Patient Characteristics and ICU Organizational Factors That Influence Frequency of Pulmonary Artery Catheterization

John Rapoport, PhD
Daniel Teres, MD
Jay Steingrub, MD
Thomas Higgins, MD
William McGee, MD
Stanley Lemeshow, PhD

Context Hemodynamic monitoring of patients with a pulmonary artery catheter is controversial because there are few data confirming its effectiveness, and patient and intensive care unit (ICU) organizational factors associated with its use are unknown.

Objective To determine pulmonary artery catheter use in relationship to type of ICU organization and staffing, and patient characteristics, including severity of illness and insurance coverage.

Design, Setting, and Patients Retrospective database study of 10 217 nonoperative patients who received treatment at 34 medical, mixed medical and surgical, and surgical ICUs at 27 hospitals during 1998 (patients were enrolled in Project IMPACT).

Main Outcome Measures Pulmonary artery catheter use based on severity of illness measured by the Simplified Acute Physiology Score, resuscitation status at ICU admission, and ICU organizational variables, including type, size, and model.

Results A pulmonary artery catheter was used for 831 patients (8.1%) in the ICU. In multivariate analysis adjusted for severity of illness, age, diagnosis, and do-not-resuscitate status, full-time ICU physician staffing was associated with a two-thirds reduction in the probability of catheter use (odds ratio [OR], 0.36; 95% confidence interval [CI], 0.28-0.45). Higher catheter use was associated with white race (OR, 1.38; 95% CI, 1.10-1.72) and private insurance coverage (OR, 1.33; 95% CI, 1.10-1.60). Admission to a surgical ICU was associated with a 2-fold increase in probability of catheter use (OR, 2.17; 95% CI, 1.70-2.76) compared with either medical or mixed medical and surgical ICUs.

Conclusion Organizational characteristics of ICUs, insurance reimbursement, and race, as well as clinical variables, are associated with variation in practice patterns regarding pulmonary artery catheter use. Understanding such influences, combined with studies measuring clinical and economic outcomes, can contribute to the development of policies for the rational use of pulmonary artery catheters.

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Use of a particular technology in practice can have major clinical and economic implications. This article examines associations between clinical and demographic characteristics, organizational aspects of practice setting, type of reimbursement, and physician decisions to monitor intensive care unit (ICU) patients with the pulmonary artery catheter (PAC). Introduced in the early 1970s, PAC monitoring in the ICU increased quickly, despite the fact that its effectiveness has never been demonstrated convincingly in a sufficiently powered randomized controlled trial.[1] Several studies have examined the effectiveness of the PAC in specific patient groups, with variable findings.[2-4] A recent study based on a large sample of ICU patients showed that patients with a PAC had higher-than-predicted mortality, as well as higher costs and length of stay compared with patients who were not monitored with a catheter.[5] The question of what is appropriate use of this technology has been considered in several consensus conferences.[6,7]

See also pp 2568 and 2577.

A survey conducted by Groeger and colleagues[8] showed substantial variations in the staffing, administration, and organization of ICUs in the United States. Of 2876 ICUs in 1706 US hospitals, approximately 50% were directed by board-certified ICU physicians. Many critical care services are

Author Affiliations: Department of Economics, Mount Holyoke College, South Hadley, Mass (Dr Rapoport); Center for Health Services Research (Dr Teres), Departments of Medicine and Surgery (Drs Teres, Steingrub, Higgins, and McGee) and Anesthesia (Dr Higgins), Baystate Medical Center, Springfield, Mass; Tufts University School of Medicine, Boston, Mass (Drs Teres, Steingrub, Higgins, and McGee); and the Biostatistics Program, Ohio State University, Columbus (Dr Lemeshow).
Corresponding Author: John Rapoport, PhD, Mount Holyoke College, 50 College St, South Hadley, MA 01075 (e-mail: rapoport@mtholyoke.edu).
Reprints: Daniel Teres, MD, Primary Care Outcomes Research Institute, Tufts University School of Medicine, 750 Washington St, PO Box 345, Boston, MA 02111.

delivered in nonteaching hospitals.[8] The organization of a critical care service impacts outcomes and resource utilization in various hospital settings and patient groups.[9-19] In a recent study of abdominal aortic surgery patients, Pronovost et al[20] found that patients followed up in ICUs with daily rounds by ICU physicians had lower mortality and length of stay than patients treated in ICUs without full-time ICU physicians.[21] While PAC use is not itself an outcome or cost measure, it may be related to both and may serve as a marker of a unit's technological aggressiveness of care.

This study documents the use of the PAC in the whole range of nonoperative diagnoses in a large database of adult ICU patients in the United States in 1998. It tests the hypothesis that the type of ICU organization and staffing affects the extent to which this technology is used. It also models the association between catheter use and severity of illness, patient age, race, and insurance coverage.

