University Hospitals Coventry and Warwickshire NHS Trust

Right Ventricle in Health & Disease

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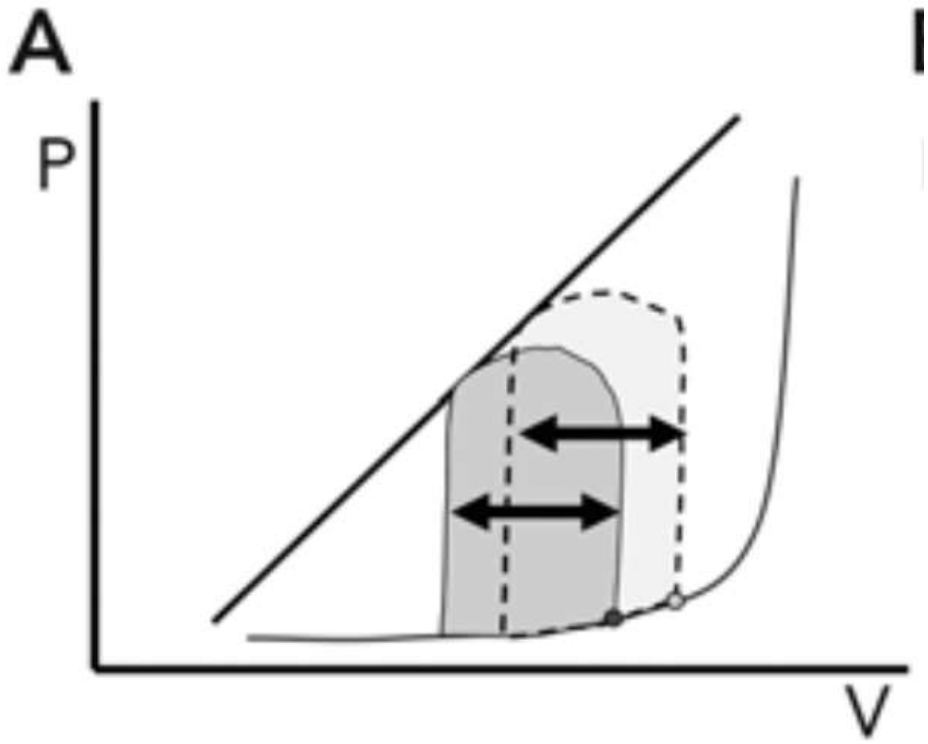
Right Ventricle - Overview

- Primary role is to **deliver all the blood it receives into the pulmonary circulation without causing Right Atrial Pressure (RAP) to rise.**
- RV function is not considered important for overall cardiovascular homeostasis until it is(!).
- Adversely affected by increased afterload (acute & chronic).
- When RAP increases (fluid overload, mechanical ventilation, disease), cardiac output responses to increased demand will be limited.

