Con: Pulmonary Artery Catheters Are Not Routinely Indicated in Patients Undergoing Elective Abdominal Aortic Reconstruction

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IN THE PAST MONTH, I have had two patients suffer cardiac arrest as a direct result of pulmonary artery catheters (PACs). One occurred as a result of heart block during insertion, and the other occurred during catheter removal, presumably from pulmonary embolization of thrombus on the catheter. A few months before, another patient whose severe left ventricular dysfunction was managed with a PAC died on the fourth day following lower extremity revascularization after PA rupture. When confronted with a monitoring tool that has such risks, we should seek evidence that its use improves outcome in our patients. It is important to focus on patient outcome when evaluating new and existing technologies rather than intermediate variables, especially given the growing pressures for cost containment in the American health care system.

Various factors may result in changes in physician practice patterns. Properly performed randomized clinical trials, when published in the literature, may alter practice.[1] The results of multiple studies may be synthesized using metaanalysis.[2] Increasingly, the federal government has sponsored expert panels to try to develop practice guidelines, such as those developed for the treatment of acute pain.[3] Recently, the American Society of Anesthesiologists has published guidelines for the perioperative use of pulmonary artery catheters by anesthesiologists.[4]

It also appears that reimbursement patterns[5] and physician availability[6] affect how services are provided. Whereas previous reimbursement patterns may have encouraged the use of PACs by anesthesiologists, future reimbursement formulas may pay a fixed amount for a patient's anesthetic care, or even for his or her entire hospitalization. Reimbursement schemes that are not based on time or the complexity of monitoring may result in decreased numbers of PACs inserted by anesthesiologists. Would patients suffer as a result? In most cases, I suspect not.

It is my impression that over the past decade the preparation of patients coming to the operating room for aortic reconstruction has improved. These improvements are multifactorial and include improved and more widespread antianginal and antihypertensive therapy, more precise preoperative risk assessment by noninvasive testing, and preoperative myocardial revascularization in those with the highest cardiac risk. Cardiac management has improved to the point where cardiac complications may no longer be the leading cause of death in surgical patients with coronary disease.[7] Successful therapy of chronic of hypertension results in a more stable induction of general anesthesia, presumably by increasing plasma volume[8] and reduces left ventricular hypertrophy.[9] Such improvements in preoperative preparation and pharmacologic therapy make it difficult to use historical controls to prove that PACs improve outcome, as purported by Rao et al.[10]

In addition to improvements in preoperative therapy, preoperative cardiac assessment is more common in my practice. This evaluation typically consists of standard echocardiography to document left ventricular function and may include dipyridamole thallium scanning (DTS) or dobutamine stress echocardiography (DSE) as a screening device for coronary artery disease. For these last two tests, there is a significant literature suggesting that patients with normal tests have very low rates of perioperative cardiac morbidity or mortality. Before entering the operating room, then, we have already identified a subset of patients (albeit it at a cost higher than that of a PAC, but with less risk) in whom the risk of a perioperative cardiac event is low (1.6% in patients with a normal dipyridamole thallium scanning[11] and 0% in those with a normal dobutamine echocardiogram[12]) and in whom the risk/benefit ratio of PA catheterization is presumably higher. In the 1990s, PA catheterization should be limited to those at highest risk, or to those about whose cardiac reserve little is known.

Cardiac evaluation before abdominal aortic reconstructive (AAR) surgery may detect coronary artery disease amenable to treatment by PTCA or CABG surgery. Preoperative coronary revascularization, in selected patients, improves long-term survival after vascular surgery.[13] Most studies have also suggested relatively low rates of perioperative cardiac morbidity after noncardiac surgery in patients with recent myocardial revascularization.[14,15] One presumes that many patients in Attia et al's[16] famous study documenting cardiac decompensation at the time of temporary aortic occlusion ("cross-clamping") would, in the 1990s, have undergone myocardial revascularization before AAR surgery. Even in patients at highest risk, however, there is little in the literature to conclusively persuade me that PA catheterization will benefit my patients.

