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Jesse B. Hall, Gregory A. Schmidt, Lawrence D.H. Wood
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Part II. General Management of the Patient > Chapter 13. Clinical Use of the Pulmonary Artery Catheter > James W. Leatherman, John J. Marini

Although the pulmonary artery catheter (PAC) has been in use for more than 30 years, [1] its value in management of critically ill patients remains controversial. Different studies have concluded that use of the PAC is associated with increased mortality, [2,3] has no effect on mortality, [4,5] or decreases major morbidity. [6,7] Several prospective, randomized studies have been initiated within the last few years in an effort to better define the impact of the PAC on patient outcome. [8] Three trials have been completed, and none found an impact of the PAC on mortality. [9–11] The appropriateness of these trials has been questioned, [8,12,13] and it has been suggested that efforts instead should be directed toward improvement of the standard of practice through intensive educational efforts, institution of more stringent accreditation policies, and evaluation of newer monitoring techniques before proceeding with expensive and time-consuming randomized clinical trials. [8,12,13] The latter view is based in part on evidence that ICU nurses and physicians who use the PAC may have significant deficiencies in knowledge about some of the most fundamental aspects of hemodynamic monitoring, [14,15] raising concern that the value of the PAC may be difficult to assess if data are not collected and interpreted optimally. [16]

We believe that carefully designed prospective clinical trials may provide some guidance regarding appropriate use of the PA catheter but are unlikely to clarify with certainty whether an individual patient who is critically ill and hemodynamically unstable will benefit from the information available from a PAC. At least for the time being, ICU physicians should continue to assess the benefits and risks of catheterization on a case-by-case basis, including in the decision analysis the applicability of alternative, less invasive methods of hemodynamic assessment. [17,18] We share the view that the PAC is an "occasionally useful tool" that can be of value in guiding therapy of selected critically ill patients, especially when empirical therapeutic trials have proven unsuccessful or are considered hazardous. [19] Implicit in this view, however, is the understanding that hemodynamic data must be collected accurately by ICU nurses and must be interpreted by physicians who are knowledgeable about cardiopulmonary pathophysiology. Faulty clinical decisions based on inaccurate or misinterpreted data may be a greater risk to the patient than the procedure per se. This chapter reviews clinical use of the PAC in the ICU, with particular emphasis on principles of data acquisition and interpretation and on the practical application of PAC-derived data in guiding therapy. Where appropriate, comparisons between the PAC and alternative methods of hemodynamic assessment will be discussed.

INDICATIONS

There are no absolute indications for PA catheterization. However, a PAC sometimes may aid in the diagnosis and management of a number of common clinical conditions (Table 13-1). These include cardiogenic and distributive shock, severe acute respiratory distress syndrome (ARDS), pulmonary edema of uncertain etiology, oliguric renal failure, perplexing lactic acidosis, and unexplained pulmonary hypertension. Preoperative insertion of a PAC also has been advocated for patients undergoing cardiac surgery and for high-risk patients undergoing major noncardiac operations. However, one large prospective study found no benefit to routine placement of a PAC before cardiac surgery and concluded that catheterization should be deferred until there was a clear indication for invasive monitoring. [20] A large prospective, randomized trial involving high-risk surgical patients found no benefit to the use of a goal-oriented hemodynamic approach based on data obtained from a PAC. [10] Anticipatory placement of a PAC because a patient *might* become unstable would not seem to be justified in most instances. Rather, placement of a PAC usually should be reserved for circumstances in which important questions about underlying pathophysiologic derangements cannot be answered confidently by less invasive means. In this regard, it is interesting to note that the controversial study linking PAC use to increased mortality found that the risk of the PAC appeared to be greatest in less critically ill patients who had the highest likelihood of survival on entry into the ICU. [2]

Table 13–1. Clinical Uses of Bedside Pulmonary Artery Catheterization

Condition	Primary Data Sought
DIAGNOSTIC USES	
Pulmonary edema	Ppw
Shock	$\dot{Q}_T$ and SVR; Ppw; Sv_{O2}
Oliguric renal failure	Ppw, $\dot{Q}_T$
Perplexing lactic acidemia	$\dot{Q}_T$, Sv_{O2}
Pulmonary hypertension	Ppa and PVR, Ppad versus Ppw
Cardiac disorders:	
Ventricular septal defect	Step-up in O_2 saturation (RA to PA)
RV infarction	Pra ≥Ppw
Pericardial tamponade	Pra = Ppw; blunted *y* descent
Tricuspid regurgitation	Broad *cv* wave, Kussmaul's, deep *y* descent

Constrictive pericarditis	Pra = Pw, Kussmaul's; deep *y* descent
Narrow-complex tachyarrhythmia	Mechanical flutter waves (Pra waveform)
Wide-complex tachyarrhythmia	Cannon *a* waves (Pra waveform)
Lymphatic carcinoma	Aspiration cytology
Caloric requirements	V_{O2} (by Fick equation)
MONITORING USES	
Assess adequacy of intravascular volume:	
Hypotension	
Oliguria	
High-risk surgical patient	
Assess effect of change in Ppw on pulmonary edema	
Assess therapy for shock	
Cardiogenic (vasodilator, inotrope)	
Septic (volume, vasopressor, inotrope)	
Hypovolemic (volume)	
Assess effects of PEEP or $\dot{Q}_T$ in ARDS	

