# Questionable Benefit of the Pulmonary Artery Catheter After Cardiac Surgery in High-Risk Patients

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***Objective:*** **The aim of this study was to determine the effect of pulmonary artery catheterization on clinical outcomes after cardiac surgery in higher-risk patients.**

***Design:*** **Retrospective national database analysis.**

***Setting:*** **U.S. hospitals.**

***Participants:*** **A weighted sample of 2,063,337 patients undergoing cardiac surgery identified from the Nationwide Inpatient Sample (NIS) from January 1, 2000 to December 31, 2010.**

***Interventions:*** **Pulmonary artery catheterization.**

***Measurements and Main Results:*** **Compared to patients who did not receive a pulmonary artery catheter, those who did on the whole were on average slightly older (66.6 ± 11.9 years *v* 65.5 ± 12.8 years, $p < 0.001$), more likely to have pulmonary hypertension (7.5% *v* 5.1%, $p < 0.001$), chronic obstructive pulmonary disease (24.6% *v* 20.7%, $p < 0.001$), obesity (15.0% *v* 13.1%, $p < 0.001$), and chronic renal failure (10.9% *v* 9.2%, $p < 0.001$). In multivariate analysis, the risk of operative mortality in patients who underwent pulmonary artery catheterization was significantly higher than in those who did not (4.6% *v* 3.1%, $p < 0.001$), adjusted OR 1.34 (95% CI 1.26-1.43, $p < 0.001$). In propensity matched subgroup analysis operative mortality risk was higher in octogenarian patients (OR 1.24, $p = 0.24$), and patients with congestive heart failure (OR 1.39, $p = 0.023$) who underwent pulmonary artery catheterization. No significant difference in operative mortality was observed in low-risk patients according to whether or not they underwent pulmonary artery catheterization. The incidence of prolonged mechanical ventilation and length of stay >30 days was higher in patients who underwent pulmonary artery catheterization in all subgroups.**

***Conclusions:*** **In contemporary practice pulmonary artery catheters do not appear to be associated with reductions in operative mortality or morbidity and are associated with increases in duration of ventilation and length of stay in the intensive care unit.**



***KEY WORDS: pulmonary artery catheter, cardiac surgery, benefits, risks, complications, monitoring***

USE OF PULMONARY ARTERY CATHETERIZATION to guide management in cardiac surgery patients in the United States has decreased by as much as 75% over the last decade,[1] with substantial variations among individual practices, which have been attributed to differences in patient mix and physician preference, and to conflicting evidence for the efficacy and safety of pulmonary artery catheterization.[2,3] In a recent Cochrane review of randomized controlled trials conducted comparing management with and without a pulmonary artery catheter, only 13 studies were included, 8 studies were in high-risk surgery patients and 5 studies in general intensive care unit patients.[4] Only one of these high-risk surgical studies focused on cardiac surgical patients.[5] The authors of the Cochrane review concluded that the pulmonary artery catheters did not alter mortality or length of stay in general intensive care patients, but preemptive monitoring in high-risk surgical patients may be of benefit for specific clinical scenarios.[4] None of the randomized trials designed to evaluate efficacy of pulmonary artery catheterization-guided therapy included cardiac surgery patients[6–11] and, with the exception of one multicenter prospective observational study,[2] data in cardiac surgery populations are limited to single-center series providing little information according to patient risk profiles[12,13] and underpowered to provide data on high-risk patient subgroups. This study was, therefore, designed to determine the effect of pulmonary artery catheterization on clinical outcomes after cardiac surgery in high-risk cardiac surgery patient subgroups identified from a national database.

## METHODS

Patients who underwent cardiac surgery between 2000 and 2010 were identified using the Nationwide Inpatient Sample (NIS). The NIS is sponsored by the Agency for Healthcare Research and Quality and is an administrative database containing information from all in-patient admissions from approximately 1,000 hospitals in 45 states. Each record in the database represents an in-patient stay and includes patient demographics as well as principal diagnoses, co-morbidities, procedures, and postoperative complications coded according to the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD9-CM). Additionally, each record includes a discharge weight, which facilitates extrapolation of more accurate estimates of national incidence and prevalence from NIS data (that include only approximately 20% of all hospital admissions in the country) by allowing for variation in patient mix among providers. The discharge weight is calculated by first stratifying patients within the NIS according to geographic region, urban versus rural location, teaching status, bed size, and public versus private ownership. Next, the actual numbers of patients in the United States belonging to each stratum are obtained from the American Hospital Association. The ratio between the actual number of patients belonging to each stratum and the number of NIS patients belonging to each corresponding stratum is the discharge weight. More data can be obtained from the Nationwide Inpatient Sample (NIS), Healthcare Cost and Utilization Project (HCUP) Agency for Healthcare Research and Quality, Rockville, MD website: www.hcup-us.ahrq.gov/nisoverview.jsp

Patients were identified using ICD-9-CM procedure codes 36.10-36.16 (bypass anastomosis for heart revascularization), 35.11-35.14 (open-heart valvuloplasty without replacement), and 35.21-35.28 (replacement of heart valve). Patients undergoing other cardiac surgical procedures were excluded from the analysis. Patients who underwent pulmonary artery catheterization were identified using ICD9-CM

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diagnosis codes 89.64 and 89.63. Baseline patient characteristics are listed in Table 1. In order to reduce the crowding effect (where limits on the number of procedures or diagnoses mean that secondary elements are less likely to be coded), hospitals limiting the number of diagnosis or procedural codes to fewer than 15 were excluded from the analysis. The study protocol was reviewed by the Icahn School of Medicine at Mount Sinai Institutional Review Board, which waived the need for informed consent given the dataset was de-identified and publically available.