METHODS

Data for nonoperative patients treated in 34 ICUs at 27 hospitals during 1998 were obtained from Project IMPACT, the critical care data system sponsored by the Society of Critical Care Medicine. Data are submitted quarterly, or more frequently if the ICU wishes, either for all patients admitted or for a random sample of at least 50% of all patients admitted. Data collectors were supplied with detailed operational definitions, clinical support for questions, and training. Data on ICU organizational and staffing characteristics were provided by each ICU. An independent study[22] to assess the validity of Project IMPACT data found good agreement between the database and patient charts for the majority of important variables. Project IMPACT data were provided to us without identifying individual hospitals. A nonoperative patient in the database was considered to be one who had no surgery within 1 week prior to ICU admission.

The following characteristics of the ICU and hospital were determined from information reported to Project IMPACT: type of ICU (medical, mixed medical and surgical, or surgical), presence of residency and critical care fellowship programs, number of staffed operational beds in the ICU, and medical care team model. The latter variable had 6 descriptions of the involvement of critical care physicians in the care of ICU patients: (1) no policy, (2) no ICU-credentialed physicians, (3) full-time ICU physicians who directed patient care, (4) full-time ICU physicians who consulted on all admissions, (5) full-time ICU physicians who consulted when requested, and (6) part-time ICU physicians who consulted when requested. In this study we characterized units with choices 3 or 4 as having full-time ICU physicians for all patients.

Project IMPACT patient demographic information includes sex, race, and age. For this study, Hispanic and Asian patients were coded as nonwhite. Primary diagnosis at ICU admission was recorded using trauma as 1 category and numerous categories for nontrauma patients, based on the body system affected. Severity of illness was measured by the Simplified Acute Physiology Score (SAPS II) probability of survival, which is based on the patient's condition during the first 24 hours of the ICU stay.[23] The SAPS II model was recalibrated to fit this study's data by customizing on the logit.[24] The database included up to 3 of the following sources of payment for each patient: Medicare, Medicaid, private insurance, managed care plan, self, and other. Resuscitation status at ICU admission indicated whether a preference for do-not-resuscitate (DNR) orders or limited intervention had been recorded. It is not known for DNR patients whether this designation was determined during the pre-ICU hospital stay, at hospital admission, or prior to hospital admission. Insertion of a PAC was established when 1 of 7 possible PAC codes was entered as an ICU procedure. Patients who had surgery within 1 week prior to ICU admission were excluded, because placement of the catheter could have been initiated by the operating room team rather than by the ICU team.

Initial analysis involved determination of the percentage of patients who were treated using a PAC in selected diagnostic categories and each type and size of ICU, medical care team model, medical teaching category, resuscitation status, and payer category. Percentage of patients using a PAC was also computed for each decile of SAPS II probability and for 5 age strata. Within each age stratum, differences in PAC use between white and nonwhite males, between white and nonwhite females, between white males and white females, and between nonwhite males and nonwhite females were analyzed. Association between categorical variables and PAC use was tested using the Pearson χ^2 test.

Within each of the 7 diagnosis categories with a total of more than 200 patients and catheter use of at least 4%, variation among ICUs in the percentage of patients for whom a catheter was used was determined. Logistic regression was used to test the significance of the effect of patient characteristics and unit organizational characteristics in a predictive model for the probability of PAC use in the major diagnostic categories. Basic clinical patient characteristics included as independent variables were survival probability (SAPS II), age, and resuscitation status. Other patient variables were race, sex, and payer. Intensive care unit organizational variables included for analysis were medical care team model, medical teaching category, type of ICU, and ICU size. Payer was entered with a dummy variable designating patients who had private insurance as either the only payer or in combination with Medicare. Type of unit was included as a dummy variable distinguishing surgical from mixed medical and surgical or medical ICUs. The continuous variables, age and SAPS II probability, were included with both a linear and a quadratic specification. Two likelihood ratio tests were conducted in each diagnosis group. The first compared the full model to a model omitting the patient characteristics of race, sex, and private insurance coverage. The second compared the full model to a model omitting the organizational characteristics: medical care team model, medical teaching category, type of ICU, and size of ICU.

For the full data set, a logistic regression model was developed to estimate the probability of catheter use based on patient characteristics, ICU organizational characteristics, and diagnostic category. Discrimination of the model was assessed using the area under the receiver operating characteristic curve,[25] and calibration was assessed with the Hosmer-Lemeshow goodness-of-fit statistic.[26] Patients with missing data were omitted in multivariate analysis.

RESULTS

The total number of patients included in the analysis is 10217, although in some tables the totals are less because of missing data (3021 patients did not have SAPS II probability available since this severity measure is not applicable for all patient groups[23]; the number of patients with SAPS II survival probability available was 7196). A PAC was used in the care of 831 patients (8.1%).

