Καθετηριασμός δεξιάς κοιλίας

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The increasing interest in pulmonary arterial hypertension (PAH), the increasing interest in implantation of LVADs, and the evolution in the percutaneous management of structural heart disease have rekindled the interest in Right Heart Catheterization and procedures.
Measuring the Cardiac Output: The **Fick Oxygen method**

\[ \text{VO2} = \left(\text{hem in g/dL} \times 1.36 \text{ ml O}_2/\text{g Hb} \right) \times 10 \times \left(\% \text{ saturation}_{\text{art}} - \% \text{ saturation}_{\text{mixed venous}}\right) \]

\[
\begin{array}{ccc}
12 & 96 & 55 \\
\end{array}
\]

not affected by tricuspid regurgitation and is more precise at a lower CO

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**1. Dehmer formula**
\[
\text{VO}_2 \text{ (ml/min)} = 125 \times \text{Body Surface Area}
\]

**2. LaFarge formula**
\[
\text{VO}_2 \text{ (ml/min)} = 138.1 - (11.49 \times \log \text{age}) + (0.378 \times \text{Heart Rate}) \times \text{Body Surface Area (Men); VO}_2 \text{ (ml/min)} = 138.1 - (17.04 \times \log \text{age}) + (0.378 \times \text{Heart Rate}) \times \text{Body Surface Area (Women).}
\]

**3. Bergstra formula**
\[
\text{VO}_2 \text{ (ml/min)} = 157.3 \times \text{Body Surface Area} + 10 - (10.5 \times \log \text{age}) + 4.8 \text{ (Men); VO}_2 \text{ (ml/min)} = 157.3 \times \text{Body Surface Area} - (10.5 \times \log \text{age}) + 4.8 \text{ (Women).}
\]
The **thermodilution** method is a specific application of the **Fick** principle.
Measured Fick vs Assumed Fick CO

$r = 0.65$

Measured Fick vs Thermodilution CO

$r = 0.74$
Principles of Pressure Recording and Measurement
Computed tomography of the chest at the level of the heart demonstrating the possible hydrostatic effects when different reference levels are used (LA left atrium, LV left ventricle, RA right atrium, RV right ventricle)

Conversion factor: cm of blood $\times 0.77 = \text{mmHg}$
Frequency Response of the Pressure Recording System

- Higher natural frequency (accurate pressure)
- Damping (friction in the system)
- Fluid acceleration
- Whipping of the catheter

PA 40 mmHg
Timing of Pressure Measurements

Baseline

Fluid challenge

Champion HC et al Circulation. 2009;120:992–1007
Interpretation of Pressure Waveforms
Right Atrium
RA waveform consistent with constriction (volume overloading – pericardial constraint)
acute right ventricular infarction
acute mitral regurgitation
acute pulmonary embolism
Cardiomyopathy with edema
10 years after a Dor ventriculoplasty procedure – restrictive physiology

LV 40 mmHg
RA 40 mmHg
Dynamic Respiratory Variation distinguishes Restrictive vs Constrictive Physiology

LV

RV

LV

RV
mitral valve replacement for mitral regurgitation 7 years earlier
Relationship of Right- to Left-Sided Ventricular Filling Pressures in Advanced Heart Failure

Pulmonary Capillary Wedge Pressure (PCWP) and Left Ventricular End-Diastolic Pressure (LVEDP)
78-year-old patient had recently diagnosed pulmonary hypertension with no evidence of chronic thromboembolic pulmonary hypertension (CTEPH).

The static PCWP may not explain clinical and imaging findings of increased lung water.
Pulmonary Artery Pressure
reflected waves and compliance revealed

![Graph showing changes in Pulmonary Artery Pressure](image)
Pulmonary Vascular Resistance (PVR)

\[ \Delta P = \frac{8 \mu L Q}{\pi R^4} \]

\[
\frac{\Delta P}{Q} = \frac{8 \mu L}{\pi R^4}
\]

1 WU = 1 mmHg min/ L = 80 dynes sec cm\(^{-5}\)

\[
\frac{\Delta P}{Q} = \frac{8 \mu L}{\pi R^4} \text{ BSA}
\]
Pressure – Flow relation in the Lung

- PAP (mmHg) vs Flow (l/min)
- Vasoconstriction
- RVF
- PH
- C
- Vasodilatation
- 81%
- 49%
- 0%
How Best to Describe the Right Ventricular Afterload

graphical representation of the ratio of pressure and flow (modulus Z) at different waveform frequencies

![Graph showing impedance modulus vs. frequency for normal and pulmonary vascular disease with RV dysfunction.](image-url)
Scleroderma PAH

