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Understanding changes in established practice: pulmonary artery catheter use in critically ill patients

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Abstract

Objective—Multiple studies suggest that routine use of pulmonary artery catheters (PACs) is not beneficial in critically ill patients. Little is known about the patterns of “uptake” of practice change that involves removal of a device previously considered standard of care, rather than adoption of a new technique or technology. Our objective was to assess recent PAC use across intensive care units (ICUs) and identify factors associated with high use.

Design—Cohort study

Setting—U.S. ICUs in Project IMPACT

Patients—Adult ICU admissions from 2001-8

Interventions—None

Measurements and Main Results—Trends in PAC use from 2001-8 were assessed. For 2006-8 we compared PAC use across ICUs. We assessed characteristics of ICUs and hospitals in the top quartile for in-ICU PAC placement (vs. the bottom quartile) using Chi-squared and t-tests and factors associated with in-ICU PAC insertion using multilevel mixed effects logistic regression. Total PAC use decreased from 10.8% of patients (2001-3) to 6.2% (2006-8; $P<0.001$); insertion of PACs in-ICU decreased from 4.2% to 2.2% ($P<0.001$). In 2006-8, ICUs in the top quartile for in-ICU PAC insertion (3.4%-25.0% of patients) were more often surgical (54.2% vs. 21.7% in the lowest quartile, $P=0.070$), teaching hospitals (54.2% vs. 4.3%, $P=0.001$), and had surgeon leadership (40.9% vs. 13.0%, $P=0.067$). After multivariable regression, surgical patients ($P<0.001$) and all patients in surgical ICUs ($P=0.057$) were more likely to have PACs placed in ICU.

Conclusions—Use of PACs in ICU patients has declined, but with significant variation across units. Removal of this technology has occurred most in non-surgical ICUs and patients.

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Keywords

Intensive Care; Utilization; Evidence-Based Medicine; Epidemiology; Catheterization; Swan-Ganz; Endovascular Procedures

Introduction

Use of technology and testing in the care of critically ill patients, such as central venous catheters, routine laboratory tests, and CT scans, is common and costly. Many of these tests and interventions are important for patient care; but others are supported by limited evidence and could be considered targets for cost-reduction strategies without anticipated changes in outcomes. Initiatives such as the American Board of Internal Medicine Foundation's new "Choosing Wisely" campaign, have enlisted many medical specialty societies in an effort to discourage unnecessary tests and treatments. (1) While many studies have examined adoption of new testing and devices, (2–4) we know little about patterns of adoption (or "de-adoption") that involve removal of a commonly used technology.

Beginning in the 1990s, the use of the pulmonary artery catheter (PAC) declined as many studies – both observational and randomized trials – found no benefit of PACs for the routine management of critically ill patients (5–7) and non-invasive technologies to estimate cardiac output became more readily available.(8) Use in the U.S. decreased by 65% from 1993 to 2004 among medical hospital admissions (9) and, in Canada, use fell from 16.4% of ICU patients in 2002 to just 6.5% of ICU patients in 2006. (10) Two additional large randomized-controlled trials were published in 2005 (11) and 2006 (12) reinforcing the finding that routine use of PACs did not impact outcomes in the critically ill. While we know that the rate of PAC use in the U.S. decreased to 2 per 1,000 medical admissions by 2004, (9) no data are available on specific patterns of PAC "de-adoption" for critically ill patients. We therefore assessed trends in rates of PAC use in U.S. ICUs. We also sought to identify hospital and/or ICU factors associated with continued higher rates of use that might suggest slower adoption of new practice patterns that specifically involves removal of a technology from practice.

