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The Performance of Intensive Care Units: Does Good Management Make a Difference?

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A significant portion of health care resources are spent in intensive care units with, historically, up to two-fold variation in risk-adjusted mortality. Technological, demographic, and social forces are likely to lead to an increased volume of intensive care in the future. Thus, it is important to identify ways of more efficiently managing intensive care units and reducing the variation in patient outcomes. Based on data collected from 17,440 patients across 42 ICUs, the present study examines the factors associated with risk-adjusted mortality, risk-adjusted average length of stay, nurse turnover, evaluated technical quality of care, and evaluated ability to meet family member needs. Using the Apache III methodology for risk-adjustment, findings reveal that: 1) technological availability is significantly associated with lower risk-adjusted mortality (beta = −.42); 2) diagnostic diversity is significantly associated with greater risk-adjusted mortality (beta = .46); and 3) caregiver interaction comprising the culture, leadership, coordination, communication, and conflict management abilities of the unit is significantly associated with lower risk-adjusted length of stay (beta = .34), lower nurse turnover (beta = −.36), higher evaluated technical quality of care (beta = .81), and greater evaluated ability to meet family member needs (beta = .74). Furthermore, units with greater technological availability are significantly more likely to be associated with hospitals that are more profitable, involved in teaching activities, and have unit leaders actively participating in hospital-wide quality improvement activities. The findings hold a number of important managerial and policy implications regarding technological adoption, specialization, and the quality of interaction among ICU team members. They suggest intervention "leverage points" for care givers, managers, and external policy makers in efforts to continuously improve the outcomes of intensive care. Key words: continuous improvement; health outcomes; unit performance. (Med Care 1994;32:508–525)

As health care reform in the United States continues to evolve, increased attention will be paid to reorganizing the way patient care is provided. This will involve a fundamental restructuring of how health care professionals relate (e.g., greater use of interdisciplinary health care teams) and of how professional work is accomplished (e.g., greater use of electronic databases and treatment protocols). Managerial and organizational scientists and their economic colleagues must join forces with the biological, biomedical, and clinical scientists for more cost-effective patient care to be realized.

Over the past two decades, there has been a growing knowledge base identifying managerial and organizational practices that appear to be associated with better patient outcomes.[1-4] Many of these, strong leadership, timely communication, and good interdepartmental coordination for example, are similar to effective practices that have been found to be associated with superior performance in organizations outside of health care.[5-7] Although the health care specific studies have been helpful, many have been limited by small sample sizes, an inability to rigorously adjust patient outcomes for differences in severity of illness, an inability to control for differences in technology, and a narrow focus on a single outcome measure as opposed to a broad array of indicators that might better capture the overall performance of a given patient care unit or organization. The present study attempts to address these challenges by examining a relatively large number (n = 42) of patient care units (intensive care units) throughout the United States; employing recent advances in severity of illness risk adjustment (APACHE III); incorporating measures of technological differences; and examining a broad portfolio of performance measures including risk-adjusted mortality, risk-adjusted length-of-stay, nursing turnover, evaluated technical quality of care, and evaluated ability to meet family member needs. The purpose is to examine the extent to which differences in performance might be associated with selected managerial and organizational practices over which health care professionals have control, thus providing a basis for taking corrective action and achieving superior outcomes.

The Treatment Setting and Its Importance

Although more health care services will be delivered in nonhospital settings, an increasing proportion of services that remain within the hospital will involve intensive care. It is conceivable that hospitals in the future largely will be intensive care units. How to manage the resources associated with such care will be of growing importance along with learning how to produce better patient outcomes.[8] These issues are of particular significance given that the cost of a patient day in an ICU is three to five times that of a day of care on a medical-surgical floor,[9] and overall ICU expenditures represent approximately 1% of the nation's gross national product.[10,11] In addition, the efficacy of intensive care has been called into question for both patients who are too well or too ill to benefit from such treatment.[12-15] Further, recent studies have demonstrated a two fold variation in risk-adjusted mortality.[16-17] Finally, an ICU is a particularly pertinent setting for study because it is a prototype of the highly interdependent team-oriented care that will characterize much of health care delivery in the future. Being able to identify and learn about processes associated with better performance in these units may hold important lessons for other settings as well.

The Model

It is important to consider performance from multiple perspectives that involve key groups including providers, patients, and their families. Relevant variables for ICUs

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include clinical outcomes of care, efficiency of utilization, technical quality of care provided, the ability to meet family member needs, and staff satisfaction. An optimal performing unit would be one that provides superior patient outcomes at less cost (than competitors or peer group averages) with high levels of patient, family, and staff satisfaction. Although the greatest weight might be placed on objective measures of patient outcomes and cost of treatment or efficiency of utilization, patient, family, and staff satisfaction also are important. Patient and family member satisfaction not only influences the decision to seek care from the same providers in the future but also influences the course of treatment and rehabilitation for the present condition. Staff satisfaction is important regarding retention, productivity, and continuity of care. High staff turnover not only results in additional costs of recruitment and training but, also, can be disruptive of patient care and, thereby, compromise quality and continuity. As a result of these considerations, the study model incorporates all five dimensions of ICU performance. This approach also recognizes that performance measures are rarely highly correlated with each other such that measuring a single dimension is likely to lead to wrong or at least incomplete conclusions regarding unit performance.[3]

The model shown in Figure 1 suggests that unit performance will be influenced by available technology, the nature of the work to be done (i.e., task diversity), staffing, and how well caregivers (physicians, nurses, and related health professionals) work together (i.e., caregiver interaction). This model, its major constructs and their measurement were prespecified before data collection and analysis.[18] The role of each of these is highlighted below.

