DOI: 10.1111/j.1475-6773.2007.00789.x
RESEARCH ARTICLE

Hospital Use and Costs

Cost of Hospital Care for Older Adults with Heart Failure: Medical, Pharmaceutical, and Nursing Costs

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Objective. To determine the impact of patient characteristics, clinical conditions, hospital unit characteristics, and health care interventions on hospital cost of patients with heart failure.

Data Sources/Study Setting. Data for this study were part of a larger study that used electronic clinical data repositories from an 843-bed, academic medical center in the Midwest.

Study Design. This retrospective, exploratory study used existing administrative and clinical data from 1,435 hospitalizations of 1,075 patients 60 years of age or older. A cost model was tested using generalized estimating equations (GEE) analysis.

Data Collection/Extraction Methods. Electronic databases used in this study were the medical record abstract, the financial data repository, the pharmacy repository; and the Nursing Information System repository. Data repositories were merged at the patient level into a relational database and housed on an SQL server.

Principal Findings. The model accounted for 88 percent of the variability in hospital costs for heart failure patients 60 years of age and older. The majority of variables that were associated with hospital cost were provider interventions. Each medical procedure increased cost by $623, each unique medication increased cost by $179, and the addition of each nursing intervention increased cost by $289. One medication and several nursing interventions were associated with lower cost. Nurse staffing below the average and residing on 2–4 units increased hospital cost.

Conclusions. The model and data analysis techniques used here provide an innovative and useful methodology to describe and quantify significant health care processes and their impact on cost per hospitalization. The findings indicate the importance of conducting research using existing clinical data in health care.

Key Words. Heart failure, hospital cost, interventions, RN staffing

Heart failure, the final common pathway of cardiovascular disease, affects about five million Americans and has been referred to as a global epidemic (Moser and Mann 2002). It is a disabling and costly chronic condition. It is becoming more prevalent as the population ages and survival increases from previously fatal acute cardiac events (Roger et al. 2004). Of the millions living with heart failure, 80 percent are 65 years of age or older.

Those with heart failure incur great economic burden, with costs exceeding those of breast and lung cancer combined (Peacock 2003). In 2004, the estimated direct and indirect cost of heart failure in the United States was $25.8 billion, of which $13.6 billion, or 53 percent, was direct hospital cost (American Heart Association 2004). Heart failure is the most expensive of the Medicare diagnoses in the United States and yet, reimbursement often does not keep up with the mean total hospital charges. Mean total charges were $15,293 per visit in 2000, with the average American hospital losing more than $1,000 per visit (Peacock 2003; Ashish et al. 2004).

Much has been written in the last decade about the positive collective effects on cost and readmission rates by using multidisciplinary disease management approaches, usually involving the continuum of care within and outside the hospital setting (Balinsky and Muennig 2003). Little is known, however, about the unique interventions or contributions to cost of care by specific disciplines; most of the research has been done with measures that come from the large Medicare data sets that describe medical care and treatments and not those of other health care disciplines. This research study analyzes data from an electronic documentation system that includes medical, nursing, and pharmacy treatments to demonstrate the unique contributions of these providers to hospital cost for older adults with heart failure.

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Study Purpose

The purpose of this study was to describe the relationships between (1) patient characteristics, clinical conditions, nursing unit characteristics, and treatments (medical, pharmacy, and nursing) and (2) cost of hospitalization for older patients with heart failure. This exploratory study was guided by an effectiveness model developed by Titler, Dochterman, and Reed (2004) that links patient characteristics, patient conditions, and processes of care, to outcomes of hospital cost. Independent variables are categorized as patient characteristics, clinical conditions, nursing unit characteristics, and treatments (see Table 1). Length of stay was not included as an independent variable as its correlation with hospital cost is, not surprisingly, high (Pearson correlation coefficient was 0.87 in this sample); we wanted to go "beyond" the traditional explanation of hospital cost by number of days in the hospital and rather examine those unit and clinical variables that relate to hospital cost and not have these masked by the length of hospitalization. A brief explanation of each variable is in Table 1; a more complete explanation of the measurement of each variable is available in Supplementary Material Appendix A.

