Right Heart Catheterization — Hemodynamic Calculations

Comprehensive reference for Fick cardiac output, vascular resistance, PAPi, and derived hemodynamics

NORMAL HEMODYNAMIC VALUES

Chamber	Systolic / Diastolic	Mean
RA	a: 2–10 v: 2–10	0–8
RV	15–30 / 0–8 (EDP)	—
PA	15–30 / 4–12	9–18
PCWP	a: 3–15 v: 3–15	4–12
Aorta	100–140 / 60–90	70–105

Parameter	Normal Range
Cardiac Output (CO)	4–8 L/min
Cardiac Index (CI)	2.5–4.0 L/min/m²
Stroke Volume (SV)	60–100 mL/beat
Stroke Volume Index (SVI)	33–47 mL/beat/m²
SVR	10–20 WU (800–1600 dyn·s·cm^{-5})
PVR	< 2 WU (< 160 dyn·s·cm^{-5})

All pressures in mmHg. WU = Wood units. Conversion: WU × 80 = dyn·s·cm^{-5}

FICK CARDIAC OUTPUT

$$\text{CO (L/min)} = \frac{VO_2 \text{ (mL/min)}}{\text{Hb} \times 13.6 \times (SaO_2 - SvO_2)}$$

VO_2 Oxygen consumption (mL/min) — measured or estimated (LaFarge)

Hb **CBC hemoglobin** (g/dL) — single value, NOT co-oximetry

13.6 = 1.36 (mL O_2/g Hb) × 10 (dL → L conversion)

SaO_2 Arterial oxygen saturation (Ao sat, decimal form)

SvO_2 Mixed venous oxygen saturation (PA sat, decimal form)

Expanded O_2 Content Form

CaO_2 = Hb × 1.36 × SaO_2 *(mL O_2/dL — arterial O_2 content)*

CvO_2 = Hb × 1.36 × SvO_2 *(mL O_2/dL — venous O_2 content)*

CO = VO_2 ÷ [(CaO_2 − CvO_2) × 10]

Always use CBC Hemoglobin. Co-oximetry Hb may vary between AO and PA samples due to measurement artifact — but Hb concentration is physiologically identical throughout the circulation (it is the same blood). Using different Hb values for arterial and venous content introduces artificial error. Always use the single CBC value.

VO_2 Estimation Methods

LaFarge equation (cath lab software): accounts for age, sex, HR — preferred estimate

Flat assumption: 125 mL/min/m² or 3 mL/kg/min — less accurate, common fallback

Gold standard = measured VO_2 via metabolic cart — rarely available in practice

CARDIAC INDEX & STROKE VOLUME

CI (L/min/m²) = CO ÷ BSA

SV (mL/beat) = (CO × 1000) ÷ HR

SVI (mL/beat/m²) = SV ÷ BSA

CI < 2.2 L/min/m²: hemodynamically significant low cardiac output
SVI < 35 mL/beat/m²: reduced — important threshold in low-flow AS assessment

VASCULAR RESISTANCE & PRESSURE GRADIENTS

Pulmonary Gradients

TPG = mPAP − PCWP (transpulmonary gradient, mmHg)

DPG = dPAP − PCWP (diastolic pulmonary gradient, mmHg)

Pulmonary Vascular Resistance (PVR)

$$\text{PVR (Wood units)} = \frac{\text{mPAP} - \text{PCWP}}{\text{CO}}$$

dyn·s·cm^{-5} = WU × 80

PVR	Interpretation
< 2 WU	Normal
2–3 WU	Borderline / mildly elevated
3–5 WU	Moderately elevated
> 5 WU	**Severely elevated**

Systemic Vascular Resistance (SVR)

$$\text{SVR (Wood units)} = \frac{\text{MAP} - \text{mRAP}}{\text{CO}}$$

dyn·s·cm^{-5} = WU × 80

SVR	Interpretation
10–20 WU (800–1600)	Normal
> 20 WU (> 1600)	Elevated (vasoconstriction, cardiogenic shock)
< 10 WU (< 800)	Low (sepsis, vasodilatory shock, cirrhosis)

PAPI — PULMONARY ARTERY PULSATILITY INDEX

$$\text{PAPi} = \frac{\text{sPAP} - \text{dPAP}}{\text{mRAP}} = \frac{\text{PA pulse pressure}}{\text{mean RA pressure}}$$

Context	PAPi Cutoff	Interpretation
General	> 1.0	Adequate RV function
Acute RV MI	**< 0.9**	**Predicts RV failure / need for MCS**
Pre-LVAD	**< 1.85**	**Predicts RV failure post-implant**
Cardiogenic shock	< 1.0	RV dysfunction contributing to shock

Pearl: PAPi integrates RV contractility (PA pulse pressure) with RV preload (RAP). A low PAPi means poor RV output relative to its filling pressure. Most useful in acute settings: RV MI, pre-LVAD assessment, and cardiogenic shock.