Materials and Methods

We performed a retrospective cohort study of adult (≥ 18 years old) ICU admissions using the Project IMPACT database to determine (1) the trends over time in PAC use across U.S. ICUs, (2) the variation across ICUs in overall PAC use and placement of PACs in-ICU, and (3) institution and patient level factors associated with higher use. Project IMPACT was owned and operated by Cerner Corporation which provided regular performance audits and feedback to participating ICUs. Participation in the database was voluntary and hospitals and ICUs paid for the service. Data were collected at each institution by on-site data collectors who were certified in advance by Project IMPACT to assure standardization and uniformity in data definitions and entry. Data were either from consecutive admissions to each ICU (16.7% of ICUs in the cohort) or a random sample of admissions (83.3% of ICUs in the cohort). Sites using the latter method collected information on 50% or 75% of all patients; the percentage was determined quarterly before data collection commenced.(13)

Patients and patient data

We included patients from 2001-8. Only the initial ICU admission for a given hospital stay was included. Patients were excluded if they were cared for in a separate neurological/neurosurgical or cardiac surgery ICU or if they were admitted to the ICU immediately following cardiac surgery as many of these patients would have had a PAC placed routinely for intra-operative monitoring. Data on demographics (age, race, gender) and health status (chronic comorbidities, severity of illness on admission as assessed by the mortality probability model at ICU admission (MPM₀-III),(14) category of admitting diagnosis, type of patient—medical, emergent surgical, elective surgical, number of organs failing during the ICU stay, and location prior to ICU arrival) were available for each admission.

Data on the use of PACs were available for each admission; the location of PAC placement (pre-ICU or during the ICU stay) was also collected. Our primary outcome was the percentage of patients without a PAC on ICU admission who had one placed in-ICU. Secondary analyses were conducted looking at the overall percentage of use (including placement prior to and in-ICU).

ICU and hospital data

We assessed specific institutional (ICU and hospital) factors that might be associated with PAC use. These included the type of ICU (surgical, including trauma/burn ICUs; medical, including coronary care units; and mixed medical-surgical), the structure of the ICU (closed unit where all patients are primarily cared for by a critical care specialist; unit with mandatory critical care consultation; unit with the possibility of critical care consultation; unit with no availability of critical care consultation), the specialty of the ICU medical director (grouped as anesthesia, including anesthesia with other certifications; surgery, including surgery with other certifications; medicine; other; or “more than one” if the specialty of the director changed over time), and the year of board certification of the ICU medical director. Each hospital was classified as academic, community, or government-run (city, state, or federal).

Statistical Analyses

We grouped data into three time periods: (1) January 2001 through December 2003, (2) January 2004 through December 2005, and (3) January 2006 through December 2008. We calculated the percentage of all ICU patients with a PAC and the percentage of PACs placed in-ICU among patients without a PAC on admission for each ICU. We summarized these data as the median (with full- and interquartile-ranges (IQRs)) for usage rates across ICUs in each time period (2001–3, 2004–5, and 2006–8) for all patients. To assess time trends, we compared percentages in the three time periods using Spearman correlation coefficients. We excluded any ICU with <20 admissions over the entire time period of 2001–2008. To ensure our results were robust, we conducted sensitivity analyses: (1) excluding units with <50 admissions; (2) excluding units with <100 admissions; and (3) including only units for which data were available for all 8 years (2001–2008).

We similarly assessed time trends in subgroups of patients in whom the impact of PAC use has been specifically investigated and/or use may be expected to be high: (1) mechanically

ventilated (MV) patients, (2) patients with Acute Lung Injury or Acute Respiratory Distress Syndrome (ALI/ARDS) as defined by the *International Classification of Diseases, 9th Revision, Clinical Modification* (ICD-CM-9) codes 518.5, 518.81, or 518.82 (15, 16) with the use of invasive mechanical ventilation, (7, 12) and (3) patients requiring vasopressor medications.(7) For each analysis, we again excluded any ICU with <20 admissions.

We used data from the most recent time period (2006–8) to identify factors associated with higher in-ICU PAC placement. First, we stratified units into quartiles based on in-ICU PAC placement in each unit. We compared patient-, ICU-, and hospital-level characteristics between admissions across quartiles using analysis of variance and Chi-squared tests as appropriate. We, secondly, constructed a multilevel multivariate random effects logistic regression model (with admissions clustered by ICU) to identify factors independently associated with having had an in-ICU PAC placed. All available patient-, ICU-, and hospital-level factors were included in the model. We performed a sensitivity analysis reclassifying units based on overall PAC use (including placement prior to ICU admission) and examining the overall receipt of a PAC by each patient to confirm whether our findings were robust.