Technological Availability

Given that the most severely ill hospitalized patients are treated in ICUs, the availability of relevant state-of-the-art technology is particularly important. Technological advances have, of course, played a major role in the evolution of intensive care. These technologies range from pacemakers and ventilators to intra-aortic balloon pumps. The availability of such technologies increase the ability to monitor patient care and decrease response time when emergencies occur (e.g., cardiac arrest). Although there is no evidence to date to suggest that ICUs with more technology achieve better outcomes than those with less, there is some evidence from the organizational literature to suggest a relationship between technology and superior performance.[19,20] Technology is likely to be particularly strongly associated with lower risk-adjusted mortality since it is the rapid and appropriate application of life-saving technology that epitomizes ICUs. Thus, the first hypothesis to be tested is:

H1: The greater the extent to which technology is available in the unit, the better the unit's performance; particularly regarding risk-adjusted mortality.

Task Diversity

Concerning intensive care, task diversity refers to the number of *different* conditions treated within the unit. A greater variety of patients to be treated challenges caregivers because their expertise, experience, and knowledge must be applied across a wider range of conditions. It also results in increased cost of communication, coordination, and problem solving. Existing research suggests that the ability to treat a high volume of patients with a limited number of conditions tends to be associated with better outcomes.[21–26] This may be due to the ability of caregivers to focus their skills, knowledge, and experience; to learn from experience; and to develop various treatment protocols and practice guidelines that result in more efficient provision and monitoring of

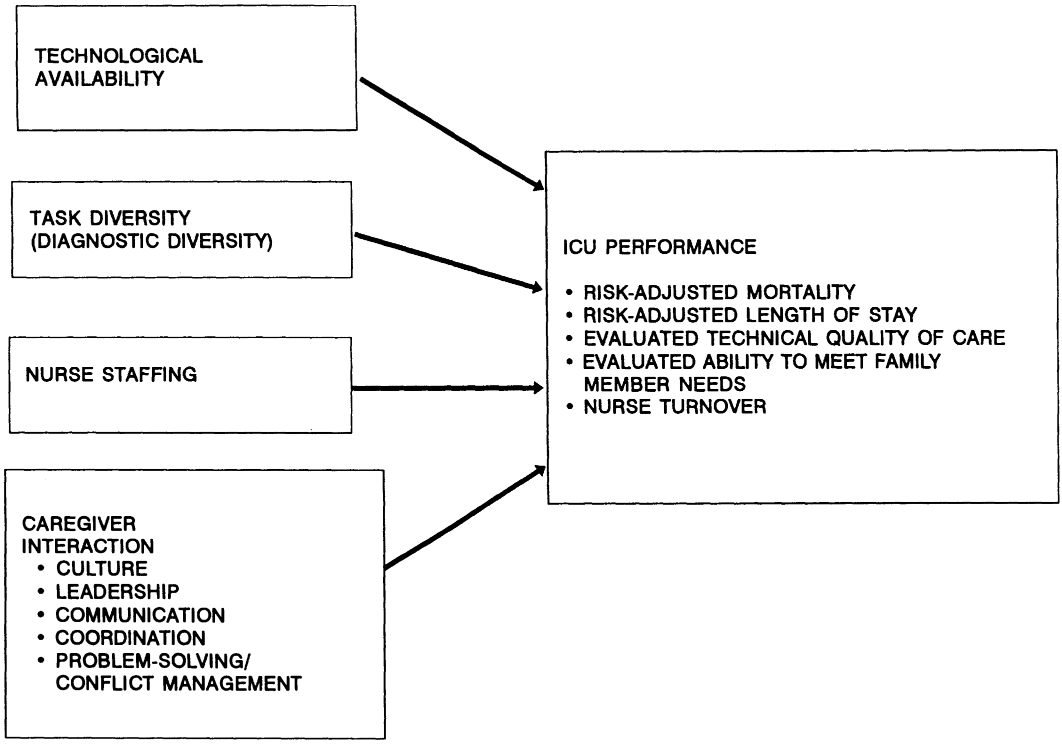

FIG. 1. Analytic model for studying ICU performance.

care. As in the case of technology, such specialization is particularly likely to affect risk-adjusted mortality. Thus, the second hypothesis to be tested:

H2: The greater the variety of conditions treated in the ICU, the poorer the unit's performance; particularly regarding risk-adjusted mortality.

Staffing

The availability of a sufficient number of competent experienced nurses can directly influence patient outcomes and the related indicators of ICU performance.[27,28] For example, units with less than a 1:2 nurse-to-patient ratio may be spread too thin to provide direct care as well as tasks associated with planning, monitoring, and coordination of such care. In general, units with higher staffing ratios are expected to achieve better performance than those with lower ratios. Thus, the third hypothesis to be tested:

H3: The higher the nurse to patient staffing ratio, the better the unit's performance.

Caregiver Interaction

The above variables, the availability of technology, the variety of conditions seen, and the availability of relevant staff, are primarily "structural" factors expected to be associated with ICU performance. Of particular interest is the role that might be played by certain "process" factors involving *caregiver interaction*. We view caregiver interaction as a composite concept which, based on existing organizational and health services research, includes sub-dimensions involving unit culture, leadership, communication, coordination, and problem solving/conflict management.[29–37] These dimensions constitute the "physiology" of the caregiver system. Each is briefly highlighted below.