RV – Diastolic Pressure-Volume Relationship



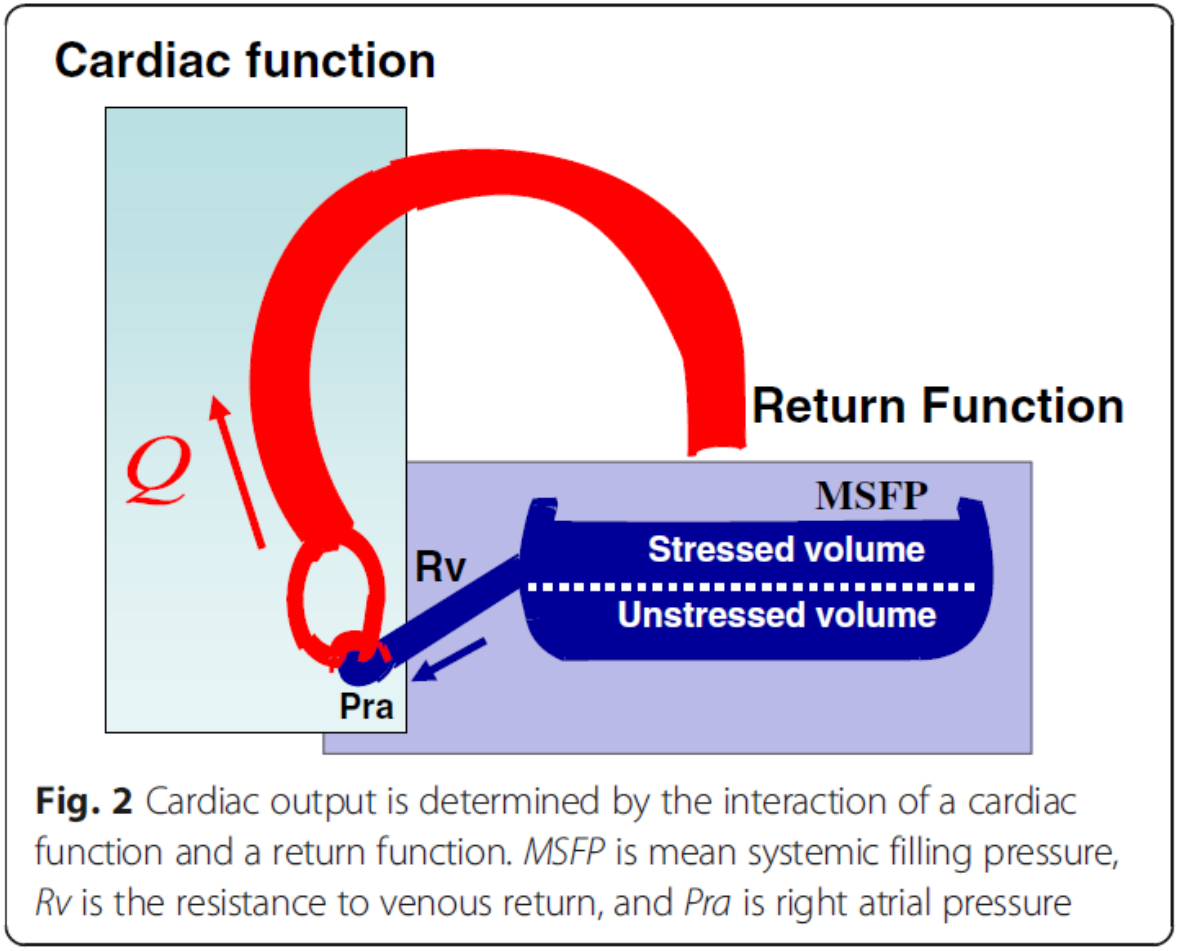


Fig. 2 Cardiac output is determined by the interaction of a cardiac function and a return function. *MSFP* is mean systemic filling pressure, *Rv* is the resistance to venous return, and *Pra* is right atrial pressure

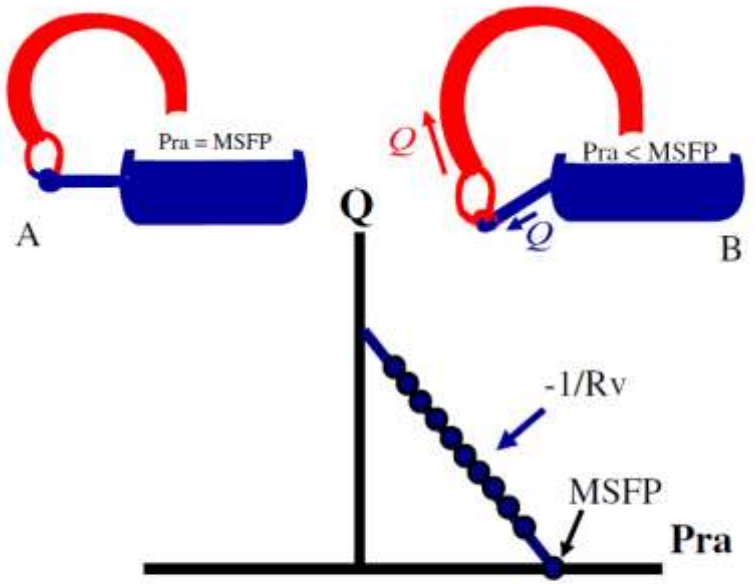


Fig. 3 Guyton's graphical analysis of the return function. **a** When right atrial pressure (*Pra*) equals MSFP, flow in the system is zero. **b** Flow occurs when the cardiac function lowers Pra with a linear relationship between flow and Pra. The slope is minus one over the resistance to venous return (*Rv*)

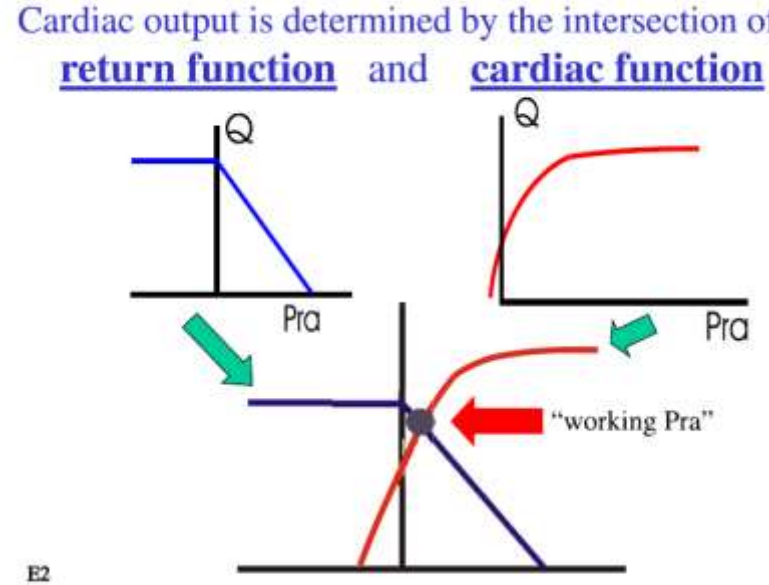


Fig. 4 Guyton's approach to solving the intersection of the return function (venous return curve) and cardiac function curve. Since these two functions have the same axes, they can be plotted on the same graph. Where they intersect gives the working right atrial pressure (*Pra*), cardiac output, and venous return for the two functions

Right Ventricle – Structure & Blood Supply

- Anatomy
  - Most anterior cardiac chamber.
  - Triangular in profile.
  - Crescent-shaped in cross-section.
  - Thin-walled compared to LV.
- Blood Supply
  - 80% - Right dominant -RV supplied by right coronary artery
  - 20% - Left dominant – RV supplied by left circumflex artery
  - RV at lower pressure &, in health, coronary flow throughout cardiac cycle