The complications of pulmonary artery catheterization are legion and well known.[17] The most common include arrhythmias, arterial damage, endocardial and valvular damage, pulmonary infarct, pulmonary hemorrhage, catheter knotting, and line sepsis. These complications probably occur less frequently, and the risk/benefit ratio is probably lower in environments where the use of PACs is common. No matter how skillfully and at low risk the catheter is placed, if the intensive care environment is not one in which the information is used effectively and in which dangers (such as a wedged PA trace) are quickly recognized, then the risks are magnified. Iberti[18] has shown that many clinicians are not skillful in interpreting the result of PA catheterization, potentially resulting in inappropriate interventions. In this study, the frequency of physicians' use of

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PA catheterization and medical school affiliation of the physician's hospital predicted correct interpretation of hemodynamic data. Indeed, one study (albeit flawed in its randomization as are most studies in this area) suggests that patients with acute myocardial infarction who are managed with PACs have worse outcome.[19]

Can we get the same information that PACs provide at less risk and expense? It appears that in 90% of patients, changes in the CVP accurately reflect changes in PCWP.[20] This should not be surprising; with infrarenal aortic occlusion, which occurs during the majority of these cases, left ventricular[21] and right ventricular[22] function are generally well maintained. Recent work suggests that simple observation of the fall in pulse amplitude with a Valsalva maneuver can predict PCWP.[23] Whereas some authors have written that PAC-guided nitrate therapy and fluid loading improve outcome after AAR surgery compared to historical controls,[24] it is not difficult to administer prophylactic nitroglycerin to patients who do not have a PAC.

Proponents of PACs argue that they can provide extensive physiologic information. In addition to the measurement of cardiac output and PCWP, the oxygen saturation of mixed venous blood ($S\bar{v}O_2$) drawn from the pulmonary artery reflects the adequacy of oxygen delivery to the tissues. Recent advances in technology have allowed for continuous monitoring of $S\bar{v}O_2$. However, simply drawing venous gases from a central line (ScO_2) may also provide useful information,[25] although differences between the values of $S\bar{v}O_2$ and ScO_2 saturation in one study were greater than or equal to 5% during half of measurements. Good correlations were obtained between changes in $S\bar{v}O_2$ and ScO_2 during periods without ($r = 0.70$) and with therapeutic interventions ($r = 0.77$).[26]

For patients who may require cardiac pacing, the insertion of a PA catheter with pacing capability may be warranted. However, even in cardiac surgery, routine placement is unwarranted because the significant predictors for the use or need for pacing catheters are few and include sinus node dysfunction/bradyarrhythmias, a history of transient complete atrioventricular block, aortic stenosis, aortic insufficiency, and cardiac reoperation.[27] In this large series (600 patients), PACs with pacing capability were used to pace only 6% of patients; in only 1% of patients without pacing PACs was cardiac pacing needed prior to cardiopulmonary bypass. One presumes that the need for pacing is even lower in patients undergoing AAR surgery, and that therefore the ability to pace the heart is not a reason to insert a PA catheter in the vast majority of AAR patients. Indeed, in patients with bifascicular block, PA catheterization may produce complete heart block.[28]

Despite early studies promoting the use of PAC for detecting myocardial ischemia,[29] subsequent research has called this practice into question.[30,31] Automated monitoring of the ST segments of the electrocardiogram probably represents a far simpler and safer way of detecting myocardial ischemia in surgical patients.[32] ST segment analysis also provides the clinician with prognostic information regarding the likelihood of perioperative and long-term cardiac morbidity and mortality.