Culture. Culture refers to the norms, values, beliefs, and expectations shared by people working in a given unit or organization.[29] For example, some organizations value change, innovation, and risk-taking whereas others place greater emphasis on dependability, efficiency, and sticking with what is tried and true. Some organizations place a high emphasis on team work and continuous improvement whereas others may emphasize competitive behavior or, conversely, place a high value on having people get along and "fit in". Although there have been few studies of the relationship between organizational culture and performance,[38] a supportive culture emphasizing team work along with the establishment of high standards is likely to be associated with better performance than cultures that emphasize competitiveness or are overly concerned with how well people fit in.[29] This is likely to be particularly true in intensive care units where there is considerable pressure for high performance in a work environment that requires considerable coordination and communication across a wide range of caregivers.

Leadership. Leadership refers to the ability of individuals to influence others toward the achievement of relevant organizational goals and objectives. Although there is an extensive conceptual and empirical literature on leadership, relatively little work has been done in health care.[39] Nonetheless, leadership that sets high standards, clarifies expectations, encourages initiative and input, and provides necessary support resources should be associated with higher performance.

Communication. There are many aspects of communication that are important including openness (i.e., being candid and honest), accuracy, timeliness, and understanding.[31] Given the complexity of conditions being treated, the relatively short time period the patients are in intensive care units, and the number of different people involved with the patient's care, ICUs have great need for effective communication among providers. The information needs to be timely, accurate, and relevant. Thus, it is expected that communication will be positively associated with better unit performance.

Coordination. Coordination refers to the extent to which functions and activities both within the unit and between units are brought together in a way that promotes cost-effective continuous care.[36] Given the high degree of interdependence that ICUs have with other units such as the emergency room, operating room, step-down units, and patient floors in addition to laboratory, radiology, pharmacy, and respiratory therapy, the need for effective coordination is particularly acute. Thus, we expect that coordination will be positively associated with better unit performance.

Problem Solving/Conflict Management. As patient care becomes more complex and inter-dependent, it is important for care givers to find ways of addressing problems and resolving conflicts. In ICUs the usual disagreements over treatment approaches and philosophies, roles and responsibilities, and differential access to resources are exacerbated by ethical issues involving death and dying and often disagreements among family members regarding wishes for their child, spouse, parent, or relative. As a result, ICUs need effective problem solving and conflict resolution mechanisms to expedite cost-effective care.[35] We expect that more effective problem solving and conflict management approaches will be associated with better unit performance.

Culture, leadership, communication, coordination, and problem solving/conflict management are viewed as interrelated components or dimensions of *caregiver interaction.* Although one can examine their individual effects, we believe they are best considered as a composite construct because it is difficult to distinguish them as one observes the work that occurs in ICUs. For example, a nurse and physician discussing whether or not a patient can be discharged to a step-down unit involves all of the above dimensions, communication, coordination, and problem solving being obvious, but, the discussion also takes place within the context of a given leadership style and unit culture. We expect that caregiver interaction will be particularly strongly associated with greater unit efficiency of utilization, evaluated technical quality of care, and evaluated ability to meet family member needs. Thus, the fourth hypothesis to be tested:

H4: The greater the quality of caregiver interaction among physicians and nurses in the unit, the better the unit's performance; particularly regarding efficiency of utilization, evaluated quality of care and evaluated ability to meet family member needs.

Methods

Sample

The population comprised 1,691 nonfederal U.S. hospitals with 200 beds or more. This group represents the vast majority of all hospitals with intensive care units. Within this group, a stratified random sample of 26 hospitals was selected based on bed size, geographic region, and teaching status, with the latter defined as offering one or more accredited graduate training programs. An additional 14 volunteer university-affiliated or tertiary care teaching hospitals participated bringing the total number of study hospitals to 40. Data were collected from the medical-surgical ICUs in each hospital using those units with the highest admission rates. For two volunteer institutions, data were collected from two medical surgical ICUs bringing the total count to 42 ICUs available for analysis. Because the 14 volunteer hospitals did not differ significantly on any of the study analytic variables from the randomly selected hospitals, the two groups were pooled for analysis.

For hospitals above 200 beds, comparisons of the ICUs involved in this study with those nationwide indicates that 88% of the study's hospitals were not-for-profit compared to 77% nationally. Fifty-three percent were affiliated with a medical school, consistent with the national rate of 53%. The average number of beds in participating hospitals was 358 compared with the national average of 372. The study ICUs had an average bed size of 13, smaller than the national average of 24. Study hospitals have an average occupancy rate of 71.1% compared to the national rate of 70.6%. The participating ICUs had an average occupancy rate of 77%. Thirty of the ICUs were mixed medical-surgical (71%), eight were surgical only (19%), and four were medical only (10%). These data suggest that the study sample is largely representative of the national population above 200 beds although the specific ICUs studied are somewhat smaller in bedsize than the national average.

Patient Selection

Data were collected on 17,440 patients representing an average of 415 patients per unit (range 299–499). For 80% of the units, data were collected on consecutive admissions. When patient volume precluded this from occurring, either every second or third patient was systematically selected. Exclusions included patients admitted with suspected acute myocardial infarction, coronary artery bypass surgery, burn injury, those younger than 16 years of age, and those remaining in the ICU for less than 4 hours. Data collection began in May 1988 and was concluded in February 1990. The study period at each ICU averaged 10 months with a range from 3 to 17 months.