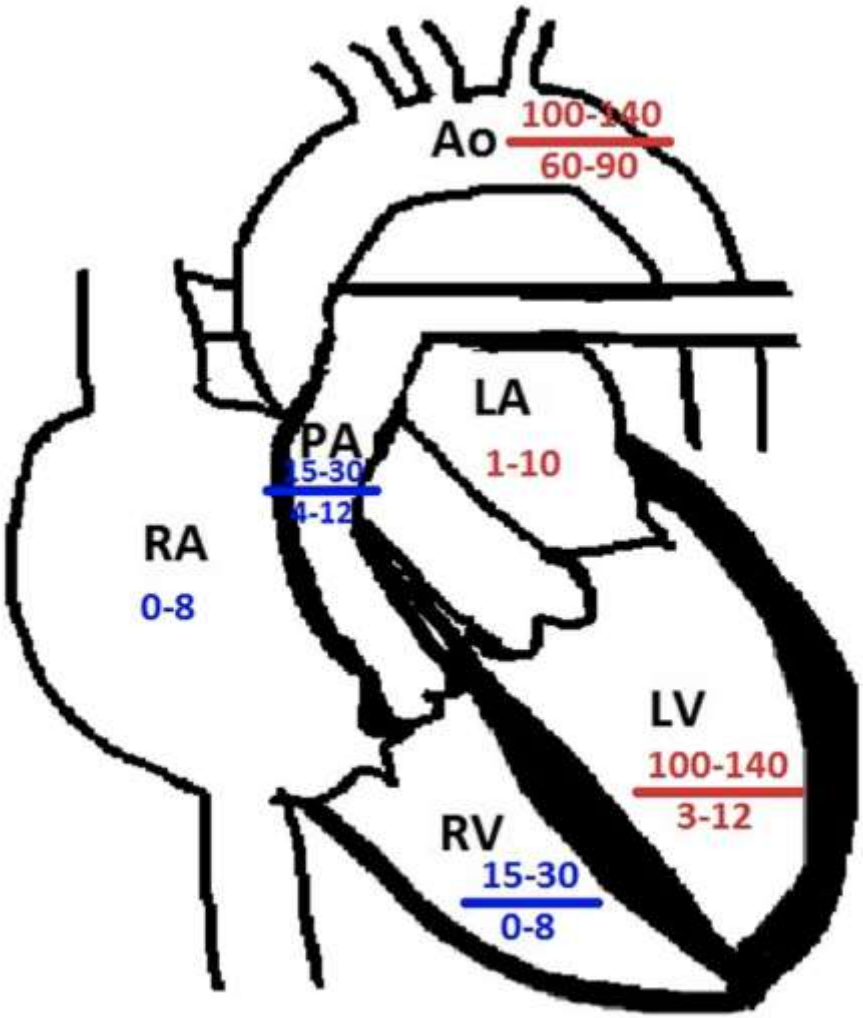


Fig. 2 Right and left heart pressures. Diagram demonstrates the right (blue) and left (red) heart pressures

Right Ventricle – Cardiodynamics(1)

- Tolerant of increased preload
- Intolerant of increased afterload

- RV vs LV - Pressure-Volume Loops

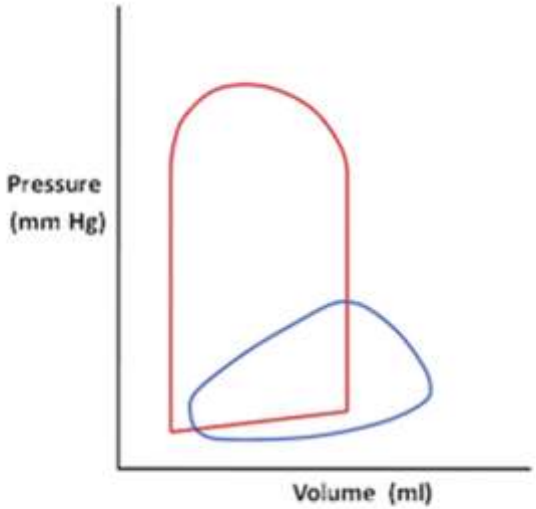


Fig 1 Pressure-volume curves of the left and right ventricle. Note the lower pressures and more triangular appearance of the PV loop for the right ventricle (blue) compared with the more rectangular left ventricle (red).