Database management and statistical analysis were performed using Excel (Microsoft, Redmond, WA) and Stata 11.0 (StataCorp LP, College Station, TX). IRB approval was obtained from Beth Israel Medical Center (IRB# 200-10).

Results

The cohort consisted of 124,043 patients across 122 ICUs in 2001-3, 101,847 patients across 101 ICUs in 2004-5, and 107,696 patients across 95 ICUs in 2006-8. Approximately half of the patients were admitted with a primary cardiovascular or respiratory diagnosis; severity of illness as assessed by average MPM₀-III was similar across the three time periods (mean (sd): 13.6% (16.6%) in 2001-3, 13.6% (16.4%) in 2004-5, and 14.0% (16.5%) in 2006-8). Most ICUs were mixed medical-surgical units (63.9% in 2001-3, 54.5% in 2004-5, and 46.3% in 2006-8); many hospitals were urban (49.6% in 2001-3, 59.4% in 2004-5, and 60.0% in 2006-8) and a minority were academic (14.8% in 2001-3, 23.8% in 2004-5, and 26.3% in 2006-8).

Trends in PAC use

Among patients who arrived in the ICU without a PAC, 4.2% received one in the ICU in 2001-3, and this percentage decreased to 2.2% in 2006-8 ($P<0.001$). The percentage of patients who received a PAC prior to or in-ICU decreased from 10.8% of ICU patients in 2001-3 to 6.2% in 2006-8 ($P<0.001$). The median rate of in-ICU PAC placement across individual ICUs fell from 3.6% of patients (range 0.0%-24.6%) in 2001-3 to 1.5% (range 0.0%-25.0%) in 2006-8 ($P<0.001$) (Figure 1). The trends were similar across the subgroups: for patients receiving MV, in-ICU PAC placement rates fell from a median of 10.3% of patients (range 0.0%-57.1%) to 3.9% (range 0.0%-28.3%, $P=0.008$; Figure 2); for patients with ALI/ARDS, from 11.0% (range 0.0%-46.8%) to 4.8% (range 0.0%-32.3%, $P<0.001$); and for patients requiring vasopressors, from 14.7% (range 0.0%-60.0%) to 5.4% (range 0.0%-57.4%, $P<0.001$). The median rates of PAC use (including PACs placed prior to ICU

admission) across individual ICUs also decreased for all ICU patients and for each subgroup (Appendix Figures 1 & 2). Sensitivity analyses using different criteria for the inclusion of ICUs in the cohort revealed similar overall results (Appendix Table 1).

Factors associated with frequent in-ICU PAC placement

In 2006-8, the ICUs in the top quartile of in-ICU PAC placement used PACs in 3.4% to 25.0% of patients versus 0.0% to 0.4% of patients in the ICUs in the lowest quartile, 0.4% to 1.5% in the 2nd quartile, and 1.6% to 3.3% in the 3rd quartile. Patients in the top quartile were younger, more often surgical (emergent or elective), came to the ICU from the operating room or postanesthesia care unit (OR/PACU), more frequently had a trauma diagnosis, and had more organs failing during the ICU stay ($P<0.001$ for all comparisons, Table 1). Predicted hospital mortality (MPM_{0-III}) was no different for patients in the highest and lowest quartiles ($P=0.47$ for two-way comparison), yet was higher in quartiles 2 and 3 ($P<0.001$). ICU length of stay, hospital length of stay, and hospital mortality were all higher for patients in the top quartile ICUs compared with the bottom quartile. With the exception of hospital mortality, findings were similar for differences in patient characteristics and outcomes in ICUs in the top quartile of total PAC use versus the bottom quartile (Appendix Table 2).

