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EDITORIAL

Is there still a place for the Swan–Ganz catheter? We are not sure

Daniel De Backer[1*], Ludhmila A. Hajjar[2] and Michael R. Pinsky[3]

The pulmonary artery catheter (PAC) was introduced in clinical practice in the 1970s [1]. The PAC provides a unique and comprehensive evaluation of the cardiovascular status of the critically ill, with measurements of cardiac output and its determinants. In addition, it provides information on the adequacy of cardiac output by measurements of mixed-venous oxygen saturation (SvO_2) and on left heart function through pulmonary artery occlusion pressure and right heart function with the measurement of pulmonary arterial pressure (PAP), right ventricular ejection fraction, and central venous pressure (CVP). Its use peaked in the 1980s; however, the publication of studies suggesting potential harm resulted in a steady decrease in its use. By the start of the new millennium, PAC use had markedly decreased even more [2], so that one could even predict its disappearance. Recent data suggest a revival in PAC [3–5]. The reasons for this revival are multiple. First, multiple randomized trials have shown that PAC does not increase the risk of death [6]. In high-risk patients, PAC may even improve mortality [7]. Second, the alternative techniques, which have markedly increased in options, do not always have enough reliability and, more importantly, do not always provide all the information provided by PAC. In the view of the authors who frequently use PAC and the alternative methods, the use of PAC and of the other methods should be based on the patient condition and the potential gain that can be gathered from the measured variables [8]. This attitude, in line with current guidelines [9, 10], will be discussed in this editorial. We will focus on PAC, echocardiography, and pulse wave analysis coupled with transpulmonary thermodilution (TPTD) which provide the same level of information.

Cardiac output can be obtained with the three techniques. PAC is semi-continuous and may fail to detect abrupt changes in cardiac output such as induced by severe arrhythmias or passive leg raising (PLR) test. Echocardiography only provides intermittent information. It can be easily repeated but this is slightly time consuming and requires some expertise. TPTD provides a beat by beat evaluation of stroke volume and can be used for detecting changes in cardiac output during PLR or respiratory changes in stroke volume (SVV) and pulse pressure (PPV). The problem with these pulse contour devices is that they require frequent recalibration, as soon as vascular tone has changed. Given the relatively similar monitoring capacities with the three techniques, cardiac output measurement alone should not be considered to define the use of any specific monitoring device.

Even though bedside physicians often use filling pressures to indicate intravascular status and the need to give intravenous fluids [11], evaluation of fluid responsiveness is best achieved by dynamic indices, such as PPV and SVV during positive-pressure breathing or the change in cardiac output in response to PLR [12]. These dynamic indices are now recommended in several guidelines [9, 13]. Filling pressures nevertheless retain some importance in the guidance of fluid management. First, extreme values can be used to reasonably predict the response to fluids [14]. Second, filling pressures can be used as a safety measure during fluid administration [14, 15]. Finally, filling pressures are important to detect fluid overload and hydrostatic cause of pulmonary edema. While echocardiography combined with lung ultrasound can also be used, it is somewhat cumbersome to frequently repeat the evaluation. TPTD is also used for this purpose. Unfortunately, cardiac volumes are less sensitive to detect volume overload than pressures, due to the

*Correspondence: ddebacke@ulb.ac.be
[1] Department of Intensive Care, CHIREC Hospitals, Université Libre de Bruxelles, Brussels, Belgium
Full author information is available at the end of the article
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curvilinear aspect of the pressure/volume relationship. For this reason, a TPTD-guided resuscitation was associated with more days spent on mechanical ventilation in patients with impaired cardiac function, compared to a PAC-guided strategy [16]. Regarding extravascular lung water, a major limitation of this variable is that it reports that the total water in the lungs may be high, but there is no insight into the mechanism (hydrostatic or non-hydrostatic) nor to the timing (is it still ongoing or was it occurring a few hours ago?). Measurements of filling pressures remain the standard for defining hydrostatic pulmonary edema and fluid overload.

