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Use of Pulmonary Artery Catheterization in US Patients With Heart Failure, 2001–2012

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The Evaluation Study of Congestive Heart Failure and Pulmonary Artery Catheterization Effectiveness (ESCAPE) trial in 2005[1] demonstrated that the addition of pulmonary artery (PA) catheterization to standard management in heart failure (HF) did not improve patient outcomes but was associated with an unanticipated increase in adverse events. Consequently, current HF guidelines recommend limiting the use of PA catheters to patients with cardiogenic shock or mechanical ventilation (American College of Cardiology–American Heart Association [ACC-AHA] class I, level of evidence C) and discourage PA catheter use in routine management of HF (ACC-AHA class III, level of evidence B).[2] Given these recommendations, we examined contemporary trends in the use of PA catheterization in patients hospitalized with HF.

Methods

Using survey analysis in the National Inpatient Sample,[3] we identified 2 492 284 adult patients (aged >18 years) from January 1, 2001, to December 31, 2012, with a primary diagnosis of HF using previously validated codes 428.x, 402.x1, 404.x1, and 404.x3 from

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Author Contributions: Drs Pandey and Khera had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.
Study concept and design: Pandey, Khera, Golwala, Fonarow.
Acquisition, analysis, or interpretation of data: All authors.
Drafting of the manuscript: Pandey, Khera.
Critical revision of the manuscript for important intellectual content: All authors.
Statistical analysis: Pandey, Khera, Kumar.
Administrative, technical, or material support: Fonarow.
Study supervision: Fonarow.

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the *International Classification of Diseases, Ninth Revision*, which translate to an estimated 11 888 525 hospitalizations for HF nationally during this period.[4] Among these codes, we identified the use of PA catheters with procedure codes 89.63, 89.64, 89.66, 89.67, and 89.68[5] while excluding hospitalizations in which PA catheterization may have been used for monitoring in a surgical procedure, mechanical circulatory support was used, and right-sided heart catheterization was performed without PA catheter use. The study was approved by the institutional review board of the University of Iowa, which waived the requirement for informed consent because the study used deidentified data.

We analyzed the data from January 1, 2011, through December 31, 2012. We examined calendar-year changes in the use of PA catheters among patients with a primary diagnosis of HF, focusing on the period before (2001–2006) and after (2006–2012) the ESCAPE trial.[1] We also examined trends in hierarchical subgroups consisting of cardiogenic shock, requirement of mechanical ventilation without cardiogenic shock, and HF without cardiogenic shock or respiratory failure.

Results

During the study period, we identified 15 786 patients translating to 75 209 HF hospitalizations with PA catheter use nationally (0.6% of all HF hospitalizations). Baseline characteristics of patients undergoing PA catheter placement changed over time, with a decrease in the mean age, incidence of acute myocardial infarction and cardiac arrest, and use of mechanical ventilation (Table).

From 2001 to 2007, use of PA catheters initially decreased from 7.9 to 4.9 per 1000 HF hospitalization in 2007, but increased thereafter to 7.9 per 1000 HF hospitalizations in 2012 (Figure). In the subgroup with cardiogenic shock, use of PA catheters dropped from 190 per 1000 in 2001 to 86 per 1000 HF hospitalizations in 2007 ($P < .001$ for trend) and increased modestly to 121 per 1000 HF hospitalizations in 2012 ($P = .04$ for trend). Among patients with respiratory failure, use of PA catheters decreased consistently from 50 per 1000 in 2001 to 10 per 1000 HF hospitalizations in 2012. In contrast, among patients without cardiogenic shock or mechanical ventilation requirements, which constituted 74% of all use of PA catheters, their use initially decreased from 5.6 per 1000 admissions in 2001 to 4.2 per 1000 in 2007, followed by a steady increase to 6.5 per 1000 admissions in 2012 ($P < .001$ for trend).

Discussion

In a national sample of hospitalizations for HF, we found a significant decline in the use of PA catheters from 2001 through 2007, consistent with findings previously reported by Wiener and Welch[5] and in agreement with other studies questioning the usefulness of PA catheterization.[6] In contrast, despite evidence against routine use in HF in the ESCAPE trial, we observed a significant increase in the use of PA catheters in HF management in recent years. Moreover, the largest increase is seen in patients without a definite indication. This finding highlights the discordance between guideline recommendations and current clinical practice regarding management of acute HF.