Measuring ICU Performance

Risk-Adjusted Mortality Rate. Each unit's expected patient mortality was calculated based on adjustments for a variety of patient demographic, physiological, and related characteristics using the APACHE III methodology.[17,18] The predictor variables included the APACHE III score, primary disease category, duration of hospitalization, location prior to ICU admission (emergency room, recovery room, hospital, or operating room, ICU readmission or transfer from another ICU or hospital), and whether surgery was elective or emergency (defined as operation for an immediate life-threatening condition). The APACHE III score was computed during the first ICU day using each patient's clinical record. The Acute Physiologic Score (APS) was derived by providing weights to 17 potential physiologic variables, weights applied to seven comorbid conditions that reduce immune function, and weights assigned to increased chronologic age all applied within 78 mutually exclusive diagnostic categories (Appendix A).[40] Patient data were entered into onsite microcomputers using specially designed software. To assure quality, data collected on the first 20 patients were reviewed at each hospital. An adjustment was also made to take into account triage pressures on the unit by computing the survivors' hospital length of stay compared to the average length of stay for all 42 units controlling for disease and the APACHE III score. An increasing APACHE III score is related to an increased risk of hospital mortality and accounts for 90% of the area under the receiver operating curve (ROC).[40]

The above information was used in a logistic regression to compute each unit's expected mortality rate.[17] A standardized mortality ratio (SMR) was then computed by dividing each unit's actual mortality by its predicted mortality. Thus, an SMR of 1 indicates that the actual and predicted death rates match exactly, whereas an SMR less than 1 indicates that the actual death rate is less than predicted and an SMR more than 1 indicates that the actual death rate is above that predicted. The study-wide mean actual mortality rate was 16.6% (range 6.2%–40%). The SMR range was from 0.67 to 1.26. The SMR was significantly better ($P \leq .05$) for five ICUs and significantly worse ($P \leq .05$) for five other ICUs. Data were also collected on survival 30 days post-hospital discharge for Medicare patients and by telephone for a 15% random sample of all other patients. These data resulted in no change in the relative rank ordering of unit performance and, thus, are not examined further here.

Risk-Adjusted Length of Stay. To measure the efficiency of utilization within the unit, a prediction equation similar to that described above for mortality was developed to determine an expected length of ICU stay. This included a correction factor using the method of cubic splines to take into account the fact that sicker patients tended to die in the first day, resulting in a low length of stay.[17] For each unit the ratio of the actual length of stay to the predicted length of stay was then calculated. The mean actual ICU average length of stay was 4.7 days (range 3.3–7.3 days). The ratio of actual to predicted length of stay ranged from .89 to 1.24. For six ICUs, the ratio was significantly lower or better ($P \leq .05$) and for five other units significantly higher or worse ($P \leq .05$). The availability and use of a stepdown or intermediate care unit was not significantly correlated with either average actual ICU length of stay or the risk-adjusted ratio of actual to expected ICU length of stay.

Evaluated Technical Quality of Care. At the same time patient care data were being collected, an organizational assessment questionnaire was used to collect data from all nurses on all shifts, physicians and residents who provided the majority of care in the unit (including attending staff who were the heaviest admitters to the unit), and ward clerks/secretaries.[41] A total of 1,418 questionnaires were completed by nurses (78%

return), 790 by eligible physicians (65% return), and 111 by ward clerks/secretaries (65% return). A five item Likert scale (1 = strongly disagree, 5 = strongly agree) of perceived absolute technical quality of care provided in the unit (Cronbach's alpha = .76) was used. Relevant items included the extent to which patient care treatment goals were met; the extent to which good outcomes were achieved taking into account patient severity; the ability to apply the most recently available technologies; the ability to function well together as a team; and the ability to respond to emergency situations.

Evaluated Ability to Meet Family Members Needs. Due to limitations of time, resources, and the nature of intensive care, it was not possible to obtain direct measures of patient satisfaction. Neither was it possible to obtain direct measures of family member satisfaction. It was possible, however, to obtain providers' evaluation of how well they felt family member needs were met. This was measured by a two item, five point Likert scale (1 = strongly disagree, 5 = strongly agree; Cronbach's alpha = .75) comprising items related to the extent to which the unit did a good job in meeting family member needs in an absolute sense and, secondly, whether relative to other ICUs in the area, the unit did a good job of meeting family member needs.

Nurse Turnover. Nurse turnover was used as one measure of staff satisfaction. It was calculated from data provided by each unit by dividing the number of nurses who left each ICU in the year of the study by the number employed that year.

Measuring Task Diversity

Task diversity or diagnostic diversity was measured using the 78 major disease categories in the APACHE III Prognostic System.[40] These disease categories provided 66 primary reasons for ICU admission covering 15,269 (87.5%) of the 17,440 patients. The remaining 2,171 admissions were grouped into seven nonoperative and five operative organ system (e.g., cardiovascular, respiratory, etc.) categories. Attempts to weight the measure by the percentage of patients seen in each category did not change overall unit ranking. As a result, a simple count of the number of different disease categories seen by each unit was used as the measure. The average number of different diagnostic conditions treated was 60 with a range from 44 to 71. As expected, greater diversity existed in the mixed medical-surgical units ($\bar{x}$ = 62.5) than the units focusing on surgical conditions only ($\bar{x}$ = 56.5) or medical conditions only ($\bar{x}$ = 47.8).

Measuring Technological Availability

Technological availability was measured by how many of 39 items recommended by the Joint Commission on Accreditation of Healthcare Organizations,[42] a NIH Critical Care Medicine Consensus Panel,[43] and The Society for Critical Care Medicine[44] were available in the unit (Appendix B). These data were provided by the Background/Structure Questionnaire and validated by on-site visits to nine ICUs. Units averaged 80% of the recommended items with a range from 59% to 97%.