Methods

Data Sources and Sample

Data for this study are part of a study funded by the National Institute for Nursing Research and the Agency for Healthcare Research and Quality that used a retrospective, descriptive design to conduct outcomes research in three older populations (Titler 2000). Descriptive data from the 4-year period July 1998 to June 2002 were accessed from an 843-bed, academic medical center in the Midwest. This study focused on hospital cost of the heart failure population defined by inpatient records with discharge diagnoses classified within the Major Diagnostic Classification (MDC) Diseases and Disorders of the Circulatory System and with a primary or secondary discharge diagnosis of heart failure. The data represent 1,435 hospitalizations of 1,035 adult inpatients, 60 years of age and older. Of the final sample, 43 percent were female, 94 percent white, 58 percent married and 27 percent widowed, and 74 percent retired. The mean age was 74 (SD = 8.9) with a median length of hospitalization of 6.26 days.

Variables used in the analysis for this study originated from four electronic hospital databases: medical record abstract, financial, pharmacy, and

Table 1: Independent and Intervening Variables

Concepts	*Variables*	*Definitions/Measures*	*Data Sources*
Patient characteristics	Age	Age in years on day admitted to hospital	Medical Record Abstract
	Gender	Male or female	Medical Record Abstract
	Ethnicity	Caucasian and all others	Medical Record Abstract
	Marital status	Married; separated, divorced or single; widowed	Medical Record Abstract
	Religion	Catholic, Protestant, other faiths, no preference/none designated	Medical Record Abstract
Clinical conditions	Medical diagnoses	Six groups of primary medical diagnoses classified using the Clinical Classification Software (www.ahrq.gov/data/hcup.ccs.htm): heart failure without hypertension, acute myocardial infarction, other cardiac conditions, conduction disorders, peripheral vascular disease, and noncardiac circulatory diseases	Medical Record Abstract
	Comorbidity	30 comorbidities that existed before the patient's hospitalization and not related to the principal reason for hospitalization measured by the Elixhauser et al. (1998) method	Medical Record Abstract, ICD-9 codes
	Severity of illness	The extent of physiological decompensation or organ system loss of function as assigned by the APR-DRG system (3M Health Information Systems 1993): 1 = minor, 2 = moderate, 3 = moderate, 4 = severe	Medical Record Abstract; Uniform Hospital Discharge Data Set
Nursing unit characteristics	Number of units resided on during hospitalization	1 = 1 unit, 2 = 2 units, 3 = 3 and 4 units, 4 = 5+ units	Nursing Information System
	Percent of time in intensive care unit	Percent of time during hospitalization spent in intensive care	Nursing Information System
	Average RN/patient ratio during hospitalization	Average ratio of RNs to patients assigned to quartiles: 76–100% (best staffing), 51–75%, 26–50%, 1–25% (worse staffing)	Nursing Information System
	RN/patient dip proportion	The largest drop in RN care for a specific hospitalization, range of 0–1 with incremental increases of 0.2 or 20%	Nursing Information System

Treatments	Number of different medical procedures	The number of procedures (0–12) prescribed by physicians during the hospitalization	Medical Record Abstract, ICD-9-CM codes
	Type of medical procedure	123 procedures classified using the Clinical Classification Software (www.ahrq.gov/data/hcup.ccs.htm) grouped into nine categories: invasive and noninvasive cardiovascular diagnostic procedures, invasive and noninvasive noncardiovascular diagnostic procedures, invasive and noninvasive cardiovascular therapeutic procedures, invasive and noninvasive noncardiovascular therapeutic procedures; and blood product therapeutic procedures (0 = No, the treatment was not received, 1 = Yes, the treatment was received at least once)	Medical Record Abstract, ICD-9-CM codes
	Total number of different medications	The number of unique medications coded by the American Hospital Formulary Service classification (McEvoy 2000) administered during the hospitalization	Pharmacy Repository
	Type of medication	Those medications (coded as 0 = not administered, 1 = at least one drug from the class or subclass was administered) used in 2% or more of the population ($N = 74$).	Pharmacy Repository
	Total number of different nursing interventions	The number of unique nursing interventions as coded by the Nursing Interventions Classification (Dochterman and Bulechek 2004), administered during the hospitalization	Nursing Information System
	Type of nursing interventions	Each intervention used in 5% or more of the hospitalizations ($N = 53$) was assigned to one of three categories determined by the percent of hospitalizations the intervention was used and its use rate (average number of times the intervention was used per day): (1) used in 95% or greater of the hospitalizations, the use rates were divided in quartiles; (2) used in $>5\%$ but $<95\%$, the use rates were divided into thirds; (3) used in 5% or less, coded as a dichotomous variable	Nursing Information System

RN, registered nurse; ICD-9-CM, International Classification of Diseases 9th Revision Clinical Modification.

nursing.[1] Operational and clinical data were linked at an individual patient level for each hospitalization. Unique patient identifiers were used to build a relational database of selected variables on a separate SQL server (Titler, Dochterman, and Reed 2004). The data obtained from patient records were accepted as reliable based on the reasoning that they are used for important clinical decisions as well as for reimbursement and research. Multiple checks were done to assure that the data in the relational database were identical to those in the patient records.