Several factors may explain the observed increase in the use of PA catheters in recent years. These factors include increasing use of advanced HF therapies and the preparatory hemodynamic evaluations and increasing prevalence of co-morbidities such as pulmonary hypertension and chronic kidney disease that may prompt invasive assessment of volume status.[7] Future studies are needed to determine whether a proportion of the increase in the use of PA catheters among patients with HF is attributable to inappropriate overuse.

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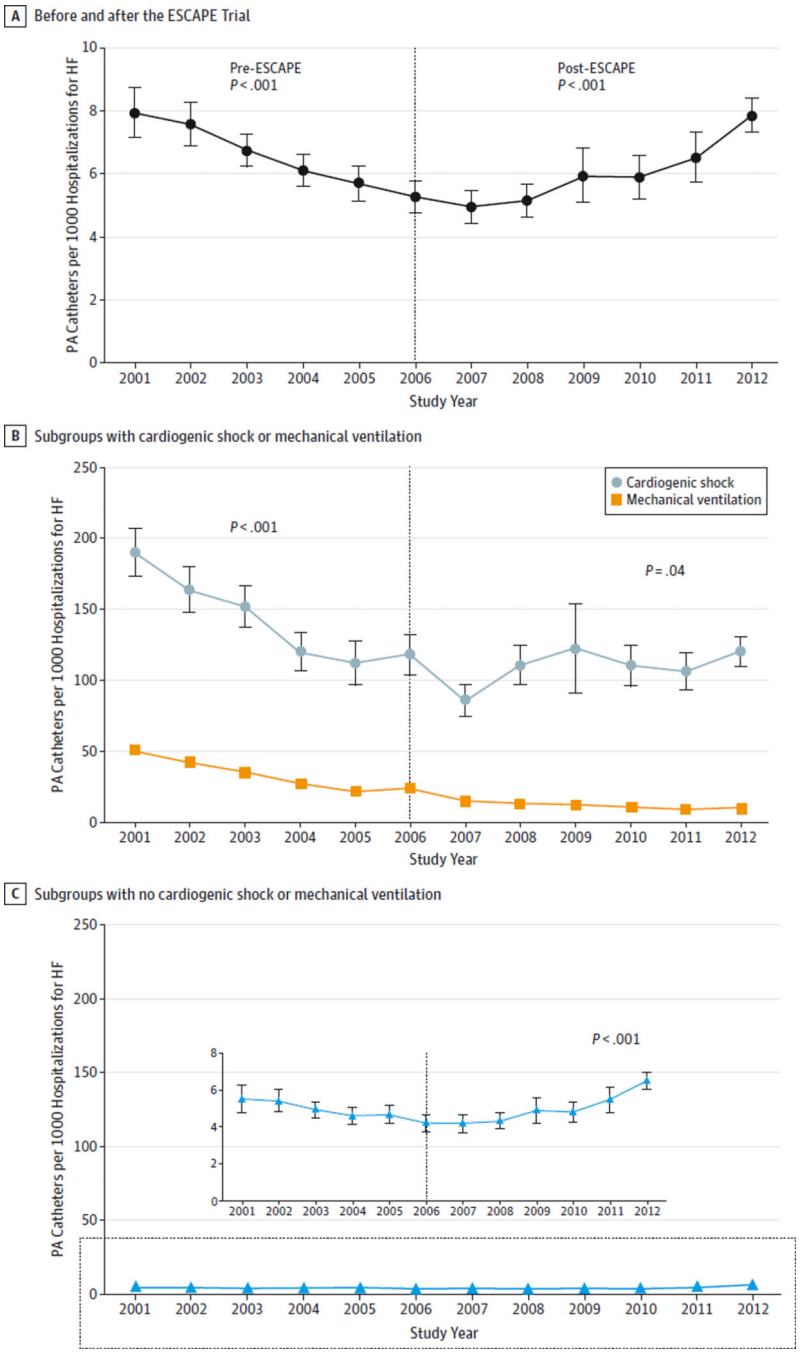

