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Case report

Ultrasound guided pulmonary artery catheter insertion: An alternative to fluoroscopic guidance

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ABSTRACT

Pulmonary artery catheters (PACs) can provide extremely valuable objective data in select patients. They are usually advanced by floatation of balloon tip along the normal blood flow and their placement is confirmed under pressure waveform guidance. Imaging such as fluoroscopy is often employed in low flow states and in cardiac catheterization suite to reduce the failure rate and time to wedge; but is not readily available at bedside. In critically ill patient, bedside insertion is feasible but can be complicated by repeated attempts to float the balloon tip through various cardiac chambers. Point of care ultrasound can be used to visualize the balloon tip of PAC inside the cardiac chambers alongside the confirmatory pressure waveform changes.

1. Introduction

Pulmonary artery catheters (PACs) also known as Swan-Ganz catheters can provide valuable information in select groups of patients. Despite having fallen out of favor recently, PACs are indicated for assessment of cardiac hemodynamics in specific groups of patients presenting with shock or pulmonary hypertension [1]. They can be inserted at bedside under sterile conditions and provide valuable information that can augment non-invasive measures such as transthoracic echocardiography.

The advancement of PACs in a patient is usually performed by flotation of a balloon tipped catheter under pressure waveform guidance. The balloon tip floats in blood and is directed into the pulmonary artery by the normal flow from superior vena cava and through the cardiac chambers into pulmonary artery. The correct positioning is crucial for safe use and accurate cardiopulmonary assessment. However, this blind method of insertion can be challenging in patients with slow blood flow in setting of heart failure or valvular disease. The abnormal flow can induce the PAC to coil in cardiac chambers such as right atrium and right ventricle or be misdirected to the inferior vena cava. Repeated attempts to retract and redirect the catheter can increase the risk of complications and should be avoided [2]. The use of fluoroscopic guidance persists in these cases and is often employed in elective procedures in catheterization lab or for femoral point of access. Fluoroscopy when used alongside pressure waveform analysis has been noted to reduce the time to wedge, number of attempts and composite complication rate in patients undergoing cardiac surgery [2]. In addition, fluoroscopy provides real time visualization that can lead to reduction of catheter malposition and ventricular arrythmias. Unfortunately, it is seldom (if not readily) available in critical care units for bedside insertion. A bulky fluoroscopy equipment can also be difficult to fit in a critical care room alongside other life support devices such as mechanical ventilator or renal replacement therapy. Finally use of fluoroscopy can led to unnecessary radiation exposure to both the patient and the proceduralist. A study highlighting the

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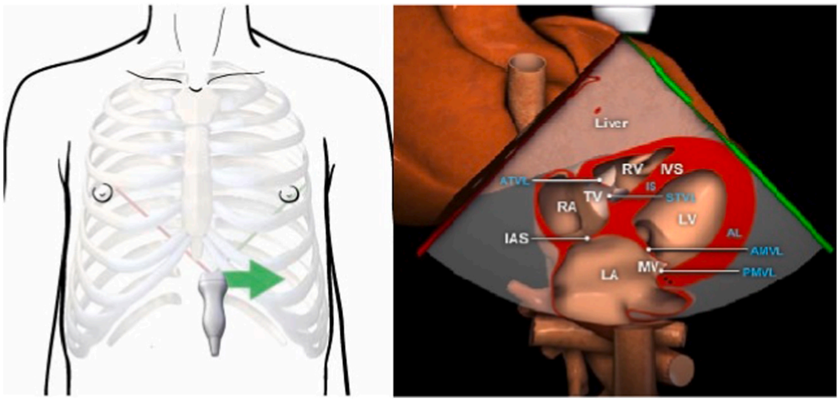

Fig. 1. Subcostal four chamber view (Image reproduced with permission from http://pie.med.utoronto.ca/TTE).

