical characteristics could be correlated with readmission. A strength of our study was reliance on the patient as the initial

source of information regarding whether a readmission took place. A review based on hospital charts or Medicare claims would not capture events for younger or out-of-state patients. It is possible that some patients

Table V. Independent predictors of readmission for congestive heart failure

Variable	Odds ratio	95% CI	Significance
Postoperative length of stay >5 d	3.05	1.18-7.87	<i>P</i> = .02
Diabetes	2.64	1.24-5.59	<i>P</i> = .01
New York Heart Association functional class IV	2.14	0.99-4.64	<i>P</i> = .06
Preoperative congestive heart failure	3.68	1.68-8.06	<i>P</i> = .001
Total blood use	0.89	0.78-1.01	<i>P</i> = .08
Fresh-frozen plasma or platelet use	2.75	1.18-6.39	<i>P</i> = .02
Postoperative inotropes	2.75	1.25-6.06	<i>P</i> = .01
Body mass index <28 kg/m ²	0.49	0.21-1.13	<i>P</i> = .1
Reoperation for bleeding	9.25	2.26-37.9	<i>P</i> = .002

-2LL = 128.238. Goodness of fit χ^2 (CC Brown) = 4.572; *df* = 2; *P* = .10. Goodness of fit χ^2 (Hosmer and Lemeshow) = 5.589; *df* = 8; *P* = .7. Constant = -5.753. CI, Confidence interval.

might have forgotten a readmission, but we believe that this would be an infrequent event. Furthermore, our methods called for chart and referring physician data review when there was any degree of uncertainty.

Our study has several shortcomings. We do not have the exact dates of readmission for all 225 readmissions (although we do know that they occurred within a 1-month period), nor do we have data regarding readmission within the first 90 days after discharge—2 issues that affect the construction of risk models. Furthermore, because of the number of interrelated clinical variables and the infrequency and varied reasons for readmission, we do not have enough data to construct a single multivariable risk model that predicts most readmissions. To create such a model we estimate that we would need approximately 500 readmissions to achieve 90% power to detect a 10% change in variation. A confounding issue that has not been broached in previous studies and that we have not resolved in this study is that of discharge to extended care or rehabilitation facilities—an increasingly common event as acute care hospitals are pressured to reduce length of stay. We found that readmitted patients, in particular patients readmitted for congestive heart failure, were more frequently discharged to such facilities. What impact do these facilities have on the overall prevalence of readmission to an acute care hospital? We did not consistently track events occurring in these facilities that did not result in hospital readmission. Finally, calculation of the financial impact of readmission was beyond the scope of this study. Our study is ongoing, and future analyses may help to resolve some of these issues.

The reasons for readmission are quite varied. However, our data as well as that of others^{6,7} show that several readmission categories predominate, such as congestive heart failure, arrhythmias, evaluation for chest pain, and management of wound problems. Not all readmissions are avoidable, but these demonstrated pat-

terns in readmission diagnoses suggest opportunities for preventive strategies. Indeed, congestive heart failure, the most common discharge diagnosis in the elderly population, has been shown to be amenable to a multidisciplinary approach aimed at reducing repetitive readmissions.⁸ Although a comprehensive risk stratification schema for early cardiac surgical readmission does not yet exist, the data presented here paint a profile of those patients who are at greater risk for readmission. Careful evaluation of these patients before discharge coupled with increased postdischarge surveillance—including more frequent telephone or office contact, increased use of visiting nurse services, more detailed and frequent communication with referring facilities, and perhaps the use of home transtelephonic monitoring systems—may reduce these readmissions by a substantial portion.