Measuring Nurse Staffing

Data were obtained on the staffing of each unit on each shift during the study period from the Background/Structure questionnaire completed by the nursing director of each unit. The overall average nurse to patient ratio was .66 (slightly more than one nurse for every two patients) with a range from .31 to 1.31.

Measuring Caregiver Interaction

The discrete dimensions of caregiver interaction, culture, leadership, communication, coordination, and problem solving/conflict management, were measured using five item Likert scales (1 = strongly disagree, 5 = strongly agree) that were part of the earlier noted organizational assessment instrument completed by unit members.[41] These scales, described below, were initially pilot tested in five medical-surgical ICUs in four Chicago area hospitals involving responses from 134 nurses and 53 physicians. Analysis of the pilot data resulted in developing separate questionnaires for physicians and nurses; developing separate questions to assess within group (e.g., within nursing) and between group (e.g., between nurses and physicians) interaction; and revision of some items (e.g., between unit coordination) to improve reliability.

Culture. Unit culture was measured by 48 items selected from the Organizational Culture Inventory (OCI)[30] Of the available measures of culture, the OCI is the most widely tested regarding reliability and validity and has demonstrated stable factor solutions across samples.[29] The items yield three factors: 1) a team satisfaction-oriented scale: 2) a people security-oriented scale; and 3) a task security-oriented scale. As previously noted, it was hypothesized that a team satisfaction-oriented culture that emphasizes self-expression, achievement, cooperation, and staff development is mostly likely to be associated with better unit performance. In contrast, a people security-oriented culture emphasizes approval, adherence to procedures, dependence, and avoidance of conflict. A task-oriented culture emphasizes perfectionism, competition, opposition, and authoritarian control. The rotated factor loadings for the team satisfaction-oriented scale (principal components analysis, varimax rotation) ranged from .47 to .78 with an Eigenvalue of 13.02.[41] Convergent and discriminant validity was assessed by correlating the team satisfaction factor with nursing and physician leadership, effective communication and coordination, open collaborative problem solving and conflict management, and team cohesion. All of these relationships were statically significant in the predicted direction.[41] Cronbach's alpha for the team-satisfaction culture dimension used in the analysis was .94.

Leadership. Both nursing and physician leadership were separately measured by two eight item scales involving the extent to which unit leaders emphasize standards of excellence to the staff, communicated clear goals and expectations, responded to changing needs and situations, and were in touch with unit members' perceptions and concerns.[41] Cronbach's alpha for the nursing leadership scale was .87 and for the physician leadership scale .88. From a convergent and discriminate validity perspective, nursing and physician leadership were positively associated with a team satisfaction-oriented culture and open-collaborative problem-solving approaches and negatively correlated with people security- and task security-oriented culture and problem solving methods related to avoidance and forcing issues.[41] Given that many units did not have full-time medical directors, the nursing leadership scale was used. This scale represents a more comprehensive measure of ICU leadership by recognizing the pervasiveness of nursing care across all hours and shifts.

Communication. Communication was measured along a number of dimensions including openness, accuracy, timeliness, understanding, and satisfaction. Because these dimensions were highly intercorrelated, timeliness of communication was selected because of the importance assigned to receiving information in a timely fashion to monitor patient care and to coordinate care between and among units. Timeliness of communication was measured by three items involving the degree to which patient care information was relayed promptly to the people who needed to be informed.[41] Cronbach's alpha for the timeless of communication scale was .64.

Coordination. Coordination between units was measured by a four item scale relating to the ICU's ability to coordinate its work with other units such as the operating room, emergency room, step-down units and patient floors.[41] This measure was highly correlated with a separate measure of coordination within the ICU. Cronbach's alpha was .75 for the between unit coordination measure.

Problem Solving/Conflict Management. A four-item scale of open-collaborative problem-solving suggested in the organizational literature was used.[33–35] These items involved the extent to which physicians and nurses work actively to make sure that all available expertise is brought to bear on a problem with the goal of arriving at the best possible solution.[41] Cronbach's alpha was .82.

Analysis of variance was conducted to determine whether between unit differences were greater than within unit differences and the degree of internal agreement was assessed using intra-class correlation coefficients.[41] This analysis indicated significant between unit differences ($P \leq .001$) and within group agreement (median eta of .08 for total sample, .12 for nurses, .11 for physicians) making aggregation to the unit level appropriate.[41] The summary measure reflecting caregiver interaction was computed by aggregating and averaging the sub-dimension scores with each dimension receiving equal weight. Cronbach's alpha for the composite index was .89. The overall average caregiver interaction score was 3.59 with a range from 3.26 to 4.07.

Results

The means, standard deviations, ranges, and zero order correlations for the study variables are shown in Table 1. The performance measures are not highly correlated with each other, confirming the utility of using a multiple indicator approach. Ordinary least squares regression was used to test the hypotheses, and the results for each performance measure are shown in Table 2.

Risk-Adjusted Mortality Rate

As shown in Table 2, technological availability and diagnostic diversity are associated with risk-adjusted mortality in the expected directions. Specifically, the greater the technological availability of the unit, the lower its risk-adjusted mortality rate. At the same time, the greater the number of different conditions that are treated in the unit (i.e., diagnostic diversity), the higher the unit's risk-adjusted mortality. Contrary to prediction, nurse staffing was not significantly associated with risk-adjusted mortality perhaps due to the relatively low variance in staffing ratios among the study units. There was no relationship between caregiver interaction and risk-adjusted mortality suggesting that mortality is more influenced by technological factors while, as will be subsequently discussed, the efficiency of delivering care is more influenced by human interaction factors.

