Journal of Shock and Hemodynamics

Volume 1
Issue 2 *Volume 1, Issue 2 (2022)*

Article 1

2022

Role of Invasive Hemodynamics in Shock Management: Is a Pulmonary Artery Catheter Always Necessary?

Ajay J. Kirtane
Columbia University Medical Center, ak189@cumc.columbia.edu

Symposium Presentation *Journal of Shock and Hemodynamics*

November 1, 2022 https://doi.org/10.57905/josh/e2022121

2022 Symposium Presentation

Role of Invasive Hemodynamics in Shock Management:

Is a Pulmonary Artery Catheter Always Necessary?

Ajay J. Kirtane, MD, SM
Columbia University Medical Center, New York

Email: ak189@cumc.columbia.edu

Received August 31, 2022
Published November 1, 2022

Abstract

The pulmonary artery (PA) catheter can be a useful tool in the management of patients with cardiogenic shock; however, there are challenges with the use of this catheter, and clinicians must balance the risks and benefits. In addition, clinicians must properly interpret data generated from a PA catheter in the context of other data to optimize a patient's hemodynamics.

Keywords: pulmonary artery catheter, cardiogenic shock, hemodynamics

Background

The pulmonary artery (PA) catheter can be a useful tool in the management of patients with cardiogenic shock. It allows for direct and accurate measurements of hemodynamic parameters during insertion and serially over time. Serial observations are very useful for patient monitoring as the measurements (central venous pressure, right ventricle [RV] pressures, PA pressures, pulmonary capillary wedge pressure, saturations) can be used to calculate certain critical data (cardiac output, vascular resistance, stroke volume, oxygen delivery, shunt fractions, PA pulsatility index). Beyond this, PA catheters can even incorporate data simulation to calculate stress blood volume and other measurements useful in patient management. Most importantly, data generated from the PA catheter can provide information on the etiology of shock. It can detail the type of issue (eg, volume, output, what side) and what to do next (volume, pressors, mechanical circulatory support).

Challenges to PA Catheter Use

The challenge with the PA line by itself is that it gives the clinical team several numbers, and the team then has to actively integrate and analyze the readings to figure out what to do. Further, the use of a PA catheter requires time, effort, and cost—not just with the insertion, but the maintenance of the catheter. If the catheter is inserted for too long, the patient can develop a line infection. Data from a PA catheter can be misinterpreted, misleading, or simply not used. Thus, the clinical program must regularly educate team members on how to appropriately use the catheter and the resulting data. Of note, the information gathered from the PA catheter could additionally be redundant to other tests (eg, echocardiogram, central venous pressure measurement alone). Finally, complications are always a risk.

Despite the challenges, many clinicians caring for patients with shock insist upon a PA catheter. For each patient, the team must balance the risks and benefits of the procedure. With the advent of checklists and their integration into electronic health records, a team can ensure the PA catheter is placed in shock patients; however, it is not of value unless the team goes beyond checking the box and understands what to do with the data once the catheter is put in to be able to then manage the patient. Using Medicare data, Ikuta and colleagues showed that, overall, the use of the PA catheter is declining over time.[1] However, for patients with heart failure, there's an

inflection point, and the use of catheters started to increase after 2005.[2]

A key trial to mention is the ESCAPE trial, which prospectively gathered data from 433 patients with heart failure at 26 sites and determined that the use of the PA catheter was not beneficial in patients who did not need it.[2] Importantly, shock patients were not included in the ESCAPE Trial. Many patients with decompensated heart failure at a variety of stages that are not that severe can, in fact, be managed without a PA catheter. The question that remains is, if the patient is in shock, should you use the catheter? Cardiogenic shock patients have very little reserve, so if the wrong decision is made, the patient could decompensate. On the other hand, inappropriately placed PA catheters could also lead to complications or suboptimal treatment decisions.