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Appendix

Statistical analysis. The following clinical data were collected for analysis. Continuous variables were age, body mass index, left ventricular ejection fraction, cardiopulmonary bypass time, aortic crossclamp time, number of distal anastomoses, total blood transfused (in units), and postoperative length of stay. Preoperative categorical variables included age (>55 years, >65 years, >75 years, and >80 years), marital status, gender, interhospital transfer, elective admission, hypertension, smoking, diabetes, previous stroke or transient ischemic attack, peripheral vascular disease, renal dysfunction, New York Heart Association functional class IV, body mass index less than 28 kg/m², chronic atrial fibrillation, congestive heart failure, and postinfarction angina. Other categorical variables included the use of aspirin, intravenous nitroglycerin, intravenous heparin, digoxin, diuretics, β -blockers, angiotensin-converting enzyme inhibitors, inotropes, or an intra-aortic balloon pump. Operative and postoperative categorical variables included emergency operation, reoperation, minimally invasive procedure, cardiopulmonary bypass longer than 90 minutes, cardiopulmonary bypass longer than 120 minutes, internal thoracic artery use, transfusion of more than 2 units blood, use of fresh-frozen plasma or platelets, and concurrent use of 2 or more inotropes after the operation. Postoperative complications included reoperation for bleeding or tamponade, perioperative myocardial infarction, stroke or transient ischemic attack, renal failure, prolonged ventilation or respiratory failure, any of the listed complications, and atrial fibrillation. Discharge medications recorded included β -blockers, calcium-channel blockers, angiotensin-converting enzyme inhibitors, diuretics, digoxin, warfarin, insulin, and histamine-2 receptor blockers. Finally, the model included postoperative stay longer than 5 days, postoperative stay longer than 8 days, and disposition (home versus extended care).

Categorical variables were evaluated by χ^2 analysis or Fisher exact test where appropriate. Continuous variables were evaluated with 1-way analysis of variance or, when frequencies of continuous variables were small, with independent *t* tests assuming equal variance. Predictors that exhibited a statistically significant relationship during univariate analyses were used to create logistic regression models. Backward stepwise deletion of variables was performed until a best-fit model was achieved. Residuals and cross-classification tables were examined to determine where the model was overpredicting or underpredicting and to determine whether outlying residuals exhibited significant influence on the mul-

tivariable model. Analyses were performed with both BMDP (BMDP Statistical Software, Inc, Los Angeles, Calif) and SPSS 9.0 (SPSS Inc, Chicago, Ill) software.

Discussion

Dr Timothy J. Gardner (*Philadelphia, Pa*). As you have clearly indicated, the incidence of rehospitalization during the first postdischarge month is not a trivial matter. In fact, about 1 in 7 patients in this report were readmitted for what I found to be a surprising variety of problems. Only about a quarter of these patients were readmitted for the management of rhythm or wound problems. A higher percentage of the patients required rehospitalization to treat clinical congestive heart failure or to assess recurrent chest pain.

I was somewhat surprised by the finding that the percentage of readmissions was greater among patients whose postoperative hospitalization was longer to begin with. Patients discharged within 6 days after the operation had the lowest readmission percentage.

Another finding from this study that I had not expected was that patients who were discharged from the hospital to extended care or rehabilitation facilities required readmission more often than did patients discharged home. This observation may emphasize the fact that these rehabilitation units and skilled nursing facilities may not in fact be equipped to deal with persistent systemic medical problems.

This fact, in conjunction with the observation in this study that more than 50% of the patients who required readmission were admitted to hospitals other than the hospital in which the operation was performed, suggests that skilled nursing facilities that are part of the parent hospital might prove to be the most efficient sites for extended care for many of these patients. This is especially the case of older patients who are ready to leave the acute care hospital but may not be ready to manage on their own.

You conclude your article by suggesting that more careful predischarge planning as well as improved postdischarge surveillance and increased use of visiting nurse services might reduce the readmission rate. I would ask you to comment specifically on how the care of an elderly patient with poor baseline cardiac function who is susceptible to recurrent episodes of pulmonary edema and congestive heart failure might be more efficiently or more appropriately managed. Is there a place for lateral transfers to the medical service? Does this continue to put the Medicare patient under the same admitting diagnosis related group? Also, should the need for early readmission be considered a negative quality indicator, as it has been viewed by many insurers and other quality assurance services?

Dr D'Agostino. I believe that the older patient with poor ventricular function who is at risk for recurrent episodes of pulmonary edema and congestive heart failure needs more frequent evaluation and proactive management to reduce the chance of readmission. The unresolved question is how to accomplish this efficiently. Visiting nurse services are help-

ful, but they are not always the answer. One conclusion that we reached is we should contact these patients earlier in the postdischarge course and reevaluate them in the office sooner than we customarily do. We have typically seen our postoperative patients about 3 to 4 weeks after discharge from the hospital. If you look at the histogram showing the time to readmission, however, you find that it averaged about 11 days after the operation. This suggests to me that we should reevaluate patients, especially the patients at higher risk, within 1 to 2 weeks after discharge.