Idiopathic PAH

Right ventricular (RV) pressure–volume loops at decreasing venous return

Ees = \frac{ESP}{(ESV) - V_0}

Ea = \frac{ESP}{SV}

\text{Ventricular} \quad \text{Arterial} \quad \text{Coupling} \quad \frac{Ees}{Ea} > 1

Ea = \frac{\text{mean PAP}}{\left(\frac{CO}{HR}\right)} = PVR \times HR
The Relation of Compliance and Resistance in the Pulmonary Vascular Tree
(a simpler way to incorporate the pulsatile component into the description of the loading condition of the RV)

\[ C = \frac{SV}{PP} \]
The Work of the Right Ventricle

The RV stroke work index (RVSWI) can be approximated by the equation:

\[(\text{meanPAP} - \text{meanRAP}) \times \text{SV/BSA}] \quad \text{mmHg mL/m}^2 \times 0.0136 \quad \text{gr m/m}^2\]

The normal values range is between 350–750 mmHg mL/m² or 5 - 10 gr m/m²

Pulmonary Hypertension in Heart Failure

An important concept in the evaluation of PH associated with heart failure is the effect of increased pulmonary venous pressure of >15 mmHg on the precapillary and postcapillary vascular resistance and the structural nonreversible changes in the pulmonary vessels.

What are the pressure limits which define an “out-of-proportion” response, i.e., an excessive reactive response of the pulmonary vasculature?

TPG >12 mm Hg or PVR > 3 Wood units
DPG > 7 mmHg
54 y/o ischemic cardiomyopathy destination LVAD > normal PA pressures

TPG: 52-31=21 mmHg/ PVR: 4.9 WU /DPG=33-31= 2 mmHg
Predictors of prognosis in “out-of-proportion” pulmonary hypertension.

Assessing the Reversibility of Pulmonary Hypertension in Heart Failure

In most transplant centers, patients with a TPG >15 mmHg or PVR >5 Wood units, despite acute vasoreactive testing, are not considered appropriate candidates.

An elevated PVR can be often reduced acutely or chronically by using agents which affect PVR either by direct vascular dilatation or indirectly by increasing CO or by decreasing LAP.
Right Atrial Pressure
How Best to Describe the Right Ventricular Afterload

by the size and wall thickness of the RV and the pressure generated (Laplace’s Law)

mean PVR, which is the ratio of mean pressure to mean blood flow during a steady state

pulsatile components
the compliance of the pulmonary vessels
arterial wave reflections
the inertance of blood during ejection
GREATER fluid viscosity
SMALLER catheter radius
LESS dense fluid
LARGER catheter radius
SHORTER catheter
LESS dense fluid
LESS dense fluid
GREATER fluid viscosity

Higher natural frequency (accurate pressure)  Damping (friction in the system)

Frequency Response of the Pressure Recording System
The hemodynamic assessment which was an essential part in the evaluation of patients with structural heart disease in the 1970s was being replaced by the rapidly evolving field of echocardiography.

In the 1980s and 1990s, the major focus in the catheterization laboratory shifted to the diagnosis and treatment of the patient with acute and chronic coronary artery disease.

But

The increasing interest in pulmonary arterial hypertension (PAH), the increasing interest in implantation of LVADs, and the evolution in the percutaneous management of structural heart disease have rekindled the interest in Right Heart Catheterization and procedures.
Measuring the **cardiac output (CO)** is based on the Fick principle

\[
VO_2 = (CO \times C_a) - (CO \times C_v)
\]

\[
CO = \frac{VO_2}{C_a - C_v}
\]
Measuring the **cardiac output (CO)** and **effective stroke volume (SV)** in absolute terms is important in the evaluation of the **systolic function** of the ventricle and the calculation of **vascular resistance**

A practical problem with the Fick oxygen method is the need for the **measurement of oxygen consumption**

not affected by tricuspid regurgitation and is more precise at a lower CO
measurements which depend on frequency analysis of the pressure waveforms, or simply measuring the diastolic or systolic pressures with fluid-filled catheters, are critically dependent on the natural frequency and damping of the system.

Frequency Response and Damping of the Pressure Recording System
Frequency Response and Damping of the Pressure Recording System

To ensure a wide response range and move the natural frequency to higher frequencies a shorter wide-bore stiff tubing, filled with a low-density fluid without air bubbles, is required, but such a system will be grossly underdamped.

- GREATER fluid viscosity
- LESS dense fluid
- SMALLER catheter radius
- LESS dense fluid
- SHORTER catheter
- LARGER catheter radius