A Prospective Study of Complications of Pulmonary Artery Catheterizations in 500 Consecutive Patients

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Five hundred twenty-eight pulmonary artery catheters were inserted in 500 patients at the New York University Medical Center between May and November, 1981. Complications occurred in 126 of 528 catheterizations. Serious complications occurred in only 23 of these 528 catheterizations (4.4 percent). These complications, while serious, did not contribute directly to any of 31 deaths seen in these patients. Pulmonary artery catheters were reported by clinicians to have been of benefit in the management of 80 percent of these patients. We conclude, in view of this experience, that the widespread use of these catheters is justified, but only if there is a probability that the catheters will significantly contribute to the management of the individual patient.

In 1970, Swan and colleagues first described the use of a flow-directed, balloon tipped catheter for cannulation of the pulmonary artery. Since then, this technique has been widely used clinically. The ability to measure cardiac output, pulmonary artery pressure and pulmonary wedge pressure has proved to be extremely helpful in the management of seriously ill patients and the indications for the use of these flow-directed catheters have widened progressively. Complications resulting from the use of pulmonary artery catheters have been reported on numerous occasions. The incidence of these complications, however, has been difficult to determine.

Material and Methods

Five hundred consecutive patients who had pulmonary artery catheters inserted at University Hospital of the New York University Medical Center from May to October of 1981 were carefully followed-up in a prospective manner. There were 344 men and 156 women, ranging in age from 24 to 78 years with an average of 63 years. Five hundred twenty-eight catheters (93A-131F, Edwards Laboratories, Santa Ana, CA) were inserted percutaneously in these 500 patients: 416 through the right internal jugular vein, 108 through the left subclavian vein, and four via the right femoral vein. These catheters were in place from four hours to nine days with an average of 1.8 days. Three hundred eighty-five of the catheters were removed within 24 hours.

These 500 patients readily fit into three distinct groups. The first consisted of 378 consecutive patients (390 catheterizations) undergoing open heart surgery with cardiopulmonary bypass. Two hundred and fifty-six were good risk patients, while 122 had pre-infarction angina, poor left ventricular function or cardiogenic shock; the second group consisted of 44 patients (52 catheterizations) who underwent pulmonary, vascular or intestinal surgical procedures and had severe angina, sepsis or hemodynamic instability; and the third, 78 non-surgical patients (86 catheterizations) from the intensive care unit who were unstable hemodynamically from myocardial infarction, hypovolemic or septic shock or congestive heart failure.

The internal jugular vein was cannulated after locating it with a 22 gauge "finder" needle. Anatomic landmarks varied according to various operators' preferences, but in general, the needle was inserted either at the apex of the triangle formed by the medial and lateral heads of the sternocleidomastoid muscle and the clavicle, or slightly above the apex, directly through the belly of the muscle. A 2½ inch 18 gauge cannula was then placed. We used a short cannula for...
to avoid laceration of structures inferior and posterior to the clavicle (the subclavian artery, thyrocervical trunk, and dome of the pleura). Venous cannulation was confirmed by the presence of dark blood drippng, not pulsating from the cannula, the flow varying with expiration. Venous pressure or blood gas analysis were not used unless the position of the cannula was in doubt. A guidewire and introduction sheath were then inserted through which the pulmonary artery catheter was passed.

Once the tip of the pulmonary artery catheter was positioned in the superior or inferior vena cava, its balloon was inflated with 1.5 ml of air and advanced through the heart while the distal pressure and the ECG were being carefully monitored. Fluoroscopic guidance was used in only 24 instances when the pulmonary artery catheters were inserted in the cardiac catheterization laboratory or in the intensive care unit fluoroscopy suite. The catheter was advanced with the balloon inflated until a wedge pressure was obtained. The catheter was then deflated, pulmonary artery pressure identified, and the catheter fixed in this position. Whenever the balloon was reinflated, the pressure tracing was carefully observed. If a wedge pressure appeared with an inflation volume of less than 1 ml, distal migration was assumed to have occurred. The balloon was immediately deflated, the catheter withdrawn centrally, and the balloon reinflated and wedged. We hoped that this technique would minimize the occurrence of pulmonary artery injury by insuring that the catheter tip was located as centrally as possible and not in a small peripheral branch of the pulmonary artery.