ICU and hospital characteristics were different for ICUs across quartiles of in-ICU PAC placement (Table 2). ICUs in the top quartile were more often in academic hospitals (54.2% vs. 4.3% in the lowest quartile, $P=0.007$). The ICUs themselves were more likely to be surgical (54.2% in the top quartile vs. 21.7% in the lowest quartile, $P=0.119$). Similar trends were seen in comparing the top quartile of total PAC use ICUs to those in the lowest quartile ICUs (Appendix Table 3).

After multilevel multivariate logistic regression with clustering by individual ICU, the patient factors associated with receipt of an in-ICU PAC were older age, higher severity of illness, admission to the ICU after surgery, having more organ failures, and specific diagnostic categories (cardiovascular or sepsis). While not meeting statistical significance, being in a surgical ICU (versus a medical ICU) was associated with higher in-ICU PAC placement (adjusted odds-ratio (OR_{adj}) 2.28 (95% CI 0.98, 5.34), $P=0.057$). This association was statistically significant for the analysis of associations with total PAC use (OR_{adj} 2.36 (95% CI 1.08, 5.13), $P=0.031$) (Appendix Table 4). The association between critical care consultation and in-ICU PAC use was not straightforward; the likelihood of receiving an in-ICU PAC was highest with no availability of critical care consultation, yet lowest in units with critical care consultation that were not closed.

Discussion

PAC use in U.S. ICUs decreased throughout the time period studied (2001- 2008). However, despite the overall decline, certain units continued to use PACs frequently – placing them in up to one quarter of patients. Moreover, in high-risk subgroups, such as those on vasopressor medications, some units continued to place PACs in more than 50% of patients. Overall, clinicians in surgical ICUs were more likely to continue to use PACs and surgical patients were more likely to receive a PAC, both prior to and after admission to the ICU, suggesting

a different willingness among practitioners in these settings to change practice in a way that involves removal of technology.

The overall trend of declining use of PACs in U.S. ICU patients is consistent with trends seen in other studies.(9, 10) A prior study from the U.S. examined all hospitalized medical patients, but was unable to distinguish between patients cared for in ICUs and those who received PACs for other reasons and in other hospital locations.(9) The rates of PAC use we found in U.S. ICUs is very similar to the rates found using Canadian ICU data, with 6.5% of Canadian ICU patients receiving a PAC in 2006 and 6.2% of U.S. ICU patients receiving a PAC in 2006-8.(10) The patient characteristics associated with an increased likelihood of receiving a PAC (being a surgical patient, requiring vasopressors, and being mechanically ventilated) were also similar in the two studies.

Our results reveal that the use of PACs varies significantly across individual ICUs suggesting, at least in part, a variation in implementation of evidence based medicine. (7, 11, 12) Adoption of a new practice in this case involves *removal* of a device, rather than adoption of a new technology or initiation of a new protocol. Adoption of new technology may be very rapid, as has been seen with the use of minimally invasive surgery for prostatectomies, (4) whereas removing a common technology from practice may be slower. Recent studies demonstrating the lack of utility of intra-aortic balloon pumps in the setting of cardiogenic shock following myocardial infarction (17) and the lack of benefit from routine replacement of peripheral intravenous catheters (18) are examples of evidence that may push clinicians to change behavior to choose *not* to initiate an intervention or protocol, rather than to adopt a new one. As we continue to be confronted with data demonstrating non-utility of “standard of care” techniques, differences between incorporating novel practices and rejecting previously-accepted ones may become clear; understanding barriers to the latter may inform strategies to enhance the former.

Variation in clinical practice in critical care is, of course, not unique to use of PACs. (19–21) Moreover, the “appropriate” rate of continued PAC use is not known and it is unlikely that each unit, with its unique make-up of patients and unique hospital environment, would use PACs with the same frequency. However, it seems equally unlikely that the degree of variation found in our cohort is ideal. In particular, the high use of PACs for management of patients requiring vasopressors or mechanical ventilation in some units may suggest a reluctance to consider alternative approaches to care.