Given the significant relationship between technology and lower risk-adjusted mortality, we examined the factors that might be associated with greater availability of technology. We hypothesized that units with a full-time medical director, located in hospitals with greater resources, having teaching activity, with ICU leaders more actively involved in quality assurance and improvement activities, and those existing in hospitals facing a greater degree of market competition (based on the number of other hospitals with which the participating hospital competes for either patients, physicians, nurses or other health professionals) might have more technology. The results, shown in Table 3, indicate significant associations in the expected direction for resources (as measured by a 3-year average of hospital net operating income as a percentage of operating revenue in the years immediately preced-

TABLE 1. Descriptive Statistics and Pearson Correlations

	Mean	STD	Range	1	2	3	4	5	6	7	8	9
Performance Measures												
1. Risk-adjusted mortality	.99	.15	0.67–1.25		−.04	−.02	−.11	.23	−.34[b]	.29[a]	−.17	−.02
2. Risk-adjusted length of stay	1.00	.09	0.89–1.24			.20	−.36[b]	−.22	−.11	.16	.01	−.43[c]
3. Nursing turnover	.19	.11	0.00–0.40				−.32[a]	−.41[b]	.25	.09	.05	−.37[b]
4. Evaluated technical quality of care	3.90	.22	3.28–4.24					.62[b]	.10	−.24	.20	.80[c]
5. Evaluated ability to meet family needs	3.66	.31	2.85–4.33						−.23	−.15	.03	.71[b]
Predictor Variables												
6. Technological availability	.80	.10	0.59–0.97							.13	.45[c]	−.07
7. Diagnostic diversity	60.0	7.28	44.0–71.0								−.12	−.34[b]
8. Nurse-patient staffing	.66	.18	0.31–1.31									.07
9. Caregiver interaction	3.59	.19	3.26–4.07									

[a] $P \leq .05$.
[b] $P \leq .01$.
[c] $P \leq .001$.

ing the study), teaching activity, and ICU leader participation in quality assurance and improvement as measured by their involvement in quality assurance/improvement task forces and committees. Hospitals with a significantly higher net operating income, involvement in teaching, and with ICU leaders having a greater involvement in quality assurance and improvement activities appear more likely to have more technology available which, in turn, is associated with lower risk-adjusted mortality.

TABLE 2. Ordinary Least Squares Regression Results

	Risk-Adjusted Mortality		Risk-Adjusted ICU Length of Stay		Nurse Turnover		Evaluated Technical Quality of Care		Evaluated Ability to Meet Family Member Needs	
Predictors	B (SE)	Beta	B (SE)	Beta	B (SE)	Beta	B (SE)	Beta	B (SE)	Beta
Technological availability	−.64[a] (.24)	−.42[a]	−.02 (.158)	−.03	−.27 (.182)	−.25	.23 (.23)	.11	−.78[a] (.38)	−.26[a]
Diagnostic diversity	.01[b] (.0032)	.46[b]	.0008 (.002)	.06	−.001 (.002)	−.07	.0009 (.003)	.03	.006 (.005)	.15
Nurse/patient staffing ratio	.12 (.137)	.14	.03 (.087)	.06	−.02 (.101)	−.04	.11 (.13)	.10	.20 (.21)	.11
Caregiver interaction	.08 (.123)	.09	−.16[a] (.078)	−.34[a]	−.21[a] (.091)	−.36[a]	.93[b] (.12)	.81[b]	1.22[b] (.19)	.74[b]
Constant	.56 (.561)		1.62 (.358)		.84 (.41)		.24 (.52)		−.58 (.86)	
Adjusted R^2	.20		.10		.18		.64		.52	
n	42		42		42		42		42	

B, unstandardized regression coefficient; SE, standard error of B; Beta, standardized coefficient (in standard deviations of both dependent and predictor variable).
[a] $P \leq .05$.
[b] $P \leq .01$.

TABLE 3. Technological Availability Results

Variable	Mean	STD	Range	B (SE)	Beta
1. Full-time medical director (Yes/No)	.36	.48	.00–1.00	.04 (.02)	.17
2. Average net operating income (as percent of operating revenue)	4.90	4.59	−.67–19.13	.008[a] (.003)	.38[a]
3. Teaching activity (yes/no)	.60	.50	.00–1.00	.08[a] (.02)	.39[a]
4. Degree of market competition	13.02	32.72	0–200	.005 (.0004)	.17
5. QA/QI participation	2.45	.92	1.00–4.00	.03[b] (.01)	.26[b]
Constant				.62 (.04)	
Adjusted R^2				.52	
n				42	

B, unstandardized regression coefficient; (SE), standard error of B; Beta, standardized coefficient (in standard deviations of both dependent and predictor variable).

[a] $P \leq .01$.

[b] $P \leq .05$.

Risk-Adjusted of Length Stay

As predicted, caregiver interaction is significantly associated with lower risk-adjusted length of stay. This suggests that factors involving culture, leadership, communication, coordination, and the ability to manage conflict are, indeed, important for efficiently managing ICU care. Technological availability, nurse staffing, and diagnostic diversity have no significant association with risk-adjusted length of stay.

Nurse Turnover

As predicted, caregiver interaction is negatively associated with nurse turnover. That is, the higher the quality of caregiver interaction, the lower the nurse turnover in the unit. Technological availability, the nurse staffing ratio, and diagnostic diversity are unrelated to nurse turnover.

