Invasive Hemodynamic Monitoring in Obstetrics*
A Critical Review of Its Indications, Benefits,
Complications, and Alternatives

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The pulmonary artery catheter was first described in 1970 by Swan, Ganz and associates. During the next decade, it rapidly evolved from a research device into a clinical tool. The pulmonary artery catheter has been successfully used for determination of cardiac output and other hemodynamic parameters to aid the clinical assessment of critically ill patients. In the United States, it has been estimated that 1 million pulmonary artery catheters are used each year; by contrast, only 6,000 are used annually in the United Kingdom. Many factors probably contribute to the dramatic increase in usage of these catheters. These include the physician's anxiety to "know all and do everything," the fear of medicolegal liability in critical care, and the lack of assurance that adequate monitoring is possible with less invasive means.

The pulmonary artery catheter has been used extensively in internal medicine, trauma care, cardiothoracic surgery, and anesthesiology. These disciplines have contributed to a growing body of literature detailing the risks and benefits of pulmonary artery catheter monitoring. The safety and utility of this modality has been controversial. Critically ill obstetric patients differ from those usually encountered in medical-surgical intensive care units; they are likely to be younger, to have fewer major organ systems involved, to have fewer chronic illnesses, and to recover fully with supportive care.

Pulmonary artery catheter monitoring of critically ill obstetric patients is a relatively recent approach, and reported experience remains limited. This critical review of pulmonary artery catheter monitoring in obstetric care was undertaken with the following goals: (1) to discuss its indications and techniques; (2) to identify methodologic risks and hazards; (3) to evaluate the current reported clinical experience; and (4) to present alternative approaches for hemodynamic management and assessment.

Indications for Pulmonary Artery Catheter Monitoring

Invasive cardiac monitoring permits the direct measurement of central venous pressure, pulmonary artery systolic and diastolic pressure, and pulmonary artery wedge pressure. Cardiac output, systemic vascular resistance, stroke work index, and other hemodynamic parameters may be derived, utilizing thermodilution techniques and physiologic equations. Critically ill obstetric patients may have altered left ventricular preload (pulmonary artery wedge pressure) and afterload (peripheral vascular resistance), which may affect ventricular performance and cardiac output. Numerous other parameters may be obtained by invasive monitoring, eg, central venous pressure, pulmonary vascular resistance, and mean pulmonary artery pressure; however, these data are generally not as important in making therapeutic decisions. It is a widely held opinion that a pulmonary artery catheter provides more specific and accurate hemodynamic measurement than physical examination and "noncentral" methods, resulting in better clinical management.

Techniques for Pulmonary Artery Catheter Monitoring

Pulmonary artery catheters are inserted through one of four major venous sites: subclavian, internal jugular, antecubital, or femoral. External jugular venous insertion, while technically possible, is seldom performed due to clinical difficulties in gaining access to central circulation via the subclavian vein. The first two sites are preferred by critical care specialists; the subclavian route is most commonly selected by gynecologic oncologists. Once inserted, the location of the catheter tip is confirmed by a chest x-ray film and by noting the characteristic pressure tracings. Sterile technique during the catheter's insertion is mandatory. Indwelling catheter sites must be frequently cleansed and inspected for evidence of drainage or cellulitis.

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(Chest 1992; 101:1429-33)
Complications of Pulmonary Artery Catheter Monitoring

Complications associated with the use of pulmonary artery catheters fall into three main categories: (1) those occurring during insertion, (2) those resulting from advancement of the catheter, and (3) those linked to maintenance of the catheter. Complications related to catheter insertion through the subclavian or internal jugular veins reflect the local anatomy of these vessels. Early complications include pneumothorax, hemothorax, inadvertent cannulation of the subclavian or carotid artery, hematoma formation, and shearing of catheters, with distal embolization. Late complications include infection of the entry site and thrombosis after the catheter's removal. The antecubital vein is less frequently used for catheter insertion, since it presents greater technical difficulties. The femoral vein is infrequently used in obstetrics due to movement of the patient and difficulty in maintaining a sterile environment.