In order to minimize variation in practice, it is important to understand the factors that drive it as well as potential barriers to change. Our study identifies patient-, ICU- and hospital-level factors that are associated with greater PAC use. In particular, our data suggest that providers in ICUs that care for surgical patients may be more likely to continue to use PACs than are clinicians practicing in other critical care environments. The possible explanations for persistent use in surgical units may include: (1) a comfort with PACs due to continued common use in the OR/PACU environment; (2) a belief that surgical patients are inherently different and may benefit from PACs preferentially; or (3) a greater acceptance of invasive monitoring for patients who have already undergone major surgery. While the rationale is

not certain, it is clear that surgical ICUs, both in the past (22) and more recently, use PACs more often.

Our study is novel in characterizing the recent epidemiology of PAC use in U.S. ICUs and in pinpointing differences in use across types of ICUs. One main strength of this study stems from the sample size of >300,000 patients admitted to approximately 100 ICUs across the U.S. Additionally, whereas potential underreporting may have impacted prior analyses that relied on documentation for billing purposes,(9) the documentation of PAC use was mandatory in Project IMPACT and the data were collected by trained data collectors in each unit. Finally, in contrast to the Canadian ICU cohort, (10) we were able to distinguish which PACs were placed within the ICU (rather than before admission) and to examine not only overall use, but also to isolate the patients for whom the decision was made to place the PAC in the ICU itself.

Our study has a number of limitations. As a retrospective analysis, we did not have access to specific information about why a PAC was or was not used for each patient as well as whether any alternative technology or approaches (e.g., echocardiography, pulse contour methods for determining cardiac output) were used to assist in hemodynamic assessment. In the mid-1990s, technologically advanced PAC which are able to report continuous cardiac output became available;(23, 24) whether these catheters were used and to what extent was not information we had available in our dataset. Similarly, we did not have information about ICU admission criteria for the units in our cohort and whether they changed over time. Additionally, while we had data on the specialty and year of board certification of the medical director of each unit, we did not have data on either the specialty of the physician in charge of each patient's care or his/her length of practice. In other areas of critical care, we know that individual physician management may vary substantially. (25) Third, reimbursement patterns are known to impact use of technologies. (26) We did account for the insurance status of each patient (which was not associated with PAC use), but we did not have access to the payment structures in each unit and therefore could not evaluate the impact of differing financial incentives across ICUs. As our study is based on data from Project IMPACT, its generalizability to the entire U.S. critically ill population and to non-U.S. ICU patients is uncertain; specifically, there is a high percentage of academic hospitals in our dataset which could skew our results. Also, we excluded patients who had undergone cardiac surgery as our interest lay with the use of PACs in the ICU setting and we expected that a significant portion of cardiac surgery patients would have received PACs for intra-operative monitoring. Our findings, therefore, do not address the use of PACs in this subpopulation of critically ill patients. Finally, as a retrospective analysis, we were not able to make any statements about the cause of PAC use declining and/or the direct results from this decline on patient outcomes including mortality.

Conclusions

PACs were a mainstay of the management of critically ill patients in the 1980s. (5, 27, 28) The overall use of PACs in the ICU setting has declined dramatically over the past 20 years, suggesting a willingness by physicians caring for critically ill patients to change practice based on new evidence. However, the variable use across ICUs, and continued use at high

rates in some units, demonstrates that PACs for hemodynamic monitoring are not an obsolete technology in U.S. ICUs. Moreover, our analysis suggests that willingness to “de-adopt” a technology is not random; high use is more consistently found in certain practice settings and for specific types of patients.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1. Rates of in-ICU PAC placement across individual ICUs for years 2001-3, 2004-5, and 2006-8.*

*Data presented as medians with interquartile (gray boxes) and full ranges for ICUs, Spearman's $\rho = -0.27$, $P < 0.001$.

A.

B.

Figure 2.