Use of the PAC was associated with race, payer, resuscitation status, and age ($P \leq .001$) (TABLE 1). Association with sex was not significant ($P = .32$). Patients with private insurance (either alone or in combination with Medicare) had a higher percentage of PAC use than other patients; patients with Medicare and no private insurance had a slightly higher rate of PAC use than patients without either Medicare or private insurance. The percentage of patients with a PAC declined from about 25% in patients with lowest probability of survival to about 2% in patients with the highest probability of survival. Use of the PAC increased with patient age. The percentage of patients with a DNR order at ICU admission monitored with a PAC was much smaller than that for patients who did not have DNR orders at ICU admission.

Table 1. Pulmonary Artery Catheter Use and Patient Characteristics*

Patient Characteristics	No. of Patients	No. (%) Receiving PAC	*P* Value (χ^2 Test)
	(N = 10217)		
Race			
White	7351	674 (9.2)	<.001
Nonwhite	2785	156 (5.6)	
Sex			
Male	5647	473 (8.4)	.32
Female	4569	358 (7.8)	
Payer			
Medicare as only payer	1970	188 (9.5)	<.001
Medicaid as only payer	758	51 (6.7)	
Private insurer as only payer	1335	156 (11.7)	
Managed care as only payer	1283	84 (6.5)	
Self as only payer	1504	80 (5.3)	
Other as only payer	220	7 (3.2)	
Medicare/Medicaid as only 2 payers	573	40 (7.0)	
Medicare/private insurer as only 2 payers	1302	145 (11.1)	
Medicare/managed care as only 2 payers	269	27 (10.0)	
Other combination of 2 payers	605	32 (5.3)	
3 Payers	398	21 (5.3)	
Resuscitation status at ICU admission			
Full code	9577	790 (8.2)	.001
No CPR/DNR	424	16 (3.8)	
Limited intervention	214	25 (11.7)	
Probability of survival (based on SAPS II)			
<0.27	709	180 (25.4)	<.001
0.271-0.50	679	138 (20.3)	
0.51-0.67	770	117 (15.2)	
0.675-0.775	618	72 (11.7)	
0.776-0.845	735	63 (8.6)	
0.846-0.905	828	49 (5.9)	
0.906-0.935	684	32 (4.7)	
0.936-0.955	655	22 (3.4)	
0.956-0.975	661	21 (3.2)	
>0.975	857	14 (1.6)	
Age, y			
<45	2705	144 (5.3)	<.001
45-59	2174	171 (7.9)	
60-69	1835	173 (9.4)	
70-79	2103	197 (9.4)	
≥80	1400	146 (10.4)	

*PAC indicates pulmonary artery catheter; ICU, intensive care unit; CPR, cardiopulmonary resuscitation; DNR, do not resuscitate; and SAPS II, Simplified Acute Physiology Score.[23] Total patients receiving PAC for race category does not equal 831 because data on race were missing for 1 patient.

Characteristics of the 34 ICUs are summarized in TABLE 2. About 48% of the patients were treated in 15 mixed medical and surgical ICUs, with about 33% of patients treated in medical ICUs and 19% in surgical ICUs. Fourteen ICUs required a full-time ICU physician to consult on or direct care for all patients admitted. ICU size ranged from 8 to 28 beds. Most of the 27 hospitals (23) were private and not-for-profit, 3 were city/county hospitals, and 1 was a Veterans Affairs hospital.

Patients treated in surgical ICUs were more likely to be treated with a PAC than those treated in either medical or mixed medical and surgical ICUs. Catheter use frequency was associated with increased ICU size. In the largest group, ICUs with 20 or more beds, 14.2% of patients in medical and mixed medical and surgical ICUs were treated with

Table 2. Pulmonary Artery Catheter Use and ICU Characteristics*

ICU Characteristics	No. of ICUs (n = 34)	No. of Patients	No. (%) Receiving PAC	*P* Value (χ^2 Test)
Type				
Medical	9	3354	239 (7.1)	<.001
Mixed	15	4934	353 (7.2)	
Surgical	10	1929	239 (12.4)	
Size†				
Medical/mixed				
≤12 beds	7	2489	104 (4.2)	<.001
13-19 beds	10	3981	291 (7.3)	
≥20 beds	5	1259	179 (14.2)	
Surgical				
≤12 beds	3	179	13 (7.3)	.08
13-19 beds	6	1724	222 (12.9)	
≥20 beds	1	26	4 (15.4)	
Medical team model				
Medical/mixed				
Full-time ICU physician must consult	9	3008	231 (7.7)	.15
No requirement for full-time ICU physician	15	5280	361 (6.8)	
Surgical ICU				
Full-time ICU physician must consult	5	782	41 (5.2)	<.001
No requirement for full-time ICU physician	5	1147	198 (17.3)	
Medical teaching activity				
Medical/mixed				
No house staff	3	952	32 (3.4)	<.001
Residents only	11	3885	239 (6.2)	
Critical care fellows	9	3451	321 (9.3)	
Surgical				
No house staff	1	110	7 (6.4)	.08
Residents only	3	773	91 (11.8)	
Critical care fellows	6	1046	141 (13.5)	

