Pulmonary Artery Catheter Migration during Cardiac Surgery

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METHODS

Sixteen men and five women patients scheduled for elective coronary artery bypass surgery were studied. A 7.5F quadruple-lumen pulmonary artery catheter was inserted by the Seldinger technique through the right internal jugular vein and advanced to a wedge position using a 1.5-ml balloon inflation volume. An external sterile shield containing approximately 15 cm of catheter allowed subsequent sterile catheter manipulations during the operation. Each catheter was secured to the patient’s forehead to prevent its accidental migration, and the length of catheter at the distal end of the introducer was measured.

Anteroposterior chest radiographs were obtained at four intervals: after endotracheal intubation (baseline) (fig. 1a), after the initiation of cardiopulmonary bypass (fig. 1b), after anterior retraction of the ventricular apex during bypass using a Janke-Barron heart support (fig. 1c), and after chest closure (fig. 1d). Only those patients with the catheter positioned in the right pulmonary artery were studied. Radiographs were taken at end-expiration except during bypass, when the lungs were allowed to deflate passively.

Radiographic determination of catheter placement was made by locating the catheter tip relative to a zero point, defined as the point at which the catheter in the pulmonary artery visually intersected the portion of the catheter in the superior vena cava (fig. 1a). Catheter tip location

FIG. 1. Radiographs of a Group 1 patient showing catheter tip placement after A. endotracheal intubation (arrowhead indicates zero point, open arrow indicates catheter tip); B. onset of cardiopulmonary bypass, note that catheter tip has passed beneath retractor flange (open arrow); C. anterior retraction of the ventricular apex (catheter tip remains behind retractor flange); and D. chest closure (open arrow indicates catheter tip). Following cardiopulmonary bypass, the pulmonary artery catheter appeared permanently wedged and required 5-cm catheter withdrawal to obtain a satisfactory tracing between C and D intervals.
to the patient's right of the zero point was designated positive; to the patient's left, negative. If the catheter tip was obscured by the sternal retractor, the relative measurement was made to the point at which the catheter disappeared beneath the retractor flange. Notation was made by an experienced radiologist of any catheter tip located in the distal intralobar pulmonary vessels or one of the segmental branches of the pulmonary artery.

During the operation, mean systemic arterial pressure (MAP), mean pulmonary artery pressure (PAP), central venous pressure (CVP), pulmonary artery wedge pressure (PAWP), heart rate (HR), temperature in degrees Celsius, and mean cardiac output (Q) from triplicate injections of iced saline were recorded. In both groups, proper catheter position was verified by the oscilloscope tracing of the waveform. Damped tracings were corrected by 1–2 cm withdrawal of the catheter before inflation of the balloon.

In Group 1 patients (n = 11), the catheter position was not manipulated before or during bypass. In Group 2 patients (n = 10), the catheter was withdrawn 5 cm just before cardiopulmonary bypass was begun. After bypass, all catheters were withdrawn or advanced as necessary to obtain PAWP using a 1.5-ml balloon inflation volume.

This study was approved by the Institutional Research Practices Committee and required patient consent. Data, expressed as mean ± SE, were analyzed using paired and unpaired t tests, with P ≤ 0.05 considered significant.

RESULTS

We found no significant differences in hemodynamic variables between Group 1 and Group 2 patients and their data were pooled (Table 1). No patient in either group had evidence of pulmonary artery perforation. Catheters in all 21 patients were located in the right pulmonary artery.

In Group 1 patients, the period of median sternotomy and initiation of cardiopulmonary bypass was associated with spontaneous distal catheter migration from −0.5 ± 0.6 cm at baseline to 4.9 ± 0.6 cm (P < 0.01); the range was 2.1–8.4 cm (Fig. 2). Anterior retraction of the ventricular apex caused slight proximal movement to 4.0 ± 0.4 cm (P ≤ 0.01, compared with baseline values). During bypass, ten catheters were located in intralobar or segmental branches of the pulmonary artery. After bypass was discontinued, seven patients in Group 1 had damped pulmonary arterial waveforms indicating permanently wedged catheters, which required 2.0 ± 0.6 cm withdrawal. Following chest closure, catheter tips remained near the baseline position at −0.5 ± 0.7 cm. In four patients, the catheter tips were obscured by the retractor flange. Radiographs from one patient in Group 1 are shown in figure 1. Of note, this catheter required 5-cm withdrawal to obtain a satisfactory waveform tracing following cardiopulmonary bypass between (c) and (d) intervals.

