CASE REPORT

PULMONARY ARTERY CATHETER COMPLICATIONS: REPORT ON A CASE OF A KNOT ACCIDENT AND LITERATURE REVIEW

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A particular event concerning a Swan-Ganz catheter complication is reported.

A 41-year-old woman was admitted at the emergency room of our hospital with massive gastrointestinal bleeding. A total gastrectomy was performed.

During the postoperative period in the intensive care unit , the patient maintained hemodynamic instability. Invasive hemodynamic monitoring with a pulmonary artery catheter was then indicated. During the maneuvers to insert the catheter, a true knot formation was identified at the level of the superior vena cava.

Several maneuvers by radiological endovascular invasive techniques allowed removal of the catheter. The authors describe the details of this procedure and provide comments regarding the various techniques that were employed in overcoming this event.

A comprehensive review of evidence regarding the benefits and risks of pulmonary artery catheterization was performed. The consensus statement regarding the indications, utilization, and management of the pulmonary artery catheterization that were issued by a consensus conference held in 1996 are also discussed in detail.

KEY WORDS: **Intensive care unity. Swan-Ganz catheterization. Invasive hemodynamic monitoring. Pulmonary artery catheter complications. Pulmonary artery catheter knot formation.**

Since it was introduced in 1970, the Swan-Ganz catheter has permitted a better understanding of the physiopathologic changes in shock states[1].

At first, the Swan-Ganz catheter was employed only in patients with myocardial infarction. In 1972, the introduction of the thermodilution technique made bedside measurement of cardiac output possible and therapeutic guidelines based on hemodynamic data a reality.

Nevertheless, after many years of continuous use in critically ill patients, there is no scientific evidence that the use of Swan-Ganz catheters improves patient prognosis[2].

Pulmonary artery catheterization (PAC) has been accepted worldwide for treating critical patients with shock states. It produces precise measurements under some technical limitations, makes the diagnosis easier, provides a better evaluation of illness grade, and reduces the doubts of the intensivist.

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Unfortunately, several types of complications can occur following invasive hemodynamic monitoring.

The aim of this study is to report a case of technical complication with the use of PAC and to make a critical reappraisal of complications and benefits of its utilization in clinical practice.

REPORT OF THE CASE

A 41-year-old female patient was admitted at the emergency room of our hospital with hematemesis. The patient presented a 15 kg weight loss in the

last 3 months, epigastric pain, and heartburn.

Endoscopic evaluation showed a giant gastric ulcer, 6 cm wide, in the lesser curvature and gastric stasis.

The patient presented a new hemorrhage during the diagnostic investigation, and then she was referred to the intensive care unit (ICU).

In the ICU, she underwent mechanical ventilation due to respiratory failure and hemodynamic instability. After aggressive resuscitation with blood and crystalloids, a laparotomy was performed. A perforated gastric ulcer was found close to the pancreas and gallbladder, and a total gastrectomy, splenectomy, partial pancreatectomy, and cholecystectomy with Roux-en-Y reconstruction was performed.

The pathologic examination showed a peptic ulcer with no signs of malignancy, and the tests for cytomegalovirus (CMV), human immunodeficiency virus (HIV), and lymphoma were negative.

In the ICU, the patient maintained hemodynamic instability, and invasive monitoring using PAC was indicated.

After puncture of the right internal jugular vein, a Swan-Ganz catheter 93 A-131H-7F (Baxter Healthcare Corporation) was placed.

During the progression of the catheter, controlled by the pressure curves, it was impossible to pull it back. The procedure was stopped and a radiological examination was performed. A knot formation was detected.

After clinical stabilization, the patient underwent a cavography by puncture in the femoral vein. A basket catheter was introduced by the Seldinger technique under fluoroscopic control.

After several unsuccessful attempts to untie the catheter, the knot was pulled tight against an 8F sheath to tie the knot firmly to reduce its diameter. Then the catheter was pulled back to maintain the knot close to the cervical skin and was fixed so that it could be removed surgically.

