Hospital Resource Consumption in Patients With Diabetes and Multivessel Coronary Disease Undergoing Revascularization

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Abstract

Objective: **To identify factors responsible for the variation in real hospital costs and length of stay for patients with diabetes undergoing coronary angioplasty or coronary bypass surgery.**

Study Design: **Retrospective study of patients with diabetes and coronary artery disease treated at a single hospital.**

Patients and Methods: **The study population included 1809 patients with diabetes and multivessel (2-vessel or 3-vessel) coronary artery disease who underwent an initial coronary angioplasty or coronary bypass surgery between 1988 and 1996. After accounting for the extent and severity of the patient's coronary artery disease, a sequential model was used to assess if diabetic characteristics were independently associated with higher hospital resource utilization during revascularization.**

Results: **Multivariate regression results indicated that for patients with diabetes who underwent coronary angioplasty, a baseline creatinine level of ≥2.0 mg/dL was associated with significantly higher hospital costs and longer length of stay. For patients with diabetes who underwent a coronary bypass surgery only, a baseline creatinine level of ≥2.5 mg/dL was associated with higher hospital costs and longer hospital length of stay.**

Conclusions: **After controlling for coronary risk factors, selected diabetes-specific characteristics are associated with higher hospital resource utilization. Risk adjustments in hospital reimbursement may be needed to assure that patients with diabetes who have cardiovascular disease have access to revascularization procedures.**

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The direct medical cost of treating cardiovascular disease in patients with diabetes in the United States was estimated to exceed $7.6 billion in 1997.[1] Compared with the cost of the same treatment for people who do not have diabetes, these expenditures are high. Patients with diabetes are at much greater risk for developing coronary disease earlier in life than patients who do not have diabetes[1,2] and tend to have a greater severity of coronary artery disease, with more extensive and diffuse atherosclerosis.[3,4] In addition, the long-term occurrence of both fatal and nonfatal events following revascularization, including percutaneous transluminal coronary angioplasty (PTCA) and coronary artery bypass graft surgery (CABG), have been shown to be higher for patients with diabetes than patients who do not have diabetes.[5-9] Furthermore, a number of economic studies have shown that of the patients undergoing revascularization for multivessel coronary disease, patients with diabetes consume significantly more hospital resources than patients who do not have diabetes.[10-15]

Despite the level of resources used in treating patients with diabetes who have coronary artery dis-

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ease, little is known about the demographic characteristics or clinical risk factors associated with increased hospital resource consumption in this patient population. Understanding the factors responsible for resource utilization associated with revascularization in patients with diabetes is important for several reasons. First, because patients with diabetes are at higher risk for developing coronary artery disease than patients who do not have diabetes,[2,16,17] the resources consumed in treating coronary artery disease may account for a substantial portion of the total healthcare expenditure for this patient group. Second, if selected characteristics are associated with higher resource costs and cannot be modified prior to performing revascularization, these factors could be used for risk adjustment in hospital reimbursement to assure that selected patients with diabetes continue to have access to revascularization procedures. Third, identifying the factors that explain resource consumption of patients with diabetes will provide a better understanding of the incremental impact that the patient's condition has on the cost of revascularization. This information could be used to better manage both resource utilization and cardiovascular care provided to patients with diabetes.

The purpose of this paper is to identify factors associated with higher resource utilization among patients with diabetes who have multivessel coronary artery disease by addressing 3 key questions concerning the resource consumption. First, are individual demographic and diabetes-specific characteristics significantly related to hospital resource consumption for patients with diabetes who are undergoing revascularization? Second, to what extent are baseline clinical indicators of coronary artery disease and postprocedural characteristics associated with hospital resource consumption? Third, after controlling for demographic, preoperative, and postprocedural variables, are any diabetes-specific characteristics independently related to hospital resource consumption?

···METHODS ···

Patient Population

The patient population for this study included all patients with diabetes and 2-vessel or 3-vessel coronary artery disease who underwent either PTCA or CABG at Emory University Hospital in Atlanta, GA, between January 1988 and October 1996. Diagnosis of diabetes was determined by either previous physician diagnosis of diabetes mellitus or by patient self-reporting. Two-vessel disease was defined as the presence of luminal narrowing of 50% or more of the diameter in 2 of the 3 major epicardial vessels. Three-vessel disease was defined as the presence of luminal narrowing of 50% or more of the diameter in all 3 major epicardial vessel systems or in the left anterior descending and proximal circumflex in left-dominant patients. Included were patients who had procedures for stable or unstable angina pectoris or who had procedures after several days of stabilization following acute myocardial infarction. Patients who had previously undergone PTCA or CABG were excluded.