*PAC indicates pulmonary artery catheter; ICU, intensive care unit; CPR, cardiopulmonary resuscitation; DNR, do not resuscitate; and SAPS II, Simplified Acute Physiology Score.[23] Total patients receiving PAC for race category does not equal 831 because data on race were missing for 1 patient.
†One hospital reported 2 ICUs combined as 1, so ICU size here is not meaningful and that ICU is omitted.

catheters (15.4% in surgical ICUs), while in the medical and mixed medical and surgical ICUs with 12 or fewer beds, the percentage was only 4.2% (7.3% in surgical ICUs). Surgical units in which a full-time ICU physician directed care or was a required consultant on all patients used the PAC less than surgical units with no such policy; for medical and mixed medical and surgical units, the difference was not significant. Units with critical care fellows used catheters more than units with only residents or those with no house staff.

The frequency of PAC use was greater for white men than for nonwhite men and for white women than for nonwhite women. Such differences were noted consistently for all age groups but were most pronounced for younger (<59 years) and older (>80 years) patient groups. They were statistically significant ($P<.05$) only in the 2 youngest age groups. In patients younger than 45 years, 6.4% of white men, compared with 2.5% of nonwhite men, were treated with a PAC ($P<.001$); in the 45- to 59-year-old age group, 9.8% of white men received a catheter, compared with 5.7% of nonwhite men ($P=.02$). There was no consistent pattern of differential use between men and women. In some comparisons between men and women of the same age and race, men had greater usage, while in other cases, the rate of use was higher in women.

PAC use by primary diagnosis at ICU admission is shown in TABLE 3. More than three fourths of patients in the study had 1 of 5 primary diagnoses at ICU admission: cardiac diagnosis (2267 patients, 6.2% with catheter), respiratory diagnosis (2097, 9.9%), trauma (1242, 8.5%), neurologic diagnosis (1246, 4.3%), and bleeding (858, 3.0%). Specific diagnostic subgroups with particularly high PAC use included septic shock (25.1%), acute pancreatitis (31.7%), subarachnoid hemorrhage (nontrauma) (18.4%), and sepsis/systemic inflammatory response syndrome (18.3%).

FIGURE 1 shows variation among ICUs in PAC use within major diagnosis groups, using box plots based on data for ICUs with at least 10 cases in the diagnosis group. Median use ranged from none in the neurologic group to 39% in shock patients. The ICU with the lowest use in each diagnostic group did not use the catheter at all, while the largest percentage of patients catheterized by an ICU ranged from 26% of trauma patients to 76% of vascular disease patients. Based on the 75th percentile, shock and infection patients had the highest frequency of PAC use.

Regression Results for Diagnostic Groups

Only in patients admitted with shock was PAC use unaffected by race, sex, type of insurance, or ICU organization. The likelihood ratio tests comparing logistic regression models that predict PAC use indicated in all but the shock group that race, sex, and private insurance coverage jointly, and/or the ICU organizational variables jointly, had a significant effect when included in a model with the other variables. The medical care team model (ie, full-time ICU physician) dummy variable had an odds ratio (OR) of less than 0.4 and was significant ($P<.01$) in all diagnostic groups except shock ($P=.12$) and respiratory diagnosis (OR, 0.7; $P=.11$).

Regression Results for the Entire Sample

The logistic regression model using the entire data set discriminated well between patients who were managed with the catheter and those who were not (area under receiver operating characteristic curve=0.80). The Hosmer-Lemeshow goodness-of-fit test showed that the model fit the data well (*P* for χ^2 test=.25). The coefficients of all the patient and organizational variables were statistically significant (*P*<.05) except for the sex variable (*P*=.81). Odds ratios for the independent variables (except for severity and age, which were entered in both linear and quadratic form) are presented in TABLE 4. White patients were about 38% more likely to be treated with a catheter than were nonwhite patients, patients who had DNR orders were only about 25% as likely to be treated with a catheter as were patients with no DNR order, and patients with private insurance had a 33% higher probability of catheter use than did patients with other insurance. Patients treated in a surgical ICU were more than twice as likely to get a catheter as patients treated in nonsurgical ICUs. An increase of 1 bed in ICU size was associated with a 4% rise in probability of catheter use. The probability of catheter use for a patient in an ICU with full-time ICU physicians was about ⅓ that for a patient in other ICUs. Finally, the probability of catheter use in ICUs with residents (and no fellows) was about twice as large as that in ICUs with no house staff, and the probability of catheter use in ICUs with critical care fellows was almost 5 times that for ICUs with no house staff.

