Occurrence and Removal of a Knotted Pulmonary Artery Catheter: A Case Report

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The challenge of treating older, obese patients with various comorbidities has become a mainstay of anesthetic practice. In order to monitor and provide anesthesia safely, the nurse anesthetist must weigh the risks and benefits of all types of monitoring when these patients undergo major invasive procedures. One such option is the Swan-Ganz pulmonary artery catheter. During the last decade an estimated 2 million pulmonary artery (Swan-Ganz) catheters were sold annually in the United States. Although the pulmonary artery catheter is a useful and popular monitoring tool, the potential for complications does exist, with some estimates suggesting a mortality rate of 0.02% to 1.5%. These figures, along with other complications, warrant consideration when evaluating the risks and benefits of this method of monitoring. The following case report describes one potential complication, a knot, and its management by the anesthesia care team in coordination with interventional radiology.

Key words: Interventional radiology, invasive hemodynamic monitoring, pulmonary artery catheter, Swan-Ganz catheter.

Pulmonary artery catheters (PACs) were introduced into clinical practice in 1970 by Swan, Ganz, and colleagues. The introduction of the thermodilution technique in 1972 provided ready access to data about cardiac output and other hemodynamic parameters. Information about cardiovascular physiologic variables is useful in managing the complexities of critically ill patients in the intensive care unit (ICU) and the operating room (OR) because it provides another tier of assessment not available from clinical signs and symptoms. During the last decade an estimated 2 million catheters were sold annually in the United States.1-4

The PAC is a popular and valuable clinical tool, but the potential for complications does exist. Some estimates suggest a mortality rate of 0.02% to 1.5%.2,3 These figures, along with other complications, warrant consideration when evaluating the risks and benefits of using this monitoring technique for a particular patient. The following case report describes one potential complication, a knot, and its management by the anesthesia care team in coordination with interventional radiology.

Case summary
A 66-year-old ASA class IV woman weighing 247 lb (112 kg) and measuring 62 in (157 cm) tall presented for definitive management of a ventral hernia. The recurrent incisional hernia was secondary to exploratory laparotomy for colon resection 6 years previously. The patient underwent 3 failed mesh repairs of the hernia, the last 2 of which were complicated by surgical wound infection requiring prolonged hospital stays. Since the most recent repair 2 years previously, the patient had increasingly severe abdominal pain and recurrent obstructive symptoms requiring repeated hospitalizations during the previous 5 months. Surgical management was a last resort because of her complex past medical history, which included morbid obesity, hypertension, hypercholesterolemia, borderline type 2 diabetes mellitus, hypothyroidism, osteoarthritis of bilateral knees and hips, kidney stones, and paroxysmal atrial fibrillation. She required 2 L/min oxygen therapy at home. Her preoperative medications included colesevelam, ezetimibe, levothyroxine, carvedilol, lisinopril, furosemide, potassium chloride, amiodarone, clopidogrel, aspirin, alendronate, calcium carbonate, vitamin B12, vitamin E, garlic, multivitamin, oxycodone, enoxaparin, docusate, and famotidine.

The patient’s history also included an ischemic cardiomyopathy and coronary artery disease status post-percutaneous transluminal coronary angioplasty, and stenting for a myocardial infarction 9 months previously. Recent persantine myocardial perfusion imaging was negative for significant, pharmacologically induced, reversible myocardial ischemia, but it did reveal extensive areas of scarring in the left anterior descending and right coronary artery/posterior descending artery. It also showed left ventricular (LV) dilatation with moderately severe reduction in global LV function. Echocardiography confirmed a moder-
ately dilated LV and revealed an estimated ejection fraction of 25% to 30%. The patient's cardiologist acknowledged the need for surgical management of the obstructing hernia while noting the complexity of the proposed procedure. The cardiologist stated that the patient was clinically stable for surgery but recommended a PAC for hemodynamic monitoring and fluid management in a potentially prolonged surgery and recovery. Previous surgical history revealed no complications with anesthesia. Preoperative vital signs, physical examination, electrocardiogram and chest x-ray results, and laboratory values were consistent with the patient's underlying conditions and revealed no acute changes in her condition.