Patients for whom a PAC might be considered often can be managed effectively with alterative methods for assessing preload, cardiac output ($\dot{Q}_T$), and cardiac contractility.[17,18,22] The decision to proceed with invasive hemodynamic monitoring should be influenced by a variety of factors, including an assessment of procedural risk, the level of confidence in clinical assessment, and especially by the availability and expertise with alternative noninvasive techniques. For example, the etiology of unexplained hypotension may become obvious when echocardiography reveals severe depression of left ventricular contraction, acute pulmonary hypertension with right ventricular failure, hypovolemia with inspiratory collapse of the vena cava, or pericardial tamponade, potentially obviating the need for insertion of a PAC to establish a diagnosis.[22] On the other hand, patients with multiple and complex hemodynamic derangements that are likely to change over time, e.g., septic shock with multiorgan dysfunction, potentially may benefit from continuous hemodynamic monitoring with a PAC.

COMPLICATIONS

Complications of PAC insertion include those related to achieving vascular access and those resulting from the catheter itself (Table 13-2). Only catheter-related complications will be considered here.

Table 13–2. Complications of Pulmonary Artery Catheterization
Complications related to central vein cannulation
Complications related to insertion and use of the PAC
Tachyarrhythmias
Right bundle branch block
Complete heart block (pre-existing left bundle branch block)
Cardiac perforation
Thrombosis and embolism
Pulmonary infarction due to persistent wedging
Catheter-related sepsis
Pulmonary artery rupture and pseudoaneurysm
Knotting of the catheter
Endocarditis, bland and infective
Pulmonic valve insufficiency
Balloon fragmentation and embolization

Both atrial and ventricular tachyarrhythmias can develop as a result of catheter insertion. [23–25] Ventricular ectopy during passage through the right ventricle (RV) is not uncommon but almost always ceases as soon as the catheter tip passes through the pulmonic valve. Sustained ventricular tachycardia is unusual, and ventricular fibrillation is rare; in two large series, only 1.3% and 1.5% of patients required antiarrhythmic therapy, chest thump, or cardioversion. [23,24] Given the low incidence of sustained ventricular tachycardia, prophylactic administration of lidocaine is not recommended. Ongoing ischemia, shock, hypoxemia, electrolyte disturbances, acidosis, and/or high endogenous catecholamine levels may increase the risk of ventricular tachycardia. Arrhythmogenic factors should be eliminated before catheter insertion, when possible, and time in the RV should be kept to a minimum.

Transient right bundle branch block has been reported to occur in 0.05% to 5% of catheterizations. [25] Although generally of little consequence, even transient right bundle branch block is obviously of major concern if the patient already has left bundle branch block. However, a study of 82 patients with left bundle branch block found no episodes of complete heart block during PAC insertion, and the two episodes of complete heart block that occurred while the catheters were in place were ascribed to the underlying disease rather than to the catheter. [26] It is not necessary to place a prophylactic transvenous pacemaker when a PAC is inserted into patients with left bundle branch block, but an external pacemaker should be at the bedside.

Clinically silent thromboses occur commonly at the site of PAC insertion, and PAC-associated clots can form occasionally in the heart or pulmonary artery. [23,27] In a recent prospective, randomized study, pulmonary emboli occurred more often in patients randomized to a PAC, but the incidence of pulmonary embolism in the PAC group was only 1.6%. [10] In a second large study, none of the 335 patients randomized to a PAC developed clinically evident pulmonary embolism. [11] Pulmonary infarction related to peripherally placed catheters is also infrequent, with an incidence of 0% to 1.4% in a large series. [25] Even when infarction does occur, it is often evidenced only by a new radiographic abnormality beyond the catheter tip without apparent clinical deterioration. In brief, clinically significant thromboembolism and infarction attributable to the PAC appear to be quite uncommon.

Pulmonary artery rupture and pseudoaneurysms can occur as a direct result of PAC-induced vascular injury. Pulmonary artery rupture, the most serious complication of pulmonary artery catheterization, usually is heralded by the abrupt onset of frank hemoptysis and carries a mortality rate of up to 50%. [25] Fortunately, this complication is rare, being observed in 0.06% and 0.2% of catheterizations in two large series. [23,24] Pulmonary hypertension, cardiopulmonary bypass, and anticoagulation place the patient at increased risk for morbidity and mortality from pulmonary artery rupture. [25] It has been suggested that pulmonary hypertension may favor distal migration of the catheter tip on balloon deflation, permitting vascular rupture when the balloon is reinflated. [28] In some cases, rupture occurs with the first reinflation. Avoidance of distal catheter placement and of balloon overinflation may reduce the risk of pulmonary artery rupture. Pseudoaneurysms can develop as a result of nonlethal pulmonary artery rupture, posing a significant risk of subsequent hemorrhage that may prove fatal. [29] The possibility of a false aneurysm should be considered whenever self-limited hemoptysis occurs after manipulation of the PAC. The diagnosis can be made by dynamic computed tomographic (CT) scanning or by angiography. Prompt treatment by coil embolization may prevent subsequent aneurysm rupture. [29]

A number of unusual complications of pulmonary artery catheterization have been reported (see Table 13-2). However, a review of nine large series found that major complications are quite uncommon. [25] A different "complication" associated with use of the PAC—erroneous recording and interpretation of hemodynamic data that results in bad clinical decisions and adverse patient outcome—may be much more frequent than these procedural risks. The remainder of this chapter will focus on the principles of data acquisition and their physiologic relevance to caring for the critically ill.