Complications of Pulmonary Artery Catheterization in the Care of Critically Ill Patients*
A Prospective Study

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In order to evaluate the incidence and the significance of complications resulting from the use of flow-directed, balloon-tipped catheters to monitor critically ill patients, we made a prospective study of 116 pulmonary artery catheterizations. Indications for catheterization included shock, pulmonary edema, or hemodynamic instability following surgery. Arrhythmias, including premature atrial or ventricular depolarizations, ventricular tachycardia, and transient right-bundle branch block occurred during 90 of the 116 insertion procedures, but were unassociated with morbidity or mortality. In two cases (1.7 percent) staphylococcal bacteremia probably originated from the catheter. In addition, the pulmonary artery catheter led to two cases (1.7 percent) of subclavian vein thrombosis. Postmortem examinations revealed perforations of the pulmonary valve in one case. We conclude that although significant complications may result from pulmonary arterial catheterization and monitoring of critically ill patients, the incidence is low.

Since the introduction of the flow-directed, balloon-tipped catheter (Swan-Ganz)¹ for continuous monitoring of hemodynamic function a number of authors have reported complications associated with the routine use of these catheters. Arrhythmias,²-⁷ infection,⁸-¹⁰ perforation of the pulmonary artery,¹¹-¹³ as well as vascular occlusion and infarction¹⁴-¹⁶ have occurred. In addition, the catheter has injured the pulmonary and tricuspid valves.¹⁷-¹⁸ The incidence and clinical implications of these complications have not been well defined. Therefore, we initiated a prospective study to determine the incidence and significance of arrhythmias, bacterial colonization and infection, thrombosis, pulmonary infarction, and vascular injury associated with the routine use of pulmonary artery catheters to monitor critically ill patients.

Materials and Methods

From August 1977 to March 1978 we made a prospective study of 116 consecutive pulmonary artery catheterizations in 81 patients at the respiratory intensive care unit and at the general/medical-surgical/intensive care unit of the LDS Hospital in Salt Lake City, Utah. The No. 7-French triple-lumen flow-directed thermodilution pulmonary artery catheter (Instrumentation Laboratories) was inserted by one of us or by a house officer with supervision. One hundred and eight of 116 catheters were inserted via the subclavian vein using a 17-gauge needle, a guide wire, a dilator, and a No. 8-French venous catheter (Universal Medical Instrument Corporation). The sites were defatted with acetone and scrubbed with povidone-iodine which was allowed to dry before the percutaneous puncture. The balloon was inflated before passing the catheter into the right ventricle. Following a baseline ECG, continuous electrocardiograms and pressure waveform tracings were used to record arrhythmias and the location of the catheter tip during the insertion procedure. The catheter was judged to be properly placed when 1 to 1.5 ml of air, injected into the balloon port, allowed it to float into a wedge position.

Following placement, the catheters were sutured to the skin. The puncture site was covered with povidone-iodine ointment and occlusive dressings. A chest x-ray examination performed immediately after the procedure was used to look for pneumothorax. Intravenous solutions containing heparin were infused through the right atrial and pulmonary arterial ports. The right atrial port was used for the injection of cooled dextrose solution to measure cardiac output, and the pulmonary artery port was used to sample mixed venous blood. Catheters were not reused. All reused transducers were disassembled and cleaned with alcohol before gas sterilization with ethylene oxide.

All patients were reviewed daily by one of the investigators. A record of antibiotic therapy, maximum temperature, blood culture results, and clinical features was maintained. Arterial, Foley and hyperalimentation catheters were routinely cultured. Episodes of hemoptysis were investigated for evidence of catheter occlusion of the pulmonary artery, and chest x-ray films were examined for infiltration suggestive of infarction in the vicinity of the catheter. When the catheters were removed, the nursing staff cleansed the site with povidone-iodine, withdrew the catheter, and using sterile scissors clipped the distal 2 to 3 cm of the catheter into thioc broth.

