Shunt Detection and Quantification

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Normal Physiology - Overview

- Right heart saturations (oxygen content) are generally about 75% and are equal in all chambers and vessels
- Left heart saturations (oxygen content) are generally over 95% and are equal in all chambers and vessels
- Streaming can occur - saturation gradients can exist in heart chambers or vessels

McLaughlin P et al. “The role of cardiac catheterization in adult congenital heart disease” Cardiol Clin. 2006;24:531.

Normal Adult Circulation

	Mean	Range (S)	Subjects
Cardiac output (L/min)	6.6	4.4-8.9	
Cardiac index (L/min/m^2)	3.5	2.8-4.2	
SVR (dynes sec cm^{-5})	1130	952-1308	
IVC sat	83.0	76-88	65-88
SVC sat	76.8	66-84	67-82
RA	79.5	72-86	74-84
RV	78.5	64-84	69-84
PA	78.4	73-85	75-84
PAW	98.2	90-100	92-100
Radial artery	97.3	95-99	95-99

Barratt-Boyes BG et al. J Lab Clin Med. 1957;50:93. 26 normal adults, supine, age 13-44, 15 were male physicians.

Normal Physiology - Inflow

- SVC saturation
  - May vary by 10%
  - Receives jugular, subclavian and azygous blood
  - Subclavian and azygous saturations are higher than jugular
- IVC saturation
  - May vary by up to 10-20%
  - Renal veins higher saturation
  - Gastrocolic and hepatic veins lower saturation
  - IVC usually about 5-10% higher than SVC
- Coronary sinus saturation
  - Makes up only about 5-7% of flow into RA
  - Low saturation of 25-45% may lower the total saturation

McLaughlin P et al. "The role of cardiac catheterization in adult congenital heart disease" Cardiol Clin. 2006;24:531.

Shunt Detection and Quantification – When to Look

- Every patient with right heart cath should have saturations measured at SVC and PA
- Usually the presence of a shunt is suspected prior to catheterization
- Unexplained arterial desaturation (<95%)
- PA saturation is unexpectedly high, >80%
- Unexpected cath results (no MR and HSM)

Grossman W. "Shunt detection and quantification" 6th ed. pp. 179-191. 2000.

Oximetry Run ("Sat Run")

- Oximetry run is obtaining sequential blood samples from PA, RV, RA, SVC, IVC
- Look for "step-up"
  - Obtain O_2 saturation in SVC and in PA
  - **If ≥ 8% step-up between SVC and PA this is abnormal, should do full oximetry run**

Grossman W. "Shunt detection and quantification" 6th ed. pp. 179-191. 2000.

Assumptions during Oximetry Run ("Sat Run")

- The patient is in a steady state (no change in blood flow, respiratory rate, heart rate, level of consciousness)

- The saturations are obtained at the same time as the oxygen consumption is measured

McLaughlin P et al. "The role of cardiac catheterization in adult congenital heart disease" Cardiol Clin. 2006;24:531.

TABLE 9.1. *Detection of left-to-right shunt by oximetry*

Level of shunt	Criteria for significant step-up: Mean of distal chamber samples − Mean of proximal chamber samples (O$_2$% sat)	(O$_2$ vol%)	Criteria for significant step-up: Highest value in distal chamber − Highest value in proximal chamber (O$_2$% sat)	(O$_2$ vol%)	Approximate minimal Q_p/Q_s required for detection (assuming SBFI = 3L/min/M^2)	Possible causes of step-up
Atrial (SVC/IVC to RA)	≥7	≥1.3	≥11	≥2.0	1.5–1.9	Atrial septal defect; partial anomalous pulmonary venous drainage; ruptured sinus of Valsalva; VSD with TR; coronary fistula to RA
Ventricular (RA to RV)	≥5	≥1.0	≥10	≥1.7	1.3–1.5	VSD; PDA with PR; primum ASD; coronary fistula to RV
Great Vessel (RV to PA)	≥5	≥1.0	≥5	≥1.0	≥1.3	PDA; aorta-pulmonic window; aberrant coronary artery origin
ANY LEVEL (SVC to PA)	≥7	≥1.3	≥8	≥1.5	≥1.5	All the above

Abbreviations: SVC and IVC, superior and inferior vena cavae; RA, right atrium; RV, right ventricle; PA, pulmonary artery; VSD, ventricular septal defect; TR, tricuspid regurgitation; PDA, patent ductus arteriosus; PR, pulmonic regurgitation; ASD, atrial septal defect, SBFI, systemic blood flow index; Q_p/Q_s, pulmonary to systemic flow ratio.

Grossman W. "Shunt detection and quantification" 6th ed. pp. 179-191. 2000.