Dependent Measure: Total Hospital Costs

The dependent variable was total hospital cost. Because actual hospital cost data were unavailable for direct analysis, hospital charges were used to represent financial burden (Ashish et al. 2004). Financial charge data were obtained from the hospital's medical record abstract database for each hospitalization. The charge data were converted to cost data using the cost-to-charge ratios obtained from the Centers for Medicare and Medicaid Services Acute Inpatient Prospective Payment System website (http:/ www.cms.hhs.gov/AcuteInpatientsPPS/). For each hospitalization, the hospital's total charge was multiplied by the overall cost-to-charge ratio for the fiscal year in which the hospitalization occurred. Total hospital costs included costs in the following categories: general services, ICU/special care, pharmacy, laboratory, radiology, operating room, supplies, and other ancillary services.

Data Analysis

Generalized estimating equations (GEE) were used for analyses to take into account that some patients had more than one hospitalization during the time frame for the study (Liang and Zeger 1986). When the sample includes some patients who have more than one admission during the study's time frame, GEE analysis is recommended over the more usual general linear model (GLM) in order to not over estimate the treatment effects (Liang and Zeger 1986). Analyses were completed using *SAS/STAT* software, Version 9 of the *SAS System for Windows* (SAS Institute Inc. 2003). PROC GENMOD was employed for the GEE analysis. A process of building an empirical model was followed to systematically reduce the number of variables used to predict the cost of care and to determine which independent variables made unique contributions to cost, after controlling for other variables. Variables were first tested singularly, using zero-order correlations, for their association with total hospital cost. If the p-value for the zero-order correlation was $\leq .15$, the variable was retained. Significant variables ($p \leq .15$ in zero-order correlations) within each category (e.g., patient characteristics, clinical conditions) (see Table 1) were then tested, controlling for other variables within that category, for a statistically significant relationship to cost, again at the $p \leq .15$ level. The $p \leq .15$ level was chosen to guard against eliminating variables too soon, when they might yet prove to have a statistically significant effect when combined with other independent variables. The final statistical model then tested the significant variables from each category against the variables in the categories appearing before it in the model. When variables from the final category were added, the final model was established, using $p \leq .05$ as the criterion. Score statistics, or the summative p-value and χ^2 for each variable that remained significant at the $p \leq .05$ in the final model, are summarized in Table 2 for each category. Proportional change in cost by variable (odds ratio) and the estimated change in median total cost are represented in Tables 3 and 4.

FINDINGS

The mean total cost of hospitalization was $18,086 (SD $26,736), with a range from $762 to $544,797 and a median total cost of $10,454. Change in median cost is reported in this study due to the wide variability in cost. This wide range may be due in part to several factors. The setting is a large academic referral center and 35 percent of the hospitalizations included invasive diagnostic procedures for heart failure (e.g., cardiac catheterizations and coronary arteriography) while 60 percent included invasive cardiovascular therapeutic procedures (e.g., operating room procedures related to open heart surgery and angioplasty and peripheral vascular surgeries), the latter having the greatest impact on hospital median cost of any single variable included in the model.

The study included 1,435 hospitalizations by 1,075 patients. A total of 183 variables were entered into the analysis with 31 significantly associated with total hospital cost in the final model (Table 2). The mean age of the sample was 72.7 years, consistent with other studies (Munger and Carter 2003). A younger age was significantly associated with greater cost with initial bivariate analysis ($p = .005$), also consistent with other reports (Wexler et al. 2001), but when other patient characteristics variables were added, this association disappeared. None of the patient characteristics were significantly related to cost in the final model (see Table 2).