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Cultures were reported to be negative only after seven days without bacterial growth. Positive cultures were interpreted to represent either "colonization" or "infection." Colonization was defined by a positive culture of the catheter tip without evidence of local or systemic infection. "Colonization with potential infection" was defined by a positive culture of the catheter tip associated with clinical manifestations of local tissue invasion or sepsis.

All blood cultures obtained while the pulmonary artery catheter was in place were recorded. Positive blood cultures were interpreted to represent contamination of the specimen only if one of multiple cultures yielded a typical nonpathogen and culture of the catheter failed to grow the same organism. In cases of bacteremia not felt to represent contamination, the role of the pulmonary artery catheter in the pathogenesis was designated to be either definite, probable, or unrelated. Assigning a definite role to the catheter required positive blood cultures and histologic or bacteriologic proof of the same bacteria at the catheter site with no other site previously or simultaneously infected. The catheter was designated to be the probable cause when the same organism was recovered from the catheter tip and from the blood stream, and there was no other primary focus apparent. Bacteremia was considered significant but unrelated if the same organism had been recovered previously from another site thought to be the primary source of the infection.

Postmortem examinations were attended by one of the investigators. The endocardial and pulmonary arterial surfaces were examined for vegetations, hemorrhages and perforations.

RESULTS

Epidemiologic Data

The patients were 49 men and 32 women who ranged in age from 17 to 91 years old (average 60 years). Seventeen of the 81 patients had more than one catheter placed. Forty-eight catheters were placed for the evaluation and treatment of shock, 53 for evaluation and treatment of pulmonary edema, and three for the evaluation of left ventricular failure in patients with decompensated chronic lung disease. Twelve catheters were positioned to monitor intravascular volume during the immediate postoperative period. Systemic antibiotics were administered during 98 of 112 monitoring periods. Antibiotic therapy was not initiated or extended for prophylaxis against catheter sepsis. Hemodynamic data including pulmonary capillary wedge pressure, pulmonary arterial pressure, and cardiac output were obtained in 112 of 116 catheterization procedures. In three cases, the catheter could not be successfully guided into the pulmonary artery in patients who probably had pulmonary arterial hypertension and a low cardiac output. In the fourth case, recurrent ventricular tachycardia related to catheter manipulation in the right ventricle, forced discontinuation of the catheterization. The mean duration of monitoring with a single catheter was 4.4 (range 1 to 14 days).

Pneumothorax, Hemorrhage, Thrombosis

In the 116 insertions studied, neither local hemorrhage nor pneumothorax were encountered. In two patients, findings of edema and collateral venous return at the shoulder suggested subclavian vein thrombosis. One of the five patients in whom antecubital veins were used developed thrombosis. In no case was there evidence of suppuration at these sites.

Arrhythmia

Review of electrocardiographic tracings revealed a deviation from the baseline rhythm in 90 of 116 insertions. Aberrant rhythms included ectopic ventricular beats alone in 53 cases, and ectopic beats accompanied by ventricular tachycardia (> 3 consecutive ectopic ventricular beats) in 27 cases (Fig 1). Ventricular arrhythmias occurred as the catheter was manipulated into the right ventricle. Transfer of the catheter from the right ventricle into

Figure 1. Arrhythmias during 116 pulmonary artery catheterizations. Each bar represents the percentage of catheterizations during which the arrhythmia was recorded. Numbers above the bars denote the number of catheterizations in which the arrhythmia was identified. APD—atrial premature depolarization; VPD—ventricular premature depolarization; VT—ventricular tachycardia; RBBB—right bundle branch block.