Changing rates of in-ICU PAC placement by individual unit for specific subgroups*

A. Stratified by ICU type (medical (Spearman's $\rho = -0.34$, $P=0.005$), surgical (Spearman's $\rho = -0.27$, $P=0.022$), combined (Spearman's $\rho = -0.32$, $P<0.001$))

B. Stratified by specific diagnoses (use of mechanical ventilation (Spearman's $\rho = -0.34$, $P<0.001$), diagnosis of acute lung injury/acute respiratory distress syndrome (Spearman's $\rho = -0.27$, $P=0.008$), use of vasopressors (Spearman's $\rho = -0.26$, $P<0.001$))

*Data presented as medians with interquartile (gray boxes) and full ranges for ICUs. MV: mechanical ventilation; ALI/ARDS: acute lung injury/acute respiratory distress syndrome

Table 1

Characteristics of patients admitted to ICUs in the highest and lowest quartiles of in-ICU pulmonary artery catheter placement in 2006-8

	In-ICU PAC Placement				P value
	Lowest Quartile ICUs	Quartile 2 ICUs	Quartile 3 ICUs	Highest Quartile ICUs	
Number of Patients	24,763	32,980	23,617	26,336	
Range of PAC use, %	0.0-0.4	0.4-1.5	1.6-3.3	3.4-25.0	
Age, mean(sd)	61.9±17.8	60.0±17.8	59.4±18.5	56.2±18.8	<0.001
Severity of Acute Illness, MPM0-III ^a , mean±sd	0.13±0.15	0.15±0.17	0.14±0.17	0.13±0.16	<0.001
Race, n(%)					<0.001
white	18136 (76.7)	26434 (82.8)	16875 (79.3)	18287 (75.6)	
black	4375 (18.5)	4312 (13.5)	2239 (10.5)	3825 (15.8)	
other	1145 (4.8)	1197 (3.7)	2174 (10.2)	2084 (8.6)	
Gender, n(%)					<0.001
male	12677 (52.0)	17660 (54.8)	12662 (57.8)	14242 (58.0)	
female	11691 (48.0)	14545 (45.2)	9250 (42.2)	10302 (42.0)	
Insurance, n(%)					<0.001
private insurance	7078 (29.2)	6618 (30.3)	8120 (33.4)	8120 (33.4)	
medicare	12853 (53.1)	9899 (45.3)	9695 (39.9)	9695 (39.9)	
medicaid	1882 (7.8)	2426 (11.1)	2430 (10.0)	2430 (10.0)	
self-pay	1611 (6.7)	1933 (8.9)	2619 (10.8)	2619 (10.8)	
other	800 (3.3)	957 (4.4)	1451 (6.0)	1451 (6.0)	
Patient Type, n(%)					<0.001
medical	17284 (70.8)	24518 (75.8)	14944 (68.0)	15385 (62.5)	
elective surgical	4563 (18.7)	4879 (15.1)	4060 (18.5)	5221 (21.2)	
emergent surgical	2564 (10.5)	2930 (9.1)	2974 (13.5)	3996 (16.2)	
Origin, n(%)					<0.001
emergency room	12544 (51.4)	16137 (49.9)	9689 (44.1)	10246 (41.7)	
operating room/post-anesthesia care unit	6180 (25.3)	6646 (20.6)	6052 (27.5)	7516 (30.6)	