PTCA and CABG Procedures

All PTCA procedures were performed using standard techniques during the time the procedure was performed and have been previously described.[18] Angioplasty procedures included balloon dilation, stent implantation, and the use of other interventional devices. Because of the period during which most of these patients were treated, the majority of PTCA patients underwent balloon angioplasty. For CABG, standard surgical techniques, extracorporeal circulation, and myocardial protection methods were used.[19]

Data Collection and Database

Baseline demographic, clinical, angiographic, and procedural data, including complications, were recorded prospectively on standardized forms and entered into a computerized database. All fields are defined in a data dictionary. Hospital charges by department and total hospital charges were obtained for each patient from the financial office. Hospital financial information was available for more than 95% of all patients with diabetes identified in the clinical database in every year since 1988 except 1989 (85%) and 1994 (93%). The only patients excluded from the data set were those with missing financial information. An analysis of the excluded patients and those remaining in the study found no statistically significant differences in the mean value of any of the demographic, preoperative, or postprocedural characteristics. The final population comprised 1809 patients with diabetes and 2-vessel or 3-vessel coronary disease that underwent an initial coronary angioplasty (783) or coronary bypass surgery (1026) during the study period.

Hospital Resource Utilization

Two alternative measures of hospital resource utilization were studied: length of stay and total hospital costs. Length of stay was defined as the number of days from admission to discharge for the hospitalization associated with the patient's initial revascularization procedure. The total hospital cost associated with the initial revascularization for each patient with diabetes was calculated from hospital charge information using the following process.

Hospital costs were determined by obtaining billing statements and multiplying the billed charges from each department by the appropriate departmental cost-to-charge ratio. The estimate of total cost for each hospitalization was obtained by adding departmental costs for all departments that provided services to a patient.[20] Total hospital costs were inflated into 1996 dollars using the appropriate year's Bureau of Labor Statistics Medical Price Index for Hospital Services.[21]

Statistical Analysis

Descriptive data are expressed as proportions or as means ± SD. Statistical differences in categorical variables were assessed using Chi-square (or Fisher's exact) tests while statistical differences in continuous variables were assessed using Student *t*-tests. Univariate analysis was used to identify which demographic, diabetes-specific, preoperative, and postprocedural characteristics were correlated with either total real hospital cost or length of stay. Multivariate correlates of total real hospital cost and length of stay were determined in a sequential model. In the first step, the multivariate regression model only included the demographic and diabetes-specific characteristics, while the preoperative and postprocedural characteristics were added to the regression model in the second step. In the third step, length of stay was added to the total real hospital cost equation to determine which demographic, diabetes-specific, preoperative, and postprocedural characteristics were associated with real hospital cost after accounting for the differences in length of stay. All multivariate regression models were estimated using the log-linear form of the estimated equation. All statistical analyses were performed using SAS statistical software.[22] Missing information for selected preoperative and postprocedural variables (eg, the patient's left ventricular ejection fraction or onset of the patient's diabetic condition) were coded as unknown and treated as separate categorical variables in the statistical analysis.

··· RESULTS ···

Description of Sample

Overall, 65% of the patients were male, with an average age of 63.2 ± 10.2 years (Table 1). Slightly more than half of the patients reported having diabetes for fewer than 10 years when they underwent their first revascularization procedure, but the onset of diabetes was unknown for 20% of the patients. Approximately one third of the patients were receiving insulin at baseline. Over 13% of the patients had a baseline creatinine level of >1.8 mg/dL, and more than half of these patients had a baseline creatinine level of ≥2.5 mg/dL. The baseline creatinine level was unknown for approximately 53% of the patients in the data set. The preoperative characteristics indicate that approximately half of the patients in the sample had prior myocardial infarctions and had 2 diseased vessels treated during the hospitalization. In addition, the average left ventricular ejection fraction was 51.4 ± 13.4 among all patients. The operator performing the revascularization procedure considered the initial procedure to be elective (ie, it did not need to be performed within 24 hours) in more than 94% of the patients. Fewer than 3% of the patients with diabetes who were undergoing revascularization died during the hospitalization in association with their initial procedure during the study period.

Table 1 indicates several statistically significant differences in the mean or proportional value for selected demographic, diabetic, preoperative, and postprocedural characteristics of patients with diabetes undergoing PTCA versus those undergoing CABG. First, patients undergoing coronary bypass surgery were generally older and more likely to be male than patients undergoing coronary angioplasty. A comparison of diabetic characteristics indicates that a significantly higher portion of patients undergoing coronary angioplasty were receiving insulin at baseline. In addition, both the distribution of baseline creatinine level and the duration of diabetes were significantly different between the 2 populations, with CABG patients more likely to have had a prior myocardial infarction, congestive heart failure, 3-vessel disease, an urgent or emergency procedure, and a lower average left ventricular ejection fraction, and they were more likely to die during their initial hospitalization. PTCA patients were more likely to have class 3 or class 4 angina.