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Table 1—Bacteriology of Positive Catheter Tip Cultures

<table>
<thead>
<tr>
<th>Bacteria</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staphylococcus epidermidis</td>
<td>21</td>
<td>66</td>
</tr>
<tr>
<td>Diphtheroids</td>
<td>5</td>
<td>16</td>
</tr>
<tr>
<td>Pseudomonas aeruginosa</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Serratia marcescens</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Staphylococcus aureus</td>
<td>3</td>
<td>9</td>
</tr>
</tbody>
</table>

the pulmonary artery resolved these arrhythmias. In three cases, right bundle branch block appeared as the catheter was passed through the right ventricle. The right bundle branch block pattern resolved within 24 hours.

Bacterial Colonization and Infection

Ninety-two of 116 catheters were cultured at the time of removal. The remaining 24 catheters were either contaminated or discarded. Thirty-two cultures were positive. Staphylococcus epidermidis and aerobic diphtheroids were identified most frequently. Enteric bacilli and Staphylococcus aureus were infrequent in cultures (Table 1). Prolonged catheterization did not increase the incidence of positive cultures (Fig 2). Signs of local infection were not found at puncture sites. Fever (rectal temperature > 38°C) was documented in 93 of the 112 catheterization periods. Positive catheter tip cultures were defined to be colonization in five cases, and represented potential sites of infection in 27 cases. In 24 of these 27 cases another site of infection adequately explained the fever.

Bacteria were isolated from 26 of 270 blood cultures drawn while the pulmonary artery catheters were in place. Cultures were positive in four of 22 samples taken from the pulmonary artery port and three of 29 samples from the right atrial port. Nineteen of 228 cultures drawn from venipuncture sites or from arterial lines were positive. Table 2 presents pertinent clinical data and assessments in cases of bacteremia. The pulmonary artery catheter was the probable source of septicemia in two cases. In both cases the catheter had been in place for five days when positive cultures were identified, and in both instances Staphylococcus aureus was cultured.

Infarction

Pulmonary infarction was diagnosed in two cases. The diagnosis was made following hemoptysis and demonstration of a new radiographic infiltrate in the area of the pulmonary artery catheter. In one case an excessive volume of air had been used to inflate and rupture the balloon, and in the other case the catheter migrated into a distal pulmonary artery segment.

Postmortem Results

Thirty-nine of the study patients died. In no case was the pulmonary artery catheter judged to have been responsible for a fatality. Nineteen postmortem examinations were performed. In two cases small petechial hemorrhages were found on the surface of the pulmonic valve, and in four cases fibrinous
Table 2—Clinical Data in 14 Cases With Bacteremia