Table 2: Results of Analysis for Heart Failure Cost

Original Variables Entered	*Variables Significant in Final Model (χ^2 and p-value)*
Patient characteristics	None significant
Age	
Gender	
Ethnicity	
Marital status	
Religion	
Occupation	
Clinical conditions	
Primary diagnosis	None significant
Heart failure without hypertension	
Acute myocardial infarction	
Other cardiac conditions	
Conduction disorders	
Peripheral vascular disease	
Noncardiac circulatory diseases	
Comorbidities	Only one significant
30 analyzed according to Elixhauser method	Deficiency anemia: $\chi^2 = 3.87$, $p = .0491$
Severity of illness	Significant
Severe IV (19.4%)	
Major III (51.4%)	Severity of illness: $\chi^2 = 10.11$, $p = .0177$
Moderate II (26.8%)	
Mild I (2.4%)	
Nursing unit characteristics	Only two significant
Number of units resided on during hospitalization	Number of units resided in during hospitalization: $\chi^2 = 24.85$, $p \leq .0001$
Percentage of time in intensive care unit (ICU)	
Average RN/patient ratio	RN/patient dip proportion: $\chi^2 = 37.83$, $p \leq .0001$
RN/patient dip proportion	
Treatments	
Medical	
Total number of medical procedures	Total number of medical procedures: $\chi^2 = 79.52$, $p < .0001$
Nine types of medical procedures	Three of nine groups significant
	Noninvasive heart failure diagnostic: $\chi^2 = 13.29$, $p = .0003$
	Invasive heart failure diagnostic: $\chi^2 = 7.19$, $p = .0073$
	Invasive cardiovascular therapy: $\chi^2 = 108.32$, $p < .0001$
Pharmacy	
Total number of different medications	Total number of different medications: $\chi^2 = 29.30$, $p \leq .0001$
74 different medications used	12 medications, $p \leq .05$

continued

Table 2. *Continued*

Original Variables Entered	*Variables Significant in Final Model (χ^2 and p-value)*
Nursing	
Total number of different interventions	Total number of different interventions: $\chi^2 = 39.05$, $p < .0001$
53 different interventions used	10 interventions, $p \leq .05$

Only two clinical conditions remained in the final model: the comorbidity of deficiency anemia and severity of illness (Table 2). Of the 30 comorbid conditions used in the Elixhauser et al. (1998) method, 27 were related to hospital cost at $p \leq .15$ in step one bivariate analysis, but only one, deficiency anemia, remained when all variables were entered sequentially in the final model (Table 2). *Deficiency anemia* was associated with a 5 percent increase in median cost in the final model with an estimated additional cost of $536 for heart failure patients with this comorbid condition (Table 3). The clinical condition, *severity of illness*, was significant in step one bivariate analysis and also was significant in the final model (see Table 2). However, there were no statistically significant differences in the final model between the costs of higher levels of severity when compared with minor levels of severity (Table 3).

Two of the four nursing unit characteristics were significant in the final model. The *number of units resided on during hospitalization* was significantly associated with increased hospital cost when the patient was on 2, 3, or 4 units. Residing on 2 units ($p = .0015$) added about 10 percent to median cost, or an estimated $1,007; residing on three or 4 units added about 17 percent, or $1,748 to median cost per hospitalization ($p = .0001$) (Table 3). Interestingly, the cost difference for 5 or more units added only about 3 percent to median cost and was not significant. The variable *registered nurse (RN)/patient dip proportion* was also significantly associated with increased cost in the final model ($p < .0001$) (Table 2). The mean RN/patient dip proportion, which represents the largest drop in available RN care during a hospitalization, was 0.4321 with a range of 0.04–0.89. The larger the RN dip proportion, the fewer RN hours available for patient care. For every 0.2 increments in RN dip proportion value, there was a 15.2 percent increase in median cost per hospitalization, or $1,589 (Table 3). The *RN to patient ratio*, which measures the overall amount of RN hours of care to number of patients, was not significantly related to cost.

Table 3: Cost of Significant Clinical Conditions, Nursing Unit Characteristics, Medical and Pharmacy Treatments* in the Final Cost Model for Heart Failure: (N = 1,435, Median Hospital Cost = $10,454)

		Estimate	p	*Proportional Change in Cost*[†]	*Change in Median Cost*[‡] *in Dollars per Hospitalization*
Clinical conditions					
Comorbidity					
Deficiency anemia		0.0500	.0483	1.051	$536.00
Severity of illness	% of sample		Overall $p = .0177$		
Severe	19.4	− 0.0318	.6355	0.969	− $327.22
Major	51.4	− 0.0062	.9187	0.994	− $64.62
Moderate	26.8	− 0.0840	.1699	0.919	− $842.29
Minor	2.4	0.0000			—
Nursing unit characteristics					
RN/patient dip proportion		0.7076	< .0001	1.152 per .2 increments	$1,589.30
Number of units resided on during hospitalization	% of sample		Overall $p = .0001$		
5 or more	36.5	0.0255	.5977	1.026	$270.01
3 or 4	33.2	0.1546	.0001	1.167	$1,747.86
2	19.0	0.0920	.0015	1.096	$1,007.43
1	11.0	0.0000			—
Multidisciplinary treatments					
Medical					
Total number of medical procedures		0.0579	< .0001	1.060	$623.17
Procedure type	% of sample				
Noninvasive heart failure diagnostic	54.0	0.0735	.0002	1.076	$797.33
Invasive heart failure diagnostic	35.0	0.0681	.0067	1.070	$736.74
Invasive cardiovascular therapeutic	60.0	0.4097	< .0001	1.506	$5,293.69