Univariate Analysis of Resource Utilization

Table 2 and Table 3 report univariate statistics for only those characteristics with significant differences ($P < .10$) in average hospital costs (1996 dollars) or average length of stay between categories. While 13 of the demographic, diabetic, preoperative, and postprocedural characteristics are significantly correlated ($P < .10$) with average real hospital costs, only 8 of these characteristics are significantly correlated with average length of stay among patients undergoing coronary angioplasty (Table 2). The univariate analysis indicates that higher hospital costs and longer length of stay are associated with being older (≥65 years of age), being female, having a higher baseline

Table 1. Descriptive Statistics for Demographic Characteristics, Clinical Characteristics, and Complications for All Patients, Patients Undergoing PTCA, and Patients Undergoing CABG

Variable	All Patients	PTCA Sample	CABG Sample	*P*
No. of patients	1809	783	1026	
Demographic characteristics				
Age (y)	63.2 ± 10.2	62.5 ± 10.7	63.8 ± 9.6	.006
Male	65.0%	61.2%	67.9%	.003
Diabetic characteristics				
Duration of diabetes:				
Less than 10 y	52.2%	54.9%	50.1%	.095
10-20 y	18.4%	18.4%	18.3%	
More than 20 y	7.7%	7.5%	7.8%	
Onset unknown	21.8%	19.2%	23.8%	
Creatinine level (mg/dL):	(n=951)	(n=367)	(n=584)	
<1.8	86.6%	87.5%	86.1%	<.001
≥1.8, <2.0	3.1%	3.0%	3.1%	
≥2.0, <2.5	3.3%	2.2%	3.9%	
≥2.5	7.0%	7.4%	6.8%	
Receiving insulin	37.9% (n=1697)	38.3% (n=745)	37.7% (n=952)	.818
Preoperative clinical characteristics				
Systemic hypertension	67.0% (n=1789)	67.7% (n=780)	66.5% (n=1009)	.595
Prior myocardial infarction	48.7% (n=1748)	45.5% (n=749)	51.1% (n=999)	.022
Congestive heart failure	14.8% (n=1731)	12.2% (n=765)	17.0% (n=996)	.005
Class 3 or 4 angina	73.1% (n=1716)	77.4% (n=758)	69.7% (n=958)	<.001
Two-vessel disease	50.9%	72.2%	34.6%	<.001
Ejection fraction (%)	51.4 ± 13.4 (n=1675)	54.0 ± 12.2 (n=729)	49.5 ± 14.0 (n=946)	<.001
Elective procedure	94.3%	96.7%	92.5%	<.001
Urgent or emergency procedure	5.7%	3.3%	7.5%	
Postprocedural characteristics				
Stent placement during PTCA	——	3.7%*	——	——
Stroke	——	——	3.7%	——
CABG after PTCA	——	2.3%	——	——
Discharged alive	97.1%	99.4%	95.4%	<.001

PTCA= percutaneous transluminal coronary angioplasty; CABG= coronary artery bypass graft surgery.
*Percent of all PTCA patients receiving a coronary stent during initial procedure.

Table 2. Univariate Analysis of Average Hospital Cost (1996 Dollars) and Length of Stay for Patients With Diabetes Undergoing PTCA

Variable	No.	Cost (1996 $)	*P*	LOS	*P*
All PTCA patients	783	$10,548 ± 7346		3.12 ± 3.65	
Demographic characteristics					
Age:					
<55 y	190	10,354 ± 6777	.0607	3.14 ± 3.58	.0453
55-64 y	229	9816 ± 5978		2.88 ± 3.93	
65-75 y	287	10,774 ± 7956		3.00 ± 2.88	
>75 y	77	12,361 ± 9505		4.20 ± 5.15	
Sex:					
Male	479	9975 ± 7070	.0061	2.84 ± 3.34	.0083
Female	304	11,449 ± 7685		3.55 ± 4.06	
Diabetes-specific characteristics					
Duration of diabetes:					
Less than 10 y	430	10,347 ± 6442	.0001	2.83 ± 2.87	.0033
10–20 y	144	12,103 ± 9195		3.58 ± 4.18	
More than 20 years	59	13,176 ± 11,087		4.49 ± 6.85	
Onset unknown	150	8597 ± 5066		2.97 ± 3.18	
Creatinine level (mg/dL):					
<1.8	321	11,534 ± 7977	.0001	3.33 ± 4.38	.0366
≥1.8, <2.0	11	9958 ± 7086		2.55 ± 1.92	
≥2.0, <2.5	8	17,449 ± 10,358		5.88 ± 4.70	
≥2.5	27	15,074 ± 8404		4.13 ± 2.56	
Unknown	416	9376 ± 6385		2.85 ± 3.03	
Insulin status:					
Receiving insulin	293	11,329 ± 7836	.0617	3.44 ± 4.36	.0744
Not receiving insulin	488	10,297 ± 7233		2.98 ± 3.17	
Preoperative clinical characteristics					
Baseline systemic hypertension status:					
Present	528	10,945 ± 7701	.0298		NS
Absent	252	9722 ± 6523			
Baseline congestive heart failure status:					
Congestive heart failure present	93	11,933 ± 7828	.0407		NS
Congestive heart failure not present	672	10,281 ± 7209			
No. of diseased vessels:					
2	565	10,168 ± 6707	.0197		NS
3	218	11,533 ± 8727			
No. of sites treated:					
1	479	9718 ± 7341	.0001		NS
2	216	11,292 ± 7215			
>2	88	13,242 ± 6909			
Procedure status:					
Elective	757	10,379 ± 7178	.0005	3.04 ± 3.64	.0014
Urgent or emergency	26	15,453 ± 10,173		5.37 ± 3.36	
Postprocedural characteristics					
Stent placement status:					
Stent used	29	15,424 ± 10,693	.0003	5.48 ± 6.46	.0004
No stent used	754	10,360 ± 7130		3.03 ± 3.48	
CABG indicator:					
CABG after PTCA	18	32,446 ± 13,923	<.0001	11.61 ± 6.29	<.0001
No CABG after PTCA	765	10,032 ± 6273		2.92 ± 3.32	
Discharge status:					
Alive	778	10,479 ± 7255	.0011		NS
Died during hospitalization	5	21,239 ± 13,381			
Length of stay					
0-3 d	579	8148 ± 4284	.0001	NA	
4-6 d	121	13,189 ± 5098		NA	
7-10 d	58	20,423 ± 7599		NA	
More than 10 d	25	30,443 ± 15,062		NA	