<table>
<thead>
<tr>
<th>Blood Cultures</th>
<th>Organism</th>
<th>Catheter Tip Culture</th>
<th>Fever (&gt;38°C)</th>
<th>Antibiotic Therapy at the Time of Culture</th>
<th>Other Sites Where the Same Organism was Cultured</th>
<th>Clinical Assessment</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>N 7 3</td>
<td>Pseudomonas aeruginosa</td>
<td>No growth</td>
<td>Yes</td>
<td>Tobramycin, Carbenicillin</td>
<td>Chest tube drainage, Tracheal aspirate</td>
<td>Pseudomonas Pneumonia</td>
<td>Unrelated</td>
</tr>
<tr>
<td>5 3</td>
<td>Staphylococcus aureus</td>
<td>No growth</td>
<td>Yes</td>
<td>None</td>
<td>Penrose drain, Tracheal aspirate</td>
<td>Staphylococcal wound infection</td>
<td>Unrelated</td>
</tr>
<tr>
<td>4 3</td>
<td>Escherichia coli</td>
<td>Streptococci Group D</td>
<td>Yes</td>
<td>None</td>
<td>Peritoneal fluid</td>
<td>Bacterial peritonitis</td>
<td>Unrelated</td>
</tr>
<tr>
<td>2 1</td>
<td>Enterobacter cloacae</td>
<td>No growth</td>
<td>Yes</td>
<td>Erythromycin</td>
<td>None—2 subsequent blood cultures without growth</td>
<td>Contaminant</td>
<td>Unrelated</td>
</tr>
<tr>
<td>3 1</td>
<td>Serratia marcescens</td>
<td>No growth</td>
<td>No</td>
<td>Cephalothin, Gentamicin</td>
<td>Sputum</td>
<td>Serratia colonization</td>
<td>Unrelated</td>
</tr>
<tr>
<td>5 1</td>
<td>Staphylococcus epidermidis Pseudomonas aeruginosa</td>
<td>Diphtheroids</td>
<td>Yes</td>
<td>Clindamycin</td>
<td>Catheterized urine specimen grew Pseudomonas</td>
<td>Urinary tract septicemia</td>
<td>Unrelated</td>
</tr>
<tr>
<td>3 1</td>
<td>Diphtheroids</td>
<td>Diphtheroids</td>
<td>Yes</td>
<td>None</td>
<td>Catheterized urine specimen grew diphtheroids prior to bacteremia</td>
<td>Urinary tract septicemia</td>
<td>Unrelated</td>
</tr>
<tr>
<td>2 1</td>
<td>Staphylococcus epidermidis</td>
<td>No growth</td>
<td>Yes</td>
<td>Clindamycin, Gentamicin</td>
<td>Sputum and catheterized urine</td>
<td>Colonization</td>
<td>Unrelated</td>
</tr>
<tr>
<td>8 8</td>
<td>Staphylococcus aureus</td>
<td>No culture (contaminated on removal)</td>
<td>Yes</td>
<td>Ampicillin</td>
<td>Arterial catheter</td>
<td>Probable catheter septicemia</td>
<td>Not classified</td>
</tr>
<tr>
<td>3 1</td>
<td>Diphtheroids</td>
<td>No culture</td>
<td>No</td>
<td>None</td>
<td>None</td>
<td>Contaminant</td>
<td>Unrelated</td>
</tr>
<tr>
<td>2 2</td>
<td>Pseudomonas aeruginosa</td>
<td>No growth</td>
<td>Yes</td>
<td>Gentamicin, Carbenicillin</td>
<td>Sputum and abdominal wound</td>
<td>Bacterial peritonitis ? pneumonia</td>
<td>Unrelated</td>
</tr>
<tr>
<td>5 3</td>
<td>Staphylococcus aureus</td>
<td>Staphylococcus aureus</td>
<td>Yes</td>
<td>None</td>
<td>Arterial line and sputum</td>
<td>Probable catheter septicemia</td>
<td>Probable</td>
</tr>
<tr>
<td>12 8</td>
<td>Staphylococcus aureus</td>
<td>Staphylococcus aureus</td>
<td>Yes</td>
<td>None</td>
<td>Arterial line</td>
<td>Probable catheter septicemia</td>
<td>Probable</td>
</tr>
<tr>
<td>7 1</td>
<td>Enterobacter cloacae</td>
<td>No growth</td>
<td>Yes</td>
<td>None</td>
<td>Tracheal aspirate</td>
<td>Probable coloniza-</td>
<td>Unrelated</td>
</tr>
</tbody>
</table>

vegetations were located on the pulmonic valve. These lesions were inspected histologically and no microorganisms were observed. In one case all three pulmonic valve cusps contained multiple perforations just below their free margins (Figure 3). This patient had pulmonary artery catheters in place longer (27 days) than the other patients.

**DISCUSSION**

Balloon-tipped flow-directed catheters are routinely used for monitoring patients with complicated myocardial infarction as well as managing pulmonary edema and shock.22,23 This is the first study in which pulmonary artery catheterization has been examined prospectively in order to define the incidence of complications arising from the routine use of this technique to monitor critically ill patients.