In my practice, we frequently use transesophageal echocardiography to monitor patients during AAR surgery. Whereas this modality has several limitations, including expense, the need for training, possible diversion from other aspects of anesthetic management, and the lack of monitoring in the postoperative period, it also offers advantages. These advantages probably include safety, and superior measurement of left ventricular preload over PCWP measurement.[33] Doppler technologies also allow estimation of left atrial pressure and cardiac output using TEE.[34]

Despite several trials that purport to demonstrate reductions in operative morbidity and mortality rates with PAC, routine use of invasive monitoring has not achieved widespread acceptance. This probably comes from the known complications of the PAC along with skepticism about the validity of some of the studies. Many of the studies use historical controls and do not have adequate randomization. However, two properly randomized studies in stable AAR patients have not shown benefits to PAC placement.[35] In a study of 102 patients without uncompensated renal disease (BUN > 60 mg/dL) or cardiac disease (severe inoperable coronary artery disease, cor pulmonale, uncompensated congestive heart failure, cardiomyopathy, ejection fraction <40%, or symptomatic valvular heart disease), PAC had no effect on patient outcome.[36] However, anesthesiologist professional charges were approximately $200 higher for patients who received PACs. In this study, it is important to note that 65 patients were not studied due to coexisting disease. It is possible that PAC use would be of greater value in this higher risk group.

In the American Society of Anesthesiologists' recently published practice guidelines on PAC use by anesthesiologists, the authors conclude that "PAC monitoring of selected surgical patients can reduce the incidence of perioperative complications." Yet, they go on to state that "due to deficiencies in the evidence, it is difficult to draw meaningful conclusions about the effectiveness or safety of PA catheterization based on currently available data. . . . The task force believes that . . . benefits have not been demonstrated in currently available research because most of these outcomes have not been properly evaluated."

Despite the lack of conclusive evidence, it is my current practice to place PACs in patients undergoing AAR surgery who have chronic renal insufficiency (creatinine ≥3.0 mg/dL), left ventricular dysfunction (ejection fraction <30% to 40%), recent history of congestive heart failure, insulin-dependent diabetes with end-organ complications, a supra-renal cross-clamp applied, valvular heart disease, and those with severe coronary artery disease (documented usually by DTS or DSE) in whom coronary revascularization has not been performed. Such patients represent approximately one third of the patients I anesthetize for AAR surgery. I usually place a sheath introducer in the right internal jugular vein, which allows for rapid volume administration during surgery, and for placement of a PAC later should I or the clinicians caring for the patient in the

ICU desire one. However, our experience has been that PACs are rarely placed subsequently, even with the availability of an introducer; Tuman et al[37] found similar results in patients undergoing coronary bypass graft surgery.

Recent additions to PAC have expanded the monitoring of critically ill patients. The ability to monitor right ventricular ejection fraction and continuous monitoring of cardiac output[38] or $S\bar{v}O_2$ may hasten detection and treatment of hemodynamic or oxygen transport abnormalities. However, at least one study addressing the use of oximetric PACs demonstrated no benefit over CVP monitoring or the use of conventional PACs during cardiac surgery.[39]

Given the risks involved with PAC, the changing reimbursement climate and the paucity of evidence suggesting improved outcome from routine use of PACs in AAR surgery, I suggest that our attention instead be directed towards prophylactic approaches that may minimize cardiac and other organ morbidity. Prophylactic approaches may include the use of regional anesthetic techniques (usually in conjunction with general anesthesia), the use of high doses of narcotics, and the use of α_2-agonists. For example, Reiz et al[40] demonstrated that the use of combined general-epidural anesthesia reduced the incidence of elevations of pulmonary capillary wedge pressure to greater than 18 mmHg during AAR surgery from 73% to 17%. In addition, patients who received epidural anesthesia with local anesthetics had lower indices of myocardial oxygen demand and less myocardial ischemia as detected by the V5 lead of the ECG. In a series of 100 patients undergoing aortic reconstruction, Roizen et al[41] found that elevated catecholamine levels were associated with an increased incidence of renal dysfunction; a high-dose sufentanil anesthetic tended to be more effective at reducing catecholamine levels. The suppression of the perioperative sympathetic response with sufentanil was also associated with less postoperative congestive heart failure. Another approach to sympatholysis is the use of clonidine, which can significantly attenuate the endocrine surge and elevated metabolic rate that typically follow AAR surgery, diminishing the need for intervention to treat hypertension.[42] Flacke et al[43] found that clonidine premedication increased cardiac output and lowered systemic vascular resistance after coronary bypass surgery compared to control.