LOS = length of stay; PTCA= percutaneous transluminal coronary angioplasty; NS = mean values for this characteristic category were not significantly different (*P*<.10); CABG= coronary artery bypass graft surgery; NA = characteristic was not included in the analysis.

creatinine level, receiving insulin treatment, receiving a stent during PTCA, having an urgent or emergency procedure, and having had CABG after PTCA during the initial hospitalization. Patients with an unknown duration of diabetes had significantly lower average hospital cost and shorter length of stay than patients with a known duration of diabetes. Five factors (congestive heart failure, systemic hypertension, 3-vessel disease, having a greater number of sites treated, and not surviving the initial hospitalization)

Table 3. Univariate Analysis of Average Hospital Cost (1996 Dollars) and Length of Stay for Patients With Diabetes Undergoing a CABG Procedure

Variable	No.	Cost (1996 $)	*P*	LOS	*P*
All CABG patients	1026	$27,307 ± 20,973		8.99 ± 8.69	
Demographic characteristics					
Age:					
<55 y	176	26,268 ± 25,508	.0910	7.83 ± 7.99	.0087
55-64 y	322	25,509 ± 16,857		8.27 ± 6.65	
65-75 y	428	28,273 ± 20,451		9.58 ± 9.40	
>75 y	100	30,788 ± 25,497		10.79 ± 11.65	
Sex:					
Male	697		NS	8.67 ± 8.89	.0855
Female	329			9.67 ± 8.24	
Diabetes-specific characteristics					
Duration of diabetes					
Less than 10 y	514	29,098 ± 24,724	.0004		NS
10–20 y	188	28,365 ± 15,906			
More than 20 y	80	28,484 ± 24,457			
Onset unknown	244	22,331 ± 11,952			
Creatinine level (mg/dL):					
<1.8	503	28,566 ± 18,582	.0001	9.17 ± 8.18	.0001
≥1.8, <2.0	18	33,384 ± 11,523		8.67 ± 2.89	
≥2.0, <2.5	23	37,842 ± 23,558		14.24 ± 11.21	
≥2.5	40	48,465 ± 47,112		15.43 ± 18.95	
Unknown	442	23,163 ± 18,257		7.95 ± 7.40	
Insulin status:					
Receiving insulin	359	29,465 ± 25,655	.0492	9.64 ± 7.68	.0689
Not receiving insulin	593	26,666 ± 18,067		8.64 ± 7.68	
Preoperative clinical characteristics					
Baseline congestive heart failure status:					
Congestive heart failure present	164	32,443 ± 24,416	.0006	11.08 ± 11.15	.0007
Congestive heart failure not present	802	26,054 ± 19,843		8.55 ± 8.15	
Ejection Fraction Category:					
<50%	415	28,577 ± 19,772	.0001	9.31 ± 8.51	.0281
≥50%	531	24,957 ± 18,881		8.43 ± 8.27	
Unknown	80	36,312 ± 33,754		11.02 ± 11.63	
Procedure status:					
Elective	949	26,967 ± 20,821	.0689		NS
Urgent or emergency	77	31,488 ± 22,484			
Postprocedural characteristics					
Stroke status:					
Stroke complication	38	44,783 ± 41,158	<.0001	18.58 ± 19.64	<.0001
No stroke	998	26,634 ± 19,521		8.62 ± 7.77	
Discharge status:					
Alive	979	25,931 ± 17,061	<.0001	8.83 ± 7.95	.0083
Died during hospitalization	47	55,963 ± 52,282		12.26 ± 18.13	
Length of stay					
0-3 d	43	18,121 ± 11,166	.0001	NA	
4-6 d	306	18,824 ± 7275		NA	
7-10 d	503	25,714 ± 8522		NA	
More than 10 d	174	49,098 ± 40,481		NA	

LOS = length of stay; CABG= coronary artery bypass graft surgery; NS = Mean value for this characteristic was not significantly different (*P*<.10) from the overall mean value; NA = characteristic was not included in the analysis.

are associated with significantly higher hospital costs but not with significantly longer length of stay ($P \leq .10$). The diabetes-specific characteristics associated with the highest average hospital cost and longest average length of stay are baseline creatinine level of ≥2.0 mg/dL and having had diabetes for more than 20 years.