For the survival probability and age variables, the coefficients of both the linear and quadratic terms were highly significant (*P*<.005 in all cases). The curvilinear relationships implied by these coefficients are demonstrated in FIGURE 2 and FIGURE 3, which also show the effect of staffing with full-time ICU physicians. The peak probability of catheter use implied by the model occurs at a survival probability of about 32% (Figure 2) and at an age of about 52 years (Figure 3).

COMMENT

The primary finding of this study is that the great variability in PAC use in the 34 ICUs examined can be explained in part by ICU organizational character-

Table 3. Pulmonary Artery Catheter Use by Primary Diagnosis at ICU Admission*

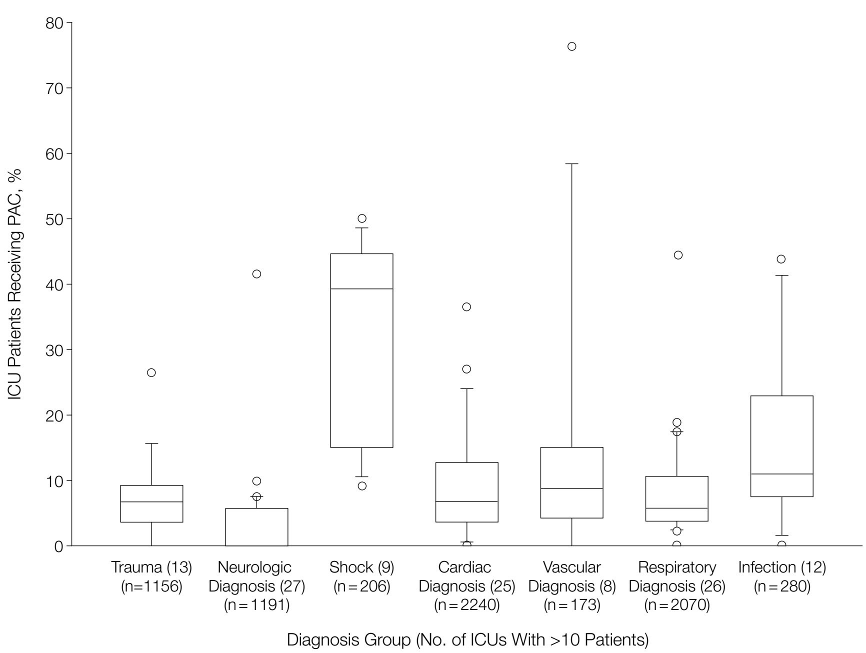
Primary Diagnosis	No. of Patients	No. (%) Receiving PAC
Trauma (all)	1242	106 (8.5)
Cerebral concussion	180	20 (11.1)
Intracerebral/intraventricular hemorrhage	72	9 (12.5)
Subarachnoid hemorrhage	82	9 (11.0)
Cerebral laceration, contusion	140	8 (5.7)
Subdural hematoma	104	7 (6.7)
Spinal cord injury, cervical level	56	4 (7.1)
Nontrauma		
Neurologic (all)	1246	54 (4.3)
Subarachnoid hemorrhage	136	25 (18.4)
Intracerebral/intraventricular hemorrhage	296	13 (4.4)
Stroke/CVA without paralysis	70	0 (0)
Stroke/CVA with paralysis	121	1 (0.8)
Seizure disorder	151	2 (1.3)
Shock (all)	289	83 (28.7)
Septic shock	175	44 (25.1)
Infectious/inflammatory disorders (all)	341	58 (17.0)
Sepsis/systemic inflammatory response syndrome	251	46 (18.3)
Cardiac (all)	2267	141 (6.2)
AMI	783	48 (6.1)
Angina/ischemia/injury without MI	502	12 (2.4)
Atrial dysrhythmia	111	3 (2.7)
Cardiac/respiratory arrest requiring CPR—time not defined	106	12 (11.3)
Cardiac arrest <24 h prior to ICU admission	169	23 (13.6)
Congestive heart failure without pulmonary edema	203	21 (10.3)
Hypertension, acute, malignant requiring IV medication	80	1 (1.3)
Vascular (all)	242	40 (16.5)
Arterial embolism/thrombosis	52	8 (15.4)
Respiratory (all)	2097	207 (9.9)
Airway obstruction (not caused by tumor or abscess)	84	3 (3.6)
Asthma, acute wheezing	128	0 (0)
Status asthmaticus	66	0 (0)
Pneumonia—bacterial	230	31 (13.5)
Pneumonia—unclear/organism not specified	262	24 (9.2)
Pulmonary embolism	70	4 (5.7)
CHF with pulmonary edema	237	34 (14.3)
ARDS	107	19 (17.8)
Gastrointestinal (all)	163	28 (17.2)
Hepatobiliary/pancreatic disorders (all)	155	33 (21.3)
Acute pancreatitis	60	19 (31.7)
Renal/genitourinary system disorders (all)	151	17 (11.3)
Acute oliguric renal failure	59	8 (13.6)
Endocrine and metabolic (all)	422	12 (2.8)
Diabetic ketoacidosis	212	5 (2.4)
Hematologic disorders (all)	68	5 (7.4)
Neoplastic disorders (all)	146	8 (5.5)
Neoplasm—central nervous system	66	0 (0)
Poisoning/overdose (all)	420	4 (1.0)
Antidepressant	84	0 (0)
Bleeding and hemorrhagic disorders (all)	858	26 (3.0)
Esophageal or gastric varices	79	4 (5.1)
Upper GI	505	11 (2.2)
Lower GI	207	8 (3.9)
Other	110	9 (8.2)