Pharmacy					
Total number of different medications		0.017	<.0001	1.017	$179.24
Individual medications	% of sample				
Benzodiazepines	57.2	0.0813	.0032	1.085	$885.44
Misc. EENT drugs	64.3	0.1573	.0001	1.170	$1,780.85
EENT antibiotics	35.1	0.1167	<.0001	1.124	$1,294.06
Antiemetics	18.8	0.0542	.0382	1.056	$582.26
Miscellaneous GI	55.5	−0.1021	.0018	0.903	−$1,014.70
Cephalosporins	28.1	0.1410	.0004	1.151	$1,583.04
Potassium sparing diuretics	10.5	0.1015	.0022	1.107	$1,116.83
Skin antibiotics	8.2	0.1681	<.0001	1.183	$1,913.71
Skin antifungals	8.1	0.1188	.0012	1.126	$1,318.75
Irrigating solutions	5.7	0.1796	.0002	1.197	$2,056.76
Vitamin K activity	4.9	0.1055	.0148	1.111	$1,163.56
Miscellaneous CNS agents	3.3	0.2346	.0036	1.264	$2,764.14

*See Table 4 for nursing interventions.

†The change in the log of hospital cost per unit change for the corresponding predictor.

‡The ratio (change in the log of hospital cost per unit change for the corresponding predictor) minus one multiplied by the median hospital cost.

EENT, eyes, ears, nose, throat; GI, gastrointestinal.

Table 4: Cost of Significant Nursing Interventions for Heart Failure by Use Rate ($N = 1,435$, Median Hospital Cost = $10,454)

	Use Levels	*Use Rate/ 24 Hours**	*Proportional Change in Cost*	*Overall p*	*p for use levels*	*Change in Median Cost*[†] *in Dollars per Hospitalization*
Total number of different nursing interventions	Count of interventions		1.027	**<.0001**		$289.33
Type of nursing intervention (% receiving at least once during hospitalization)						
Fluid Management (99.7%)	Highest 25%	6.08	0.917	**.0176**	**.0036**	– $870.12
Promotion of fluid balance and	Next highest 25%	3.31	0.945		**.0678**	– $571.33
prevention of complications	Next lowest 25%	2.10	0.926		**.0046**	– $772.83
resulting from abnormal or undesired fluid levels.[‡]	Lowest 25%	1.19				—
Routine Care (96.7%)	Highest 25%	7.71	0.925	**.0108**	.1151	– $781.54
Provision of care to the adult	Next highest 25%	7.02	0.998		.9671	– $20.89
patient newly admitted to an	Next lowest 25%	5.98	0.920		.0919	– $831.71
inpatient setting, such as call light within reach, asking about sleep, giving AM care, observing	Lowest 25%	2.63				—
IV Therapy (94.5%)	Top third	6.50	1.084	**.0108**	.1687	$867.31
Administration and monitoring of	Middle third	3.02	0.997		.9569	– $30.27
intravenous fluids and	Lower third	1.32	1.052		.3405	$548.10
medications	No use	0				—
Pressure Ulcer Care (89.3%)	Top third	0.90	0.786	**<.0001**	**<.0001**	– $2232.30
Facilitation of healing in pressure	Middle third	0.38	1.037		.4767	$390.80
ulcers	Lower third	0.22	1.107		**.0285**	$1115.67
	No use	0				—