In Group 2 patients, despite 5-cm catheter withdrawal just before the start of cardiopulmonary bypass, catheters migrated from −0.1 ± 0.6 cm (baseline) to 3.5 ± 0.6 cm (P < 0.01) over a range of 0.7 cm to 7.2 cm. This amount of migration with bypass was similar in both groups of patients. During ventricular retraction, the migration distance decreased to 1.9 ± 0.8 cm, which was greater than baseline (P < 0.01), but less than that in Group 1.

### Table 1. Hemodynamic Variables in Group 1 and 2 Patients (n = 21)

<table>
<thead>
<tr>
<th>Metric</th>
<th>Baseline</th>
<th>Cardiopulmonary Bypass</th>
<th>Apical Retraction</th>
<th>Chest Closure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean arterial pressure (mmHg)</td>
<td>78 ± 1</td>
<td>56 ± 2</td>
<td>58 ± 2</td>
<td>79 ± 2</td>
</tr>
<tr>
<td>Heart rate (beats/min)</td>
<td>64 ± 2</td>
<td>67 ± 5</td>
<td>52 ± 7</td>
<td>92 ± 2</td>
</tr>
<tr>
<td>Pulmonary artery pressure (mmHg)</td>
<td>20 ± 1</td>
<td>4 ± 1</td>
<td>4 ± 1</td>
<td>23 ± 1</td>
</tr>
<tr>
<td>Pulmonary artery wedge pressure (mmHg)</td>
<td>12 ± 1</td>
<td>*</td>
<td>*</td>
<td>15 ± 1</td>
</tr>
<tr>
<td>Central venous pressure (mmHg)</td>
<td>10 ± 1</td>
<td>4 ± 1</td>
<td>4 ± 1</td>
<td>15 ± 1</td>
</tr>
<tr>
<td>Cardiac output (l/min)</td>
<td>5.2 ± 0.3</td>
<td>5.5 ± 0.2</td>
<td>5.3 ± 0.2</td>
<td>5.4 ± 0.3</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>35.8 ± 0.1</td>
<td>32.3 ± 0.4</td>
<td>31.5 ± 0.5</td>
<td>35.1 ± 0.1</td>
</tr>
</tbody>
</table>

* No wedge determinations taken during cardiopulmonary bypass.

![Fig. 2. Catheter tip migration distances during cardiac surgery in patients without prebypass catheter manipulation (Group 1) and with 5-cm prebypass catheter withdrawal (Group 2). Positive displacement indicates catheter tip migration into the distal pulmonary vasculature.](image-url)
patients ($P < 0.02$). Six catheter tips were located in lobar or segmental branches during bypass. Following bypass, all Group 2 patients maintained a normal waveform pattern ($P < 0.01$, compared to Group 1 patients). Catheter tips remained in the pulmonary artery in nine of the 10 patients; the catheter in the tenth patient was located in the right ventricle, and was advanced without difficulty. Following bypass, catheters in Group 2 patients were repositioned to a wedge position on the first attempt without arrhythmias and required reinsertion of distances of 2.2 ± 0.9 cm. After chest closure, catheter tip location was −0.8 ± 0.6 cm. Catheter tips in three Group 2 patients were obscured by the retractor flange.

**DISCUSSION**

Although catheter perforation of the pulmonary artery is a rare complication occurring in 0.06–2.9% of cases,$^{4,6–9}$ more than one-third of all cases have occurred in cardiac surgical patients,$^2$ which can increase subsequent mortality by 45–53%.$^{1,10,11}$ Typically, the diagnosis of pulmonary artery perforation is not made until cardiopulmonary bypass has been discontinued and pulmonary perfusion has resumed.$^{1–3,5,11,12}$

Factors associated with catheter perforation of the pulmonary artery are pulmonary hypertension,$^{11–14}$ advanced age,$^{10,11,14}$ hypothermia,$^4$ anticoagulation,$^{15}$ and distal catheter migration.$^{2,4,9,11}$ Even without the influence of cardiac surgery, catheters in the pulmonary artery tend to migrate distally within the first 12 h of insertion.$^{16}$ Chen et al. attribute this spontaneous movement to shortening of the catheter loop in the right ventricle.$^2$ Catheters inserted in patients undergoing cardiopulmonary bypass are thought to migrate distally with collapse of the right ventricle, extrapericardial positioning of the heart, and lung deflation$^{4–5}$; hypothermia may increase catheter rigidity and potentiate this problem.$^4,17$ Subsequent perforation of the pulmonary artery can occur directly from the catheter tip with small vessel rupture or following balloon inflation.