The univariate analysis of patients undergoing CABG (Table 3) indicates that 9 of the demographic, diabetic, preoperative, and postprocedural characteristics are significantly correlated ($P < .10$) with hospital costs, and 8 of these characteristics are significantly correlated with longer length of stay. Eight factors (older age, higher baseline creatinine level, congestive heart failure, low left ventricular ejection fraction, having a stroke, and not surviving the initial hospitalization) are significantly associated with both higher hospital cost and longer length of stay. Two factors (known duration of diabetes and urgent or emergency procedure) are significantly associated with higher hospital costs but not significantly associated with a longer length of stay. One factor (being female) is significantly associated with longer length of stay but not higher hospital cost. For CABG patients, a baseline creatinine level of >1.8 mg/dL was the only diabetic characteristic significantly associated with both higher real hospital costs and a longer length of stay.

Multivariate Analysis

Regression results (Table 4 and Table 5) were obtained from the following equations: Model 1 contains the regression results of the log of total hospital costs using only the demographic and diabetes-specific characteristics; Model 2 contains the regression results of the log of costs using all of the demographic, diabetes-specific, preoperative, and postprocedural characteristics; Model 3 contains the regression results of the log of costs, including all variables in Model 2 but also controlling for length of stay; Model 4 contains the regression results of the log of the length of stay using only the demographic and diabetes-specific characteristics; and Model 5 contains the regression of the log of the length of stay using all characteristics. For ease of presentation, all characteristics not significantly different (ie, no association to hospital costs or length of stay) from 0 at the $P \leq .10$ level of significance have been omitted from Table 4 and Table 5. The appendix contains the definition of all variables used in the multivariate analysis.

PTCA Sample

Model 1 in Table 4 indicates that 6 of the demographic and diabetes-specific characteristics are significantly associated with the log of total hospital cost (in 1996 dollars) among patients with diabetes undergoing an angioplasty procedure. The log of hospital costs showed significantly higher costs for patients who were female, older than 75 years of age, had baseline creatinine levels between 2.0 mg/dL and 2.5 mg/dL, or had baseline creatinine levels of ≥2.5 mg/dL. The log of hospital costs showed significantly lower costs for patients with unknown values for both baseline creatinine level and time of onset of diabetes. The regression equation based on demographic and diabetes-specific variables only explained 7% of the observed variation in logged total real hospital costs. Adding the preoperative and postprocedural variables to the regression model increased the adjusted R^2 to 0.279 (Model 2). Overall, 13 of the demographic, diabetes-specific, preoperative, and postprocedural characteristics were significantly associated with the log of hospital costs. All demographic and diabetes-specific variables significantly associated ($P \leq .10$) with the log of hospital costs in Model 1 remain significantly associated, after including the preoperative and postprocedural variables. Adding length of stay to the equation increased the adjusted R^2 to over 0.43 (Model 3). After controlling for length of stay, 2 variables (being older than 75 years of age [$P = .213$] and having a baseline creatinine level between 2.0 mg/dL and 2.5 mg/dL [$P = .115$]) that were significantly associated with log of hospital cost in Model 2 lost their statistical significance. All other statistically significant variables in Model 2 retained their statistical significance in Model 3.

Model 4 indicates that 6 of the demographic and diabetes-specific variables (being older than 75 years of age, being female, having diabetes duration of more than 20 years, having a baseline creatinine level between 2.0 mg/dL and 2.5 mg/dL, having a baseline creatinine level of ≥2.5 mg/dL, and having an unknown baseline creatinine level) are significantly associated with length of stay at the $P < .10$ level of significance. As a group, however, these variables explained less than 4% of the observed variation in length of stay during the initial hospitalization among patients with diabetes undergoing coronary angioplasty.

Model 5 indicates that including the preoperative and postprocedural variables in the log of length of stay equation increases the adjusted R^2 to approximately 0.20. After including the preoperative and

postprocedural variables, one additional diabetes-specific variable (patient receiving insulin) was associated with a statistically significant shorter length of stay. Patients who died during the hospitalization associated with their initial coronary angioplasty procedure also had significantly shorter hospital stays.

CABG Sample Regression Results

Model 1 in Table 5 indicates that 8 of the demo-

Table 4. Regression Coefficients and *P* Values Obtained From the Multivariable Regression Analysis of the Log of Total Hospital Cost (1996 Dollars) and the Log of Length of Stay for Patients With Diabetes Undergoing a PTCA Procedure