Coagulopathy associated with sepsis made a cervical approach unsafe, and the patient underwent an inguinotomy with dissection of the right saphenous vein and introduction of a basket catheter by the Seldinger technique. The catheter was advanced to the superior vena cava under fluoroscopic control.

The knot was attached to the basket, and then the Swan-Ganz catheter was severed close to the cervical skin. The catheter was pulled back to the saphenous vein and removed through the inguinal incision.

Independent of the complication reported, the patient developed a multiple-organ dysfunction due to septic shock as well as enteric fistulae with dehiscence of the abdominal incision, and she died on the 42th postoperative day.

DISCUSSION

Complications from PAC may be classified into 2 main categories: technical problems and misinterpretation of data.

The technical complications can be divided in 3 groups: 1) complications of establishing central venous access, 2) complications of the catheterization procedure, and 3) complications of the catheter residence.

Patients who are monitored by PAC have high mortality rates, but in few cases is it possible to attribute their deaths specifically to PAC and not the underlying illness. The mortality rate associated with PAC is 0.02% to 1.5%[2,3].

An estimated 2 million catheters are sold annually in the Unites States, and considering the mortality rate discussed above, an estimated 20,000 deaths per year are associated with these diagnostic procedures[2,3,4].

The complications include**:**

1) **Complications of establishing central venous access:** These include unintentional puncture of nearby arteries such the carotid or subclavian artery, bleeding, pneumothorax, nerve lesions, and air embolism[5-10].
2) **Complications of catheterization procedure:** Dysrhythmias are the primary complication of the catheterization procedure. Minor dysrhythmias such as premature ventricular and atrial contractions occur commonly with the catheter insertion (70% of the pulmonary artery catheter insertions) but usually resolve spontaneously after the catheter is advanced or withdrawn through the right ventricle. Ventricular tachycardia or fibrillation occurs occasionally (in 0.3% of cases) and cardioversion can usually be achieved with antiarrhythmic drugs or electrical defibrillation. Catheter introduction can produce right bundle-branch block and, in patients with previous left bundle-branch block, can induce a complete heart block. In these patients, a PAC with a pacemaker line should be utilized. The most serious adverse effect of the catheterization procedure is the pulmonary artery lesion. This complication occurs in 0.1% to 1.5% of the cases and is associated with a high mortality rate (53%) influenced by factors such age, coagulopathy, pulmonary hypertension, and heparinization[11-25].
3) **Complications due to catheter residence:** these include venous thrombosis thrombophlebitis, pulmonary embolism and infarction, cardiac mural thrombi, valvular injury, infection, and pulmonary artery rupture. Sepsis is a potential complication of pulmonary artery catheter residence, but its exact incidence is uncertain. Cultures from

pulmonary artery catheters are often positive, but it is unclear whether these represent contamination, colonization from another source, or the primary nidus of infection. The infection rates reported in the literature vary considerably—17% for puncture-site infection, 0.7% to 11.4% for catheter-related sepsis, and 1.4% to 34.8% for positive cultures of pulmonary artery catheter tips[26-29].

Although uncommon, intracardiac knotting of catheter represents an important complication associated with pulmonary artery catheter insertion[30-37].

The knot or looping formation occurs during an attempt to direct the catheter to pulmonary wedge position. Looping and kinking, the precursors of knotting occur when an excessive length of catheter has been inserted. In such an event, the catheter should be carefully withdrawn to the 30 cm mark and re-advanced, avoiding careless maneuvers. Partial loops with large diameters can be formed in the right atrium or ventricle and must be immediately recognized by the catheter length marks. At this point, the catheter must be gently withdrawn to the right atrium before a new attempt to direct it to the pulmonary artery is made. If resistance is found during these maneuvers, the procedure must be stopped, and an X-ray examination must be obtained to diagnose a looping or knotting formation.

Another recommendation is to partially inflate the pulmonary artery catheter balloon when it is located in the vena cava. Only after it reaches the right ventricle it should be completely inflated. This maneuver can facilitate the progression of the pulmonary artery catheter tip to the pulmonary artery without producing cardiac valve lesions and can also reduce the possibility of pulmonary artery catheter looping.