Use of PA Catheter Data

To optimize hemodynamics with a PA catheter, variables should not be interpreted (or overinterpreted) in isolation. Serial observations must be interpreted in the context of other data, and trends are generally more useful than isolated variables at a single point in time. Integration of measurements with the clinical situation increases the accuracy of the assessment. Thus, in a way, the best mantra for shock management could be summarized as "Keep calm and check, check, and recheck again on how patients are doing." If one does not integrate serial measurements into the clinical picture, one might end up with a scenario where an agent such as an inotrope is given to a patient with active ischemia, which could induce ventricular tachycardia. The blame should not be on the agent but rather on the team for making the wrong decision in terms of what to give that patient. Clinicians can overreact to numbers, and that overreaction can result in unfavorable outcomes.

Clinical Studies

Studying patients with severe cardiogenic shock is difficult. However, when an invasive therapy is used in the sickest patients, and a benefit is still seen in observational studies of that therapy, that is a powerful outcome. Studies of the sickest populations usually show worse outcomes because the patients were so sick to begin with. Even if it is observational data, beneficial outcomes in these sick populations are rare. Thus, any benefit signal from observational studies in severely sick populations should be further explored in randomized trials. An excellent example is from the Cardiogenic Shock Working Group which observed that PA catheter utilization positively impacted the mortality rates of patients in cardiogenic shock.[3]

Another study compared PA catheter-based assessments of volume optimization and cardiac index to clinical judgment and found that clinical assessments had low accuracy across all training levels.[4] Thus, clinical teams need to understand the importance of using objective data derived from helpful tools, like a PA catheter. PA catheter measurements can also help the team determine the ideal device selection[5] and volume optimization.[6] Similarly, both sides of the heart must be assessed to determine the best treatment, as a significant proportion of patients have biventricular congestion.[7] Emerging data has shown how PA catheter measurements can be used to identify RV dysfunction.[8] Ultimately, PA catheter assessments have been useful in determining device weaning protocols.[9] While the PA catheter measurements cannot be used alone, they have been shown to be a valuable tool in the clinical toolbox.

Randomized trials of PA catheters in cardiogenic shock are currently being planned by the Cardiogenic Shock Working Group. However, the proposed PAC-CS Trial has the potential for failure if it is not done right; just placing the PA catheter alone is unlikely to be associated with improved outcomes. Specific guidance is needed to detail what should be done after the PA catheter is placed. Optimization and regulation of monitoring the readings from the catheter are vital for the success of the study.

History of the Swan Catheter

I had the privilege of hearing James Forrester present a talk on the development of the Swan catheter at the Transcatheter Cardiovascular Therapeutics meeting in 2019.[10] The following story is excerpted and paraphrased from his talk, which to me was awe-inspiring.

"Dr. Jeremy Swan was inspired by watching sailboats in the ocean off the coast of California. He hypothesized that a balloon-tipped catheter could enable a device to go into the PA or other vessel. As a favor, folks from Edwards Lifesciences used an infant feeding tube with a balloon and gave it to Swan to test, and the first animal catheterization by Diamond and Forrester was completed in 1969. They put the catheter into the venous system and saw an unusual waveform. In fact, the catheter had traversed the right heart and was advanced into the PA. As today's institutional review board processes were not in place, they sterilized the catheter and then used it in a patient admitted to the medical intensive care unit. Unfortunately, once the catheter was placed, the patient had a horrific run of ventricular tachycardia that was induced by the catheter tip flailing wildly within the RV. A later modification to move the balloon on the tip of the catheter increased the safety of this catheter. Likewise, today as clinicians work with really sick patients, it always behooves us to think about how the placement of a PA catheter could cause complications.

Dr. Willie Ganz was 49 years old and abandoned all his worldly possessions and fled communism. Philanthropy enabled his journey to the United States, and through serendipity, the unknown lab researcher developed a way to measure cardiac output through thermistors in an animal

laboratory. Through collaboration with Dr. Swan and the team that had developed the PA catheter, the Swan-Ganz catheter was born."

In some ways, this is how we must take care of our sick patients; every one with individual expertise and experiences must come together to manage the patients with an individualized treatment plan.

