Video Fluoroscopy for Positioning of Pulmonary Artery Catheters in Patients Undergoing Cardiac Surgery

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Objectives: **To determine whether video fluoroscopy combined with traditional pressure waveform analyses facilitates optimal pulmonary artery catheter (PAC) flotation and final positioning compared with the traditional pressure waveform flotation technique alone.**

Design: **Prospective, single-center, randomized, controlled trial.**

Setting: **Single-center university teaching hospital.**

Participants: **The study included 50 cardiac surgery patients at higher risk for PAC complications.**

Interventions: **Use of video fluoroscopy to facilitate optimal PAC flotation and positioning.**

Measurements and Main Results: **The primary outcome was the time taken to float and position the PAC balloon in the pulmonary artery as confirmed by transesophageal echocardiography. Secondary outcomes included number of attempts at flotation, ventricular rhythm disturbances, and catheter malposition. Patients were evenly matched in baseline demographics, New York Heart Association symptoms of heart failure, severity of left and right ventricular dysfunction, end-diastolic pressures and dimensions, severity of tricuspid valvular disease, and atrial and pulmonary artery pressures. Mean (SD) time to float the PAC was significantly shorter in the video fluoroscopy group than in the usual care group: 73 seconds (SD, 65.1) versus 176 seconds (SD, 180.6), respectively; p = 0.014. The median (interquartile range [IQR]) number of attempts to successful flotation was fewer in the video fluoroscopy group than in the usual care group: 1 (IQR 1:2) attempt versus 2 (IQR 1:4) attempts, respectively; p = 0.007. The composite complication rate (malposition and arrhythmias) was lower in the video fluoroscopy group than in the usual care group (16% *v* 52%, respectively; p = 0.01).**

Conclusions: **In cardiac surgery patients at higher risk for PAC complications, video fluoroscopy facilitated faster and safer catheter flotation and positioning compared with the traditional pressure waveform flotation technique.**

KEY WORDS: cardiac surgery, pulmonary artery catheter, video fluoroscopy, complications

SINCE THEIR INTRODUCTION in clinical practice 4 decades ago, balloon-tipped, flow-directed pulmonary artery catheters (PACs) have found widespread use in the clinical management of critically ill patients undergoing cardiac surgery. The PAC originally was developed as a "balloon-tipped catheter" to be used at the bedside without requiring radiology or fluoroscopy for insertion. PAC-derived hemodynamic data can provide information critical to the effective management of critically ill patients, even if other monitoring modalities, such as transesophageal echocardiography (TEE), are used.[1,2] Correct positioning of the PAC in the pulmonary artery (PA) is essential for its safe use, and pressure waveform analysis is the most common method used to guide flotation of the PAC tip into position. However, due to abnormal or slow intracardiac blood flow, this technique may be difficult in patients with poor cardiac function or severe valvular heart disease, resulting in repeated attempts at flotation, arrhythmias, and catheter malposition. Therefore, in patients undergoing cardiac surgery who are considered at higher risk for PAC complications, the authors hypothesized that video fluoroscopy combined with pressure waveform analysis would achieve a faster, more reliable and therefore safer catheter flotation and final positioning compared with the traditional pressure waveform flotation technique alone.

METHODS

After receiving Austin Health Research Ethics Committee approval (H2009/03740) and written informed participant consent, the authors conducted a single-center, randomized, clinical trial between July 2010 and July 2012 at a university teaching hospital that is experienced in complex cardiac surgery. The study was registered with the Australian New Zealand Clinical Trials Registry (number: 12614001081606). Inclusion criteria included adult patients considered to be at higher risk for difficult PAC insertion who were undergoing elective or semi-urgent cardiac surgery that necessitated a PAC as part of routine perioperative care. Because there are no validated criteria for patients at "high risk" for difficult PAC insertion, the authors defined "high-risk" as 1 or more of the following criteria: left ventricular ejection fraction $<35\%$, low-cardiac-output syndrome (cardiac index <1.5 L/min/m^2), severe pulmonary hypertension (mean pulmonary artery pressure >40 mmHg), and severe tricuspid insufficiency. Criteria for inclusion were obtained from routine preoperative transthoracic or transesophageal echocardiography, coronary angiography, and right heart catheterization studies. Exclusion criteria included age <18 years, inability to provide informed and written consent (eg, patients awaiting surgery in the intensive care unit who had been administered sedatives), and time-critical surgery in which induction of anesthesia was imperative before the PAC being inserted (eg, acute aortic dissection). Patients were assigned randomly into 2 groups using a computer-generated program: those in whom the PAC was floated using video fluoroscopy combined with real-time pressure

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1053-0770/2601-0001$36.00/0

http://dx.doi.org/10.1053/j.jvca.2015.07.033

waveform monitoring (fluoroscopy group) and those in whom the PAC was floated by real-time pressure waveform monitoring alone (usual-care group). If the PAC was unable to be floated within a 10-minute period, patients were transferred to the alternative group.