PULMONARY HYPERTENSION — HEMODYNAMIC CLASSIFICATION (2022 ESC/ERS)

Type	mPAP	PCWP	PVR
Pre-capillary PH	> 20	≤ 15	> 2 WU
Isolated post-capillary (IpcPH)	> 20	> 15	≤ 2 WU
Combined pre & post (CpcPH)	> 20	> 15	> 2 WU

2022 update: PH threshold lowered from > 25 to > 20 mmHg. PVR threshold lowered from > 3 to > 2 WU. A DPG > 7 mmHg also suggests a pre-capillary component.

FICK VS THERMODILUTION — WHICH CO METHOD TO USE?

	Thermodilution (TD)	Fick (Assumed or Measured VO_2)
Pros	Easy, reproducible, less operator-dependent	Physiologically grounded; preferred in low CO, valvular disease, intracardiac shunts
Cons	Inaccurate in: severe TR, low output states, intracardiac shunts	VO_2 often estimated (not measured) → propagation error in CO and all derived values
Best for	Routine hemodynamic screening	Gorlin valve areas, PVR/SVR calculations, structural heart assessment

Practical Rule: If TD and Fick CO differ meaningfully, **use Fick for Gorlin and derived hemodynamics** — especially in AS, MS, or low output.

Always document in your report:
• Which CO method was used
• Whether VO_2 was measured or estimated

WORKED EXAMPLE — COMPLETE HEMODYNAMIC CALCULATION

Input Data

Age: 65 | Sex: M | HR: 88 bpm | BSA: 1.51 m² | Hb_{CBC}: 14.3 g/dL
SaO_2: 92.8% | SvO_2 (PA sat): 53.6%
RA: 13/22/16 (a/v/mean) | RV: 41/6/12 | PA: 47/22 mean 32
PCWP: 18/17/15 (a/v/mean) | AO: 121/77 mean 96

VO_2 by LaFarge

VO_2 index = 138.1 – (11.49 × ln 65) + (0.378 × 88) = **123.4 mL/min/m²**
VO_2 = 123.4 × 1.51 = **186.3 mL/min**

Step-by-Step Calculations

a-vO_2 = 14.3 × 1.36 × (0.928 – 0.536) = **7.62 mL O_2/dL** (wide → low output)
Fick CO = 186.3 ÷ [14.3 × 13.6 × (0.928 – 0.536)] = 186.3 ÷ 76.2 = **2.44 L/min**
CI = 2.44 ÷ 1.51 = **1.62 L/min/m²**
SV = (2.44 × 1000) ÷ 88 = **27.7 mL/beat** **SVI** = 27.7 ÷ 1.51 = **18.3 mL/beat/m²**
TPG = 32 – 15 = **17 mmHg** **DPG** = 22 – 15 = **7 mmHg**
PVR = 17 ÷ 2.44 = **6.97 WU** (557 dyn·s·cm^{-5})
SVR = (96 – 16) ÷ 2.44 = **32.8 WU** (2623 dyn·s·cm^{-5})
PAPi = (47 – 22) ÷ 16 = **1.56**

PEARLS & COMMON PITFALLS

- **Low CO → wide a-vO_2 difference** — normal a-vO_2 is 3.5–5.0 mL O_2/dL; values > 5.5 suggest inadequate cardiac output
- **Estimated VO_2 error** — ±25% is common; even small VO_2 errors produce large CO errors. Use LaFarge over flat 125 mL/min/m²
- **PCWP ≠ LVEDP** — PCWP may overestimate (large V-wave, overdamped waveform) or underestimate (mitral stenosis) the true LVEDP
- **Prominent V-waves in PCWP** — always use mean PCWP for calculations, not the peak; a large V-wave suggests significant MR
- **Atrial fibrillation** — hemodynamics vary beat-to-beat; average ≥ 5–10 consecutive cycles for reliable values
- **TD in severe TR** — thermodilution underestimates CO because the cold saline indicator recirculates; use Fick in this setting
- **PAPi caveats** — unreliable when RAP is very low (< 3 mmHg); small denominator creates artificially high PAPi
- **Safe documentation language:** "*Hemodynamics calculated using Fick CO with LaFarge estimated VO_2. Findings interpreted in the context of flow conditions.*"

One-Line Memory Anchors

- **Fick CO = VO_2 ÷ [Hb × 13.6 × (SaO_2 – SvO_2)]**
- **PVR = (mPAP – PCWP) ÷ CO** | **SVR = (MAP – RAP) ÷ CO**
- **PAPi = PA pulse pressure ÷ mean RAP**
- Use **CBC Hb** (not co-ox) | Use **Fick > TD** for valve areas | **WU × 80** = dyn·s·cm^{-5}