In this study, catheter tips migrated peripherally nearly 5 cm with the sternotomy and onset of cardiopulmonary bypass; anterior retraction of the ventricular apex caused no further migration. Ninety-one percent of the tips were located in lobes or segmental branches of the pulmonary artery. In addition, seven out of 11 catheters appeared to be permanently wedged after bypass. Balloon inflation at this time could potentially cause vessel rupture.

Since central placement of the catheter tip appears preferable, several authors recommend withdrawal of the catheter before bypass is begun.$^{3–5,18,19}$ Stone et al. reported 200 cases in which the catheter was withdrawn 15 cm, leaving the tip in the right ventricle during bypass.$^{18}$ Although they found no evidence of pulmonary artery rupture, reinsertion of the catheter caused ventricular ectopy in 20 patients and was difficult in 24 patients, requiring as long as 5 min. The ability to diagnose left ventricular distention and pulmonary venous obstruction was lost with the catheter tip in the right ventricle.$^{20}$ Shah et al. reported a case where readvancing the inflated catheter from the right ventricle during bypass caused obstruction of the caval cannula and, thus, return of blood to the oxygenator. Another potential consequence of catheter tip withdrawal into the right ventricle is perforation of the ventricular wall, particularly during surgical manipulation. Consequently, catheter withdrawal to the main pulmonary artery before cardiopulmonary bypass seems preferable to withdrawal into the right ventricle.$^{7,20,21}$

Based on results in Group 1 patients, we expected the 5-cm catheter withdrawal in the prebypass period in Group 2 patients to correct any spontaneous distal tip migration. However, Group 2 patients had a similar amount of catheter migration with bypass, and 60% of tips during cardiopulmonary bypass were located in small vessels. In both groups, the greatest distal migration occurred after sternotomy and the onset of bypass and not with extrapericardial positioning. Apical retraction caused no further tip migration, but actually decreased the migration distance in Group 2 patients. Prebypass catheter withdrawal did significantly lessen the incidence of permanent catheter wedging in the postbypass period.

Patients included in this study did not have pulmonary hypertension. Catheter tip placement and migration during bypass in patients with pulmonary hypertension may be different and warrant further study.

We conclude that pulmonary artery catheters spontaneously migrate into the distal pulmonary vasculature with cardiopulmonary bypass and apical retraction. Five-centimeter catheter withdrawal just before bypass maintains functional integrity of the catheter and lessens the amount of distal migration with apical retraction. However, distal catheter migration should be anticipated during cardiopulmonary bypass and the anesthetist should carefully reposition the catheter by looking for a typical pulmonary artery pulse pressure tracing before inflating the balloon.

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**REFERENCES**

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Amniotic fluid embolism (AFE) is a rare peripartum complication (1 case for every 8,000 to 80,000 deliveries), with a reported mortality rate of 86%. The main clinical signs include cyanosis and shock of sudden onset, pulmonary edema, occasional neurologic signs, and coagulopathies. The diagnosis of AFE, previously made on postmortem examination of the lungs, can now be made in vivo by examination of a blood aspirate from the right heart, which shows lanugo and fetal squamae. Causes of death include coagulopathy and "circularatory collapse" of unclear pathophysiology. We report a case of AFE in which severe acute left heart failure with complete resolution was observed.

**REPORT OF A CASE**

A 25-year-old woman was admitted for delivery of her first child shortly after the spontaneous rupture of her membranes. Amniotic fluid was clear; her pregnancy was full-term and had been uneventful. She had no known cardiac or pulmonary diseases and complained of no symptoms during the late stages of her pregnancy. A clinical examination performed 5 days before admission was normal (arterial blood pressure: 120/60 mmHg; heart rate: 64 beats/min).

Labor started 5 h after admission, and oxytocin (5.10^{-9} IU·min^{-1}) was administered by IV continuous infusion until the second stage of labor. Between uterine contractions, heart rate was 80 beats/min and arterial blood pressure was 120/65 mmHg. Nine hours after admission, when active expulsive efforts began during the second stage of labor, cyanosis, respiratory distress, and hypotension (systolic arterial blood pressure 70 mmHg, heart rate 135 beats/min) suddenly occurred. Immediate iv administration of thiopental, 200 mg, and succinylcholine, 40 mg, permitted tracheal intubation. Large amounts of frothy pink fluid were aspirated from the trachea. Ventilation was controlled with a fractional inspired O2 concentration (FiO2) of 1.0 without positive

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**Left Heart Failure in Amniotic Fluid Embolism**

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