Discharge Planning (84.0%)	Top third	1.23	0.959	**.0301**	.2645	– $424.97
Preparation for moving a patient	Middle third	0.91	1.016		.6562	$165.43
from one level of care to another	Lower third	0.52	0.944		.1039	– $581.20
within or outside the current	No use	0				—
health care agency						
Oral Health Restoration (83.5%)	Top third	2.16	1.019	<**.0001**	.6029	$199.47
Promotion of healing for a patient	Middle third	1.75	0.893		**.0017**	– $1122.63
who has an oral mucosa or	Lower third	0.81	0.903		**.0058**	– $1015.65
dental lesion	No use	0				—
Fall Prevention: adult (83.3%)	Top third	3.89	1.002	**.0001**	.9675	$15.69
Instituting special precautions with	Middle third	1.87	0.940		.0718	– $631.43
patients at risk from falling	Lower third	0.19	1.059		.1056	$612.10
	No use	0				—
Bowel Management (76.9%)	Top third	2.88	0.960	**.0040**	.2290	– $418.95
Establishment and maintenance of	Middle third	1.56	0.925		**.0171**	– $784.44
a regular pattern of bowel	Lower third	0.46	1.023		.4215	$241.10
elimination	No use	0				—
Infection Protection (73.2%)	Top third	3.08	0.939	**.0038**	.0693	– $636.34
Prevention and early detection of	Middle third	2.56	0.887		**.0002**	– $1180.31
infection in a patient at risk	Lower third	1.03	0.943		.0658	– $594.03
	No use	0				—
Medication Management (10.8%)	Top third	1.58	0.806	<**.0001**	<**.0001**	– $2026.69
Facilitation of safe and effective	Middle third	0.40	1.007		.8803	$74.49
use of prescription and over-the-	Lower third	0.13	1.220		**.0001**	$2295.47
counter drugs	No use	0				—

*The change in the log of hospital cost per unit change for the corresponding predictor.

†The ratio (change in the log of hospital cost per unit change for the corresponding predictor) minus one multiplied by the median hospital cost.

‡Definitions from Dochterman and Bulechek (2004). Nursing Interventions Classification (NIC), 4th edition, Mosby Inc.

Bold face indicates statistically significant p values ($p \leq .05$).

Medical, pharmacy, and nursing treatments were each significantly associated with total hospital cost (Tables 2 and 3). The *total number of medical procedures* was associated with cost ($p < .0001$); with the addition of each medical procedure, median costs were estimated to increase $623 (see Table 3). Types of medical procedures included both medical and surgical procedures. There were 123 different types of medical procedures performed, for a total of 5,193 medical and surgical procedures for the 1,035 heart failure patients. To distinguish between the cost effects of nonsurgical versus surgical procedures, the different types of procedures were grouped into nine subgroups (see Table 1). Three of these nine groups were significantly associated with cost; two of the three were invasive (Tables 2 and 3). *Noninvasive heart failure diagnostic procedures*, such as echocardiograms and radioisotope scans, were associated with an increase in median cost of about $800, or 8 percent; *Invasive cardiovascular diagnostic procedures* (e.g., coronary angiography) were associated with an increased cost of $736, or 7 percent; and *invasive cardiovascular therapeutic procedures* (e.g., angioplasties, open-heart surgeries) were associated with an increased median hospital cost of $5,294.

The *number of different medications* used during hospitalization and several specific medications were significantly related to cost (Tables 2 and 3). The addition of any one *unique type of medication* added $179 to the median costs. *Miscellaneous GI* (gastrointestinal) medications reduced median costs by over $1,000 per hospitalization. *Benzodiazepines* were used in 57 percent of hospitalizations at an estimated additional cost of $885 per hospitalization. Nursing interventions included in the study were those used in at least 5 percent of the hospitalizations. The *number of different nursing interventions* employed during the hospital stay, was statistically significant, and associated with an estimated increased cost of $289 for each additional type of nursing treatment ($p < .0001$) (Tables 2 and 4).