*Subcategories listed only if No. of patients >50. ICU indicates intensive care unit; PAC, pulmonary artery catheter; CVA, cerebrovascular accident; AMI, acute myocardial infarction; MI, myocardial infarction; CPR, cardiopulmonary resuscitation; IV, intravenous; CHF, congestive heart failure; ARDS, acute respiratory distress syndrome; and GI, gastrointestinal.

istics. Indications for insertion of a PAC vary considerably, from relatively strict criteria for patients with refractory hypoxemia, persistent hypotension or shock despite resuscitation, or hemodynamic instability with renal and/or cardiac involvement to looser guidelines for monitoring or assessing volume status during early or late resuscitation, multiorgan dysfunction, and diagnosis of patients with congestive heart failure. Pulmonary artery catheterization is considered to be useful in the management of cardiogenic shock or mechanical complications, in trauma patients, and in patients with respiratory failure, although the evidence supporting these indications includes primarily nonrandomized studies, studies with historical controls, and expert opinion.[6] It is not surprising that catheter use was greater in patients who appeared most ill; we observed higher utilization in shock, trauma, and vascular patients and lower use in patients with neurologic and other diagnoses.

Intensive care units that differ in the distribution of patients among diagnoses and in average level of severity would be expected to differ in PAC use. However, diagnosis, severity of illness, and patient age only partly explain the observed differences in probability of PAC use in this database. Factors such as ICU organizational characteristics, race, and payer provide additional explanations. These factors are more important for some diagnoses than for others. For diagnoses in which the clinical indications for catheter use are more controversial, these nonclinical factors may be more likely to come into play. The association of race, sex, insurance, and ICU organizational variables with catheter use was absent for shock patients in this study. Management of shock based on hemodynamic subsets of PAC data is an integral part of residency training in ICUs, and agreement among clinicians on how to interpret hemodynamic data for these patients may be higher than for other conditions.

Figure 1. Percentage of ICU Patients Receiving PAC



Box plot of intensive care unit (ICU) percentage of patients receiving pulmonary artery catheterization (PAC) for ICUs with at least 10 patients in the diagnostic group, for major diagnostic groups with 200 or more patients and PAC use of at least 4%. The median value is indicated by the central horizontal line; the lower and upper quartiles, by the corresponding ends of the box; the 10th and 90th percentiles, by the bars; and circles show individual outliers.

Patients treated in units with full-time ICU physicians were only about 36% as likely to be monitored with a catheter as were similar patients in units staffed in other ways. This effect was most apparent for trauma, neurologic, and vascular patients. In other patient groups with greater catheter use (shock, infection), full-time ICU physicians used the catheter slightly more frequently. We speculate that indications for PAC use in shock and sepsis may be more uniform than for other diagnoses, leading to less variability in the decision to place a catheter for these diagnoses. For other diagnoses, in which the indications for catheter use were less clear or compelling, experienced clinicians may have justified managing patients without the aid of a catheter.

Studies of the impact of staffing models on critical care generally have focused on outcomes, not on the use of specific technologies. However, 1 study in the early 1980s[10] found that a change to full-time ICU physician staffing resulted in an increase in the use of PACs. This is in contrast to our finding that the presence of full-time ICU physicians was associated with lower probability of catheter use. The difference may be explained by the state of knowledge about the effects of PAC use between 1979-1981 vs our data from 1998. Early reports of this relatively new technology were mostly favorable.[27,28] By 1998, a number of reports critical of the catheter had appeared.[5,29-35] Our findings raise the possibility that ICUs with full-time ICU physicians react more quickly to findings in the literature, suggesting moderation in the use of a controversial technology.