Complications encountered during the catheter's advancement include the induction of cardiac arrhythmias, injury, and perforation or infarction of vascular structures due to catheter malpositions. Cardiac arrhythmias, pulmonary hemorrhage, pulmonary infiltrates, and pulmonary artery rupture have been described. Indwelling pulmonary artery catheters are associated with infectious morbidity resulting from the long-term placement of a foreign body which communicates with the skin and external environment. It has been noted that the endothelial surface of tricuspid and pulmonic valves traversed by these catheters may show evidence of disruption. Such injury may provide a nidus for bacterial colonization leading to endocarditis. Since some patients undergo central vascular monitoring for complications related to an established infection (e.g., septic shock), it may not always be possible to determine whether the organisms recovered in blood cultures are related to catheter usage. The overall incidence of infection associated with pulmonary artery catheter use ranges from 0.9 percent to 1.7 percent.

Currently Accepted Indications for Invasive Monitoring in Critically Ill Obstetric Patients

A limited group of medical problems in obstetric patients usually requires prompt institution of central hemodynamic monitoring to obtain vital cardiovascular data. The most common problems encountered are summarized in the following tabulation, listing indications for a pulmonary artery catheter in obstetric patients:

1. Cardiac disease or dysfunction
   - Severe valvular heart disease (usually stenotic or atricte lesions)
2. Pulmonary disease or dysfunction
   - Management of fluids with positive end expiratory pressure greater than 15 mm Hg in adult respiratory distress syndrome
   - Progressive pulmonary edema or hypoxemia
3. Renal dysfunction
   - Persistent oliguria or renal failure despite volume challenge and afterload reduction (e.g., severe pre-eclampsia).
4. Sequelae of systemic infection
   - Septic shock, regardless of etiology, refractory to standard volume and pressor therapies

In general, these patients are characterized by underlying systemic diseases associated with a grave prognosis.

Special consideration should be addressed to obstetric patients in septic shock. This relatively rare condition may arise in previously healthy women. The patients may often present with predictable physiologic alterations, i.e., hypotension coupled with high cardiac output and low systemic vascular resistance. An unknown proportion of these patients may demonstrate altered left ventricular function. The initial supportive therapy for their condition relies on increasing peripheral perfusion by increasing systemic blood pressure with volume infusion, and the use of vasoconstrictors with inotropic drugs. While it is generally accepted practice to manage these patients with pulmonary artery catheters, no current studies have shown that this modality dramatically improves clinical outcome.

Studies of Pulmonary Artery Catheter Monitoring

Table 1 summarizes the major reported studies of pulmonary artery catheter monitoring in obstetric patients. Of the 14 reports listed in this table, ten are purely investigational and seek to determine central hemodynamic parameters in normal and diseased pregnancies. Of the four remaining reports, only three describe the actual use of pulmonary artery catheters in clinical management and document experience totaling 20 patients. Only three studies in this table state whether any complication related to catheter usage occurred. Only one previous summary study has addressed the complications related to the use of pulmonary artery catheters in obstetric patients. In that particular study, placement of the catheter was performed by residents under the supervision of the author or, in his absence, by physicians in the departments of internal medicine or anesthesiology. While this experience may not be typical for all medical centers, the lack of similar data from other programs suggests that

References 7, 8, 10, 11, 13, 15-17, 19, and 20.
the potential for most obstetricians and gynecologists to learn pulmonary artery catheter placement may be quite limited. This point is important, since complication rates associated with catheter placement appear to be inversely related to the operator’s experience.28

The most common clinical problem addressed in the studies in Table 1 is severe preeclampsia. Patients with this condition exhibit varying degrees of intravascular volume depletion, intermittent vasospasm, oliguria, and increased left ventricular afterload due to systemic hypertension; however, these studies do not indicate that hemodynamic data obtained would have been helpful in their clinical management. If the major concern in such patients is to anticipate and prevent pulmonary edema, this can be accomplished by less technically dangerous means.29 The appearance of new S_{3} and S_{4} gallop rhythms, pulmonary rales, and oxygen saturation below 90 percent either by pulse oximetric recordings or arterial blood gas levels can serve this purpose. These findings generally precede the radiologic signs of pulmonary edema by 24 h.30 If pulmonary edema should occur, is it a catastrophe for such patients? Alternative approaches to clinical management have been used successfully for many years to prevent clinical sequelae. If patients with underlying cardiac disease are excluded, then the remaining patients should have normal intrinsic cardiac function and can be managed with a standard approach of volume restriction and diuresis.30