Technique of Oximetry Run

- Two or more samples from each of at least 3 sites on both sides of the shunt location in rapid sequence (no more than 1-2 minutes for entire saturation run)
- Duplicate samples obtained and within 1-2% of each other
- Before withdrawing blood for a sample, the catheter must be cleared of flush and blood in the catheter
- The catheter should be well connected with the syringe so air bubbles cannot be introduced
- Samples should not be obtained from the side arm of a bleed-back tap or stop-cock valve because they have a chamber where contamination can occur
- Inspired oxygen concentration should be <30%

McLaughlin P et al. "The role of cardiac catheterization in adult congenital heart disease" Cardiol Clin. 2006;24:531.

Sites of Oximetry Run

1. Left and/or right pulmonary artery
2. Main pulmonary artery*
3. Right ventricle, outflow tract*
4. Right ventricle, mid†
5. Right ventricle, tricuspid valve or apex*,†
6. Right atrium, low or near tricuspid valve
7. Right atrium, mid
8. Right atrium, high
9. Superior vena cava, low (near junction with right atrium)
10. Superior vena cava, high (near junction with innominate vein)
11. Inferior vena cava, high (just at or below diaphragm)
12. Inferior vena cava, low (at L4–L5)
13. Left ventricle
14. Aorta (distal to insertion of ductus)

Grossman W. "Shunt detection and quantification" 6th ed. pp. 179-191. 2000.

Calculation of Systemic Blood Flow (Q_s)

Use the following equation for systemic blood flow:

$$\underset{(\text{L/min})}{Q_s} = \frac{O_2 \text{ consumption (mL/min)}}{\begin{bmatrix} \text{SA } O_2 \\ \text{content} \\ \text{(mL/L)} \end{bmatrix} - \begin{bmatrix} \text{MV } O_2 \\ \text{content} \\ \text{(mL/L)} \end{bmatrix}} \quad (9.2)$$

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TABLE 9.2. *Calculation of systemic blood flow in the presence of left-to-right shunt*

Location of shunt as determined by site of O_2 step-up	Mixed venous sample to use in calculating systemic blood flow
1. Pulmonary artery (e.g., patent ductus arteriosus)	Right ventricle, average of samples obtained during oximetry run
2. Right ventricle (e.g., ventricular septal defect)	Right atrium, average of all samples during oximetry run
3. Right atrium (e.g., atrial septal defect)	$\frac{3(\text{SVC } O_2 \text{ content}) + 1(\text{IVC } O_2 \text{ content})}{4}$

Grossman W. “Shunt detection and quantification” 6th ed. pp. 179-191. 2000.

The Flamm Formula

- "Measurement of Systemic Cardiac Output at Rest and Exercise in Patients with Atrial Septal Defect"
- 28 patients without shunts (2 normal and 26 aortic or mitral disease – rest data in 18, exercise in 19)
- IVC sat was higher than SVC in 14/18 patients
- PA sat was closer to SVC than IVC
- During supine leg exercise, IVC sat was lower than SVC in every case, with 15/19 patients having >10% difference
- 0.71*SVC + 0.29*IVC = MVB

Flamm MD et al. Am J Cardiol. 1969;23:258.

Regional Flow

- “Measurement of Systemic Cardiac Output at Rest and Exercise in Patients with Atrial Septal Defect”
- 28 patients without shunts (2 normal and 26 aortic or mitral disease – rest data in 18, exercise in 19)
- SVC flow is about 35%, IVC flow is about 60% and CS flow is about 5% of right heart flow

Flamm MD et al. Am J Cardiol. 1969;23:258.

Calculation of Pulmonary Blood Flow (Q_p)

Pulmonary blood flow is calculated by the same formula used in the standard Fick equation:

$$\underset{(\text{L/min})}{Q_p} = \frac{O_2 \text{ consumption (mL/min)}}{\begin{bmatrix} \text{PV } O_2 \\ \text{content} \\ (\text{mL/L}) \end{bmatrix} - \begin{bmatrix} \text{PA } O_2 \\ \text{content} \\ (\text{mL/L}) \end{bmatrix}} \tag{9.1}$$

Grossman W. "Shunt detection and quantification" 6th ed. pp. 179-191. 2000.