The manufacturers stress that kinking and looping occurs when an excessive length of catheter is inserted, and they recommend that no more than 10 to 15 cm should be inserted into the right atrium or ventricle during the attempt to position the catheter. If the pulmonary artery or wedge pressure are not obtained, the pulmonary artery catheter must be carefully withdrawn to the 30 cm marking and then reintroduced.

The knot formation is a technical complication that could be prevented by a skilled professional team following the recommended procedures.

If a knot formation is detected, there are many technical possibilities for solving this problem. The best and the least invasive option is the use of a 0.038-inch movable core-guided wire through the lumen of the catheter to untie the knot under fluoroscopic control. Fluoroscopic control is necessary because of the theoretical hazard of perforating the catheter, blood vessels, or cardiac chambers. If the knot is not too tight, this technique should not introduce an extra hazard to the patient.

Failure to unknot the catheter occurs when the knot is not loose enough and/or is located a long distance away from the tip of the catheter. When this procedure is unsuccessful, 2 technical possibilities of combined radiological and surgical interventions can be employed.

After local anesthesia at the venotomy site, the flexible sheath is removed and the end of the external portion of the catheter is cut and occluded by a hemostat. The catheter is thoroughly cleansed with antiseptic solutions, the hemostat is momentarily released, and a 8F venous sheath is introduced over the end of the catheter and advanced until the tip is in the superior vena cava. Under fluoroscopy control, the knot is pulled tight against the sheath to reduce its diameter, almost to the caliber of the sheath. The catheter is then withdrawn with the sheath to the internal jugular vein and removed surgically by a venous cut down.

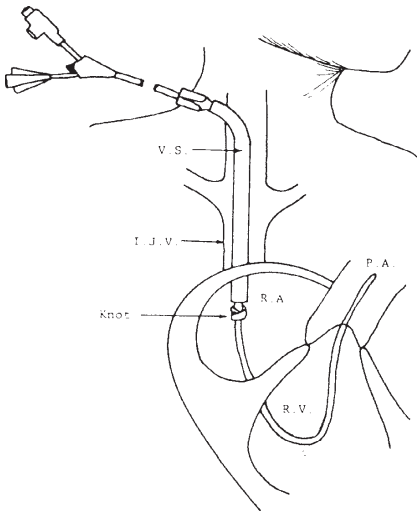

Figure 1 - Diagram showing the venous sheath (VS) introduced into the internal jugular vein (IJV) to tighten the knot in the right atrium (RA). RV = right ventricle; PA = pulmonary artery.

The traction and removal of the catheter through the puncture site can also be done, and this procedure has already been described. If an internal jugular vein access was made, the catheter could be withdrawn through the puncture site, which is then compressed for 5 minutes for hemostasis. Nevertheless, this is not considered a safe procedure because a 7F catheter has a knot of no less than 0.65 cm, which could cause vein laceration and bleeding.

Finally, surgical access to the vein, withdrawal of the catheter, and suture of the defect on the vein wall is the safer procedure.

Another technical possibility is surgical access through the saphenous vein at the groin. A stone-retriever basket or a pig-tail catheter is inserted by fluoroscopic control to snare the distal end of the pulmonary artery catheter and direct it to the inferior vena cava. Afterwards, a loop-snare catheter is used to attach it firmly at its balloon site.

By exerting simultaneous forceful pulling from both ends of the catheter, maximum tightening of the knot is achieved. The proximal exposed end of the catheter is thoroughly cleansed with sterile saline, and the knotted portion of the catheter is withdrawn through saphenous vein.

This is a safe procedure, but it results in the introduction into the blood stream of the non-sterile proximal end of the catheter and posterior ligature of the saphenous vein. It was the procedure of choice in the reported case.

Complications caused by misinterpretations

The most hazardous complication of the use of PAC is the uncorrected collected hemodynamic data, leading to inappropriate therapeutic strategies.