	In-ICU PAC Placement				P value
	Lowest Quartile ICU's	Quartile 2 ICU's	Quartile 3 ICU's	Highest Quartile ICU's	
other	5683 (23.3)	9537 (29.5)	6235 (28.4)	6837 (27.8)	
Admitting Diagnosis Category, n(%)					<0.001
respiratory	4720 (19.3)	6636 (20.5)	3316 (15.1)	4853 (19.7)	
cardiovascular	6177 (25.3)	8504 (26.3)	7117 (32.4)	5529 (22.5)	
sepsis	2306 (9.4)	3278 (10.1)	1699 (7.7)	2290 (9.3)	
trauma	946 (3.9)	2308 (7.1)	2679 (12.2)	4065 (16.5)	
neurologic (non-trauma)	4984 (20.4)	5325 (16.5)	3708 (16.9)	3403 (13.8)	
metabolic/renal	2274 (9.3)	2947 (9.1)	1289 (5.9)	1695 (6.9)	
gastrointestinal	3004 (12.3)	3329 (10.3)	2170 (9.9)	2767 (11.2)	
Number of chronic illnesses ^b n(%)					<0.001
0	17649 (72.3)	23803 (73.6)	16461 (74.9)	18050 (73.4)	
1	5655 (23.2)	7378 (22.8)	4740 (21.6)	5766 (23.4)	
2	908 (3.7)	934 (2.9)	644 (2.9)	656 (2.7)	
3+	199 (0.8)	212 (0.7)	133 (0.6)	130 (0.5)	
Number of organs failing during ICU stay ^c , n(%)					<0.001
0	19305 (79.1)	21379 (66.1)	13708 (62.4)	16291 (66.2)	
1	2957 (12.1)	5756 (17.8)	4953 (22.5)	4483 (18.2)	
2	1137 (4.7)	2791 (8.6)	1784 (8.1)	2033 (8.3)	
3+	1012 (4.1)	2401 (7.4)	1533 (7.0)	1795 (7.3)	
Hospital Mortality, n(%)	2671 (10.9)	4415 (13.7)	2799 (12.7)	3550 (14.4)	<0.001
ICU length of stay (days), mean±sd	3.2±4.1	3.5±5.0	3.6±5.4	4.1±6.1	<0.001
Hospital length of stay (days), mean±sd	8.8±9.8	9.5±11.1	10.3±12.5	12.0±14.1	<0.001

^aMPM0-III only available for 44,982 (88.0%) of the sample

^bincludes gastrointestinal, respiratory, cardiovascular, renal, immunosuppressive, and malignant diseases; maximum number = 16

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c
maximum number = 7

Table 2

Institutional characteristics of ICUs in the highest and lowest quartiles of in-ICU pulmonary artery catheter placement in 2006-8

	In-ICU PAC Placement				P value
	Lowest Quartile ICUs	Quartile 2 ICUs	Quartile 3 ICUs	Highest Quartile ICUs	
Number of ICUs	23	25	23	24	
Hospital Organization, n(%)					0.007
city/state/federal government	1 (4.3)	2 (8.0)	1 (4.3)	1 (4.2)	
community	21 (91.3)	19 (76.0)	10 (43.5)	10 (41.7)	
academic	1 (4.3)	4 (16.0)	12 (52.2)	13 (54.2)	
Hospital Class, n(%)					0.596
urban	15 (65.2)	12 (48.0)	14 (60.9)	16 (66.7)	
suburban	6 (26.1)	9 (36.0)	4 (17.4)	6 (25.0)	
rural	2 (8.7)	4 (16.0)	5 (21.7)	2 (8.3)	
ICU Specialty ^a , n(%)					0.119
medical ICU	4 (17.4)	8 (32.0)	6 (26.1)	3 (12.5)	
surgical ICU	5 (21.7)	5 (20.0)	7 (30.4)	13 (54.2)	
mixed medical-surgical ICU	14 (60.9)	12 (48.0)	10 (43.5)	8 (33.3)	
ICU Structure, n(%)					0.414
closed	0 (0.0)	1 (4.0)	2 (9.1)	3 (13.0)	
mandatory critical care consult	6 (26.1)	5 (20.0)	3 (13.6)	8 (34.8)	
possibility for critical care consult	17 (73.9)	19 (76.0)	17 (77.3)	12 (52.2)	
no critical care consult available	0 (0.0)	0 (0.0)	1 (0.0)	1 (0.0)	
Medical Director Specialization ^b , n(%)					0.213
anesthesia	1 (4.3)	0 (0.0)	1 (5.0)	1 (4.5)	
surgery	3 (13.0)	2 (8.0)	6 (30.0)	9 (40.9)	
medicine	16 (69.6)	19 (76.0)	9 (45.0)	7 (31.8)	

	In-ICU PAC Placement				P value
	Lowest Quartile ICUs	Quartile 2 ICUs	Quartile 3 ICUs	Highest Quartile ICUs	
other	1 (4.3)	1 (4.0)	1 (5.0)	0 (0.0)	
>1 specialty	2 (8.7)	3 (12.0)	3 (15.0)	5 (22.7)	
Year of Medical Director Board Certification, mean(sd)	1979.3±5.0	1980.7±6.9	1982.4±6.2	1983.8±6.2	0.016