### Noninvasive Monitoring Techniques

Noninvasive technologies recently have been introduced which can help clinicians give reliable insight into central hemodynamic parameters. Hemodynamic measurements, many of which were previously obtainable only through invasive methods, are available noninvasively.31-34 Monitors, such as the pulse oximeter, used with automated sphygmomanometers, allow the estimation of tissue oxygen delivery.31 Thoracic electrical bioimpedance is a newer approach which determines changes in electrical bioimpedance of chest wall blood flow. Cardiac output can be calculated.32 Doppler devices for estimating hemodynamic parameters such as cardiac output and stroke volume have been used clinically in obstetric patients.33 M-mode echocardiography, in conjunction with electrocardiography and phonocardiography, has also been used to measure pulmonary capillary pressure, stroke volume, cardiac output, and peripheral vascular resistance in obstetric patients.34 The reported clinical experience with noninvasive monitoring in obstetric patients is still quite limited. In the future, these approaches may reduce the morbidity associated with hemodynamic monitoring.
RISK-BENEFIT RATIOS AND MINIMIZATION OF POTENTIAL RISKS

The issue of the risk-benefit ratio associated with the usage of pulmonary artery catheters is extremely important for clinicians. A recent Food and Drug Administration bulletin concerning the use of central vascular devices in nonobstetric patients is summarized in the following tabulation, listing precautions recognized by the Food and Drug Administration as necessary for central venous catheters:

Except in emergencies, placement should be done aseptically with hand washing, sterile gloves, masks, hats, gowns, drapes, and suitable skin antiseptic applied
Performed only when potential benefits appear to outweigh risks
Except for the pulmonary artery catheters, catheter tips should not be in the heart
Catheter tips should be confirmed by roentgenogram or other imaging modality
Personnel performing placement should be trained in anatomic landmarks, safe technique, and potential complications
Personnel caring for indwelling catheters should be alert to complications

Neither this review nor those previously cited conclusively establish the efficacy of pulmonary artery catheter monitoring. A prospective study of more than 5,000 intensive care patients in 13 tertiary-care hospitals was unable to show that survival rates were improved by the use of pulmonary artery catheters. The hospital with the highest adjusted survival rate had one of the lowest rates of pulmonary artery catheter utilization. There are insufficient clinical data to determine such ratios for obstetric care applications.

When central hemodynamic monitoring appears to be indicated for obstetric patients, can the complication rate be minimized? From the previous discussion, complications are less likely when pulmonary artery catheters are inserted and managed by experienced personnel. While this does not preclude the training of obstetric residents in the principles and applications of hemodynamic monitoring, the only obstetricians likely to retain their expertise will be those who practice in tertiary-care facilities. An operator's experience cannot prevent all of the complications described in this report. Complications are more likely to occur when there is an urgent need to establish central vascular access, when the patient has a coagulation disturbance, or when the anatomy of the selected vascular site is aberrant. Emphasis should be placed on the care with which the catheter is advanced, with verification of placement, so that prompt recognition and treatment of related complications can be accomplished. The risks of infection, thrombosis, and vascular damage are associated with long-term use of pulmonary artery catheters. These risks may be reduced by continuing reevaluation of the need for central monitoring. If critical medical problems have been resolved and central hemodynamic data are no longer necessary for clinical management, the catheter should be promptly removed and other monitoring techniques instituted.

SUMMARY

The monitoring of critically ill obstetric patients occasionally requires a level of consistent and reliable hemodynamic information which may be difficult to obtain by noninvasive means. Unusual acute demands for volume replacement undoubtedly support a continuing role for central vascular catheter placement. The decision to use a pulmonary artery catheter must weigh the perceived value of such information or therapy against the potential risk. A risk-benefit analysis for pulmonary artery catheter monitoring in obstetric patients should be completed as promptly as possible to aid the processes of clinical decision-making and informed consent. In each case, one must answer the question of whether sufficient data for competent medical management can be obtained through less invasive, safer methods. The continued development of sophisticated, noninvasive hemodynamic monitoring tools suggests that clinical alternatives will become more available for critical obstetric care.

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