Shoemaker et al[44] have suggested that using PACs to guide therapy to produce supranormal oxygen delivery decreases mortality in surgical ICU patients. However, merely monitoring hemodynamics with PACs did not improve outcome in this study. Whereas such a strategy may be useful in the patient with sepsis and multi-system organ failure, I would rather suppress postoperative increases in oxygen consumption than make a compromised heart work harder. Indeed, Berlauk et al,[45] who used preoperative PACs to guide hemodynamic optimization, produced two preoperative myocardial infarctions in the process. I prefer to use anesthetic and sympatholytic techniques to blunt the adrenergic response to surgery and pain rather than wait to start a nitroglycerin infusion once the PA pressures inevitably rise.

I believe that two other tasks deserve more attention from the anesthesiologist caring for the patient undergoing AAR surgery than does routine PAC use: aggressive attempts at heat conservation, and when appropriate, extubation of patients at the end of surgery. Postoperative hypothermia may precipitate shivering[46] and appears to be associated with myocardial ischemia.[47] Myocardial ischemia occurs frequently around the time of emergence, and the anesthesiologist must be as vigilant during emergence as during induction. Extubation in the operating room is facilitated by normothermia and aggressive use of nitroglycerin[48] and β-adrenergic blocking drugs.[49] One does not need a PAC to know that the hypertension accompanying surgical stimulation, tracheal suctioning, or extubation is usually associated with acute pulmonary hypertension, which is amenable to treatment with nitrates.

In summary, preoperative evaluation allows identification of high-risk AAR patients who might benefit from PAC placement. Despite the beliefs of some clinicians, however, there is little conclusive evidence to demonstrate that this practice improves outcome. PACs should not be used routinely in AAR patients. Rather, our efforts should be focused on blunting the adrenergic response to surgery, particularly in the postoperative period.

REFERENCES

1. Lamas GA, Pfeffer MA, Hamm P, et al: Do the results of randomized clinical trials of cardiovascular drugs influence medical practice? The SAVE Investigators [see comments]. N Engl J Med 23:241-247, 1992

2. Simes J: Meta-analysis: Its importance in cost-effectiveness studies. Med J Aus 153:S13-S16, 1990 (suppl)

3. Acute Pain Management Guideline Panel: Acute pain management in adults: Operative procedures. Quick reference guide for clinicians. AHCPR pub. No. 92-0019. Rockville, MD: Agency for Health Care Policy and Research. US Department of Health and Human Services, 1992

4. Roizen MF, Berger DL, Gabel RA, et al: Practice guidelines for pulmonary artery catheterization. A report by the American Society of Anesthesiologists task force on pulmonary artery catheterization. Anesthesiology 78:380-394, 1993

5. Wenneker MB, Weissman JS, Epstein AM: The association of payer with utilization of cardiac procedures in Massachusetts [see comments]. JAMA 12:1255-1260, 1990

6. Leape LL, Park RE, Solomon DH, et al: Relation between surgeons' practice volumes and geographic variation in the rate of carotid endarterectomy. N Engl J Med 321:653-658, 1989

7. Browner WS, Li J, Mangano DT, et al: In-hospital and long-term mortality in male veterans following noncardiac surgery. JAMA 268:228-232, 1992

8. Prys-Roberts C, Meloche R, Foex P: Studies of anaesthesia in relation to hypertension. I. Cardiovascular responses of treated and untreated patients. Br J Anaesth 43:122-137, 1971

9. Schulman SP, Weiss JL, Becker LC, et al: The effects of antihypertensive therapy on left ventricular mass in elderly patients [see comments] N Engl J Med 322:1350-1356, 1990

10. Rao TL, Jacobs KH, El-Etr AA: Reinfarction following

anesthesia in patients with myocardial infarction. Anesthesiology 59:499-505, 1983

11. Lette J, Waters D, Cerino M, et al: Preoperative coronary artery disease risk stratification based on dipyridamole imaging and a simple three-step, three-segment model for patients undergoing noncardiac vascular surgery or major general surgery. Am J Cardiol 69:1553-1558, 1992