Evaluation of right/left ventricular (dys)function is a crucial aspect of hemodynamic monitoring. Admittedly, echocardiography is the preferred method for this aspect, but, as a result of the intermittent nature of echocardiography, it is important to have warning signals detected by continuous monitoring devices that can be used to indicate (repetition of) echocardiography. For this purpose, PAC is very useful because as it continually tracks hemodynamic variables directly influenced by heart dysfunction, and its ability to separate out predominantly right or left ventricular dysfunction or global dysfunction. In addition, in case of right ventricular dysfunction, PAC allows one to separate dysfunction predominantly related to an increased afterload (with high PAP) or due to pump failure (without pulmonary hypertension). PAC is not solely useful for diagnosis but also, and even more importantly, for the evaluation of the response to therapy. TPTD allows one to diagnose cardiac dysfunction (low cardiac output together with elevated cardiac volumes) but cannot identify its cause. Repeated echocardiography is thus important for the management of patients with cardiac dysfunction monitored solely with TPTD.

One limitation of both PAC and TPTD is their inability to detect left ventricular outflow tract obstruction and cardiac tamponade. In these conditions both PAC and TPTD would provide incomplete and sometimes erroneous information: in left ventricular outflow tract obstruction PAC measurements with elevated pulmonary artery occluded pressure and low cardiac output would suggest left ventricular failure indicating the use of inotropes while fluid loading and eventually beta-blockers may be desired. For tamponade, TPTD will disclose low cardiac volumes and cardiac output with elevated SVV, suggesting hypovolemia. Only echocardiography will rapidly provide the right diagnosis for these conditions. Altogether, these conditions illustrate that hemodynamic monitoring should be integrative, combining several methods, rather than exclusive limited to one single technique applied to all patients. In low-resource settings, the care of these patients is challenging because of many factors, including limitations in infrastructure, lack of available devices, and low numbers of trained healthcare workers to interpret, analyze, and apply the data. Hemodynamic monitoring is costly [17] but the strategy of goal-directed therapy based on minimally invasive monitors decreased length of hospital and ICU stay, improved quality of life, avoided complications, and consequently reduced costs [18, 19].

In conclusion, PAC, echocardiography, and TPTD all have a place in the hemodynamic monitoring and management of selected critically ill patients. As one size does not fit all, we suggest to combine the three techniques according to the algorithm presented in Fig. 1.

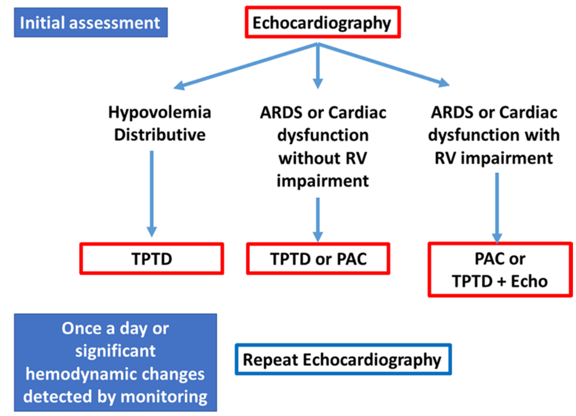

Fig. 1 Proposed algorithm for the individualization of advanced monitoring techniques. Of note every critically ill patient should not be monitored. Severe critically ill patients, especially when not responding to initial therapy, may benefit from advanced hemodynamic monitoring. TPTD transpulmonary thermodilution, ARDS adult respiratory distress syndrome, RV right ventricle, PAC pulmonary artery catheter, Echo echocardiography

Author details

[1] Department of Intensive Care, CHIREC Hospitals, Université Libre de Bruxelles, Brussels, Belgium. [2] Department of Cardiopneumology, Heart Institute, University of Sao Paulo, Sao Paulo, Brazil. [3] Department of Critical Care Medicine, University of Pittsburgh, Pittsburgh, PA, USA.

Compliance with ethical standards

Conflicts of interest

Daniel De Backer: Consultant to and material for studies by Edwards Lifesciences. Ludhmila Hajjar: No conflict of interest. Michael R Pinsky: Consultant to Edwards Lifesciences, Cheetah Medical, LiDCO Ltd, Honoria for lectures from Masimo Inc, Edwards LifeSciences, Cheetah Medical. Stock options with LiDCO Ltd, Cheetah Medical.

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