General anesthesia via endotracheal tube, invasive monitoring via arterial line (A-line) and PAC were discussed in depth with the patient, as was the need for ICU monitoring with potential postoperative ventilatory support. Informed consent was obtained.

In the preoperative holding area, a peripheral intravenous (IV) catheter was inserted and the patient was premedicated with midazolam, 1 mg, and fentanyl, 150 µg, IV for invasive line placement. A left radial A-line was inserted, followed by a double-stick puncture of the right internal jugular (RIJ) vein for a double-lumen central line and cordis introducer. A Swan-Ganz PAC was then placed through the cordis sheath. The PAC was easily advanced using pressure curves and secured for periodic evaluation of pulmonary capillary wedge pressure.

The patient was then transported to the OR, where standard monitors were applied and the patient was preoxygenated with 100% oxygen. Upon transducing, it was noted that the PAC appeared to have migrated back into the right ventricle (RV). The plan was made to proceed with a rapid sequence induction and then refloat the PAC into the pulmonary artery (PA). The patient was intubated with a 7.0-mm endotracheal tube under direct visual laryngoscopy. Proper position was confirmed and anesthesia was maintained with desflurane in oxygen.

During 3 sequential attempts to refloat the PAC, it was retracted to 20 cm, the balloon inflated, and readily advanced to 40 cm without the appearance of the anticipated RV waveform. Upon pulling back during the third attempt, the catheter failed to pull back easily at the 30-cm mark. At this point it could not be easily advanced or pulled back, which suggested a problem. In the OR, fluoroscopic radiographic examination was undertaken, which revealed a knot in the catheter near the head of the clavicle. The patient was clinically stable. An interventional radiologist (IR) was consulted, who recommended leaving the catheter in place until surgery completion. Central venous pressure was monitored via the PAC; however, infusions were discontinued. The intraoperative course was otherwise uneventful from an anesthesia standpoint. Upon completion of the surgical procedure, the patient was transferred to the ICU and intubated. The patient was in stable condition to await the removal of the knotted PAC by the IR the following day.

According to the IR report from postoperative day (POD) 1, further fluoroscopic evaluation of the PAC demonstrated it to be knotted at the level of the cordis sheath site (Figure 1). The PAC was pressed tightly against the sheath, preventing its removal or advancement centrally. After much manipulation over an Amplatz Super Stiff guidewire (Boston Scientifics, Inc, Natick, Massachusetts), the PAC was manipulated away from the sheath. The PAC was cut, and once the sheath was removed, a 12 Fr all-purpose drain with the tip cut was advanced over the PAC. The drain was used to tighten and reduce the knot (1.8 x 1.0 cm) to

**Figure 1. X-ray of the knotted pulmonary artery catheter**
its smallest diameter (0.8 cm). The PAC was then removed in its entirety and secured tightly against the distal opening of the drain (Figure 2). Hemostasis was achieved with manual compression. The patient tolerated the procedure well with conscious sedation by the IR nursing staff and she was returned to the ICU. The patient subsequently was extubated and transferred to the medical intensive care unit. She required a return trip to the OR on POD 4 for completion of the repair. A medical record review revealed that the patient was discharged from the medical intensive care unit to a subacute rehabilitation facility 12 days after the initial surgery with no further complications attributed to the PAC.

Discussion

The invasive monitoring capabilities of PACs provide practitioners with measurements of several hemodynamic variables that often cannot be predicted accurately from standard clinical signs and symptoms. Information gained can be used to supplement or even correct clinical observations, but the use of PACs remains controversial because of a lack of clear evidence showing improved clinical outcomes, especially given the complications that can occur with their use. PACs can be advanced from any central venous cannulation site. The right internal jugular vein, as chosen in this case, is the preferred site because it allows the most direct route to the right heart chambers and increases the likelihood of success in placement. PACs range in size from 7.0 Fr to 8.0 Fr and are typically 110 cm long.