Disclosures

Dr. Kirtane reports institutional funding to Columbia University and/or the Cardiovascular Research Foundation from Medtronic, Boston Scientific, Abbott Vascular, Amgen, CSI, Philips, ReCor Medical, Neurotronic, Biotronik, Chiesi, Bolt Medical, Magenta Medical, Canon, and SoniVie. In addition to research grants, institutional funding includes fees paid to Columbia University and/or the Cardiovascular Research Foundation for consulting and/or speaking engagements in which Dr. Kirtane controlled the content. Dr. Kirtane is a consultant for IMDS and has received in-kind support (travel and meals) from Medtronic, Boston Scientific, Abbott Vascular, CSI, Siemens, Philips, ReCor Medical, Chiesi, OpSens, Zoll, and Regeneron.

Acknowledgments

Dr. Kirtane would like to thank Reshad Garan, Justin Fried, and the Columbia University/New York Presbyterian Shock Team.

References

[1] Ikuta K, Wang Y, Robinson A, Ahmad T, Krumholz HM, Desai NR. National Trends in Use and Outcomes of Pulmonary Artery Catheters Among Medicare Beneficiaries, 1999-2013. *JAMA Cardiol*. 2017;2(8):908-913. doi: 10.1001/jamacardio.2017.1670.

[2] Binanay C, Califf RM, Hasselblad V, et al. Evaluation study of congestive heart failure and pulmonary artery catheterization effectiveness: the ESCAPE trial. JAMA. 2005;294(13):1625-33. doi: 10.1001/jama.294.13.1625. DOI:10.1161/CIRCHEARTFAILURE.120.007405.

[3] Garan AR, Kanwar M, Thayer KL, et al. Complete Hemodynamic Profiling With Pulmonary Artery Catheters in Cardiogenic Shock Is Associated With Lower In-Hospital Mortality. *JACC Heart Fail*. 2020;8(11):903-913. doi: 10.1016/j.jchf.2020.08.012.

[4] Narang N, Chung B, Nguyen A, et al. Discordance Between Clinical Assessment and Invasive Hemodynamics in Patients With Advanced Heart Failure. *J Card Fail*. 2020;26(2):128-135. doi: 10.1016/j.cardfail.2019.08.004.

[5] Whitehead EH, Thayer KL, Sunagawa K, et al. Estimation of Stressed Blood Volume in Patients With Cardiogenic Shock From Acute Myocardial Infarction and Decompensated Heart Failure. *J Card Fail*. 2021;27(10):1141-1145. doi: 10.1016/j.cardfail.2021.04.002.

[6] Fincke R, Hochman JS, Lowe AM, et al. Cardiac power is the strongest hemodynamic correlate of mortality in cardiogenic shock: a report from the SHOCK trial registry. *J Am Coll Cardiol*. 2004;44(2):340-8. doi: 10.1016/j.jacc.2004.03.060.

[7] Thayer KL, Zweck E, Ayouty M, et al. Invasive Hemodynamic Assessment and Classification of In-Hospital Mortality Risk Among Patients With Cardiogenic Shock. *Circ Heart Fail*. 2020;13(9):e007099. doi: 10.1161/CIRCHEARTFAILURE.120.007099.

[8] Jain P, Thayer KL, Abraham J, et al. Right Ventricular Dysfunction Is Common and Identifies Patients at Risk of Dying in Cardiogenic Shock. *J Card Fail*. 2021;27(10):1061-1072. doi: 10.1016/j.cardfail.2021.07.013.

[9] Randhawa VK, Al-Fares A, Tong MZY, et al. A Pragmatic Approach to Weaning Temporary Mechanical Circulatory Support: A State-of-the-Art Review. *JACC Heart Fail*. 2021;9(9):664-673. doi: 10.1016/j.jchf.2021.05.011.

[10] Forrester J. Reflections from a Rich Interventional History: A Series of Featured Lectures. Transcatheter Cardiovascular Therapeutics Conference 2019.