Other studies on staffing models have suggested an advantage of full-time intensivists.[9-19] The large observational study by Pronovost et al[20] of postoperative aortic aneurysm surgery patients involved 46 ICUs in Maryland and a large sample of patients with this single procedure. Using a complex, multitiered analysis, there were decreased mortality and lower medical complications with full-time ICU directors, daily rounds by an intensivist, and comprehensive nurse staffing in the evening. Because teaching hospitals' mission goes beyond patient care to include education and research, it is possible that the increased probability of a patient being monitored with a PAC in those hospitals reflects these additional responsibilities. Teaching and research on data generated by use of the PAC may explain increased utilization in teaching hospitals.[36] The effect of an educational mandate is quite large, with the probability of PAC use in a hospital with critical care fellows being almost 5 times as great as for a similar patient in a nonteaching hospital.

Providers of ICU services may benefit economically from use of a particular medical technology. The influence of economic incentives is suggested by the finding that patients with private insurance were about 30% more likely to be monitored with a catheter than were similar patients who did not have private insurance. The economic impact of catheter use on the hospital will depend on the specific payment contract under which the hospital is reimbursed. Catheter use will certainly increase costs: both directly, because of labor and material costs associated with catheter placement and care, and indirectly if catheter use is associated with longer duration of stay.[5] If the hospital is paid under the diagnosis related group or a similar system, there will be no additional revenue derived from catheter use. However, if the hospital payment system is charges-based, catheter use may generate added revenue. The economic incentives for physicians may depend on how they are paid. Salaried physicians will not benefit financially in a direct way from more catheter use, while fee-for-service billing will generate income from a decision to use a catheter. From our data, it is not possible to trace in detail the links between economic incentives and decision making for the PAC.

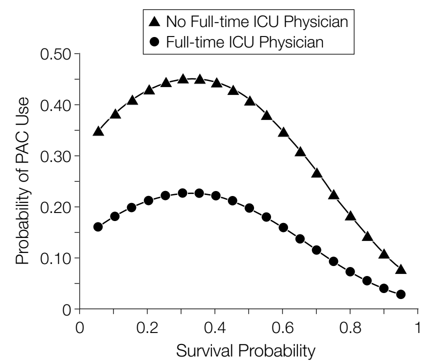
Although this study demonstrated no significant sex difference in the frequency of PAC use, we found that socioeconomic factors were associated with whether patients received a PAC. White patients, especially relatively younger white patients, were more likely than similar nonwhite patients to be monitored with a PAC. While this may

Table 4. Logistic Regression Results (n = 6937)*

Variable	Coefficient	Wald Statistic (z)	*P* Value for z	Odds Ratio (95% CI)
Patient characteristics				
SAPS II survival probability	3.71	5.28	<.001	NA
SAPS II survival probability squared	−5.73	−9.21	<.001	NA
Age	0.049	3.27	.001	NA
Age squared	−0.00048	−3.65	<.001	NA
Do not resuscitate	−1.39	−4.09	<.001	0.25 (0.13-0.49)
White race	0.32	2.81	.005	1.38 (1.10-1.72)
Private insurance	0.28	2.92	.004	1.33 (1.10-1.60)
Male sex	0.02	0.25	.81	1.02 (0.86-1.22)
ICU organizational characteristics				
Surgical unit	0.77	6.28	<.001	2.17 (1.70-2.76)
ICU size (beds)	0.04	2.95	.003	1.04 (1.01-1.07)
Full-time ICU physician	−1.04	−8.27	<.001	0.36 (0.28-0.45)
Residents	0.77	2.76	.005	2.16 (1.25-3.74)
Critical care fellows	1.57	5.36	<.001	4.79 (2.70-8.50)
Diagnostic categories				
Trauma	−0.46	−2.56	.01	0.63 (0.44-0.90)
Neurologic	−1.1	−5.77	<.001	0.33 (0.23-0.48)
Shock	1.06	5.81	<.001	2.89 (2.02-4.13)
Cardiac	−0.079	−0.48	.63	0.92 (0.67-1.28)
Vascular	1.17	5.09	<.001	3.24 (2.06-5.09)
Respiratory	0.097	0.74	.46	1.10 (0.85-1.42)
Infection	0.81	4.11	<.001	2.24 (1.52-3.29)
Intercept	−4.54	−7.92	<.001	NA

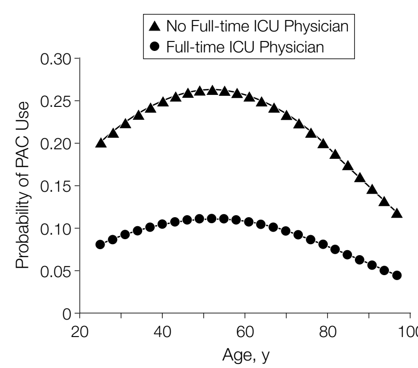
*Logistic regression results are based on the entire sample. The dependent variable is pulmonary artery catheter use. SAPS II indicates Simplified Acute Physiology Score[23]; CI, confidence interval; ICU, intensive care unit; and NA, not applicable. *P*<.001 for likelihood ratio test comparing full model vs model with only probability of survival, age, DNR status, and diagnosis.