The accuracy of the wedge pressure measurement is estimated at 85%. The measurements are exposed to a number of technical issues and the intensivist should have a critical appraisal of the data obtained. The wedge pressure reflects the filling pressure of the left ventricle (when it has normal or constant compliance) and helps decisively with fluid management of critically ill patients. Another common problem is the positioning of the pulmonary artery catheter out of the III West zone where the wedge pressure is greater than alveolar pressure. Therefore, the blood flow in this area is continuous and less influenced by mechanical ventilation and positive end-expiratory pressure (PEEP). This is a functional and not an anatomical concept, because low flow states, bronchospasm, or PEEP alterations can induce a functional change from the III West zone to the II zone, (where the alveolar pressure is greater than the wedge pressure), or to the I zone (where the alveolar pressure is greater than all)[38-41].

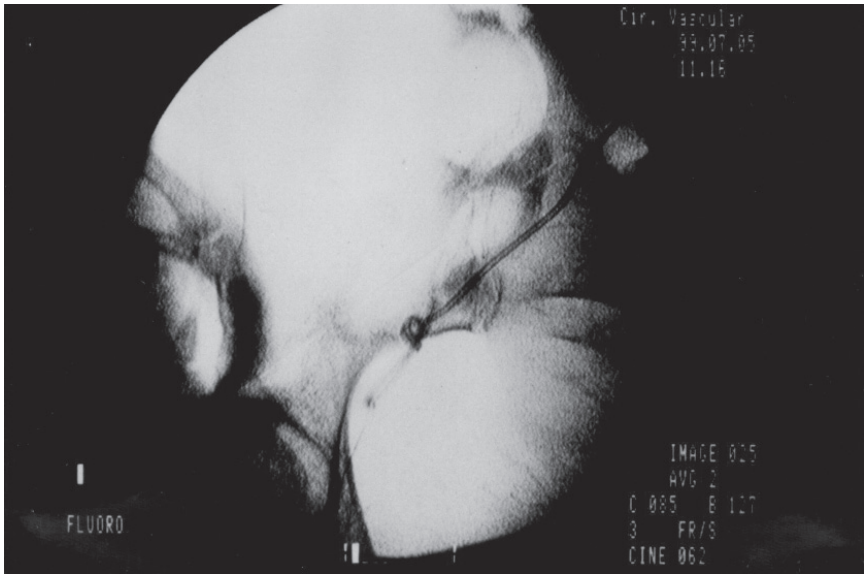

Figure 2 - The distal end of the catheter into the superior vena cava after tightening the knot.

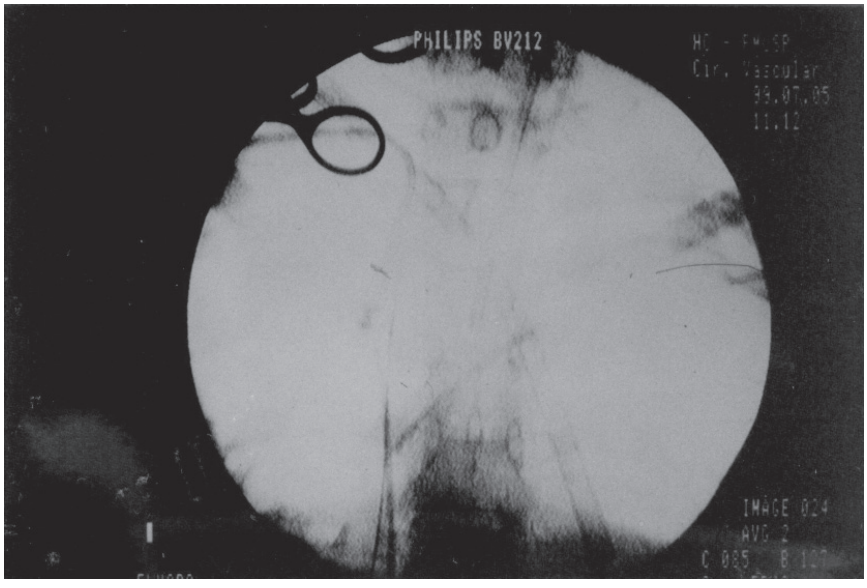

Figure 3 - The distal end of the catheter securely snared at the balloon site and withdrawing the knotted portion of the catheter through the saphenous vein.