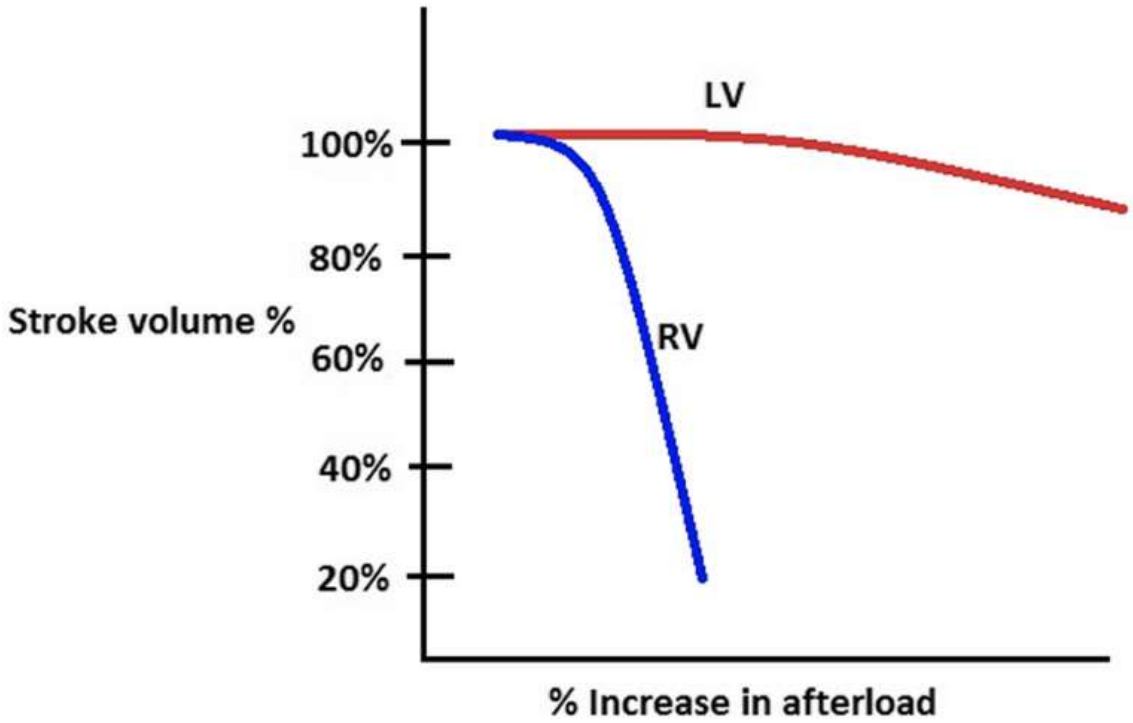


Fig. 3 Relationship of afterload and stroke volume. Right ventricular (red) stroke volume response to increases in afterload is devastating compared to the left ventricular (blue) stroke volume response which is more gradual

Right Ventricle – Cardiodynamics(2)

- Preload
  - Compliant RV dilates to accommodate increased venous return without increased RAP
  - However, with ongoing distension RV failure can occur (commonly accompanied by tricuspid regurgitation).

- Afterload
  - Pulmonary Vascular Resistance
  - Pulmonary Vascular Distensibility (distension in exercise keeps RAP normal)
  - Reduced muscle mass makes RV intolerant of increased afterload
  - In chronic pressure overload (Pulmonary Hypertension), there is an element of compensation (RV hypertrophy)

Right Ventricle – Cardiodynamics(3)

- Ventricular Interdependence
  - Where abnormal function/volume/pressure of one ventricle adversely affects the other ventricle.
  - Occurs because (a) pericardium is non-distensible & (b) the shared interventricular septum.
  - RV pressure- or volume-overload compromises LV filling & contractility.