Following placement of the catheter, a data sheet was begun by the physician inserting the catheter and subsequently completed by one of the authors (KB). The physicians in charge of each patient were asked to estimate the value of the pulmonary artery catheter in the care of their patients. If the data obtained from the pulmonary artery catheter caused a definite alteration in therapy, such as a change in fluid management or medication, the catheter was judged to be “very helpful.” If the data did not alter therapy but confirmed that the therapy was appropriate in an unstable or a potentially unstable patient, the catheter was judged to be “helpful.” If the data were entirely as expected and did not influence fluid or drug therapy in a stable patient, the catheter was judged to be “of little value.”

Patients were closely observed until their discharge from the hospital. Puncture sites were inspected and redressed under sterile conditions at 24-hour intervals. Daily chest x-ray films were reviewed to confirm the position of the catheter and to determine any abnormalities which could be related to it. At the time of removal, the walls of the catheter were carefully inspected for clot and their tips were cultured. If sepsis was suspected, blood cultures were obtained, the pulmonary artery catheters were removed, and their tips cultured.

**RESULTS**

Complications occurred in 126 of the 528 catheterizations (24 percent) performed in the 500 patients included in the present study. A total of 161 complications were encountered. In 100 catheterizations, one complication was encountered per catheterization; in 17 catheterizations, two complications per catheterization were encountered; and in nine catheterizations, three complications per catheterization were experienced. There appeared to be no correlation between the urgency with which the catheters were inserted and the incidence of recognized complications. Also, there was no difference in the frequency or severity of complications among the three groups of patients. Consequently, the data from the three groups were pooled.

The complications, listed in Table 1, are divided into two types. The first type (N = 138) were of a minor nature, and the second type (N = 23) were serious and potentially life-threatening.

The minor complications consisted of difficulties with catheter insertion, premature cardiac contractions, and localized inflammation at the site of catheter insertion. Problems with catheter insertion occurred 65 times and were the most frequent of the multiple complications. Multiple punctures (two or more attempts usually with a 20-gauge exploring needle) were frequently required to cannulate the internal jugular vein. Arterial punctures (again usually with a 20-gauge exploring needle) occurred eight times and hematomas (of small or moderate size) were present in 15 patients. Wedge pressures could not be obtained in 11 patients. These complications, while frequent, in all instances were of little consequence.

Minor cardiac complications occurred 65 times and consisted of atrial and ventricular premature contractions. Five patients had marked inflammation at the puncture site which rapidly cleared following removal of the pulmonary artery catheters. The catheter tip from three asymptomatic patients yielded positive cultures which were felt to be due to skin contamination and required no therapy.

Serious complications were encountered in 23 catheterizations (4.4 percent). Eight patients developed ventricular tachycardia which responded to either an intravenous bolus of lidocaine (six patients) or

| Table 1—Complications—Swan Ganz Catheters (528 Catheterizations) |
|------------------------|-----------------|
| Minor Complications    | Number | Percent |
| Complications with Insertion |        |
| Multiple sticks        | 27     | 5.1     |
| Arterial punctures     | 8      | 1.5     |
| Hematomas              | 15     | 2.8     |
| Inability to cannulate right ventricle | 3 | 0.6 |
| Inability to wedge     | 11     | 2.1     |
| Looped catheter        | 1      | 0.2     |
| Cardiac Complications  |        |
| Atrial premature contractions | 7 | 1.3 |
| Ventricular premature contractions | 58 | 11.0 |
| Infections             |        |
| Infamed puncture site  | 5      | 0.9     |
| Positive blood culture (asymptomatic patients) | 3 | 0.6 |
|                       | 138    |         |
| Serious Complications (Potentially Life Threatening) |        |
| Ventricular tachycardia | 8      | 1.5     |
| Ventricular fibrillation | 0       |       |
| Endocarditis           | 0      |         |
| Valve rupture          | 0      |         |
| Septicemia             | 7      | 1.3     |
| Pulmonary hemorrhage   | 1      | 0.2     |
| Pulmonary infiltrates  | 7      | 1.3     |
|                       | 23     |         |
to cardioversion (two patients). No patient in this series developed ventricular fibrillation, endocarditis or valve rupture.