Evaluated Technical Quality of Care

As shown in Table 2, caregiver interaction is strongly associated with evaluated technical quality of care provided in the unit. Because both of these are perceived measures coming from questionnaire data, the finding is subject to mono-method variance bias.[45] To correct for this, split sample analyses were conducted whereby half of the sample's score on caregiver interaction was used to predict the other half of the sample's score on evaluated technical quality of care. Essentially the same results were obtained (beta = .58; $P \leq .001$) indicating that the relationship is less likely to be an artifact of data collection. Technological availability, diagnostic diversity, and the nurse staffing ratio are not significantly associated with evaluated technical quality of care.

Evaluated Ability to Meet Family Needs

As predicted, caregiver interaction was also positively associated with staff members' evaluated ability to meet family member needs. In addition, technological availability was *inversely* associated with the ability to meet family member needs. Neither the nurse staffing ratio nor diagnostic diversity were significantly associated with the evaluated ability to meet family member needs. As above, split sample analysis was conducted for the caregiver interaction variable yielding results similar to those presented in Table 2 (beta = .38; $P \leq .05$).

Discussion and Implications

The study findings have important managerial and policy implications. The availability of more technology in intensive care units was significantly associated with lower risk-adjusted mortality. This provides preliminary support for the hypothesis that investment in technology and services is associated with improved outcomes. This finding is contrary to some recent studies emphasizing the lack of evidence that technology, e.g., pulmonary artery catheters, improves patient outcome.[46–48] The result, however, is consistent with a recent study of mortality among Medicare patients in which those patients with a greater level of access to high technology equipment had lower risk-adjusted mortality.[49] The result is also supported by previously documented but often forgotten improvements in outcome from conditions such as drug overdose with the application of intensive care[50,51] and the introduction of specific life support technologies such as ventilators,[52,53] pacemakers,[54,55] and hemodialysis.[56–58] The existence of greater technology may also reflect a greater priority placed on monitoring and treatment of the critically ill.

The findings pertaining to the positive association of technology with hospital operating income, teaching activity, and ICU leader involvement in quality assurance/quality improvement also are interesting. To the extent that health care reform initiatives maintain some degree of market competition, it appears that hospitals that are financially better off will be able to secure the necessary technology to achieve better patient outcomes than those less well off. These variables, financial resources, teaching activity, and quality improvement initiatives, could also be included among a larger set of criteria for making technology diffusion decisions.

The negative relationship between diagnostic diversity and risk-adjusted mortality is relevant because it supports a growing body of literature suggesting that the application of specialized skills to a more concentrated volume of patients is associated with better patient outcomes.[21–26] Although this finding should not be interpreted as directly supporting the development of specialty ICUs, it does suggest that focusing on a narrower range of conditions might be associated with better outcomes. Focusing on a narrower range of conditions permits nurses and physicians to more easily apply their expertise and experience, makes it easier to coordinate activities and communicate relevant information, and deal with problems and conflict situations. In this regard, Table 1 contains an interesting negative correlation ($-.34$, $P \leq .01$) between diagnostic diversity and the nurse/patient staffing ratio. To some extent, the diversity encountered in an ICU is the result of uncontrollable factors such as the geographic area in which the hospital is located. For example, an ICU in an inner-city hospital may have a high number of substance abuse cases. ICUs in communities with a high percentage of elderly patients may treat a much more diverse case mix reflecting the greater number of illnesses associated with aging. Creation of more specialized or homogenous groupings of patients, of course, carries important staffing, cost, and access implications for caregivers, hospital executives, third-party payers, and policy makers. The issue merits further study using an even larger sample of ICUs drawn from both teaching and nonteaching hospitals.

Taken together, the findings pertaining to the availability of technology and diagnostic diversity are important to external organizations such as the Joint Commission on Accreditation of Healthcare Organizations (JCAHO), the Professional Review Organizations (PROs), other third-party payers such as the Health Care Finance Administration (HCFA), and relevant professional societies such as the Society for Critical Care Medicine (SCCM). Organizations, such as the JCAHO and SCCM for example, might further refine their standards related to the technological requirements of institutions to provide care relative to the severity of patients treated in ICUs. Attention might also be given to the homogeneity of patient groups relative to the skill mix of the caregivers. HCFA and other payers might use such information for purposes of reimbursement and for ongoing monitoring of the relationship between such structural factors and patient outcomes. In this regard, greater attention should be given to moving all institutions toward the high performer end of the distribution rather than merely focusing on the poor performer tail of the distribution.

We also examined whether or not technological availability was more important the greater the degree of diagnostic diversity in a unit. This was tested by the statistical interaction term technological availability × diagnostic diversity but was found to be nonsignificant.

Of particular interest is the fact that the caregiver interaction scale was positively associated with four out of the five unit performance measures, risk-adjusted length of stay, evaluated technical quality of care, evaluated ability to meet family member needs, and nurse turnover. The association of caregiver interaction with risk-adjusted length of stay is particularly significant given the growing demand for ICU care and the consequent triage pressures generated. The findings suggest that ICUs that have a team-oriented culture with supportive nursing leadership, timely communication, effective coordination, and with collaborative open problem solving approaches are significantly more efficient in terms of moving patients in and out of the unit. These units also have lower nurse turnover that can result in further cost savings through reduced expenses for recruitment and training.