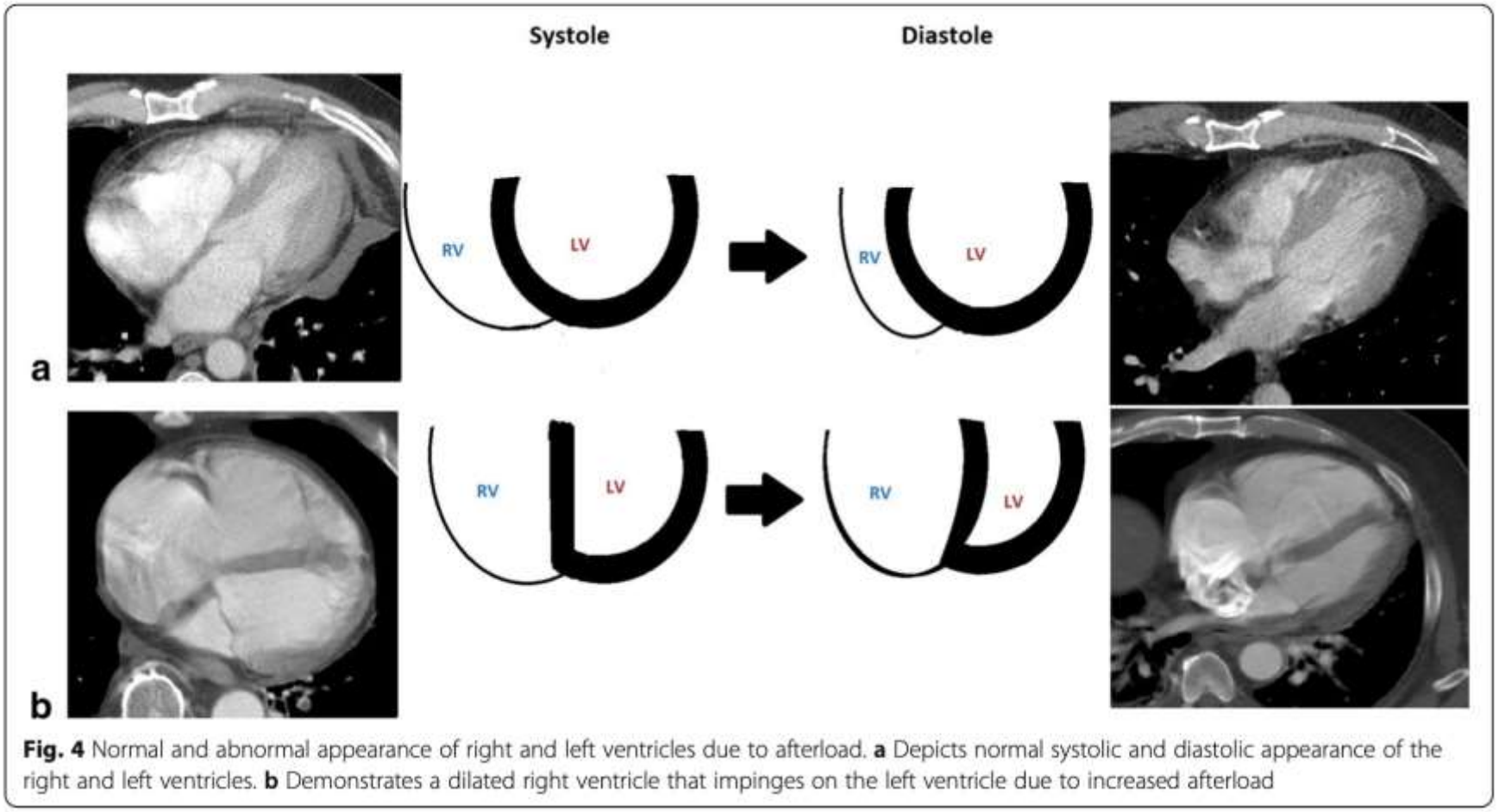
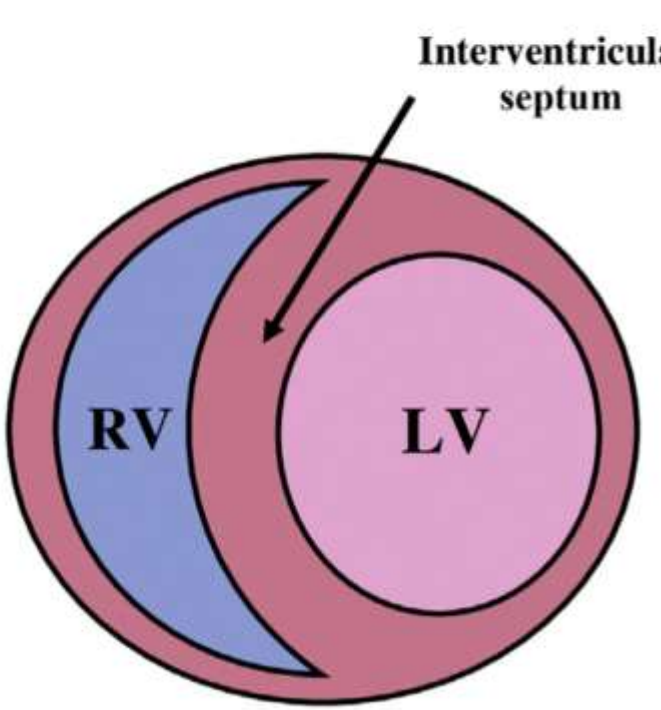


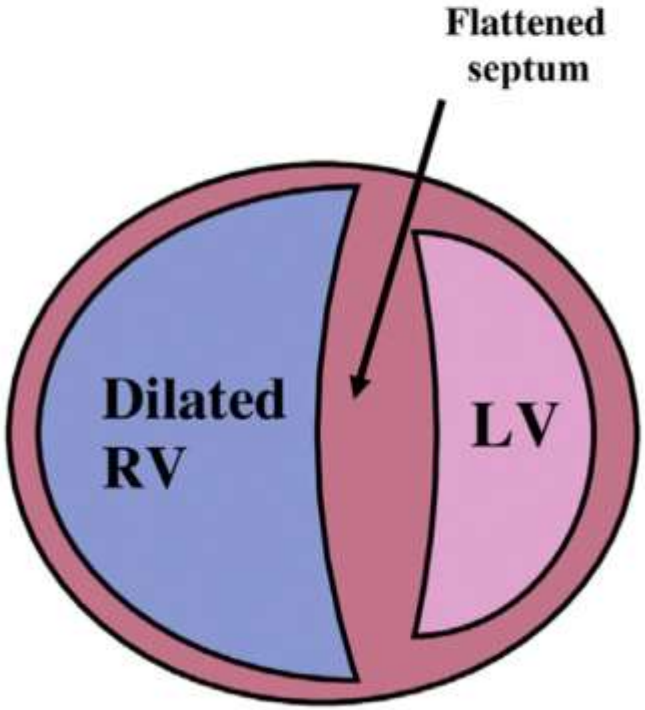
Fig. 4 Normal and abnormal appearance of right and left ventricles due to afterload. **a** Depicts normal systolic and diastolic appearance of the right and left ventricles. **b** Demonstrates a dilated right ventricle that impinges on the left ventricle due to increased afterload

(a) Normal RV
(b) Failing RV – compromises LV filling & performance

Normal heart



RV failure



Assessment of RV Function (1)