	Log of Hospital Cost			Log of Length of Stay	
	Model 1 b (*P*)	Model 2 b (*P*)	Model 3 b (*P*)	Model 4 b (*P*)	Model 5 b (*P*)
Demographic characteristics					
Age >75 y	0.159 (.035)	0.152 (.024)	NS	0.213 (.041)	0.250 (.010)
Male	-0.093 (.026)	-0.100 (.009)	-0.067 (.048)	-0.182 (.002)	-0.199 (<.001)
Diabetes-specific characteristics					
Diabetic for 20 y or more	NS	NS	NS	0.218 (.052)	0.207 (.046)
Onset unknown	-0.114 (.039)	-0.120 (.015)	-0.130 (.004)	NS	NS
Creatinine level (mg/dL):					
≥2.0, <2.5	0.414 (.035)	0.409 (.020)	NS	0.574 (.035)	0.596 (.019)
≥2.5	0.278 (.014)	0.298 (.004)	0.253 (.005)	0.301 (.051)	0.387 (.008)
Unknown creatinine level	-0.168 (<.001)	-0.196 (<.001)	-0.153 (<.001)	-0.117 (.051)	-0.142 (.011)
Receiving insulin	NS	NS	NS	NS	-0.098 (.087)
Preoperative characteristics					
Ejection fraction:					
< 30%	NA	0.193 (.030)	0.138 (.080)	NA	0.338 (.008)
≥30% , < 50%	NA	0.091 (.047)	0.077 (.057)	NA	NS
Number of Sites	NA	0.177 (<.001)	0.154 (<.001)	NA	0.149 (<.001)
Urgent or emergent procedure	NA	0.413 (<.001)	0.263 (.004)	NA	0.640 (<.001)
Postprocedural characteristics					
Stent placement	NA	0.484 (<.001)	0.286 (.001)	NA	0.439 (.001)
CABG after PTCA	NA	1.219 (<.001)	0.637 (<.001)	NA	1.614 (<.001)
Died during hospitalization	NA	0.484 (.029)	0.490 (.013)	NA	-0.539 (.091)
Length of stay	NA	NA	0.068 (<.001)	NA	NA
Intercept term	9.209 (<.001)	8.845 (<.001)	8.672 (<.001)	0.903 (<.001)	0.588 (<.001)
Adjusted R^2	0.071	0.279	0.435	0.039	0.195

NS=regression coefficient was not significantly different (*P*<.10) from 0 in this model; NA= characteristic was not included in the model; CABG= coronary artery bypass graft surgery; PTCA= percutaneous transluminal coronary angioplasty.

graphic and diabetes-specific characteristics are significantly related to the log of total hospital costs (in 1996 dollars) for patients with diabetes undergoing coronary bypass surgery. This regression equation explained 12.4% of the observed variation in the log of hospital costs. The log of hospital costs was significantly higher for patients who were female, between 65 and 75 years of age, over the age of 75, or had baseline creatinine levels of ≥1.8 mg/dL. The log of hospital costs showed significantly lower costs for patients whose onset of diabetes is unknown and whose baseline creatinine levels are unknown. Adding the preop-

Table 5. Regression Coefficients and *P* Values Obtained From the Multivariable Regression Analysis of the Log of Total Hospital Cost (1996 Dollars) and the Log of Length of Stay for Patients With Diabetes Undergoing a CABG Procedure

	Log of Hospital Cost			Log of Length of Stay	
	Model 1 b (*P*)	**Model 2 b (*P*)**	**Model 3 b (*P*)**	**Model 4 b (*P*)**	**Model 5 b (*P*)**
Demographic characteristics					
Age 65 to 75 y	0.073 (.090)	NS	NS	0.133 (.009)	0.113 (.020)
Age >75 y	0.158 (.009)	0.106 (.068)	NS	0.230 (.001)	0.184 (.007)
Male	-0.094 (.004)	-0.074 (.019)	-0.055 (.035)	-0.101 (.008)	-0.101 (.006)
Diabetes-specific characteristics					
Onset unknown	-0.143 (<.001)	-0.117-0.089 (.002)	-0.098 (.005)	-0.098 (.034)	(.028)
Creatinine level (mg/dL):					
≥1.8, <2.0	0.229 (.024)	NS	0.185 (.044)	NS	NS
≥2.0, <2.5	0.398 (<.001)	NS	NS	0.260 (.029)	NS
≥2.5	0.409 (<.001)	.289 (<.001)	0.118 (.067)	0.305 (.001)	0.302 (.001)
Unknown creatinine level	-0.194 (<.001)	-0.200 (<.001)	-0.170 (<.001)	-0.134 (.001)	-0.143 (<.001)
Receiving insulin	NS	NS	NS	NS	NS
Preoperative characteristics					
Congestive heart failure	NA	NS	NS	NA	0.125 (.010)
Ejection fraction					
≥30%, < 50%	NA	NS	0.070 (.092)	NA	NS
Unknown	NA	0.195 (.001)	0.161 (.001)		0.114 (.082)
Postprocedural characteristics					
Stroke during hospitalization	NA	0.325 (<.001)	NS	NA	0.740 (<.001)
Died during hospitalization	NA	0.417 (<.001)	0.405 (<.001)	NA	-0.601 (<.001)
Length of stay	NA	NA	0.031 (<.001)	NA	NA
Intercept term	10.161 (<.001)	10.089 (<.001)	9.821 (<.001)	2.018 (<.001)	2.023 (<.001)
Adjusted R^2	0.124	0.188	0.442	0.063	0.146

NS = regression coefficient was not significantly different (*P*<.10) from 0 in this model; NA = characteristic was not included in the model.

erative and postprocedural variables to the regression model increased the adjusted R^2, but only to 0.188 (Model 2). Two of the diabetes-specific characteristics (patients with a baseline creatinine level between 1.8 mg/dL and 2.0 mg/dL [P=.114] and patients with a baseline creatinine level between 2.0 mg/dL and 2.5 mg/dL [P=.238]) that were statistically significant in Model 1 were not significant in Model 2. The regression coefficients reported in Model 2 indicate that having a baseline creatinine level of ≥2.5 mg/dL is 1 of the 3 variables that is associated with the greatest increase in hospital costs for patients undergoing coronary bypass surgery. Adding length of stay to the real hospital cost equation (Model 3) increased adjusted R^2 to 0.442. As a result of including length of stay in the cost equation, 2 of the statistically significant factors in Model 2 (patients older than 75 years of age and patients who had a stroke during their initial hospitalization) lost their statistical significance. Two factors not statistically significant in Model 2 (patients with a baseline creatinine level between 1.8 mg/dL and 2.0 mg/dL and patients with baseline left ventricular ejection fraction between 30% and 50%) gained statistical significance in Model 3.

