

CON: Pulmonary artery catheter use should be forgone in modern clinical practice

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ABSTRACT

The pulmonary artery catheter (PAC) and its role in the practice of modern medicine remains to be questioned and has experienced a substantial decline in its use in the most recent decades. The complications associated to its use, the lack of consistency of the interpretation provided by the PAC among clinicians, the development of new hemodynamic methods, and the deleterious cost profile associated to the PAC are some of the reasons behind the decrease in its use. Since its introduction into clinical practice, the PAC and the data obtained from its use became paramount in the management of critically ill patients as well as for the high-risk/invasive procedures. Initially, many clinicians were under the impression that regardless the clinical setting, acquiring the information provided by the PAC justified its use, until a growing body of evidence demonstrated its lack of mortality and morbidity improvement, as well as several reports of the presence of difficulties—some of them fatal—during its insertion. The authors present an updated review discussing the futility of the PAC in current clinical practice, the complications associated to its insertion, the lack of mortality benefit in critically ill patients and cardiac surgery, as well as present alternative hemodynamic methods to the PAC.

Keywords: Hemodynamics, outcomes, pulmonary artery catheterization

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INTRODUCTION

From the time of its introduction in clinical practice, the employment of the pulmonary artery catheter (PAC) has been a subject of multiple debates. The majority of these have been related to an evident intersubject variability and ambiguity in the interpretation of the data derived from the device.^[1] The PAC was developed by Drs. Jeremy Swan and Williams Ganz and their findings were first published in 1970.^[2] The PAC soon became commercially available and started being used in a variety

of clinical settings including cardiac catheterization units, high-risk surgical patients, and coronary care and medical intensive care units.^[3] The PAC provides direct measurement of central venous and pulmonary artery pressure, mixed venous blood gases, pulmonary capillary wedge pressure, cardiac output by thermodilution technique, as well as left and right ventricular stroke work index. Theoretically, with this information, the PAC should allow more precise therapeutic interventions and decrease morbidity and mortality in different clinical

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populations, but unfortunately, this is not proven to be accurate.^[3-5]

Cited complications from the PAC use

The use of pulmonary artery catheterization carries a high risk of complications, some of which can prove to be fatal. Several of these complications were already described by Elliot *et al.*^[6] Cardiac arrhythmias (during PAC insertion or removal) are common, especially premature ventricular contractions.^[7] Complete heart block has also been documented during PAC placement (particularly in patients with prior left bundle branch block) which may necessitate acute implementation of cardiac pacing.^[8] In addition, mechanical damage to cardiac structures and vessels including right ventricular perforation and tricuspid valve damage can occur during PAC insertion or manipulation, with a higher incidence in patients with difficult catheter placement.^[9,10] Rare but potentially lethal complications including pulmonary artery rupture or perforation, right-sided infective endocarditis, knotting and coiling of the device as well as difficult flotation and wedge infarction have also been described.^[11-14]

Decline in the use of PAC

The popularity of the PAC use has been experiencing a precipitous decline in the United States. Wiener and Welch demonstrated that the use of PAC among medical admissions decreased by 65% through a time trend analysis between 1993 and 2004.^[15] More recent data published by Ikuta *et al.* showed a 67.8% relative decrease in PAC employment (6.28 per 1000 admissions in 1999 vs. 2.02 per 1000 admissions in 2013; $P < 0.001$). The PAC, previously a hallmark of the perioperative and critical care practice is on the downtrend, likely due to growing evidence that this invasive procedure does not carry any mortality benefit.^[16]

Lack of clinical benefit and mortality impact from the PAC use in critically ill patients

Use of PAC for medical patients in the intensive care unit (ICU) is based on the premise that additional hemodynamic data, especially in critically ill patients, including those with acute myocardial infarction, can trigger timely interventions to improve mortality. Unfortunately, clinical trials on critically ill patients have in fact shown worse outcomes with PAC use as demonstrated by Gore *et al.* and Zion *et al.* who independently suggested that PAC use in patients with acute myocardial infarction was associated with a significant increase in mortality rates.^[17,18]

The ESCAPE trial was a randomized controlled trial that studied the use of the PAC in the management of patients with congestive heart failure compared to

clinical assessment alone. The authors concluded that use of the PAC did not significantly affect the primary end point of days alive and out of the hospital during the first 6 months (133 days in PAC group *vs.* 135 days no PAC group, hazard ratio [HR] 1.00, 95% confidence interval [CI] 0.82–1.21; $P = 0.99$), mortality (10% *vs.* 9%, $P = 0.35$), or number of days hospitalized (8.7 days *vs.* 8.3 days; $P = 0.67$).^[19]

Connors *et al.* in a prospective, multicenter, cohort study on mortality risk with PAC use in the ICU analyzing 5735 critically ill adults, found that those in the PAC group had higher mortality rate at 30-day (odds ratio [OR] 1.24, 95% CI 1.03–1.49, $P = 0.03$), 60-day ($P = 0.01$) and 180-day ($P = 0.09$), additionally patients with higher baseline probability of surviving at 2 months had the highest relative risk of death following PAC insertion.^[20] Furthermore, the PAC-Man trial involving 1041 critically ill patients who were managed with or without a PAC concluded that there was no difference in hospital mortality (68% PAC group *vs.* 66% no PAC group; $P = 0.39$) although 46 out of 486 patients who required PAC placement suffered complications during insertion of the device.^[21]