- Clinical assessment:
  - Characterised by congestion
  - Oedema, Hepatomegaly, Raised JVP
  - Kussmauls sign – JVP ↑ on inspiration
    - Feature of ↓RV Compliance (RV infarction, Constrictive pericarditis, Cor Pulmonale, Restrictive cardiomyopathy)

- Central Venous Pressure
  - Poor index of preload
  - Surrogate marker of RV function
  - CVP . 15mmHg is never normal
  - Raised CVP & Tricuspid Regurg is an ominous sign

Assessment of RV Function (2)

- ECG
  - May be normal in RV dysfunction
  - Right axis deviation
  - RBBB
  - RV Hypertrophy
  - S1Q3T3 as marker of RV strain in acute Cor Pulmonale

Assessment of RV Function (3)

- Echocardiography
  - In comparison to the LV, RV imaging is **qualitative**.
  - RV Size (compared to LV)
  - RV systolic function
    - Tricuspid Annular Plan Systolic Excursion (TAPSE) < 17mm is indicative of RV dysfunction
    - RVSP = $4V^2$ + CVP (where V is peak velocity or TR jet)

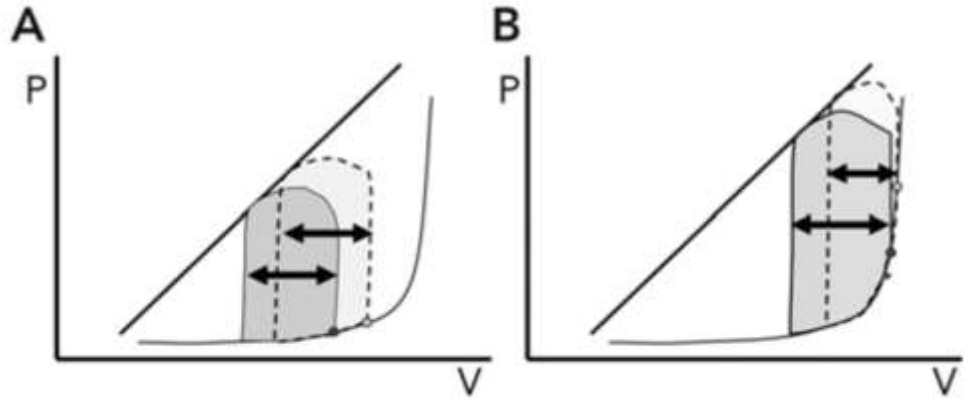
- Pulmonary Artery Catheter
  - In acute RV dysfunction:
    - CVP > Wedge pressure & Low cardiac index

Causes of RV Failure

- ↓Contractility
  - RV Infarction
  - Sepsis
- Acute/Chronic ↑Afterload
  - Pulmonary Embolism
  - Mitral valve disease with pulmonary hypertension
  - Congenital heart disease
  - Obstructive sleep apnoea
  - Post-CPB (multi-factorial)
- Volume Overload

Pathophysiology of RV Failure (1)

Figure 4. Schema of effects of afterload on right ventricle output



A. *Schematic pressure–volume loop of right ventricle. An increase in pulmonary pressure (y axis) is compensated by a right shift of the pressure–volume loop, and stroke volume remains almost the same (dashed lines).*

B. *The end-diastolic pressure is on the steep part of the ventricular passive-filling curve, and the rise in afterload results in a rise in end-diastolic pressure and fall in stroke volume (dashed lines).*