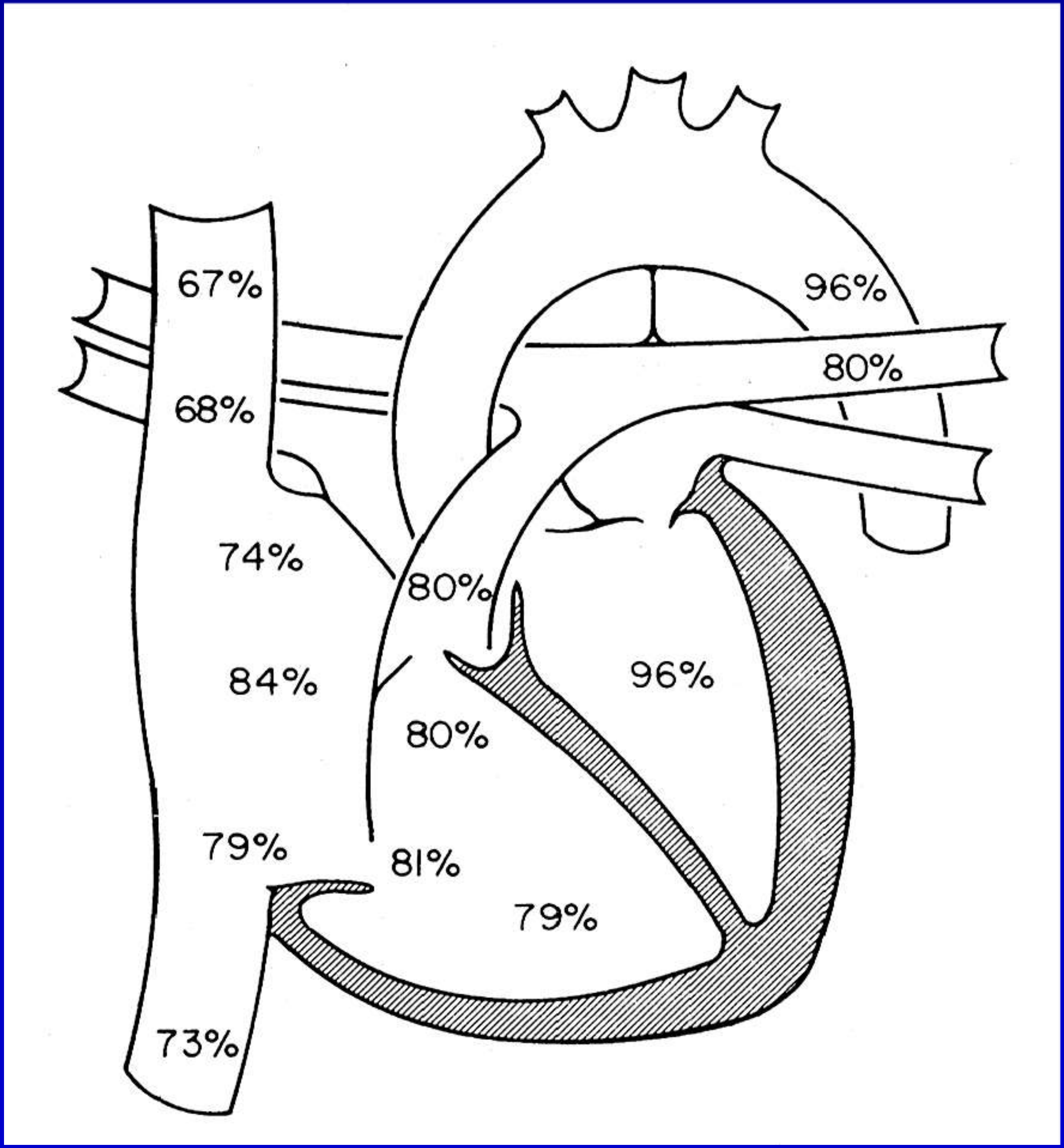
Calculation of Left-to-Right Shunt

If there is no evidence of an associated right-to-left shunt, the left-to-right shunt is calculated by

$$\text{L} \rightarrow \text{R Shunt} = Q_\text{p} - Q_\text{s} \quad (9.3)$$
$$\text{(L/min)}$$

Grossman W. "Shunt detection and quantification" 6th ed. pp. 179-191. 2000.

Example 1



Grossman W. “Shunt detection and quantification” 6th ed. pp. 179-191. 2000.

$$Q_p = \frac{O_2 \text{ consumption (mL/min)}}{\begin{bmatrix}\text{PV } O_2\\ \text{content}\\ \text{(mL/L)}\end{bmatrix} - \begin{bmatrix}\text{PA } O_2\\ \text{content}\\ \text{(mL/L)}\end{bmatrix}} \qquad (9.4)$$

PV O_2 content was not measured, but left ventricular (LV) and arterial blood O_2 saturation was 96% (effectively ruling out a right-to-left shunt), and therefore it may be assumed that PV blood O_2 saturation was 96%. As described in Chapter 8, oxygen content for PV blood is calculated as follows:

$$0.96\left(\frac{14 \text{ g Hgb}}{100 \text{ mL blood}}\right) \times \left(\frac{1.36 \text{ mL } O_2}{\text{g Hgb}}\right)$$

$$= 18.3 \text{ mL } O_2/100 \text{ mL blood} \qquad (9.5)$$

$$= 183 \text{ mL } O_2/\text{liter}$$

Grossman W. “Shunt detection and quantification” 6th ed. pp. 179-191. 2000.