Figure 2. Probability of PAC, Survival Probability, and Presence of Full-time ICU Physician



Relationship implied by logistic regression model among survival probability (based on Simplified Acute Physiology Score[23]), presence of full-time intensive care unit (ICU) physicians, and probability of pulmonary artery catheter (PAC) use. Assumes the following patient and ICU characteristics: 60-year-old white male, no do-not-resuscitate orders, private insurance, neurologic diagnosis, 16-bed surgical ICU with critical care fellows.

Figure 3. Probability of PAC, Patient Age, and Presence of Full-time ICU Physician



Relationship implied by logistic regression model among patient age, presence of full-time intensive care unit (ICU) physicians, and probability of pulmonary artery catheter (PAC) use. Assumes the following patient and ICU characteristics: white male, no do-not-resuscitate orders, private insurance, respiratory diagnosis, 16-bed nonsurgical ICU with critical care fellows, survival probability = 0.8.

represent the effect of suboptimally measured illness severity, some other clinically important variable associated with race, or the willingness to consent to an invasive procedure, we cannot exclude the possibility of racial discrimination. Similar findings for race but not sex have been reported about physician recommendations for cardiac catheterization.[37] Additional study with a large database and controlling for other confounding variables is needed to examine whether patients with lower socioeconomic status receive less technologically advanced care.

We chose to study nonoperative patients to better observe the result of decisions made in the ICU rather than by operating room staff. It is possible that our study design was only partially successful in doing so. Patients in surgical ICUs who are classified as nonoperative by the Project IMPACT definition might include trauma patients who never have surgery, patients who have surgery and experience a late complication, and patients who come to the ICU to be stabilized before surgery. Some patients in our data set may have been admitted to the ICU as nonoperative patients, left the ICU for surgery, and returned with a catheter. If this happened more often for patients in surgical ICUs than for those in nonsurgical ICUs, our finding regarding the higher probability of catheter use in surgical ICUs may reflect decisions made in the operating room rather than in the ICU. However, the higher probability of catheter use in surgical units may also represent a different practice style and orientation toward the use of invasive technology. The increase in catheter use with larger ICU size may be due to more complex and seriously ill patients not fully reflected in our severity measure.

This study has a number of limitations. First, the Project IMPACT group of ICUs is a self-selected, nonrepresentative sample of ICUs; how they differ from the larger national population of ICUs is unknown. It is likely that the Project IMPACT group includes more large teaching hospitals than would a random sample. It may be that a decision to join Project IMPACT indicates a particular interest in quantitative data. If this data-driven culture affects clinical choices, it could make these ICUs particularly inclined to use a monitoring technology.

Second, our data do not indicate when during the ICU stay the catheter was inserted or what the indications were for it. One implication of this was noted above, ie, that our nonoperative patients may have in fact undergone operations after the start of the ICU stay and catheter placement may have occurred during that operation.

Third, our diagnosis variable was at ICU admission, and the SAPS II survival probability is derived from data during the first 24 hours of the ICU stay, whereas the PAC may have been inserted at any time during the ICU stay. Thus, the severity and diagnosis variables used may mischaracterize patients compared with measures determined at the time of catheter placement.

Fourth, our ICU organizational variables are only a few, simplified measures of a complex structure.[38] The major organizational variable, the presence of full-time ICU physicians directing care or consulting on all admissions, does not describe how practice is actually conducted.[39] Many aspects of ICU organization, such as nurse-patient ratios, regular mortality and morbidity review policies, and use of physician and nurse extenders are not considered but also might be associated with PAC utilization.[40-42]

The findings of this study suggest that the use of an invasive monitoring technology in ICUs varies considerably among patients. Some of the variation is systematically associated with factors unrelated to clinical considerations, such as ICU organization, economic incentives, and insurance coverage. Intensive care units with full-time ICU physicians appear more conservative in the use of the PAC. These data cannot be generalized to technology use in general, because the same physicians may be aggressive users of other technologies.[43] However, specialized ICU physicians might be associated with moderation of the technological imperative for patients in whom a technology's effectiveness is unproved and its use discretionary. This analysis provides a utilization review of PACs and their determinants, identifying questions for future research about this classic ICU technology.

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