Other sources of errors include a catheter introduced too far, a balloon excessively inflated, incorrect building of the pressurization system and lines of saline infusion, and incorrect calibration.

Studies both in the United States and in Europe among ICU personnel have revealed a lack of familiarity with hemodynamic theory and practice among of the staff involved with PAC insertion and maintenance. Only 47% of the physicians identify a wedge pressure curve in a clear monitoring registry, and fewer than 41% could make a correct interpretation of the data collected[42].

In another study in France, Belgium, and Switzerland, 54% of the intensivists did not correctly interpret the information obtained from the wedge pressure measurement.

Over the past decade, there have been vigorous debates concerning the indications and clinical utility of PAC,

considering the costs and complications of the procedure[43].

An important consequence to the physician in critical care practice is the necessity to consider pathophysiologic concepts in the management plan. Pulmonary artery catheterization allows the physician to selectively alter the preload or afterload, to construct a Starling curve, and to estimate cardiac performance under varying physiological or pharmacological conditions. In addition, the ability of PAC to determine pressure gradients across the pulmonary circulation has enabled physicians to differentiate cardiogenic from non-cardiogenic pulmonary edema. Furthermore, based on the assessment of the cardiac output and oxygen delivery, the pulmonary artery catheter is used to guide the application of fluid and titration of vasoactive drugs to treat shock states based on physiological criteria[44].

The ideal method would be a system that provides hemodynamic information at the bedside and that determines beneficial therapeutic changes in the patients, and that also is easily operated, produces data that is easily interpreted, and has a low risk of complications.

Alternatives choices to PAC are the central venous pressure (CVP), transesophageal echocardiography, thoracic bioimpedance, gastrointestinal tonometry, and serum lactate.

The prospective assessment of the benefits of PAC has been hampered by the lack of clinically prospective, randomized multicenter studies. This is a consequence of the prevailing faith in the merits of the PAC and the perceived ethical dilemma of randomly "denying" patients access to PAC.

We reviewed studies with surgical patients in which the pulmonary artery catheter was inserted, and the hemodynamic data was utilized to change therapeutic approach. Prospective and randomized studies have been conducted by several authors to investigate the results of goal-oriented hemodynamic therapy with PAC. Supranormal values of oxygen delivery index ($D0_2I$), oxygen consumption index ($V0_2I$), and cardiac index (CI) in critically ill postoperative patients were compared to those with normal physiological parameters for these variables[45-56].

The therapeutic goals were: DO_2I >600 mL/min/m^2 (supranormal) or 450 mL/min/m^2 (normal), VO_2I >170mL/min/m^2 (supranormal) or 150 mL/min/m^2 (normal), CI >4.5L/min/m^2 (supranormal) or CI 2.8-3.8 L/min/m^2 (normal), systolic arterial pressure >120 mm Hg, pulse <110 bpm, Hb >10 g%, CVP 8-12 mmHg, and diuresis of 30-50 mL/kg/h. The analysis of these studies shows conflicting results.

Gattinoni et al. (1995) performed a multicenter, prospective, randomized controlled trial with 762 patients in 56 ICUs to investigate the effect of supranormal CI (CI >4.5 L/min/m^2) versus a normal CI (2.5-3.5 L/min/m^2) control group. In this trial, no difference was found in mortality or organ dysfunction between the treatment and the control group by the end of the 5-day study period[46].

Boyd et al. (1993) randomized 107 high-risk surgical patients to receive either preoperative goal-oriented therapy for supranormal (protocol group) or normal values, finding a reduction in mortality in the protocol group[47].

Bishop et al. (1995) studied 115 trauma patients in a prospective randomized trial of resuscitation to supranormal endpoints of CI, DO_2I, and $V0_2I$ versus resuscitation to normal hemodynamic endpoints in patients monitored with PAC or CVP. The protocol group had lower mortality and organ dysfunction per patient[48].

Flemming et al. (1992) reported similar results in a study with 67 trauma patients prospectively analyzed with the same methodology. The authors found a trend of lower mortality (not statistically significant) and a significant reduction in the organ dysfunction indices in the protocol group[49].