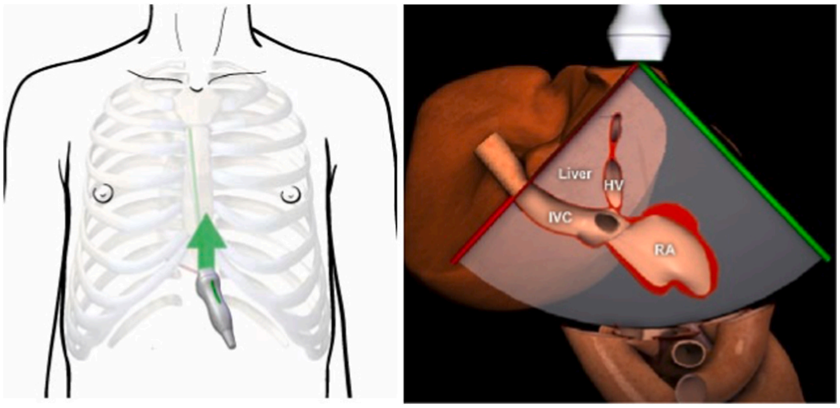

Fig. 2. Subcostal Inferior Vena Cava view (Image reproduced with permission from http://pie.med.utoronto.ca/TTE).

merits of fluoroscopy for PAC placement also noted an additional exposure to radiation for up to 300 seconds [2]. Although the dose of radiation received during PAC placement is comparable to diagnostic Xray, it is contributing the cumulative radiation exposure to patients receiving numerous diagnostic imaging test during a critical illness. Furthermore, efforts to limit exposure of healthcare personnel to emerging infections such as SARS-CoV-2 often necessitate bedside procedures with limited equipment.

The point of care ultrasound (POCUS) has emerged as a safe, portable, bedside imaging modality that is readily available in virtually all critical care units. Most critical care training programs incorporate the use of bedside ultrasound for assessment of cardiac hemodynamics. Here we describe a technique of floating the balloon tip of the PAC under sonographic visualization. The visual feedback augments the confidence in PAC placement, can reduce the number of attempts, and potentially replaces fluoroscopy for guidance.

2. Discussion

This article only describes the steps for sonographic visualization of PAC balloon tip during advancement/floatation. This technique requires two operators, the 'Proceduralist' who manipulates the PAC under a sterile environment and the 'Sonographer' who operates the ultrasound probe to obtain transthoracic views visible to both operators. Due to the two-dimensional nature of imaging obtained in the plane of ultrasound, the probe may require dynamic manipulation to keep the balloon tip in view.

Additional resources should be sought for procedural training related to insertion of introducer sheath, technique of PAC placement and interpretation of waveforms in different cardiac chambers [3]. Both operators should be skilled in obtaining and interpreting basic and/or advanced transthoracic echocardiography views. Online resources can be sought to gain additional knowledge of cardiac and vascular structures [4]. We also recommend using a high quality, phased array, sector probe to obtain clear transthoracic views for sonographic visualization of PAC balloon which should be correlated with pressure waveform changes of that chamber at each step.

Step 1: Insertion through sheath - The PAC is inserted slowly through the introducer sheath until the tip lies outside the sheath and the pressure waveform for central venous tracing is visualized (usually at 15 cm). Balloon tip is inflated to manufacturer recommended volume (usually 1–1.5 ml).

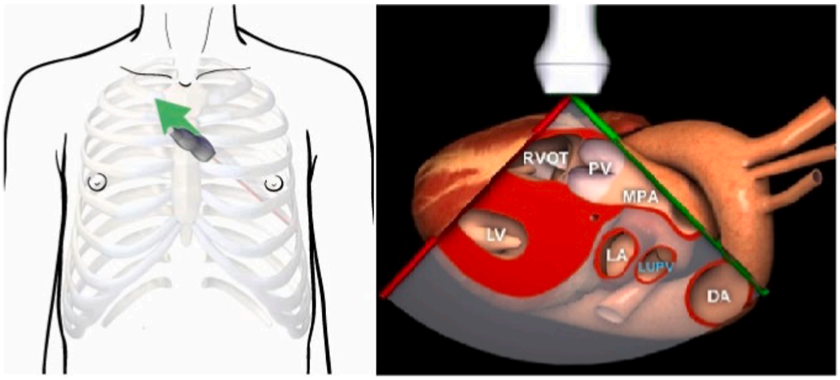

Fig. 3. Parasternal long axis view: Right Ventricular Outflow Tract (Image reproduced with permission from http://pie.med.utoronto.ca/TTE).