^a medical includes coronary care units; surgical includes trauma/burn ICUs

^b anesthesia includes anesthesia plus other certifications; surgery includes surgery plus other certifications; > one specialty is denoted if the specialty of the director changed over time

Table 3

Patient and organizational factors associated with increased odds of in-ICU pulmonary artery catheter placement in 2006-8

	OR (95% CI)	P value
Patient Factors		
Age		
<50	1	
50–64	1.30 (1.10,1.54)	0.002
65–84	1.48 (1.21,1.81)	<0.001
85+	1.07 (0.78,1.46)	0.69
Severity of Acute Illness, MPM0-III		
<=2%	1	
>2–5%	1.75 (1.19,2.59)	0.005
>5–10%	2.72 (1.85,3.99)	<0.001
>10–20%	3.20 (2.16,4.74)	<0.001
>20%	2.82 (1.89,4.21)	<0.001
Race		
white	1	
black	0.94 (0.79,1.11)	0.46
other	0.91 (0.72,1.16)	0.46
Gender		
male	1	
female	0.94 (0.84,1.06)	0.30
Insurance		
private insurance	1	
medicare	0.87 (0.73,1.03)	0.108
medicaid	0.88 (0.70,1.10)	0.27
self-pay	0.95 (0.75,1.20)	0.68
other	1.11 (0.84,1.46)	0.46
Patient Type		
medical	1	
elective surgical	2.20 (1.73,2.81)	<0.001
emergent surgical	2.39 (1.93,2.96)	<0.001
Origin		
emergency room	1	
operating room/post-anesthesia care unit	0.64 (0.50,0.81)	<0.001
other	1.29 (1.12,1.49)	0.001
Admitting Diagnosis Category		
respiratory	1	
cardiovascular	1.64 (1.36,1.98)	<0.001

	OR (95% CI)	P value
Patient Factors		
sepsis	1.23 (1.01,1.49)	0.036
trauma	1.20 (0.94,1.53)	0.144
neurologic (non-trauma)	0.64 (0.48,0.86)	0.002
metabolic/renal	0.55 (0.37,0.81)	0.003
gastrointestinal	1.22 (0.98,1.53)	0.081
Number of chronic illnesses		
0	1	
1	0.82 (0.71,0.95)	0.006
2	1.04 (0.78,1.39)	0.80
3+	0.22 (0.05,0.91)	0.037
Number of organs failing during ICU stay		
0	1	
1	4.44 (3.62,5.45)	<0.001
2	14.75 (12.02,18.10)	<0.001
3+	42.93 (34.95,52.73)	<0.001
Hospital/ICU Factors		
Hospital Organization		
city/state/federal government	1	
community	0.68 (0.25,1.85)	0.45
academic	1.79 (0.66,4.90)	0.25
Hospital Class		
urban	1	
suburban	0.85 (0.41,1.76)	0.67
rural	0.85 (0.39,1.82)	0.67
ICU Specialty		
medical ICU	1	
surgical ICU	2.28 (0.98,5.34)	0.057
mixed medical-surgical ICU	1.37 (0.65,2.90)	0.41
ICU Structure		
closed	1	
mandatory critical care consult	0.32 (0.12,0.85)	0.022
possibility for critical care consult	0.39 (0.15,1.00)	0.050
no critical care consult available	11.00 (1.07,112.67)	0.043
Medical Director Specialization		
medicine	1	
anesthesia	2.29 (0.65,7.99)	0.195
surgery	1.17 (0.53,2.54)	0.70
other	0.19 (0.02,1.90)	0.157

	OR (95% CI)	P value
Patient Factors		
>1 specialty	1.65 (0.83,3.28)	0.157
Year of Medical Director Board Certification		
<1980	1	
1980–1989	1.33 (0.78,2.28)	0.30
1990+	1.20 (0.55,2.63)	0.65