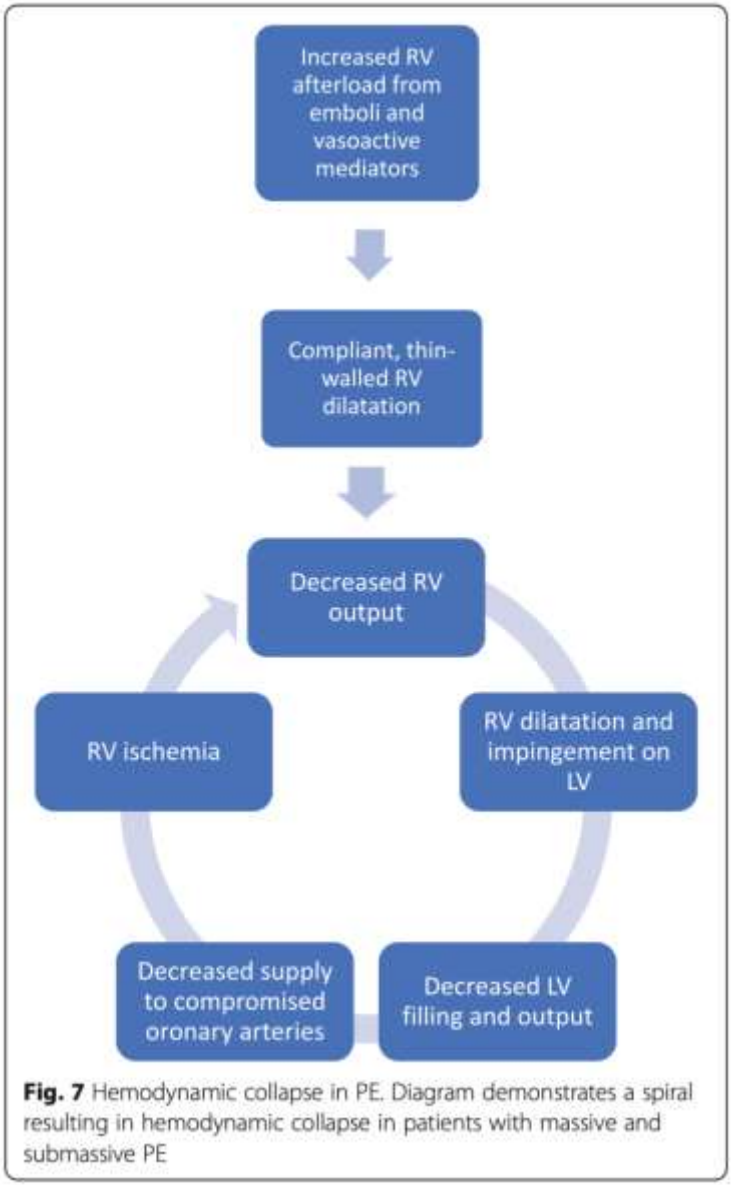


Fig. 7 Hemodynamic collapse in PE. Diagram demonstrates a spiral resulting in hemodynamic collapse in patients with massive and submassive PE

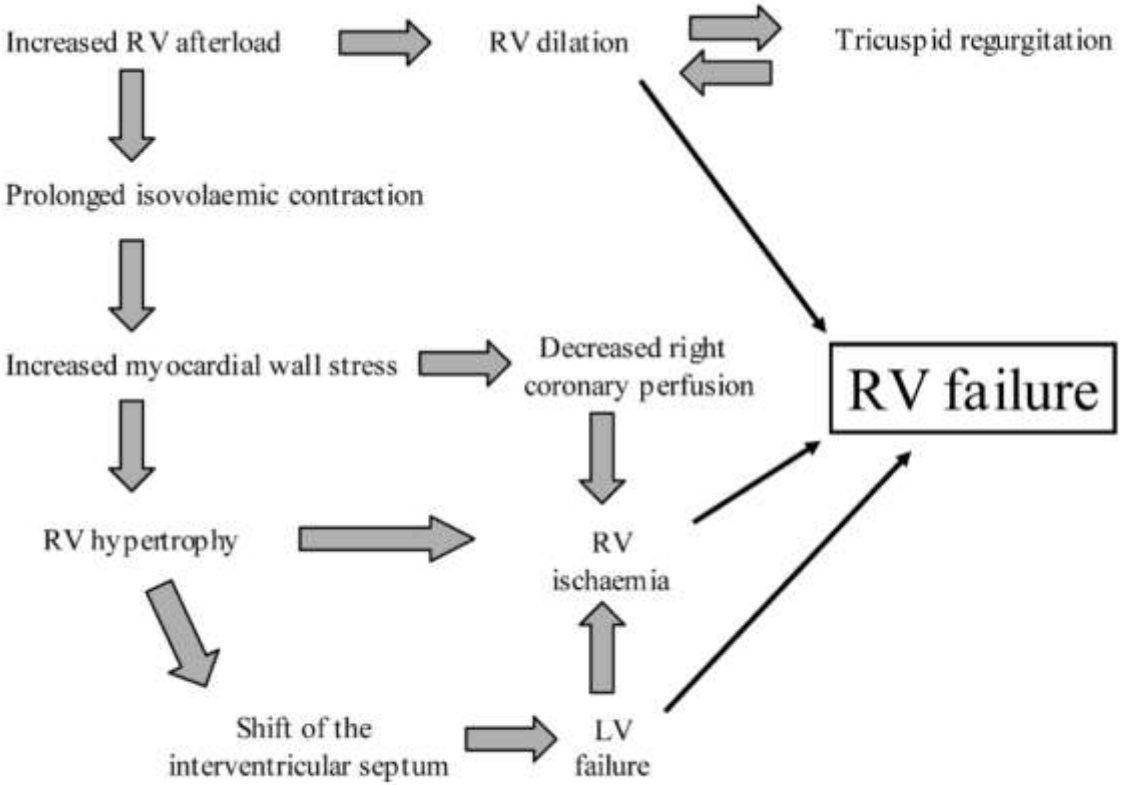


Fig. 2 Pathophysiology of RV failure.

Peri-Operative Management of RV Dysfunction (1)

- Common scenarios:
  - RV infarction, Congenital Heart Disease, MV disease with PH
- Principles
  - Maintain rate & sinus rhythm
  - Maintain preload
  - Avoid ↑Afterload
  - Preserve myocardial contractility & maintain systemic BP

Peri-Operative Management of RV Dysfunction (2)

- Maintain rate & sinus rhythm
  - Higher rates avoid RV distension → LV distortion & TR
  - However, higher rate may compromise LV blood supply
  - Importance of atrial contraction in poorly compliant RV
- Maintain preload
  - Small volume fluid challenges & use CVP as ‘stopping rule’.
- Avoid ↑Afterload
  - Avoid hypoxia, acidosis, hypercarbia
  - Minimise PEEP & Peak airway pressure

