Right heart catheterisation: how to avoid the most common mistakes

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AIMS

- To discuss practical issues: vein cannulation, type of catheter, catheter placement, waveform interpretation, measurements and calculations.
- To identify possible pitfalls and caveat.
- To improve the skills in performing a correct diagnosis integrating RHC and other imaging modalities.

SUMMARY

Right heart catheterization (RHC) represents the gold standard for measuring pulmonary haemodynamics. RHC is mandatory to confirm the diagnosis of pulmonary hypertension (PH), to assess the severity of haemodynamic impairment and to perform vasoreactivity testing in selected patients.

PH is defined as a mean pulmonary arterial pressure (mPAP) ≥25 mmHg by RHC measured at rest, with pre-capillary PH being defined by a pulmonary artery wedge pressure (PAWP) ≤15 mmHg and post-capillary PH by a PAWP >15 mmHg. Among post-capillary PH, “isolated post-capillary PH” (Ipc-PH) is defined by a diastolic pulmonary gradient (DPG) <7 mmHg and pulmonary vascular resistance (PVR) ≤3 WU, and “combined post- and pre-capillary PH” (Cpc-PH) by DPG ≥7 mmHg and/or PVR >3 WU.

The term pulmonary arterial hypertension (PAH) describes a group of PH characterized by the presence of pre-capillary PH and a pulmonary vascular resistance (PVR) >3 Wood units (WU) in the absence of other causes of pre-capillary PH such as PH due to lung diseases, chronic thromboembolic pulmonary hypertension (CTEPH) or other rare diseases.

RHC, as an invasive diagnostic tool, is part of a complex algorithm for PH diagnosis. The interpretation of invasive haemodynamics should consider the context of the clinical picture and imaging, in particular echocardiography.

RHC is a challenging procedure requiring careful attention, meticulous measurement and extensive expertise. In order to obtain valuable clinical information and to minimize the risk related to the procedure RHC should be limited to expert centres.

Cannulation of a sufficiently large systemic vein is the first step for performing RHC.

The practice of using surface anatomy and palpation to identify target vessels before cannulation attempts (“landmark technique”) is based on the supposed location of the vessel, the identification of anatomic landmarks, and blind insertion of the needle until blood is aspirated. Depending on the site and patient population, landmark techniques for vascular cannulation are associated with a 60% to 95% success rate. The landmark technique can be augmented by the use of ultrasound; this is
recommended in the case of jugular vein cannulation and very helpful when using the brachial vein approach.

The gold standard for pressure and blood flow measurement of the pulmonary circulation are respectively the high-fidelity micromanometer-tipped catheters and the direct Fick method. The fluid-filled flow-directed thermodilution catheters are much more widely used and have been demonstrated to be accurate though with lack of precision of +/- 1 L/min for cardiac output, +/- 8 mmHg for mPAP and -15 to +8 mmHg for PAWP. Precision on otherwise accurate measurements can be improved by repetition and averaging. This is why it is recommended to average 3 to 5 thermodilution cardiac output measurements with less than 10% variation, and to read pulmonary vascular pressures in triplicate.

In clinical practice, the catheter commonly used for RHC is a balloon floatation tip catheter, known as “Swan-Ganz” catheter.

A correct zero level set is pivotal in performing RHC. The wrong zero level set is one of the most common mistakes and a major confounding factor during RHC. Zero level setting must be meticulous because it represents the starting point for all pressure measurements. In fact, each pressure measured during RHC is a difference between the pressure at the chosen zero level and the pressure in the chamber (or vessel) where the fluid-filled catheter tip is located, assuming there is no obstruction and no significant flow within the catheter.

The question of zero leveling was raised before the introduction of cardiac catheterization, during the early measurements of the peripheral and central venous pressure. An ideal zero reference would be not only independent of chest diameter but also insensitive to changes in body position and represent a “hydrostatic indifference point”. Recently, it has been proposed a standardized reference point valid in any body position, defined by the intersection of the mid-thoracic frontal plane with the transverse plane passing through the fourth anterior intercostal space and the mid-sagittal plane.

Kovacs et al. assessed retrospectively the position on computed tomography the right and left atrial centre levels in 196 consecutive patients with PH undergoing RHC, found that the centre of the left atrium was best described by the “mid-thoracic level”. As a consequence, zeroing the system at this level seems reasonable for the assessment of PAWP.

Accurate measurement of left ventricular filling pressure is essential to distinguish between PAH and PH due to left heart diseases, mainly heart failure with preserved ejection fraction (HFpEF). Commonly, PAWP is used as a surrogate measure of left atrial pressure and left ventricular end-diastolic pressure. PAWP is the pressure measured from a catheter wedged in a branch pulmonary artery. Actually, the term “wedge pressure” derives from the measurement obtained by a “wedged” catheter without an inflated balloon. Using an inflated balloon we measure a “pulmonary artery occluded pressure”. Both are usually referred to as a PAWP and used indifferently, but the measured pressures will be different if there is an increased large vein resistance (such as in sepsis for example).

In clinical practice, determination of CO and CI is typically done by either the Fick method or thermodilution, in order of reproducibility the direct Fick is preferable to thermodilution which is in turn preferable to the indirect Fick.

The Fick principle is based on the observation that the total uptake (or release) of a substance by the peripheral tissues is equal to the product of the blood flow to the peripheral tissues and the arterial-venous concentration difference (gradient) of the substance. In the determination of cardiac output, the substance most commonly measured is the oxygen content of blood thus giving the arterio-venous oxygen difference, and the flow calculated is the flow across the pulmonary system.

This provides an easy way to calculate the cardiac output: Cardiac output = oxygen consumption / arteriovenous oxygen difference.
Measurement of the arterial and venous oxygen content of blood involves the sampling of blood from the pulmonary artery and from the pulmonary vein. In practice, sampling of peripheral arterial blood is a surrogate for pulmonary venous blood.

The first step during RHC in congenital heart disease is to obtain pressure measurements at different levels of the systemic venous return, the right heart, and the pulmonary circulation. This should include measurements in the superior vena cava, inferior vena cava, right atrium, right ventricle (or sub-pulmonary ventricle), pulmonary artery, and PAWP. Systemic pressures are also required to calculate the ratio between pulmonary and systemic artery pressure. The ratio between the systemic and pulmonary pressures and resistance may be especially useful if shunt closure is contemplated.

RHC in patients with pulmonary hypertension can be very challenging and has been associated with serious, sometimes fatal, complications. For this reason, RHC should be performed only in expert centres.

REFERENCES