Model 4 indicates that 7 characteristics (being between 65 and 75 years of age, being older than 75 years of age, being female, having an unknown onset of diabetes, having an unknown baseline creatinine level, and both variables indicating the baseline creatinine level) are significantly associated with length of stay at the P<.10 level of significance. However, these variables only explained approximately 6% of the observed variation in length of stay among patients undergoing coronary bypass surgery. In addition, the only diabetes-specific variables associated with longer length of stay for patients undergoing CABG involved having a baseline creatinine level of ≥1.8 mg/dL. Including the preoperative and postprocedural variables in the logged length of stay model increased the adjusted R^2 to approximately 0.15% (Model 5). After adding these variables, only a baseline creatinine level of >2.5 mg/dL was statistically associated with longer length of stay.

··· DISCUSSION ···

In the current market-driven healthcare system, the significant amounts of healthcare resources ($7.6 billion in 1997) being consumed in treating patients with diabetes and coronary artery disease is of increasing concern.[1] A number of factors associated with increased hospital resource consumption by patients with diabetes undergoing either PTCA or CABG are discussed in this paper. Four major themes that emerge from the analysis of hospital resource consumption conducted in this study warrant further discussion.

One major theme is that a patient's baseline creatinine level prior to revascularization is associated with significantly higher hospital resource utilization. For example, multivariate regression analysis (Model 2) indicates that patients with diabetes who have a baseline creatinine level of ≥2.5 mg/dL are predicted to have total hospital costs that are approximately 29% higher than their counterparts who have a baseline creatinine level of <1.8 mg/dL whether they undergo PTCA or CABG. This finding suggests that selected patients with diabetes will consume a disproportionate share of healthcare resources during a hospitalization, even after controlling for other demographic, preoperative, and postprocedural characteristics. This finding has financial implications for hospitals, especially if a patient's creatinine level is not amenable to treatment. In this case, even hospitals that have extremely efficient management can do little to avoid these higher costs, which are approximately $3700 more for patients with diabetes undergoing PTCA and $8000 more for those undergoing CABG than the same procedures for patients with diabetes who have a creatinine level of <1.8 mg/dL.

Also warranting further discussion is the finding (Table 1) that there is a statistically significant (P<.10) difference in the distribution of diabetes duration and the distribution of the baseline creatinine categories between the 2 samples. In particular, a consistent pattern is not seen in the distribution of baseline creatinine level toward either PTCA or CABG. For example, more PTCA patients had a baseline creatinine level of <1.8 mg/dL or a baseline creatinine level of ≥2.5 mg/dL, while more of the CABG patients had a baseline creatinine level between 1.8 mg/dL and 2.5 mg/dL. This finding may reflect the considerable controversy regarding the optimal medical management of patients with diabetes and multivessel coronary disease.[23,24] This finding is also consistent with the suggestion in the medical literature that the choice of revascularization approach is often based largely on the feasibility of percutaneous coronary revascularization, with little regard for the presence or absence of diabetes.[25]

A third theme that emerges from the multivariate analysis is that many of the same diabetes-specific and preoperative characteristics were significant predictors of hospital costs and length of stay for

patients undergoing either PTCA or CABG, especially in Model 2 reported in Table 4 and Table 5. Given that this model accounts for differences in a patient's preoperative clinical and postprocedural characteristics, it implies there are diabetes-specific characteristics that are independently associated with hospital resource consumption.

Finally, a strong, positive correlation is seen between hospital resource consumption and postprocedural characteristics among patients with diabetes undergoing either procedure. This finding is consistent with previous studies in the literature that have shown that complications associated with revascularization procedures increase hospital resource consumption inexorably for patients who do not have diabetes.[11,12,26] It further suggests the need for additional clinical trials with enough patients with diabetes to identify which, if any, clinical factors are associated with better outcomes for patients with diabetes undergoing PTCA versus CABG.

Limitations

This study had several limitations. First, all patients included in the study were treated at the Emory University Hospital, which is a teaching hospital and may not reflect the typical resource utilization of patients with diabetes who undergo revascularization in community hospitals. Additionally, patients referred to Emory University Hospital may have complications and comorbidities not captured by the diabetes-specific and preoperative characteristics included in the data set used.

Another limitation is that the Emory Cardiac Database contains a limited number of diabetes-specific measures. As a result, the significant association shown in Table 4 and Table 5 between the baseline creatinine level categories and hospital resource consumption could potentially become not significant if additional diabetes-specific measures were included in the regression model. Future research in this area should focus on identifying additional diabetes-specific characteristics, such as measures of glucose, lipids, and body mass, to more fully understand the association between hospital resource utilization and revascularization among patients with diabetes.