The positive relationship between caregiver interaction and evaluated technical quality of care suggests that physicians and nurses believe that technical quality is higher when a team-oriented culture and supportive leadership exists along with effective communication, coordination, and problem-solving approaches. This is true even though there was no significant association with risk-adjusted mortality per se. The positive association with the ability to meet family member needs recognizes that high quality comprehensive ICU care also has an important service dimension involving the ability to listen to family members and provide compassionate support. These results are particularly important because the caregiver interaction variables, culture, leadership, communication, coordination, and problem solving/conflict management, are under the influence and control of physicians, nurses, and executives associated with the unit.[59] Thus, they represent levers for corrective action and continuous quality improvement.[60–62]

Finally, it is of interest to note that technological availability is *negatively* associated with the ability to meet family member needs. It appears that units with more technology are able to do a better job regarding risk-adjusted patient mortality but do less well in focusing on family member needs. It may be that units with more technology pay greater attention to the technological aspects of medicine that takes away from devoting attention to the interpersonal aspects of meeting family member needs.[63] In any event, the findings indicate the difficulty that high technology medical care has in balancing the growing technological demands of patient care with the need to be more responsive to patients' and family members' concerns and anxieties.

We also explored two additional interaction possibilities: namely the possibility that where technological availability was lower, caregiver interaction might be more important; and, secondly, where diagnostic diversity was greater, caregiver interaction might be more important. Neither of the interaction terms, however, were significant.

Taken as a whole, the results suggest partial support for all study hypotheses. A key result, however, is that different factors appear to be associated with different aspects of performance. Clearly, technological availability and diagnostic diversity are the strongest correlates of risk-adjusted mortality. In contrast, managerial process variables related to the quality of caregiver interaction is the strongest correlate of unit efficiency, evaluated technical quality of care, the ability to meet family member needs, and nursing turnover.

ICUs now have the capability to risk adjust their outcomes for purposes of internal and external comparison.[40] This information can be used to meet the external accountability requirements of regulators and payers of care and, perhaps, more importantly, to meet the desires for continuous internal quality improvement.[60–62,64] Although this study was limited to 42 intensive care units and was unable to address issues of possible seasonality in the conditions treated, it nonetheless represents the largest study of ICUs undertaken to date. Using refined adjustments for differences in patient characteristics, physiology, and severity, taking into account differences in technology, and using a multiple indicator approach to performance, the study establishes important relationships between caregiver management processes and outcomes of care. Further verification and extension of these findings will provide a basis for ICUs to monitor their performance similar to the way in which individual patients are now monitored. When such monitoring detects less than optimal or desired performance, examining both technological and organizational/managerial practices associated with the effectiveness of caregiver interaction will provide clinicians with a starting point for corrective action and ongoing improvement.

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Appendix A. The Apache III Variables

Acute Physiology Abnormalities (Most abnormal within initial 24 hours)	
Pulse rate	0–17
Mean blood pressure	0–23
Temperature	0–20
Respiratory rate	0–18
PaO2/AADO2	0–15
Hematocrit	0–3
White blood count	0–19
Creatinine	0–10
Urine output	0–15
Blood urea nitrogen	0–12
Sodium	0–4
Albumin	0–11
Bilirubin	0–16
Glucose	0–9
Acid-base	0–19
Neurologic	0–41

Total APACHE III Score Theoretical Range = 0–252

Age Points		Comorbid Condition Points[a]	
≤44	0	AIDS	23
45–59	5	Hepatic failure	19
60–64	11	Lymphoma	19
65–69	13	Metastatic cancer	14
70–74	16	Leukemia/multiple myeloma	10
75–84	17	Immune suppression	10
≥85	24	Cirrhosis	4

Source: W.A. Knaus, D.P. Wagner, E.A. Draper, et al. The APACHE III Prognostic System Risk Prediction of Hospital Mortality for Critically Ill Hospitalized Adults., Chest 1991; 100: 1619.

[a] [Excluded for *elective* surgery patients]

Appendix B. Technological Availability

Services and Equipment Available in Over 95% of ICUs

- Electrocardiograph
- Intra-arterial pressure
- Pulmonary artery catheter
- Cardiac pacemaker (external)
- Transvenous pacer wire
- Defibrillator
- Resuscitation cart
- Intubation equipment
- Mechanical ventilator
- Continuous positive airway
- Pressure apparatus
- 24 hour radiologic services
- Chest/abdominal x-ray
- Computerized tomography 24 hours/day
- Infusion pumps
- Pulse oximeter
- Sengstaken-Blakemore tube
- Nutritional support services
- Isolation beds
- Peritoneal dialysis
- Positive end expiratory pressure
- Capable manual ventilation device

Services and Equipment Available in Less Than 95% of ICUs (% of ICUs)

- Cardiac pacemaker-AV sequential (90%)
- Portable electrograph and pressure monitor (88%)
- Ultrasound 24 hours/day (85%)
- Nuclear medicine 24 hours/day (85%)
- Hemodialysis (83%)
- Intracranial pressure monitor (80%)
- Ventriculostomy (77%)
- Plasmapheresis (75%)
- Continuous arterial-venous hemofiltration (68%)
- Fluoroscopy (68%)
- End Tidal CO_2 monitor (67%)
- Intra-arterial vasopressin infusion (58%)
- Portable ventilator (50%)
- Intra-aortic balloon pump (50%)
- Pulmonary artery catheter with continuous SVO_2 (43%)
- In unit blood gas testing (38%)
- In unit blood chemistry testing (28%)
- In unit hematologic testing (15%)
- In unit "Stat Lab" (8%)