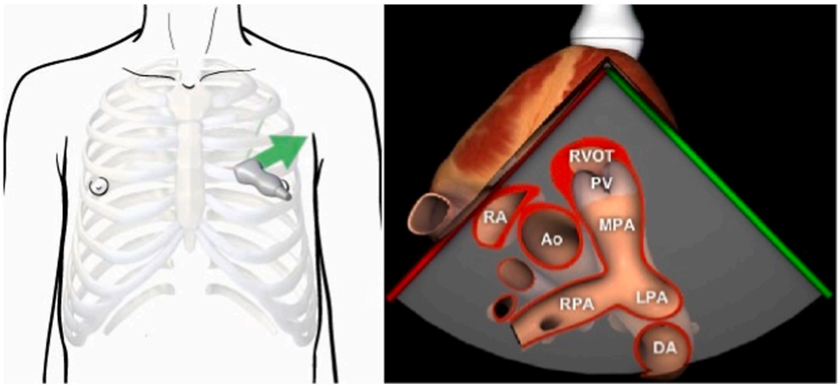

Fig. 4. Parasternal short axis view: Pulmonary Artery Bifurcation (Image reproduced with permission from http://pie.med.utoronto.ca/TTE).

Step 2: Right atrium is visualized in the "Subcostal four chamber view". To obtain this view, place the probe in sub-xiphoid region of abdomen, marker towards 3 o' clock (patient's left) and position it flat and gently pushed down. This view allows visualization of the Right atrium and Right ventricle. (Fig. 1). Advance the PAC slowly to allow the balloon tip to float along the blood flow into the Right atrium (Video 1).

Supplementary video related to this article can be found at https://doi.org/10.1016/j.rmcr.2022.101678

Troubleshooting – Occasionally, the PAC balloon can get diverted into the Inferior vena cava. This can be visualized in the "Subcostal Inferior Vena Cava view" by rotating the probe 90° counterclockwise, marker towards 12 o' clock (Fig. 2) to visualize the Inferior vena cava (Video 1) and note the lack or presence of PAC balloon tip.

Step 3: The Right ventricle is also visualized in the "Subcostal four chamber view" described previously (Fig. 1). The PAC balloon tip is advanced till it crosses the Tricuspid valve (Video 1) and concomitant pressure waveform is noted for the Right ventricle.

Troubleshooting - If the catheter is noted to coil in the Right ventricle on further advancement, the balloon can be deflated and the retracted slowly until the catheter tip is noted to barely cross the Tricuspid valve.

Step 4: The Right ventricular outflow tract is visualized in a modification of the "Parasternal long axis view" by positioning the probe in the 3rd or 4th left intercostal space, marker toward patient's right shoulder and by tilting the probe superiorly and laterally towards left shoulder (Fig. 3). PAC balloon is advanced slowly till it crosses the pulmonic valve (Video 1) and a concomitant change in pressure waveform is noted for the Pulmonary artery.

Step 5: The Pulmonary artery bifurcation is visualized in a modification of the "Parasternal short axis view" by placing the probe in 3rd of 4th intercostals space at the left intercostals border, marker towards left shoulder and with the probe tilted superiorly and medially (Fig. 4). The PAC balloon is noted in the Pulmonary artery (Video 1) and is advanced slowly until it diverts into one of the main pulmonary artery branches until it wedges in place and a concomitant change in pressure waveform is noted. At the end of the procedure, the balloon should be deflated.

Finally, a portable chest radiograph should be obtained to accurately confirm the position of PAC tip in the main pulmonary artery branch within 4–5 cm from midline.

3. Conclusion

Point of care ultrasound can serve as an additional visual tool during insertion of pulmonary artery catheters. It is easy to learn and can be used to troubleshoot right heart catheterization at bedside. This method can potentially replace the need for fluoroscopy and is safer in comparison.

Declaration of competing interest

Enambir Josan – None.
Ziad Shaman – None.
Nicholas Pastis - None.

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