Ten types of nursing interventions were significantly associated with cost in the final model (Tables 2 and 4). The average number of times the intervention was used in 24 hours (use rate) was reported in quartiles (for interventions used in ≥ 95 percent of the hospitalizations) or in thirds (for interventions used in <95 percent but ≥ 5 percent of hospitalizations) (see further explanation in the Supplementary Material Appendix A). Follow-up tests for these 10 were conducted by use rate categories. Six of the 10 interventions were also significant for use rate effect on cost (Table 4): *Fluid Management, Pressure Ulcer Care, Oral Health Restoration, Bowel Management, Infection Protection*, and *Medication Management* (Table 4). The *Fluid Management* intervention, used in 99.7 percent of hospitalizations, was significantly associated with cost ($p = .017$). When comparing a daily use rate of 6.08 times/24 hours with a daily use rate of 1.19 times/24 hours, the *Fluid Management* intervention was estimated to save $870 per hospitalization (see Table 4). Performing this nursing intervention two or more times a day is estimated to save $571–$870 per hospitalization. *Pressure Ulcer Care* was used in 89.3 percent of the hospitalizations but in very small doses. When the average use rate was less than one time per day, the intervention (or lack thereof) appears to increase cost; a use rate of 0.22 is associated with an additional estimated median cost of $1,116 per hospitalization. However, when performed even one time per day (use rate 0.90), the intervention was estimated to save $2,232 per hospitalization ($p < .0001$). The intervention *Oral Health Restoration* was used in 83.5 percent of hospitalizations and was estimated to save money when used between 0.8 and 1.75 times per day ($1,016–$1,123). *Bowel Management* was significantly associated with an estimated $784 reduction in median hospital cost. *Infection Protection* was used in 73 percent of the hospitalizations and was estimated to reduce cost by more than $1,180 at a use rate of 2.6 times per day. Finally, *Medication Management* was documented in only 11 percent of the hospitalizations but was estimated to save $2,027 per hospitalization with the top one-third use rate of 1.58 times per day ($p < .0001$). In the lower one-third use rate, (0.13 times per 24 hours), the "lack" of *Medication Management* was estimated to add an additional $2,295 to median costs ($p < .0001$).

GEE analysis does not result in an R^2 statistic, so to estimate the extent of variance in cost explained by the statistical model, a GLM procedure was used (SAS Institute, Inc. 2003). As the GLM procedure requires that the unit of analysis be independent, repeat hospitalizations for the same patient were removed, thereby reducing the sample size to 1,075 patients. The resulting R^2 was 0.877 indicating that the model accounts for 88 percent of the variance in hospital costs for heart failure patients 60 years of age and older.

DISCUSSION

The average total costs per heart failure hospitalization in this study ($18,086) were higher than the national average for 2000 of $15,293 (AHRQ 2002), perhaps related to the large academic setting and the mixed medical and surgical population. Only one comorbid condition, *deficiency anemia*, was associated with increases in median heart failure costs in this study. In general, reports about the effect of comorbidity specific to heart failure vary. Previous studies have reported either no impact of multiple comorbidities on hospital costs of heart failure patients (Weintraub et al. 2003), or significant increases in heart failure hospital cost (Zhang, Rathouz, and Chin 2003). Our results support the reported clinical and economic importance of anemia in progressive heart failure (Horwich et al. 2002; Komajda 2004; Nordyke et al. 2004).

Two nursing unit characteristics were significant in this cost model. Given the ongoing debate about minimum levels of nursing staff, it is important to note the findings that staffing below the average (RN/patient dip proportion) increased hospital costs. This variable was created for this study to address the nationwide concern about low staffing levels and to complement the usual measure of overall RN hours of care (see the *RN patient ratio* in Table 1 and Supplementary Material Appendix A, which was not significantly associated with hospital costs). A 0.2 incremental increase in the *RN/patient dip proportion* corresponded to a 15 percent increase in cost. The mean value of the RN dip proportion in this study was 0.4321, which would correspond to a 31 percent increase in cost due to staffing variability below a defined average limit. (Note—this variable was calculated using *hourly* figures for both the number of RNs assigned to deliver care and the number of patients needing care and includes 24 hours for all days of hospitalization; the findings reported here do not address the specific hours when the dips occurred.) Reducing hospital cost by reducing RN staff appears to be a compelling but expensive and potentially dangerous myth (Titler et al. 2005, 2007). Number of units resided on during hospitalization (moving patients from unit to unit during hospitalization) is also associated with increased costs. These costs might be associated with incomplete hand-off communication between units resulting in adverse medical error occurrences that may increase total hospital cost (Kanak et al. in press).

The types of medications significantly related to cost in this study were not the most frequently used cardiac medications (e.g., diuretics, β blockers, etc.) (Stroupe et al. 2004). In contrast, many of the medication categories associated with increased costs (Table 3) are less common in typical heart failure patients. The eyes, ears, nose, throat (EENT) drugs, and EENT antibiotics administered in 64 and 35 percent of the hospitalizations, respectively, are likely related to surgical patients. By contrast, one frequently used medication inversely related to cost is *GI medication*. This impressive reduction ($1,015) may reflect a subgroup of heart failure patients in which the diagnostic and treatment effects of *GI medications* assisted in ruling out cardiac etiologies of chest pain and may have resulted in earlier discharge for otherwise stable heart failure patients. *Benzodiazepines* (such as Versed, Lorazepam, and Valium), usually contraindicated in the elderly due to side effects of delirium and falls, were used in 57 percent of the hospitalizations. This drug category may represent prediagnostic or preprocedural sedation. However, in this elderly population, it would be of interest to follow-up the choice of this drug during acute heart failure hospitalizations in future studies to determine appropriateness and potential alternatives to use. With use in 57 percent of an estimated one million primary heart failure hospitalizations per year, a benzodiazepine would be prescribed during 570,000 hospitalizations. At an additional cost of $900 per hospitalization, the inappropriate administration of benzodiazepines may represent an avoidable cost.