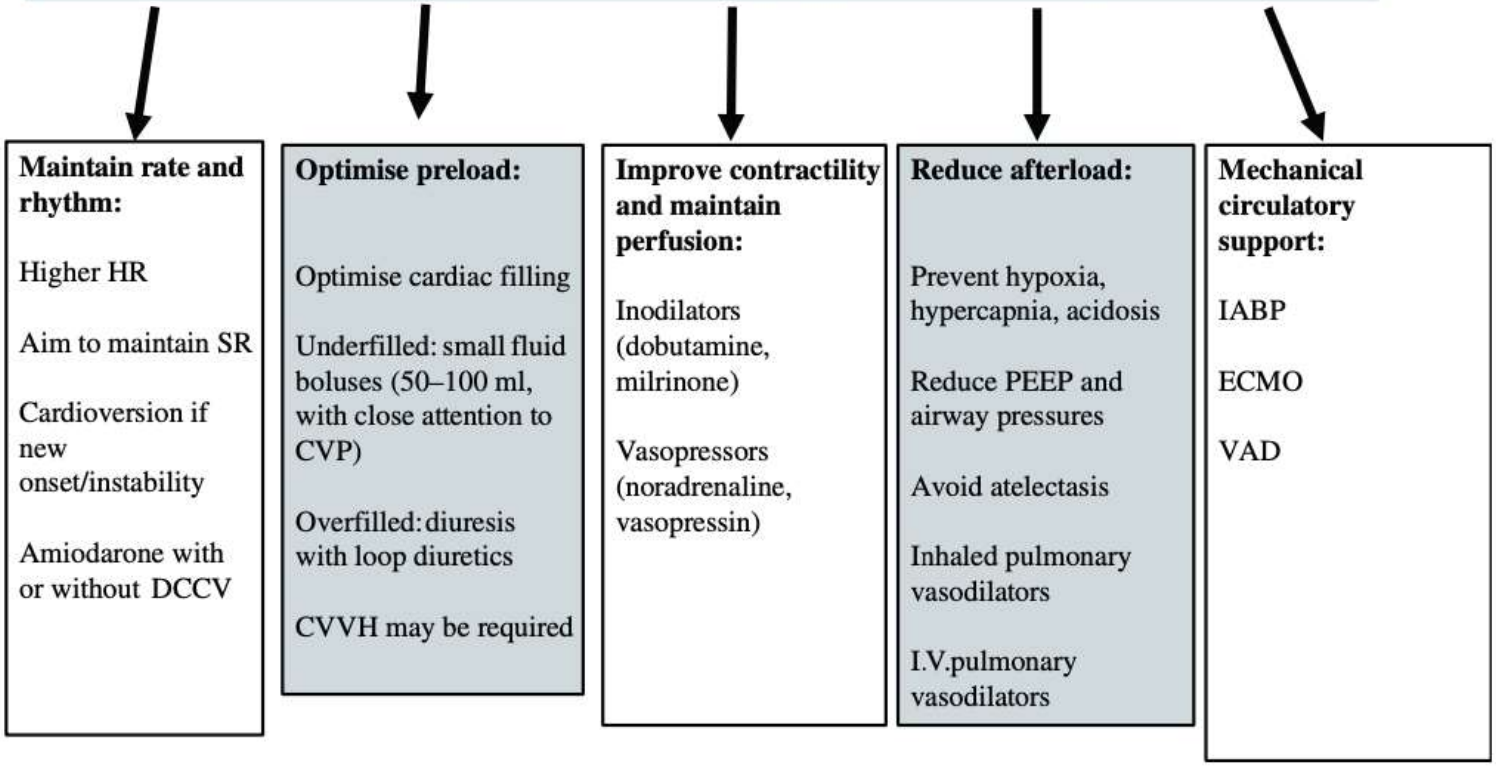
Peri-Operative Management of RV Dysfunction (3)

- Preserve myocardial contractility & maintain systemic BP
  - Coronary artery perfusion dependent on systemic BP
  - Eg Dobutamine or Milrinone are conceptually attractive as inotropes, but co-incident vasodilatation may drop systemic pressure.
  - In practice, start a vasoconstrictor first to counteract any vasodilatation

- Specific Treatments
  - Thrombolysis for PE
  - Nitric oxide or Inhaled prostacyclin as pulm vasodilators
  - Sildenafil (usually used chronically)

Management of acute RV failure

In all cases identify and treat underlying causes where possible



RV Failure Complicating Cardiac Surgery

- Consider RV failure when:
  - Failing to separate from CPB
  - Haemodynamic instability when LV function appears good
  - NB Pulm artery catheter as diagnosis
- Causes:
  - RV Infarction/Ischaemia (graft thrombosis)
  - Air embolus (Right coronary ostia is anterior in aortic root)
  - Pre-existing PH exacerbated by mechanical ventilation or hypoxia
  - Post CPB - ↑pulmonary afterload
  - Protamine (may cause extreme pulm. vasoconstriction)
  - MR with TR – Presence of TR may mask RV dysfunction at preop assessment. This can be revealed when TV is repaired

Right Ventricle - Summary

- You don’t need a Right Ventricle but when it fails you are in trouble!
- Essential role is to pump all the blood it receives & maintain low RAP (to maintain venous return).
- Tolerant of increased preload, Intolerant of increased afterload.
- In RV failure, ↑RAP compromises venous return & RV dilatation shifts septum (ventricular interdependence); Both compromise LV filling & function
- Maintain systemic pressure in RV dysfunction to maintain coronary perfusion.