One management strategy that we are planning to investigate is that of using transtelephonic monitoring equipment to include monitoring of blood pressure, electrocardiogram, and pulse oximetry for our patients at higher risk. This will provide us with daily or twice daily data that might allow us to spot incipient congestive heart failure as well as manage some of the arrhythmias on an outpatient basis. I think that it is too early to say whether readmission should be considered a negative quality indicator, because it may reflect patient-related factors more than quality of care issues.

Dr Salim Walji (*Albuquerque, NM*). When we initiated our ultrafast discharges in Albuquerque, whereby many of our patients were discharged by postoperative days 1 to 4 after various configurations of cardiac surgical procedures, we looked at readmission data as valuable feedback to assess our discharge strategies. That is, we used it to determine whether we were rushing patients out of the hospital too soon. We found that our own rate of readmission, admittedly in a smaller group of patients, was 5.6%.

I believe that in time to come this article will become a standard of care against which each of us will measure our own standards of care. Standards reflect mortality and morbidity, but they also include readmission rate.

I have 2 questions. First, do you believe from your analysis of readmission causes that lengthening the initial hospitalization by another 2 or 3 days would have prevented readmission? Second, immediately after discharge, say postdischarge day 1 or 2, did you have any of your personnel calling the patients to assess whether they had dealt with their medications and other concerns adequately?

Dr Stephen J. Lahey (*Boston, Mass*). As you know, we looked at a similar project published in *Circulation* and a supplement of *Circulation* this winter. I think that the issue of readmission after cardiac operations is an interesting academic project for people like you and me, but it will be an extremely important issue for the rest of the membership if and when Medicare reimbursement schemes change. If in fact we are given a global fee that will encompass perhaps 90 days or 120 days, then readmission becomes more than an academic interest; it is going to impose an enormous financial burden on every hospital. This is thus an important project, and I think that you have done a superb job.

I think that maybe you saw the same thing that we did. The Achilles heel is the readmissions to outside hospitals. When people say, "Yes, we have a 2% readmission rate," I wonder whether in reality they are seeing the same thing that we did; that is, nearly a 50% readmission rate. Were you in contact

with any of the referring physicians, who have a completely different incentive for readmission with respect to diagnosis related groups, with primary care physicians or whoever in outside hospitals that have absolutely no allegiance to you? How can we control those people, who might just as well readmit the patient as do anything else, or handle it over the phone? It might be to their benefit.

Second, how did you find out whether patients were readmitted? We came up against issues of privacy when we tried to get discharge summaries from those hospitals, and one of the things that we ended up doing eventually was to have patients sign a release at the same time that they signed the consent for the original operation.

Dr D'Agostino. Dr Lahey, we did not in any routine way maintain contact with referring physicians at the time patients were being considered for readmission to outside hospitals. On those occasions when a referring physician would contact us regarding a postoperative problem, such as a wound infection, we did make every effort to see the patient in our offices for treatment. Regarding your second question, we found that tracking readmissions to outside hospitals was an onerous task indeed. We too found the privacy issues to be a problem for us when trying to obtain discharge summaries from outside hospitals. This was less of a problem when dealing directly with primary or referring physicians. We tried to obtain as much information as possible from the patient at the time of office visit or with a follow-up survey. When there was any question and we could not get information from the referring doctors, we would then mail the appropriate consent forms to the patient to allow us to obtain discharge summaries from the treating hospital.

Regarding your question as to how we can prevent primary physicians from unnecessarily readmitting patients, I think that this will require a proactive effort on our parts. Clearly there are occasions and clinical problems for which there is no incentive for referring physicians to keep patients out of the hospital. For instance, as I am sure you have seen, physicians may be totally unfamiliar with management of wound problems or pleural effusions, and this results in unnecessary hospital readmission. I think that the only way we can deal with this type of problem is to head it off at the pass, so to speak, by contacting both the patient and the referring physician on a more frequent basis. There is no question that this is a lot of work and will require significant manpower, a resource we may be increasingly hard pressed to fund as we deal with increasing cost constraints.

With respect to Dr Walji's question, it came as no surprise to me that patients who were discharged home earlier were less likely to be readmitted. The patients who follow the critical pathway are the ones who are doing well and are the least likely to have problems. Patients discharged between 8 and 14 days after the operation have a higher incidence of readmission, but I am uncertain whether this risk could be reduced by an additional 2 to 3 days of hospitalization. Finally, our patients operated on since 1997 were contacted by our hospital nurse within 3 to 5 days of discharge for a status report. In some instances that contact helped to avoid a hospital readmission.