Rajaram *et al.* performed a large meta-analysis including 13 studies and 5686 ICU patients in whom the use of PAC was analyzed. No beneficial effects were demonstrated on mortality and hospital length of stay in general ICU in the PAC group. In addition, studies conducted in the United States demonstrated higher overall hospital cost billed in ICU patients receiving PAC.^[22] Sandham *et al.* performed a large multicenter randomized controlled clinical trial involving blinded assessment of outcomes with 1994 patients undergoing elective noncardiac surgeries (abdominal, thoracic, vascular, and orthopedic). There was no significant difference in mortality rates, 6-month or 12-month survival rates between the two groups (7.8% PAC group *vs.* 7.7% no PAC group; $P = 0.93$). Morbidity was similar in the two groups except for a higher incidence of pulmonary embolism associated with the catheter group ($P = 0.004$).^[23]

Lack of clinical benefit and mortality impact from the PAC use in cardiac surgery patients

Based on the discussion thus far, although the data on PAC use in critically ill patients and those undergoing noncardiac surgeries is not promising, some clinicians may still argue the PAC may be valuable in patients undergoing cardiac surgeries where hemodynamics become increasingly more complex and might be more valuable for guided therapeutic interventions. Nevertheless, studies have revealed that the use of PAC provides no mortality benefit and can in fact

result in higher risk of mortality as well as an increased rate of complications.

In a retrospective national database analysis by Chiang *et al.*, among 2,063,337 patients undergoing cardiac surgery (coronary and/or valve surgery) in the US between 2000 and 2010, those who underwent pulmonary artery catheterization were found to have a significantly higher operative mortality (4.6% PAC group *vs.* 3.1% no PAC group, adjusted OR 1.34, 95% CI 1.26–1.43; $P < 0.001$), higher incidence of prolonged invasive mechanical ventilation ($P < 0.001$), and higher proportion with a total length of stay greater than 30 days ($P < 0.001$).^[24]

A recent database analysis by Brovman *et al.* found that among 116,333 patients undergoing coronary artery bypass graft (CABG) or valve replacement surgeries in the US between 2010 and 2014, the presence of PAC did not result in significant decreases in the odds of cardiac arrest ($P = 0.739$) or death ($P = 0.086$). The presence of a resident or midlevel provider was associated with a 25% to 35% increased likelihood that a PAC would be placed compared to a reference group of board-certified anesthesiologists. Thus, use of PAC seems to play a more educational role rather than a tool to reduce mortality.^[25]

Shaw *et al.* published a retrospective study of 6844 patients undergoing a variety of cardiac surgeries including CABG, valve surgery, complex nonvalvular surgery as well as heart transplant, analyzed in two cohorts (without or with a PAC). There was no difference in the 30-day in-hospital mortality rate between groups, and PAC use was associated with an increased infectious morbidity ($P < 0.001$).^[26]

Similarly, Schwann *et al.* studied 5065 patients undergoing CABG surgery in a large, international prospective observational study design. The PAC group compared to the matched non-PAC group had a significantly higher rate of in-hospital death from any cause (3.5% *vs.* 1.7%, respectively, adjusted OR 2.08, 95% CI 1.11–3.88; $P = 0.02$), and had increased organ function decline (including cardiac, cerebral and renal dysfunction), increased inotrope and fluid administration, and longer ICU stay. The authors suggested that use of PAC triggered more frequent and intensive hemodynamic interventions leading to increased complications and adverse outcomes.^[27]

Alternative methods to the PAC

Presently, several minimally invasive or noninvasive techniques for hemodynamic monitoring in this modern era may substitute the use of PAC, including:

- Pulse contour devices including the PiCCO (Pulse Contour Cardiac Output, Pulsion Medical Systems, Munich, Germany), LiDCO (Lithium Dilution Cardiac Output, Lidco Group, United Kingdom), and FloTrac (Edwards Lifesciences, Irvine, CN, US) are less invasive compared to PAC and typically require only an arterial line with or without a central line. A cross-comparison study by Hadian *et al.* found that PAC thermodilution, FloTrac, LiDCO, and PiCCO display similar mean CO values.^[28]
- Thoracic electrical bio-impedance is a noninvasive technique that measure electrical resistance of the thorax to a high frequency, low amplitude current. Spiess *et al.* compared a second-generation thoracic electrical bio-impedance (TEB) hemodynamic monitoring system with the PAC thermodilution system. They concluded that TEB showed a strong degree of agreement with PAC thermodilution during CABG surgery.^[29]
- Transesophageal echocardiography (TEE) has evolved into a routinely used monitor, especially in cardiac surgeries. Cardiac output measurements can easily be accomplished using both non-Doppler and Doppler-based methods. Studies comparing TEE and PAC thermodilution techniques have shown clinically acceptable agreement or suggested interchangeability in tracking directional changes in cardiac output^[30,31]

SUMMARY

In summary, while the PAC still remains a valid technique for calculating hemodynamic parameters, based on current literature, there is no beneficial effect on mortality or patient outcomes in the ICU as well as in the perioperative setting for both noncardiac and cardiac surgeries. Lack of mortality benefit coupled with rare, but possibly fatal complications of PAC utilization, with added hospital cost has led to a notorious decline in its use. In this modern age, with the availability of a wide variety of minimally invasive techniques to obtain hemodynamic parameters, the decision to use a PAC should be thoroughly deliberated and finally left to the discretion of the clinician.

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Conflicts of interest

There are no conflicts of interest.

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