Seven patients became septic while a pulmonary artery catheter was in place and grew out the same organisms from their blood and catheter tips. In all seven patients, however, other sites of infection were also present and were felt to be the primary cause of the septicemia (two infected median sternotomy incisions, three extensive pneumonias, one peritonitis and one urinary tract infection). No infectious complication was seen in catheterizations of less than 24 hours' duration, but the length of catheterization could otherwise be correlated with these infectious complications.

Eight patients had potentially serious pulmonary complications. One had hemoptysis following inflation of the pulmonary artery balloon. After the balloon was promptly deflated and the catheter withdrawn, hemoptysis stopped and there was no further difficulty. Seven patients developed wedge-shaped infiltrates distal to the pulmonary artery catheter. Two of these patients developed a clinical picture of pulmonary embolism while the other five had only radiographic abnormalities.

Thirty-three percent of the catheters had clots on their walls at the time of removal, while clots were present on the catheter walls in 30 of 33 patients who had their right heart opened during open heart surgery.

The overall mortality rate was 6 percent among these 500 patients. None of the deaths, however, was felt to be directly related to the pulmonary artery catheters, but rather to the severity of the patient's underlying disease.

The numerous physicians caring for these patients reported that the data obtained from the pulmonary artery catheters altered therapy and was therefore "very helpful" in patient management in 35 percent of the catheterizations, confirmed the adequacy of therapy ("helpful") in 45 percent, and was "of little value" in 20 percent.

DISCUSSION

This prospective study, as well as that reported by Puri et al10 and Elliott et al8 clearly shows that complications from the use of pulmonary artery catheters occur frequently. Fortunately, however, serious potentially life-threatening complications are uncommon. In the present study, the serious complications were septic, pulmonary and cardiac in nature and a clear recognition that these complications can occur is important.

Sepsis was not a major problem in our patients. The seven patients who had had positive results of cultures from their catheter tips and blood also had infections in other areas, and it was our impression that these catheters became infected secondarily rather than being the primary cause of the infection. This experience was similar to that reported by Michel et al10 and seems to indicate that while sepsis is a very serious possibility, the incidence of its occurrence is low enough not to contraindicate the use of these catheters.

Pulmonary embolic complications from the use of pulmonary artery catheters were surprisingly infrequent. Thirty-three percent of the catheters, when removed, had clots on their wall while 30 of 33 catheters (91 percent) observed in the right atrium at the time of an open heart procedure had clots present. Undoubtedly, some clot was stripped from the catheter at the time of removal so that the presence of clot on these catheters was probably closer to that seen on the catheters in the right atrium than that noted at the time of removal. This suggests that pulmonary emboli should be relatively frequent in patients with these catheters in place. This, however, was not the case and only seven patients had any indication of a pulmonary embolus. Two of these patients had a clinical picture suggesting the presence of a pulmonary embolus, while the other five had only radiographic changes of a wedge-shaped density distal to the site of the pulmonary artery catheter. In two patients, the catheter tips were very peripheral and may have occluded the pulmonary artery. In the others, the catheter tips were centrally located. It is interesting to note that this experience closely parallels that of Foote et al.9 Recently heparin-bonded catheters10 have become available and it is hoped they will eliminate clot formation on pulmonary artery catheters. Further experience, however, will be required to confirm this expectation.