A final limitation to this study is that the study period includes procedures performed between 1988 and 1996. One possible explanation for the model's inability to explain a larger portion of the observed difference in hospital resource utilization, especially hospital length of stay, is that the treatment of patients undergoing either PTCA or CABG has become considerably refined during this time period. The sensitivity of this model to a time trend was tested in 2 ways. First, an estimation of the models reported in Table 4 and Table 5 was made using a series of variables to indicate the year the procedure was performed. Second, we estimated the regression models using only procedures performed between 1991 and 1996. In both cases, diabetes-specific measures remained independently associated with hospital resource consumption after controlling for preoperative and postprocedural characteristics.

Conclusion

In summary, this study finds that selected diabetes-specific characteristics are associated with increased consumption of hospital resources by patients with diabetes undergoing PTCA or CABG after controlling for coronary risk factors. To the extent that these factors can be modified prior to the revascularization, especially the patient's creatinine level, or if the events associated with elevated creatinine level are reversible, utilization of hospital resources could be reduced by integrating the management of the patient's diabetic and cardiovascular disease. If the elevated creatinine level is not modifiable prior to revascularization, these factors could be used for risk adjustment in hospital reimbursement to assure that patients with diabetes who have cardiovascular disease have access to revascularization procedures. In the future, researchers need to identify both the factor and the process that accounts for the observed association between higher creatinine levels and resource utilization. If this process is not better understood in the current market-driven healthcare system, patients with diabetes, especially those with high creatinine levels, may find reduced access to revascularization procedures.

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Appendix follows on next page.

Appendix. Definition of All Variables Included in the Regression Models

Variable	Definition
Demographic characteristics	
Age 55-64 y	A dummy variable that was set to equal 1 if the patient was between age 55 and age 64.
Age 65–75 y	A dummy variable that was set to equal 1 if the patient was between age 65 and age 75.
Age >75 y	A dummy variable that was set to equal 1 if the patient was older than age 75.
Male	A dummy variable that was set to equal 1 if the patient was male.
Diabetes-specific characteristics	
Diabetic for 10-20 y	A dummy variable that was set to equal 1 if the onset of diabetes occurred between 10 years and 20 years prior to revascularization.
Diabetic for 20+ y	A dummy variable that was set to equal 1 if the onset of diabetes occurred more than 20 years prior to revascularization.
Onset of diabetes unknown	A dummy variable that was set to equal 1 if the onset of diabetes is unknown.
Creatinine level <1.8 mg/dL	A dummy variable that was set to equal 1 if the patient's creatinine level was less than 1.8 mg/dL at admission.
Creatinine level ≥1.8 mg/dL, <2.0 mg/dL	A dummy variable that was set to equal 1 if the patient's creatinine level was greater than or to equal 1.8 mg/dL but less than 2.0 mg/dL at admission.
Creatinine level ≥2.0 mg/dL, <2.5 mg/dL	A dummy variable that was set to equal 1 if the patient's creatinine level was greater than or to equal 2.0 mg/dL but less than 2.5 mg/dL at admission.
Creatinine level ≥2.5 mg/dL	A dummy variable that was set to equal 1 if the patient's creatinine level was greater than or to equal 2.5 mg/dL at admission.
Creatinine level unknown	A dummy variable that was set to equal 1 if the patient's creatinine level was not recorded.
Receiving insulin	A dummy variable that was set to equal 1 if the patient was treated using insulin.
Preoperative clinical characteristics	
Systemic hypertension	A dummy variable that was set to equal 1 if the patient had a history of high blood pressure.
Previous myocardial infarction	A dummy variable that was set to equal 1 if the patient had a previous myocardial infarction.
Congestive heart failure	A dummy variable that was set to equal 1 if the patient had congestive heart failure.
Three-vessel disease	A dummy variable that was set to equal 1 if the patient had 3-vessel disease.
Ejection fraction <30%	A dummy variable that was set to equal 1 if the patient had an ejection fraction of less than 30%.
Ejection fraction ≥30%, <50%	A dummy variable that was set to equal 1 if the patient had an ejection fraction that was greater than or to equal 30% but less than 50%.
Ejection fraction value unknown	A dummy variable that was set to equal 1 if the patient's ejection fraction value was unknown.
Urgent or emergency procedure	A dummy variable that was set to equal 1 if the physician indicated that the revascularization was an urgent or emergent procedure.
No. of sites	A variable indicating the number of sites treated during the revascularization.
Postprocedural characteristics	
Stroke	A dummy variable set to equal 1 if the patient had a stroke during the hospitalization.
CABG after PTCA	A dummy variable set to equal 1 if the patient had a CABG following PTCA during the initial hospitalization.
Stent placement during PTCA	A dummy variable set to equal 1 if the patient received a stent during PTCA.
Died during hospitalization	A dummy variable set to equal 1 if the patient died during the hospitalization.
Length of stay	The number of days the patient was hospitalized.

CABG= coronary artery bypass graft surgery; PTCA= percutaneous transluminal coronary angioplasty.