Yu et al. (1993) prospectively studied 89 surgical patients with the diagnosis of adult respiratory distress syndrome (ARDS), sepsis, septic shock randomized to supranormal or normal $D0_2I$, finding no difference between the groups in the rates of myocardial infarction, ARDS, renal dysfunction, hepatic dysfunction, intravascular disseminated coagulopathy (IVDC), ICU length of stay, hospital length of stay, and costs[50].

Hayes et al. (1994) performed a prospective, randomized trial of 109 patients admitted to an ICU postoperatively. Protocol patients were treated to achieve supranormal values of CI, $D0_2I$, and $V0_2I$, whereas the control patients were given inotropes only if CI was <2.8 L/min/m^2 after fluid resuscitation. This study was terminated before sufficient size of statistical power was achieved, because in-hospital mortality for the protocol group was higher due to multiple organ dysfunctions. The median of the maximal dose of norepinephrine given was higher in the protocol group[51].

Isaacson et al. (1990) performed a prospective, randomized, controlled trial of preoperative PAC versus CVP on 102 patients who underwent elective abdominal aortic reconstructive surgery after appropriate preoperative cardiac investigation. No statistical difference was found between the PAC and CVP groups with regard to postoperative morbidity, duration of ICU stay, or total number of postoperative hospital days[52].

Critical appraisal of the literature did not demonstrate conclusive findings about the use of PAC in surgical patients. The American Society of

Anesthesiologists has performed a comprehensive review of evidence regarding the benefits, risks, and costs of PAC, which was published as Practice Guidelines for Pulmonary Artery Catheterization (American Society of Anesthesiologists Task Force on Pulmonary Catheterization)[4].

In this extensive review, a total of 860 clinical trials, controlled observational studies, uncontrolled case series reports, and individual case reports were reviewed (studies in which the clinical outcome of the patients was not mentioned were excluded). The task force did not directly examine the accuracy of PAC monitoring, the value of PAC data as predictor of morbidity and mortality, or evidence of the effectiveness of treatment for PAC-detectable conditions. Issues related to the performance of PAC, such as rates of utilization and practitioner skill, resource constraints imposed by the staff, and equipment availability were not a specific focus of the literature review.

Considerable discussion and debate about the benefits and impact of PAC monitoring on the treatment success, increasing survival rates, and morbidity reduction remains.

In 1996, the Pulmonary Artery Catheter Consensus Conference[3] was organized as an aid to clinicians to review the state of knowledge concerning PAC in specific patient populations, to define specific critical unanswered questions, and make recommendations for clinical practice, and to provide guidance for future clinical and epidemiological research in this area.

The Conference participants utilized a methodology based on that described by Sackett. To better serve the needs of the Consensus Conference and more precisely grade the levels of evidence used to support responses to the questions posed, Sackett's original 3 grades of A, B, and C were expanded to A, B, C, D, and E[3,57]**.** The grade given for the response to a question simply reflects the level of evidence currently available to answer the question. The grade given to an answer is extremely important since it differentiates between an answer that may be based on well-designed, randomized, controlled trials, and an answer based on expert opinion. The answer "uncertain" means that the available evidence is conflicting or that Consensus Conference participants perceived significant methodological errors in the investigation, making interpretation difficult or impossible.

The traumatically injured patient represents a challenge to the intensivist, and PAC monitoring for better diagnostic or therapeutic management is of great interest. In the Consensus Conference review, no controlled trials that met their inclusion criteria proved the benefit of PAC in traumatically injured patients. Expert opinion suggests that in the multiple traumatized patient, PAC may alter diagnosis and improve outcome when the therapeutic objectives are as follows: 1) to ascertain the status of underlying cardiovascular performance; 2) to direct therapy when noninvasive monitoring is inadequate or misleading; 3) to assess response to resuscitation; 4) to potentially decrease secondary injury when severe close head or spinal cord injuries are components of multisystem trauma; 5) to augment clinical decision making when major trauma is complicated by ARDS, progressive oliguria, myocardial injury, congestive heart failure, or major thermal injury; or 6) to establish futility of care.