The cardiac complications encountered in this study were likewise of little consequence. Eight patients (1.5 percent) developed ventricular tachycardia which required therapy; however, ventricular fibrillation was not seen. The incidence of arrhythmias and ECG changes noted in this group of patients was smaller than that noted by Elliott et al8 in their recent report. They used continuous ECG tracings to identify abnormalities, while in the current study only observation of an ECG monitor was used. In both series, cardiac complications were infrequent, but catastrophic complications are always a possibility.

Difficulty with catheter insertion, while frequent, was of little significance. Since the completion of this study, however, three patients have required cervical exploration for control of arterial bleeding which developed during pulmonary artery catheter insertion. This makes it clear that serious local complications can occur whenever one of these catheters is used and great care must be employed during their insertion.
Prior to the beginning of the current study, massive hemoptyis occurred in four of our patients as a result of the use of pulmonary artery catheters. We therefore introduced the technique of catheter insertion and maintenance described above hoping to obtain consistently the most central possible wedge position for the catheter tip and to prevent pulmonary artery injury. This regimen seemed to be successful in this group of patients. Only one patient who was not receiving anticoagulants had hemoptyis which proved to be mild. Since the completion of this study, however, a fifth and sixth patient who were receiving anticoagulants had massive hemoptyis. While improper technique was probably used in at least two of these six patients, our experience demonstrates that in spite of the exercise of great care in trying to maintain the balloon as centrally as possible and out of small branches, the pulmonary artery can still be injured resulting in massive hemoptyis.

Pulmonary artery injury in a heparinized patient is so likely to result in fatality, as was the case in two of our patients, that we presently do not measure wedge pressures in patients on cardiopulmonary bypass, but rather use the pulmonary artery diastolic (PAD) pressure. Pulmonary artery diastolic pressure frequently correlates closely with and can be substituted for pulmonary artery wedge pressure. In patients where there is a substantial difference between the PAD and the wedge pressures, we measure left atrial pressure directly. Correlation between the PAD and wedge pressures must be checked periodically, but when distention of the balloon is not required, pulmonary artery injury should be much less likely to occur.

From our experience with approximately 5,000 catheterizations, six episodes of massive hemoptyis resulting in five deaths occurred, an incidence of approximately one pulmonary artery injury in each 800 catheterizations (0.125 percent). This incidence is similar to that reported in other series.17,18 These estimates must be considered when deciding to use a pulmonary artery catheter in any patient.

University Hospital receives relatively few patients with severe burns or multiple trauma so that these critically ill, immunocompromised patients made up only a small percentage of the patients included in this study. It should also be noted that approximately half the patients in this series were good risk patients undergoing routine heart surgery and in whom the pulmonary artery catheters were in place for less than 24 hours. In spite of this fact, we could not correlate severe complications with the length of catheterization except that no infectious complications occurred if the PA catheters were in place for less than 24 hours. It is possible that if there had been more severely ill patients, requiring longer periods of catheterization, severe complications might have been seen more frequently.

Pulmonary artery catheters have proven to be of great help in the management of critically ill and injured patients. Recent studies have shown pulmonary artery catheters to be effective in preventing renal failure,7 diagnosing and treating myocardial ischemia,19 and preventing perioperative myocardial infarctions.30 Our experience confirms the usefulness of these catheters since they were felt to be helpful in the management of 80% of the patients. Although a 24 percent complication rate may seem high, it must be remembered that only 4.4 percent of the complications were of a serious nature and none of these complications contributed to the 31 deaths seen in these 500 patients. The most disastrous possible complication from the use of a pulmonary artery catheter, of course, is a ruptured pulmonary artery and the consequent massive hemoptyis. Even though we estimate this complication occurred only once per 800 catheterizations (0.125 percent) in our total experience, this possibility must be borne in mind when contemplating using a pulmonary artery catheter. Overall it seems to us that the use of pulmonary artery catheters is justified, but that the potential benefit to each individual patient from their insertion must be real and the risk of complications considered before deciding to use them.

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