12. Poldermans D, Fioretti P, Forster T, et al: Dobutamine stress echocardiography for assessment of perioperative cardiac risk in patients undergoing major vascular surgery. Circulation 87:1506-1512, 1993

13. Hertzer NR, Young JR, Beven EG, et al: Late results of coronary bypass in patients with infrarenal aortic aneurysms. The Cleveland Clinic Study. Ann Surg 205:360-367, 1987

14. Hertzer NR, Beven EG, Young JR, et al: Coronary artery disease in peripheral vascular patients. A classification of 1000 coronary angiograms and results of surgical management. Ann Surg 199:223-233, 1984

15. Huber KC, Evans MA, Bresnahan, et al: Outcome of noncardiac operations in patients with severe coronary artery disease successfully treated preoperatively with coronary angioplasty. Mayo Clin Proc 67:15-21, 1992

16. Attia RR, Murphy JD, Snider M, et al: Myocardial ischemia due to infrarenal aortic cross-clamping during aortic surgery in patients with severe coronary artery disease. Circulation 53:961-965, 1976

17. Boyd KD, Thomas SJ, Gold J, et al: A prospective study of complications of pulmonary artery catheterizations in 500 consecutive patients. Chest 84:245-249, 1983

18. Iberti TJ, Fischer EP, Leibowitz AB, et al: A multicenter study of physicians' knowledge of the pulmonary artery catheter. Pulmonary Artery Catheter Study Group [see comments]. JAMA 264:2928-2932, 1990

19. Gore JM, Goldberg RJ, Spodick DH, et al: A community-wide assessment of the use of pulmonary artery catheters in patients with acute myocardial infarction. Chest 92:721-731, 1987

20. Rice CL, Hobelman CF, John DA, et al: Central venous pressure or pulmonary capillary wedge pressure as the determinant of fluid replacement in aortic surgery. Surgery 84:437-440, 1978

21. Roizen MF, Beaupre PN, Alpert RA, et al: Monitoring with two-dimensional echocardiography. Comparison of myocardial function in patients undergoing supraceliac, suprarenal-infraceliac, or infrarenal aortic occlusion. J Vasc Surg 1:300-305, 1984

22. Vandermeer TJ, Maini BS, Hendershott TH, et al: Evaluation of right ventricular function during aortic operations. Arch Surg 128:582-585, 1993

23. McIntyre KM, Vita JA, Lambrew CT, et al: A noninvasive method of predicting pulmonary-capillary wedge pressure. N Engl J Med 327:1715-1720, 1992

24. Bush HL Jr, Huse JB, Johnson WC, et al: Prevention of renal insufficiency after abdominal aortic aneurysm resection by optimal volume loading. Arch Surg 116:1517-1524, 1981

25. Glamann DB, Lange RA, Hills LD: Incidence and significance of a "step-down" in oxygen saturation from superior vena cava to pulmonary artery. Am J Cardiol 68:695-697, 1991

26. Martin C, Auffray JP, Badetti C, et al: Monitoring of central venous oxygen saturation versus mixed venous oxygen saturation in critically ill patients. Inten Care Med 18:101-104, 1992

27. Risk SC, Brandon D, D'Ambra MN, et al: Indications for the use of pacing pulmonary artery catheters in cardiac surgery. J Cardiothorac Vasc Anesth 6:275-279, 1992

28. Thomson IR, Dalton BC, Lappas DG, Lowenstein E: Right bundle-branch block and complete heart block caused by the Swan-Ganz catheter. Anesthesiology 51:359-362, 1979

29. Kaplan JA, Wells PH: Early diagnosis of myocardial ischemia using the pulmonary arterial catheter. Anesth Analg 60:789-793, 1981

30. Haggmark S, Hohner P, Ostman M, et al: Comparison of hemodynamic, electrocardiographic, mechanical, and metabolic indicators of intraoperative myocardial ischemia in vascular surgical patients with coronary artery disease. Anesthesiology 70:19-25, 1989

31. van Daele MERM, Sutherland GR, Mitchell MM, et al: Do changes in pulmonary capillary wedge pressure adequately reflect myocardial ischemia during anesthesia? Circulation 81:865-871, 1990