In the sepsis/septic shock states, the improvement of clinical outcomes by PAC-guided management was considered to be an uncertain possibility. Mimoz et al. (1994) suggested that outcomes may be better in patients with septic shock who are unresponsive to fluid resuscitation and vasoconstrictors if the information from the PAC prompts a change in the therapy[58].

Reynolds et al. (1988) demonstrated an improved outcome in patients with septic shock after physicians formally trained in critical care medicine began staffing a medical ICU in a university hospital. The Consensus Committee recommended PAC utilization in patients with septic shock who do not respond to initial aggressive fluid resuscitation and low doses of inotropic/vasoconstrictor therapy[59].

Supranormal oxygen delivery to patients with systemic inflammatory response syndrome—organ-related dysfunction from septic shock, trauma, or postoperative complications—is not recommended either for lowering mortality rates, decreasing the incidence of organ dysfunction, or improving function of compromised organs.

The discussion about the risks and benefits of PAC utilization still occurs after 30 years of clinical practice. The following recommendations reflect the collective opinion of the Consensus Conference participants:

- There is no basis for an FDA moratorium of PAC use at this time. A pulmonary artery catheter is considered a class II device—one that requires general and specific control to reasonably assure safety and effectiveness. A reasonable assurance of safety occurs when the probable benefits to health from the use of the device outweighs any probable risks. Effectiveness is assured when, in a significant proportion of the target population, the use of the device as intended provides clinically important results.
- Deaths and serious injuries caused by PAC use are extremely rare. The indications for use identified by pulmonary artery catheter manufacturers are measurements such as

hemodynamic pressures, thermodilution cardiac output, continuous cardiac output, mixed venous oxygen saturation, and blood sampling; intended uses have not included claims of clinical benefit. Evidence suggests that PAC-derived data that are not obtainable clinically and that help in guiding therapy adjustments may lead to a more appropriate approach.

- Clinicians should continue to carefully weigh the risks and benefits of PAC, and patients or guardians should be fully informed before use.
- Criteria for the appropriate use of the PAC in specific clinical situations should be developed.
- Clinician knowledge about use of the PAC and its complications should be improved.
- Current training, credentialing, and continuing quality improvement issues related to the PAC should be re-evaluated.
- The indications and contraindications for PAC use where clinical equipoise is lacking should be well determined.
- Clinical trials for indications where clinical equipoise exists should be performed.

RESUMO

LOPES MC e col. - Complicações do cateter de artéria pulmonar: relato de caso de formação de nó verdadeiro revisão da literatura**. Rev. Hosp. Clín. Fac. Med. S. Paulo 59**(2):77-85, 2004.

É relatada uma complicação infreqüente , associada ao uso do Cateter de Artéria Pulmonar.

Uma paciente de 41 anos foi admitida no Pronto Socorro do nosso hospital com hemorragia digestiva alta grave. A doente foi submetida à gastrectomia total.

Na Unidade de Terapia Intensiva, evoluiu com instabilidade hemodinâmica, sendo indicada a monitorização hemodinâmica invasiva com cateter de artéria pulmonar. Durante as manobras para o correto posicionamento do cateter na artéria pulmonar, foi diagnosticado formação de nó verdadeiro, ao nível da veia cava superior.

Os autores discutem as várias opções técnicas empregadas para a resolução desta complicação, através do emprego da radiologia intervencionista endovascular.

Extensa revisão da literatura procurando discutir os benefícios e riscos envolvidos na monitorização hemodinâmica invasiva com o cateter de artéria pulmonar, no período peroperatório, foi realizada. Assim como as orientações práticas emitidas pela Conferência de Consenso sobre o cateter de artéria pulmonar, realizada nos EUA em 1996, são discutidas com profundidade.

UNITERMOS: **Unidade de Terapia Intensiva. Cateter de Artéria Pulmonar. Monitorização hemodinâmica invasiva. Complicações do cateter de artéria pulmonar. Formação de nó no cateter de artéria pulmonar.**

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