Figure. Temporal Trends in the Use of Pulmonary Artery (PA) Catheters in Hospitalization for Heart Failure (HF)

A decline in the use of PA catheters is seen in the era before the Evaluation Study of Congestive Heart Failure and Pulmonary Artery Catheterization Effectiveness (ESCAPE) trial (2001–2006) and an increased use of PA catheters in the post-ESCAPE era (2007–2012). Similar use of PA catheters is observed in hierarchical subgroups of patients with HF and cardiogenic shock or with no mechanical ventilation or cardiogenic shock, but not in those with mechanical ventilation without cardiogenic shock, in whom use has continued to decline ($P < .001$). Dotted vertical line represents publication of ESCAPE trial; error bars,

SEs for national estimates. *P* values are calculated for trend. Inset graph in part C shows the trend plot with a smaller scale.

Table

Trends in Characteristics for Patients With Use of PA Catheters Among Patients Hospitalized for HF

Characteristic	Study Year[a] 2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	*P* Value for Trend[b]
No. of PA catheters, mean (SD)	8482 (842)	7953 (712)	7302 (573)	6446 (557)	5777 (577)	5278 (507)	4682 (517)	4883 (499)	5739 (848)	5494 (638)	6136 (757)	7035 (486)	
No. of catheters per 1000 hospitalizations for HF, mean (SD)	7.9 (0.8)	7.6 (0.7)	6.7 (0.5)	6.1 (0.5)	5.7 (0.6)	5.3 (0.5)	4.9 (0.5)	5.2 (0.5)	5.9 0.(9)	5.9 (0.7)	6.5 (0.8)	7.9 (0.5)	<.001
Patient characteristics													
Age, mean (SE), y	67.2 (0.8)	67.1 (0.8)	66.6 (0.6)	66.6 (0.7)	66.2 (0.8)	65.0 (0.8)	64.0 (0.9)	62.5 (0.7)	62.9 (0.7)	61.1 (0.7)	63.2 (0.8)	62.9 (0.5)	<.001
Aged ≥65 y	62.1 (2.4)	61.4 (2.4)	60.0 (2.0)	58.7 (2.3)	57.6 (2.4)	54.6 (2.2)	49.9 (2.7)	49.0 (2.4)	47.3 (2.1)	43.7 (2.1)	47.7 (2.3)	49.0 (1.8)	<.001[c]
Female	43.2 (1.7)	43.4 (1.6)	44.0 (1.6)	42.3 (1.7)	42.2 (1.8)	41.5 (1.7)	41.2 (2.1)	37.4 (1.8)	38.2 (1.5)	35.0 (1.8)	37.1 (1.7)	41.0 (1.6)	<.001[c]
Race													
White	55.1 (3.4)	47.6 (3.7)	50.0 (3.6)	54.5 (3.3)	47.0 (4.9)	51.6 (3.4)	47.4 (3.8)	48.2 (4.0)	44.2 (6.4)	51.4 (3.5)	57.8 (3.8)	59.0 (2.2)	<.001[d]
Black	11.8 (1.7)	12.0 (1.6)	10.7 (1.4)	13.6 (2.2)	7.5 (1.3)	15.6 (2.2)	15.3 (2.7)	17.6 (2.7)	15.4 (3.1)	24.7 (3.3)	21.4 (2.6)	25.3 (1.9)	
Other	8.2 (1.3)	8.4 (1.5)	9.5 (1.3)	7.0 (1.2)	7.2 (1.2)	9.2 (1.5)	10.2 (1.5)	12.6 (1.7)	10.9 (2.2)	11.8 (1.7)	9.6 (1.8)	11.4 (0.9)	
Missing	24.8 (4.2)	32.0 (5.1)	29.7 (4.3)	25.0 (3.7)	38.2 (6.0)	23.6 (3.9)	27.1 (4.9)	21.6 (5.6)	29.4 (9.9)	12.1 (4.2)	11.2 (4.9)	4.3 (1.2)	
Secondary cardiovascular discharge diagnoses													
Cardiogenic shock	8.2 (1.0)	7.6 (0.9)	8.1 (0.8)	7.5 (0.7)	6.9 (1.0)	7.6 (1.0)	6.3 (0.9)	8.7 (0.9)	11.4 (2.3)	12.4 (1.4)	12.4 (1.2)	14.2 (1.1)	<.001
AMI	7.6 (0.9)	7.3 (0.7)	7.8 (0.8)	6.9 (0.8)	5.9 (0.7)	4.7 (0.7)	4.2 (0.6)	4.1 (0.6)	3.9 (0.5)	4.5 (0.7)	4.6 (0.6)	3.8 (0.7)	<.001[c]
CAD	48.4 (1.4)	46.7 (1.3)	48.8 (1.4)	45.5 (1.7)	45.7 (1.9)	45.6 (1.7)	46.6 (3.5)	46.9 (1.9)	52.2 (1.7)	47.4 (1.7)	54.8 (1.7)	53.7 (1.4)	<.001
Cardiac arrest	5.5 (0.6)	3.6 (0.5)	4.0 (0.6)	3.8 (0.5)	3.1 (0.5)	2.3 (0.5)	1.9 (0.4)	2.8 (0.6)	2.5 (0.4)	2.6 (0.5)	2.4 (0.4)	2.7 (0.4)	<.001[c]
Comorbid conditions													
Hypertension	48.3 (1.7)	49.6 (2.3)	50.2 (1.7)	50.8 (1.9)	52.8 (2.2)	54.4 (2.1)	53.7 (2.6)	55.7 (2.1)	64.2 (1.8)	64.1 (2.4)	67.3 (2.4)	70.2 (1.5)	<.001
Diabetes mellitus	34.2 (1.4)	34.1 (1.4)	33.0 (1.6)	34.0 (1.4)	35.6 (1.5)	34.2 (1.9)	36.1 (1.8)	36.2 (2.0)	43.2 (1.4)	39.0 (2.1)	41.3 (1.5)	45.9 (1.4)	<.001
CKD	6.0 (0.6)	5.4 (0.6)	5.9 (0.7)	4.4 (0.6)	9.3 (0.9)	23.2 (1.4)	37.0 (2.5)	33.9 (2.2)	39.9 (1.6)	42.6 (2.0)	43.8 (2.0)	42.2 (1.4)	<.001
Tobacco abuse	4.1 (0.5)	4.6 (0.6)	5.2 (0.7)	5.0 (0.7)	5.0 (0.7)	7.3 (0.9)	7.5 (1.1)	9.8 (1.2)	13.3 (1.5)	13.4 (1.7)	17.4 (1.6)	18.3 (1.4)	<.001