32. Ellis JE, Shah MN, Briller JE, et al: A comparison of methods for the detection of myocardial ischemia during noncardiac surgery: Automated ST-segment analysis systems, electrocardiography, and transesophageal echocardiography. Anesth Analg 75:764-772, 1992

33. Dennis JW, Menawat SS, Sobowale OO, et al: Superiority of end-diastolic volume and ejection fraction measurements over wedge pressures in evaluating cardiac function during aortic reconstruction. J Vasc Surg 16:372-377, 1992

34. Kuecherer HF, Muhiudeen IA, Kusumoto FM, et al: Estimation of mean left atrial pressure from transesophageal pulsed doppler echocardiography of pulmonary venous flow. Circulation 82:1127-1139, 1990

35. Joyce WP, Provan JL, Ameli FM, et al: The role of central haemodynamic monitoring in abdominal aortic surgery: A prospective randomised study. Eur J Vasc Surg 4:633-636, 1990

36. Isaacson IJ, Lowdon JD, Berry AJ, et al: The value of pulmonary artery and central venous monitoring in patients undergoing abdominal aortic reconstructive surgery: A comparative study of two selected, randomized groups. J Vasc Surg 12:754-760, 1990

37. Tuman KJ, McCarthy RJ, Spless BD, et al: Effect of pulmonary artery catheterization on outcome in patients undergoing coronary artery surgery. Anesthesiology 70:199-206, 1989

38. Yelderman ML, Ramsay MA, Quinn MD, et al: Continuous thermodilution cardiac output measurement in intensive care unit patients [see comments]. J Cardiothorac Vasc Anesth 6:270-274, 1992

39. Pearson KS, Gomez MN, Moyers JR, et al: A cost/benefit analysis of randomized invasive monitoring for patients undergoing cardiac surgery. Anesth Analg 69:336-341, 1989

40. Reiz S, Balfors E, Sorensen MB, et al: Coronary hemodynamic effects of general anesthesia and surgery. Modification by epidural analgesia in patients with ischemic heart disease. Reg Anesth 7:S8-S20, 1982

41. Benefiel D, Roizen MF, Lampe GH, et al: Morbidity after aortic surgery with sufentanil vs isoflurane anesthesia. Anesthesiology 65:A51, 1986

42. Quintin L, Viale JP, Annat G, et al: Oxygen uptake after major abdominal surgery: Effect of clonidine. Anesthesiology 74:236-241, 1991

43. Flacke JW, Bloor BC, Flacke WE, et al: Reduced narcotic requirement by clonidine with improved hemodynamic and adrenergic stability in patients undergoing coronary bypass surgery. Anesthesiology 67:11-19, 1987

44. Shoemaker WC, Appel PL, Kram HB, et al: Prospective trial of supranormal values of survivors as therapeutic goals in high-risk surgical patients. Chest 94:1176-1186, 1988

45. Berlauk JF, Abrams JH, Gilmour IJ, et al: Preoperative optimization of cardiovascular hemodynamics improves outcome in peripheral vascular surgery: A prospective, randomized clinical trial. Ann Surg 214:289-299, 1991

46. Guffin A, Girard D, Kaplan JA: Shivering following cardiac surgery: Hemodynamic changes and reversal. J Cardiothorac Anesth 1:24-28, 1987

47. Frank SM, Beattie C, Christopherson R, et al: Unintentional hypothermia is associated with postoperative myocardial ischemia. The Perioperative Ischemia Randomized Anesthesia Trial Study Group. Anesthesiology 78:468-476, 1993

48. Dodds TM, Stone JG, Coromilas J, et al: Prophylactic nitroglycerin infusion during noncardiac surgery does not reduce perioperative ischemia. Anesth Analg 76:705-713, 1993

49. Stone JG, Foex P, Sear JW, et al: Myocardial ischemia in untreated hypertensive patients: Effect of a single small oral dose of a beta-adrenergic blocking agent. Anesthesiology 68:495-500, 1988