PA catheter insertion is usually accomplished in the operating room by simultaneously monitoring the pressure waveform. The placement also can be achieved under fluoroscopic guidance in difficult circumstances or with the aid of transesophageal echo-cardiogram (TEE). Insertion of a PAC is typically done blindly, without visualization of the catheter as it passes the central veins through the right heart into the PA. Sterile central cannulation with a large-bore (7.5 Fr to 9.0 Fr) introducer sheath or cordis should be performed first. The PAC is readied, maintaining sterile technique by removing the PAC from its package and placing it directly into a sterile plastic sheath. A skilled assistant then helps to evacuate air from the PAC and confirms its functionality by flushing the various ports that correspond to the separate internal lumens. Confirmation of symmetrical inflation and balloon competence is next. With continued assistance, the PAC is then inserted through the hemostasis valve of the large introducer to a depth of 20 cm, delineated by marks at 10-cm intervals from the tip. The PAC is advanced while the pressure waveform of the distal lumen is observed, looking for the typical change upon entering the RV and then the PA.

The position of the PAC tip in the vena cava or right atrium (RA) is confirmed by a characteristic central venous pressure waveform. The gentle curvature of the PAC is then oriented left of the sagittal plane, to facilitate an anteromedial path for passage through the tricuspid valve. With the monitor in view for identification of the characteristic waveforms, the assistant is instructed to inflate the balloon. The catheter is then advanced rapidly after the 20-cm delineation. This allows ready movement from the RA through the tricuspid valve into the RV, through the pulmonic valve into the PA, ending in the wedge position. Once the pulmonary capillary wedge pressure is measured, the balloon is deflated, allowing the pulmonary artery pressure waveform to reappear for continuous monitoring. This was the precise technique used for the initial PAC placement in this case.

During the continuous monitoring phase of this case, when the original pulmonary artery pressure waveform was noted to have changed to the RV waveform, the problem of improper tip placement was considered. Waveform morphology is the key to verifying proper placement. Typically, with the RIJ vein puncture the RA is reached at 20 to 25 cm, the RV at 30 to 35 cm, the PA at 40 to 45 cm, and the wedge position at 45 to 55 cm. In this case, the PAC placed beyond 50 cm was still showing an RV waveform, and required repositioning, which is strongly advised. When a PA waveform is not observed at 50 cm, coiling in the RV has likely occurred. The catheter should be withdrawn to 20 cm and the PAC floating sequence described above should be repeated. This was the management undertaken in our case.
During PAC reinsertion, when the RV waveform was not observed after inserting the catheter 40 cm, coiling in the RA was likely occurring. The attempted repositioning is what the literature then advises.\(^1\) When attempts to advance the PAC to the RV prove difficult, one possible reason is abnormal venous anatomy.\(^1\) The literature also shows that the knotting in this case is not an isolated event but only one potential PAC-related complication. The incidence of knotting is unclear because complications with PACs historically have been reported in isolated case reports or series.\(^1,5,6,9\)

Since the inception of the Swan-Ganz catheter, the American Society of Anesthesiologists Closed Claims database reveals that closed malpractice claims associated with central venous or pulmonary artery catheters generally have a high severity of patient injury. An analysis of injuries suggests that the most common complications were wire/catheter embolus, cardiac tamponade, carotid artery puncture/cannulation, hemothorax, and pneumothorax. The highest proportion of deaths involves cardiac tamponade, hemothorax, and pulmonary artery rupture. When considering patient risk and liability, anesthesia practitioners should keep in mind that the proportion of claims for vascular access injuries increased from 47% during 1978 to 1983 to 84% during 1994 to 1999.\(^10\)

It is important for practitioners to realize that the use of such invasive tools carries a certain degree of risk. Acknowledgement by providers and patients that central venous pressure and PA catheters are dangerous forms of invasive monitoring and entail potentially fatal complications is crucial to safely planning care.\(^1,9\)

One of the most troublesome complications of PA catheters is perforation of the PA or RA.\(^1,11\) Other rare but life-threatening complications also have been reported. These include cannulation of the carotid artery during PAC insertion via the RIJ vein resulting in an arteriovenous fistula (carotid artery-internal jugular vein) and rupture of the RA in conjunction with the superior vena cava during PAC flotation.\(^9,12,13\) In cardiac surgery, catheter complications involving entrapment in sutures are common and well documented.\(^1,14,19\)