The finding of almost 100 percent use of the *Fluid Management* nursing intervention is not only biologically plausible in medical and nursing management of the heart failure patient, but the number one priority in acute heart failure management. When this critical thinking and skill-based nursing intervention is done even twice a day, the cost reduction is again compelling and consistent with the expected biologic benefit to the patient. Conversely, it is concerning that the intervention, *Medication Management,* is only used in 11 percent of hospitalizations and at the lowest use rate, 0.13 times per day. This "lack of medication management" is associated with a projected 22 percent increase in cost, or $2,303 in this study. However, when this primarily critical thinking intervention is performed only one and a half times per day (use rate 1.58) it is associated with a 19 percent reduction in cost per hospitalization, or a savings of $2,027. Extrapolating once again to one million heart failure acute care admissions per year in the United States, the potential cost impact of improving quality nursing care is enormous and literally worth the attention of nurses, nurse leaders, administrators, boards, and public policy makers.

SUMMARY

This exploratory study used electronic data from one academic medical center, which limits the generalizability of findings, and thus, it needs to be replicated using multiple hospitals of varying size, type, and geographic distribution. A limitation is that the outcome variable does not address quality but only cost of care and making decisions about resource allocation based on cost without considering quality of care is shortsighted (Institute of Medicine 2001). Thirdly, data used in this study were obtained from electronic data sources developed for other purposes and may not reflect all care delivered. Despite these limitations, this study illustrates the feasibility and importance of including processes of care variables, particularly nursing treatments, in cost and analyses. The exploratory study also begins to address the importance of empirically demonstrating what nurses do (nursing interventions) and nurse staffing in analytic cost models.

The methodological techniques used herein can be used to explicate contributions of processes of care for other outcomes such as patient safety, complications, and patient satisfaction. Most of the variables that impact cost are interventions (medical, pharmacy, and nursing), validating the overall model used to guide this research. That is, cost of care should be related to services (interventions) delivered and not patient demographics. In this research, it was demonstrated that hospital cost was chiefly related to services. The results indicate that the total number of medical, pharmacy, and nursing treatments add to the cost of care and suggest that medical procedures and new medications be carefully considered for a possible therapeutic effect before they are added to the treatment plan. A number of nursing interventions, notably those related to risk management or prevention of complications (e.g., Fall Prevention, Infection Protection, and Medication Management) did not increase hospital cost. More research is needed to study the impact of nursing interventions on hospital cost as well as on clinical outcomes.

The importance of having adequate RN staffing was demonstrated in the study with staffing below the unit average associated with increased cost. The reasons for these findings are not included in the study but likely relate to nurses ability to prevent, recognize, and provide early treatment for complications (as per the interventions listed in the above paragraph) thereby assisting in recovery time and reducing cost.

Overall, the findings of this study indicate the importance of conducting research in health care that includes the interventions of multiple providers. This is one of the first studies to our knowledge that includes nursing unit and nursing intervention variables as predictors of hospital cost. The study was possible because the hospital used a standardized classification (e.g., the Nursing Interventions Classification [NIC] [Dochterman and Bulechek 2004]), to document nursing interventions and collected nurse staffing data frequently on each patient unit.

Acknowledgments

This study was supported by the National Institute of Nursing Research and the Agency for Healthcare Research and Quality (PI: Titler. R01 NR005331).

The authors would like to acknowledge Kim Jordan for her superb assistance in preparing this manuscript for publication.

Disclosures: None.

Disclaimers: None.

Note

1. Approval for the research was obtained from the University's Institutional Review Board.

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Supplementary Material

The following supplementary material for this article is available online:
Appendix A. Expanded Definitions of Independent and Intervening Variables.

This material is available as part of the online article from: http://www.blackwell-synergy.com/doi/abs/10.1111/j.1475-6773.2007.00789.x (this link will take you to the article abstract).

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