Characteristic	Study Year[a] 2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	*P* Value for Trend[b]
CCI	1.3 (0.0)	1.3 (0.0)	1.3 (0.0)	1.3 (0.0)	1.4 (0.0)	1.4 (0.0)	1.3 (0.0)	1.3 (0.0)	1.3 (0.0)	1.4 (0.0)	1.5 (0.0)	1.5 (0.0)	<.001
History													
MI	10.6 (1.0)	9.0 (0.8)	9.6 (0.8)	9.7 (1.0)	8.3 (0.9)	9.9 (1.0)	10.6 (1.0)	11.2 (1.0)	13.4 (1.5)	12.4 (1.3)	14.4 (1.2)	14.4 (1.1)	<.001
CABG	10.9 (0.8)	11.7 (0.8)	11.8 (1.1)	9.6 (0.9)	10.1 (1.0)	11.2 (1.1)	8.1 (0.9)	10.5 (1.0)	13.0 (1.4)	11.9 (1.2)	13.4 (1.1)	14.1 (1.0)	<.001

Abbreviations: AMI, acutemyocardial infarction (MI); CABG, coronary artery bypasses graft; CAD, coronary artery disease; CCI, chronic coronary insufficiency; CKD, chronic kidney disease; HF, heart failure; PA, pulmonary artery.

[a] Unless otherwise specified, data are expressed as percentage (SE) of patients.

[b] Calculated for positive trends, unless otherwise stated.

[c] Calculated for negative trend.

[d] Calculated for trends between white vs nonwhite races.