Differences in baseline characteristics, co-morbidities, and outcomes in the final cohort were analyzed by comparing patients who underwent pulmonary artery catheterization with patients who did not. To derive national estimates, the authors applied discharge weights for each case record. The primary outcome of interest was in-hospital all-cause mortality. To test the hypothesis that use of pulmonary artery catheters in cardiac surgery patients is not associated with improved operative mortality or reduced morbidity in high-risk patients, univariate analysis of outcomes between each patient group was performed using Pearson's chi-squared and Fisher's exact test for categoric variables and Student's t-test for continuous variables. Multivariate analysis then was performed using binary logistic regression using patient demographics and co-morbidities as covariates to identify predictors of pulmonary artery catheterization.[14] To quantify linear trends in this study, univariate generalized linear models were constructed with year used as the independent covariate and the desired outcome mean or rate as the dependent variable. A risk score validated for use in cardiac surgery patients was calculated for each patient (Appendix Table 1).[15]

Results are demonstrated as odds ratios (OR) and 95% confidence intervals. A p value of $< 0.05$ was considered to be statistically significant. Prolonged invasive mechanical ventilation was defined as total postoperative ventilation longer than 96 hours, including reintubation. This definition was chosen because the only way to determine duration of mechanical ventilation in the NIS is based on ICD-9-CM procedure codes 96.71 (defined as "continuous invasive mechanical ventilation for less than 96 consecutive hours") and 96.72 (defined as "continuous invasive mechanical ventilation for 96 consecutive hours or more"). To evaluate the efficacy of pulmonary artery catheterization in specific patient risk groups, subgroup analyses were performed in octogenarian patients, patients presenting with congestive heart failure, patients undergoing double- or triple-valve surgery, and patients undergoing reoperative cardiac surgery (Appendix Tables 2-8). These subgroups were chosen because they have been associated with excess mortality in cardiac surgery.[16,17] All analyses were performed by Y.C. at the Icahn School of Medicine at Mount Sinai with SPSS for Macintosh, Version 21 (IBM Corporation, Armonk, New York).

## RESULTS

A total of 2,063,227 case records of patients undergoing coronary and/or valve surgery were identified between 2000-2010, of whom 69.4% underwent isolated coronary artery bypass grafting, 27.8% underwent a single-valve procedure with or without coronary artery bypass grafting, and 2.8% underwent double- or triple-valve surgery with or without coronary artery bypass grafting. Compared to patients who did not receive a pulmonary artery catheter, those who did, on the whole, were on average slightly older (66.6 ± 11.9 years *v* 65.5 ± 12.8 years, $p<0.001$), more likely to have pulmonary

**Table 1. Baseline Patient Characteristics**

| Baseline Characteristic | All Cardiac Surgery Patients | Cardiac Surgery Patients Who Did Not Receive PAC | Cardiac Surgery Patients Who Did Receive PAC | p Value |
|---|---|---|---|---|
| Demographic Characteristics | | | | |
| Age (mean ± SD) | 65.60 (12.75) | 65.55 (12.82) | 66.06 (11.93) | <0.001 |
| >80 years old (%) | 11.9 | 11.8 | 12.3 | 0.038 |
| Female (%) | 31.8 | 31.7 | 32.8 | <0.001 |
| Preoperative characteristics | | | | |
| Hypertension (%) | 67.3 | 67.1 | 68.8 | <0.001 |
| Hypercholesterolemia (%) | 17.8 | 18.0 | 15.2 | <0.001 |
| Diabetes mellitus (%) | 33.3 | 33.1 | 34.8 | <0.001 |
| Obesity (%) | 12.3 | 13.1 | 15.0 | <0.001 |
| Prior stroke (%) | 1.5 | 1.5 | 1.4 | 0.158 |
| Coronary disease (%) | 83.7 | 83.7 | 84.0 | 0.246 |
| Endocarditis (%) | 1.3 | 1.2 | 1.4 | 0.003 |
| Chronic obstructive pulmonary disease (%) | 21.0 | 20.7 | 24.6 | <0.001 |
| Pulmonary hypertension (%) | 5.3 | 5.1 | 7.5 | <0.001 |
| Peripheral vascular disease (%) | 13.7 | 13.5 | 15.8 | <0.001 |
| Chronic renal failure (%) | 9.4 | 9.2 | 10.9 | 0.001 |
| Dialysis (%) | 1.2 | 1.2 | 1.4 | 0.008 |
| Liver disease (%) | 1.0 | 1.0 | 1.2 | 0.054 |
| Substance abuse (%) | 0.7 | 0.7 | 0.7 | 0.911 |
| Previous CABG (%) | 4.7 | 4.7 | 5.0 | 0.055 |
| Previous valve surgery (%) | 1.0 | 1.0 | 0.9 | 0.97 |
| Operative characteristics | | | | |
| Elective surgery (%) | 51.9 | 52.3 | 49.2 | <0.001 |
| Type of cardiac surgery (%) | | | | |
| CABG (%) | 69.4 | 69.6 | 67.2 | <0.001 |
| Single-valve surgery ± CABG (%) | 27.8 | 27.6 | 29.6 | — |
| Double- or triple-valve surgery ± CABG (%) | 2.8 | 2.8 | 3.2 | — |

Abbreviations: CABG, coronary artery bypass grafting; PAC, pulmonary artery catheterization; SD, standard deviation.