PAC monitoring is not limited to cardiac surgery, and a variety of other complications are possible. This includes the knotting that occurred in this case, arrhythmias such as ventricular fibrillation, right bundle branch block, complete heart block, catheter resistance, thromboembolism, infection-like endocarditis, endocardial damage, cardiac valve injury, and PA pseudoaneurysm. In addition, the misuse of equipment, or misinterpretation of data can result in complications.\(^1\)

Since the incidence of these complications is unknown, it is easy to consider a knot theoretical or rare, but reports of knots in PACs are plentiful in the literature.\(^20-28\) Even in the latest generation of cardiac output thermodilution catheters, there exists the risk for knotting.\(^29\) One key to proper management and avoidance of serious complications of PACs is an awareness of the potential for catheter complications, especially when resistance is met during catheter withdrawal.\(^1,12\)

All intravascular devices are at risk for knots, but PACs appear to be the most susceptible to knotting because of their need for back-and-forth manipulation and their balloon-guided tips. Knowing that the potential of knots exists may prevent their occurrence and improve their detection and management.\(^1,12\)

Problems typically occur when repeated attempts are made to advance a catheter beyond the estimated distance to obtain a PA tracing. This leads to coiling of the catheter, which can eventually knot. In our case, when no PA tracing was obtained, the catheter was indeed advanced farther, 10 to 15 cm, repeatedly. Finally, the current case is consistent with previous reports that resistance to withdrawing the PAC may indicate a problem.\(^27,29,30\)

Anticipating the possibility of knotting can provide the means to minimize its occurrence. First, if a change in waveform does not occur at 10-cm intervals after the RA has been entered, then do not continue to advance the catheter any farther. Blind insertion is typically used, but the literature suggests the option of using ultrasound or TEE guidance.\(^31-35\) With any technique, avoiding repeated advancement and withdrawal of the catheter is important. Once a problem is encountered during floating, TEE, or fluoroscopy, it is advisable to confirm or further diagnose it.\(^1,12,29,30,36-39\)

Coiling or knotting of a PA catheter may be detected by radiography. In many cases of knotting, the catheter functions fine and the problem is not realized until resistance is met upon attempting withdrawal or repositioning of the catheter.\(^20,22,24,27,30\)

The literature suggests a variety of techniques for managing fixed or knotted intravascular catheters, but all have risks. Options include surgical and nonsurgical techniques, which are associated with additional morbidity and mortality.\(^27,40\) In cardiac surgery a knotted intracardiac catheter can be removed via cardiomyotomy.\(^29\) In general surgery cases, where access to the heart is unavailable, one option is to reduce the knot’s diameter by introducing another sheath to tie
the knot more firmly, pulling it back to the skin, and then surgically extracting it. 27 Other low-invasive techniques for removing knotted PACs include simple traction, extraction using a larger sheath or guide-wires, cut-down techniques, removal via snare under fluoroscopy, and open surgery. 20, 28 A potential complication during removal is venous dissection in the thoracic or cervical region, so an alternative is transfemoral extraction. 28, 30

Interventional radiological techniques, such as the one used in this case, have for the most part replaced open surgical extraction. Surgery is typically reserved for cases where intracardiac fixing of the knot is encountered. 41 In one analysis of 115 patients with knotted intravascular catheters, most could be removed by radiological intervention, with only one requiring open surgical extraction. 40

Conclusion
In summary, the literature reveals that there is a risk of serious injury in placing PA catheters, and the benefits to the patient remain unclear. A detailed discussion with the patient describing the risks of and alternatives to invasive monitoring techniques is necessary. This conversation is as warranted as the informed consent process for general anesthesia and surgical procedures, to let patients choose the risks they are willing to assume. As with all choices anesthesia providers make, a full assessment of the risk-benefit ratio is in the patient’s best interest.

The catheter was not difficult to place initially, but the fact that it migrated out of proper position necessitated refloating. This alone may have been an indication for using one of the placement techniques suggested in the literature. These include ultrasound or TEE to allow visualization during placement. In this case there was no adverse outcome or injury related to the PAC complication, but as the literature suggests, the possibility exists.

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