In the majority of our patients the flow-directed catheter was placed using a percutaneous approach to the subclavian veins. With this technique, pneumothorax, subclavian artery puncture, nerve injury and other complications of subclavian vein catheterization did not occur. In two cases subclavian vein thrombosis developed while the catheter was in place. The data suggest that pulmonary artery catheters can be placed and maintained in the central venous system with a low incidence of local complications.
Our report on rhythm changes during 78 percent of catheter insertions represents a higher incidence than previously recognized.24 We detected rhythm changes by reviewing continuous electrocardiograms, and reported all variations from the baseline rhythm. Previous reports were retrospective and depended upon visual monitoring of an oscilloscope.3,5,25-27 Nevertheless, the 78 percent incidence remains higher than the 30 percent incidence reported in a study of pulmonary artery catheterization with the No. 7 French triple-lumen catheter.28 Since a majority of our patients had acute respiratory failure, oxygen deprivation of the right ventricular subendocardium may have contributed to the higher incidence of ventricular arrhythmias detected.

In 1974, Foote et al.14 presented evidence of ischemic damage to the lungs in 9 percent of patients in whom the pulmonary artery catheter had been positioned. They suggested that infarction could result from thrombi formed around the catheter, or by the catheter occlusion of the small pulmonary arteries. We identified this complication in two of 112 successful catheterizations. In both cases, infarctions appeared to result from occlusion of the pulmonary artery by the catheter.

Local and systemic infections are well-recognized complications of indwelling catheters. The pulmonary artery catheter poses special risks beyond the fundamental problems of infection at the catheter site or contamination of infusion solutions. The transducer has been identified as a potential source of bacteremia in patients undergoing hemodynamic monitoring.10 Furthermore, blood samples must be drawn through the catheter in order to measure mixed venous oxygen tension. Blood sampling from catheters increases the risk of nosocomial septicemia.29,30 In addition to blood sampling, determination of cardiac output by the thermodilution technique requires injections of iced solutions through the catheter with the attendant risk of bacteremia.

In spite of the additional potential for infectious complications which the thermodilution flow-directed catheter poses, our results suggest that the incidence of local and systemic infections is low during routine hemodynamic monitoring. Since systemic antibiotics impair identification of bacteremia, the true incidence of bacteremia may have been underestimated. The incidence of positive cultures of catheter tips and the finding that this was not related to the duration of catheter placement agrees with a previous study of percutaneous insertion of subclavian vein catheters.31 The significance of the positive catheter tip culture remains unclear although our data suggest that these organisms rarely result in bacteremia or infection.

The two patients who developed staphylococcal bacteremia both survived following treatment with parenteral antibiotics. Although staphylococcal endocarditis has been recognized in association with the pulmonary artery catheter9 neither patient presented evidence of right-sided endocarditis during their hospitalization. This suggests that the superficial abrasion of the endocardium produced by the catheters does not invariably lead to endocarditis when staphylococcal bacteremia occurs. In support of this hypothesis, a retrospective study of staphylococcal bacteremia failed to identify clinical evidence of endocarditis when central venous catheters or pacemakers were identified as a removable source of infection.32

Finally, intravascular catheters traumatize the intimal surface and may produce intramural thrombosis or hemorrhage.11 Reviews of autopsy reports
have documented the presence of petechial hemorrhages on the pulmonary valve leaflets and thrombotic vegetations on the endocardial surface of the right atrium as well as on the tricuspid and pulmonic valves. Evidence has been presented that the pulmonary artery catheter produces both septic and aseptic vegetations within the right heart and that those vegetations may embolize. The present study confirms the occurrence of petechial hemorrhages and thrombotic vegetations in patients monitored with pulmonary artery catheters, but embolization of the vegetations was not identified. In this prospective analysis we found aseptic vegetations in four of 19 autopsy cases—an incidence of 21 percent. This incidence exceeds previous estimates based upon the retrospective analysis of autopsy material. The higher incidence may reflect the prospective design of the study or the duration of the catheterizations.

In one case perforation of the leaflets of the pulmonic valve was noted. This complication has not been reported previously. In this case three consecutive catheters were in place for a total of 27 days. In previous studies the duration of catheterization ranged up to 22 days. Thus, the longer duration of catheterization may have resulted in perforation of the pulmonic valve.

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