Three senior consultant cardiac anesthesiologists, who are proficient in PAC insertion and video fluoroscopy, performed all PAC insertions using a protocol designed to standardize care in both groups. On arrival to the operating room, all patients underwent placement of a peripheral intravenous cannula and an arterial blood pressure monitoring line. A conscious sedation technique with midazolam (0.02-0.05 mg/kg) and fentanyl (0.5 ug/kg) was used to place patients supine in the Trendelenberg position (30-degree tilt of the bed below horizontal, with the head in lowest position) on a standard radiolucent operating room table. Per the authors' institution's radiology protocols, the anesthesiologists were not required to wear a dosimeter because the procedure was performed in the cardiac operating room and screening times were of very short duration. A trained radiologist operated the fluoroscopy machine. In keeping with stringent hospital policy, protective garments, including thyroid shielding, were worn by all personnel. The standard garment worn is a 0.5-mm lead apron, which stops approximately 95% of the scatter radiation. Fixed screening barriers provided additional protection from scattered radiation for all personnel, except for the anesthesiologist performing the procedure. Using real-time ultrasound guidance and the standard aseptic Seldinger technique, a 9-French Arrow-Flex Sheath (Teleflex Inc., Morrisville, NC) was inserted into the internal jugular vein of all patients. The PAC sheath was primed with normal saline and sutured to the neck. A Swan-Ganz CCOmbo PAC (Edwards Lifesciences, Irvine, CA) was prepared per normal protocol and used in all patients.

Technique for PAC Flotation in the Usual-Care Group

1. The distal port of the PAC was connected to a pressure transducer and monitor.
2. The patient was repositioned by rotating the operating table 15 degrees to the right from the supine position in the reverse Trendelenberg position (30-degree tilt of the bed above the horizontal, with the head in the highest position).
3. The patient was connected to an electrocardiograph, which continuously recorded the electrocardiogram (ECG) tracing.
4. An independent research nurse started timing when the catheter was inserted 5 cm into the PAC sheath. Two stopwatches were used for timing.
5. When the catheter tip first entered the vessel lumen and oscillations appeared on the pressure tracing, the balloon was inflated with 1.5 mL of air.
6. The catheter then was advanced continually at a rate of 2 cm every second using slow continuous motions and rotated as required by the operator. Conventional pressure waveform analyses were used to identify the position of the PAC as it traversed from the superior vena cava (SVC) into the right atrium (RA) (central venous pressure trace), into the right ventricle ([RV] pressure trace), and then into the PA (PA pressure waveform trace).
7. The number of attempts at insertion were recorded. An attempt was defined as the necessity to withdraw the catheter back into the RV, RA, or SVC to assist with PAC insertion.
8. If more than 4 attempts to advance the catheter into the PA were unsuccessful, the following technique was used to facilitate placement of the PAC in the PA:

First, the catheter was removed from the PA sheath and "stiffened" by flushing 20 mL of cold normal saline at a temperature of 4°C through it after its tip was bent into a three-fourths circle. Three further attempts to position the PAC in the PA were allowed.

1. When the anesthesiologist was satisfied that the catheter was in an optimum position in the PA, timing was stopped and the catheter was secured.
2. If the PAC was unable to be floated into the PA within 10 minutes, patients were transferred to the video fluoroscopy group.

Technique for PAC Flotation in the Fluoroscopy Group

The technique for PAC flotation in the fluoroscopy group was identical to that performed in the usual-care group; however, before the commencement of floating the PAC, the video fluoroscopy machine was positioned over the patient, enabling direct visualization of the course of the PAC from the distal end of the PAC sheath to the PA. Video fluoroscopy was used to visualize catheter positioning from the SVC into the RA, into the RV, and then into the PA. Video fluoroscopy demonstrating flotation of the PAC in a patient undergoing re-do cardiac surgery is presented in Figure 1 and Video 1. If the PAC was unable to be floated into the PA within 10 minutes, patients were transferred to the usual-care group.

After the PAC was inserted in both groups, anesthesia was induced using a standardized opioid induction technique (fentanyl, 10 ug/kg). After intubation of the patient's trachea, an independent echocardiographer, who was blinded to the randomization and was not present during the PAC insertion, performed standardized TEE views to ascertain the position of the PAC in the main PA, proximal or distal right PA, or

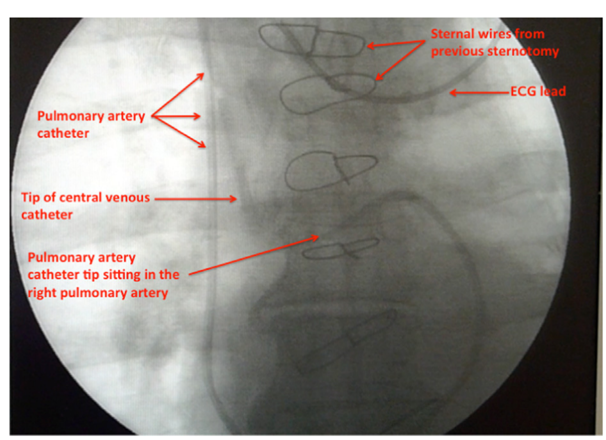

Fig 1. Video fluoroscopy image demonstrating the normal position of the pulmonary artery catheter tip in the right pulmonary artery.