Similarly, PA O_2 content is calculated as

$$0.80(14)1.36 \times 10 = 152 \text{ ml } O_2/\text{liter} \tag{9.6}$$

Therefore;

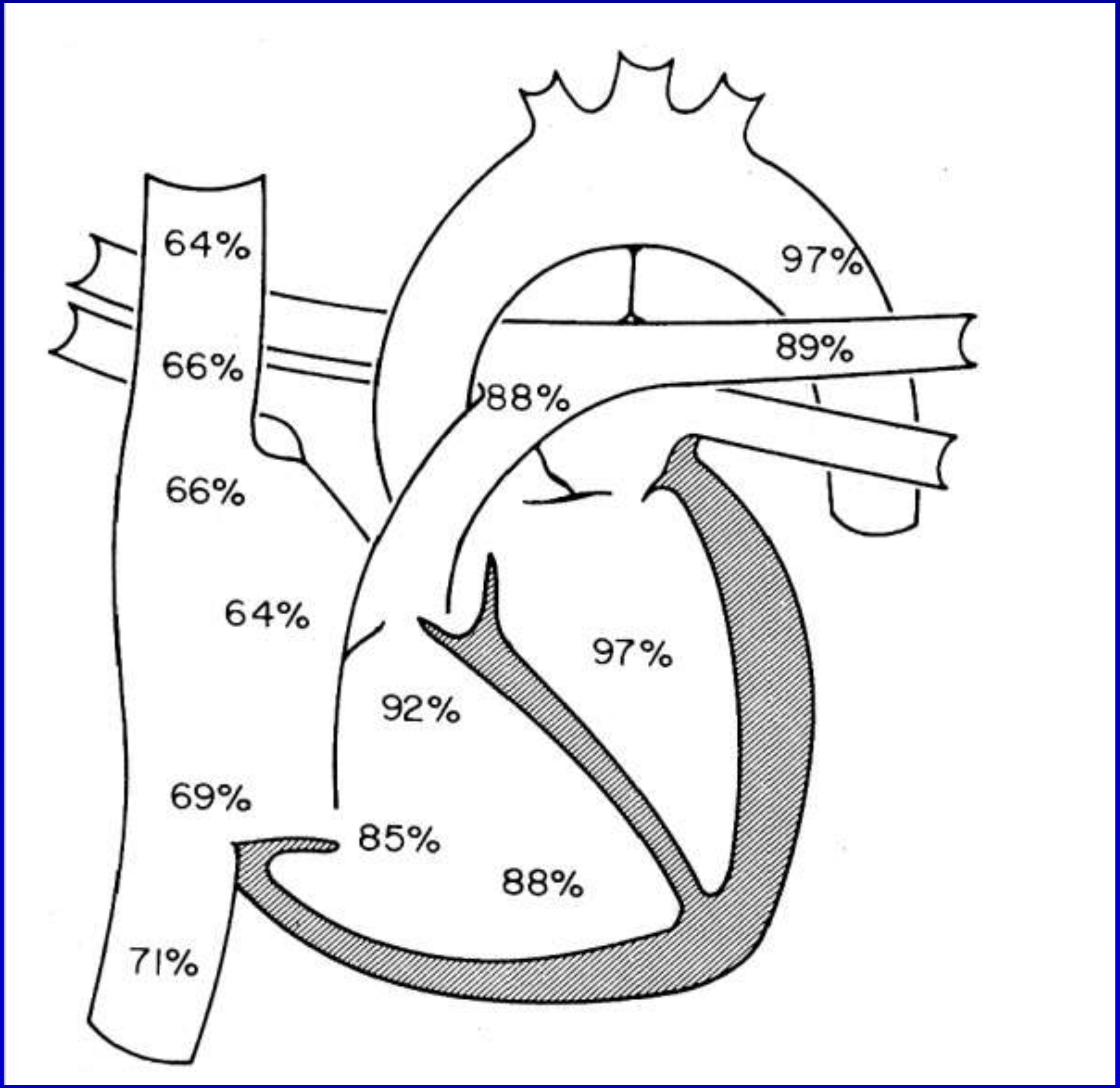
$$Q_p = \frac{240 \text{ mL } O_2/\text{min}}{[183 - 152] \text{ mL } O_2/\text{L}} = 7.74 \text{ L/min} \tag{9.7}$$

Systemic blood flow for the patient in Fig. 9.1 is calculated as

$$Q_s = \frac{240 \text{ mL } O_2/\text{min}}{\begin{bmatrix}\text{systemic}\\ \text{arterial}\\ O_2 \text{ content}\end{bmatrix} - \begin{bmatrix}\text{mixed}\\ \text{venous}\\ O_2 \text{ content}\end{bmatrix}} = \frac{240}{(0.96 - 0.69)14(1.36)10} = 4.6 \text{ L/min} \tag{9.8}$$

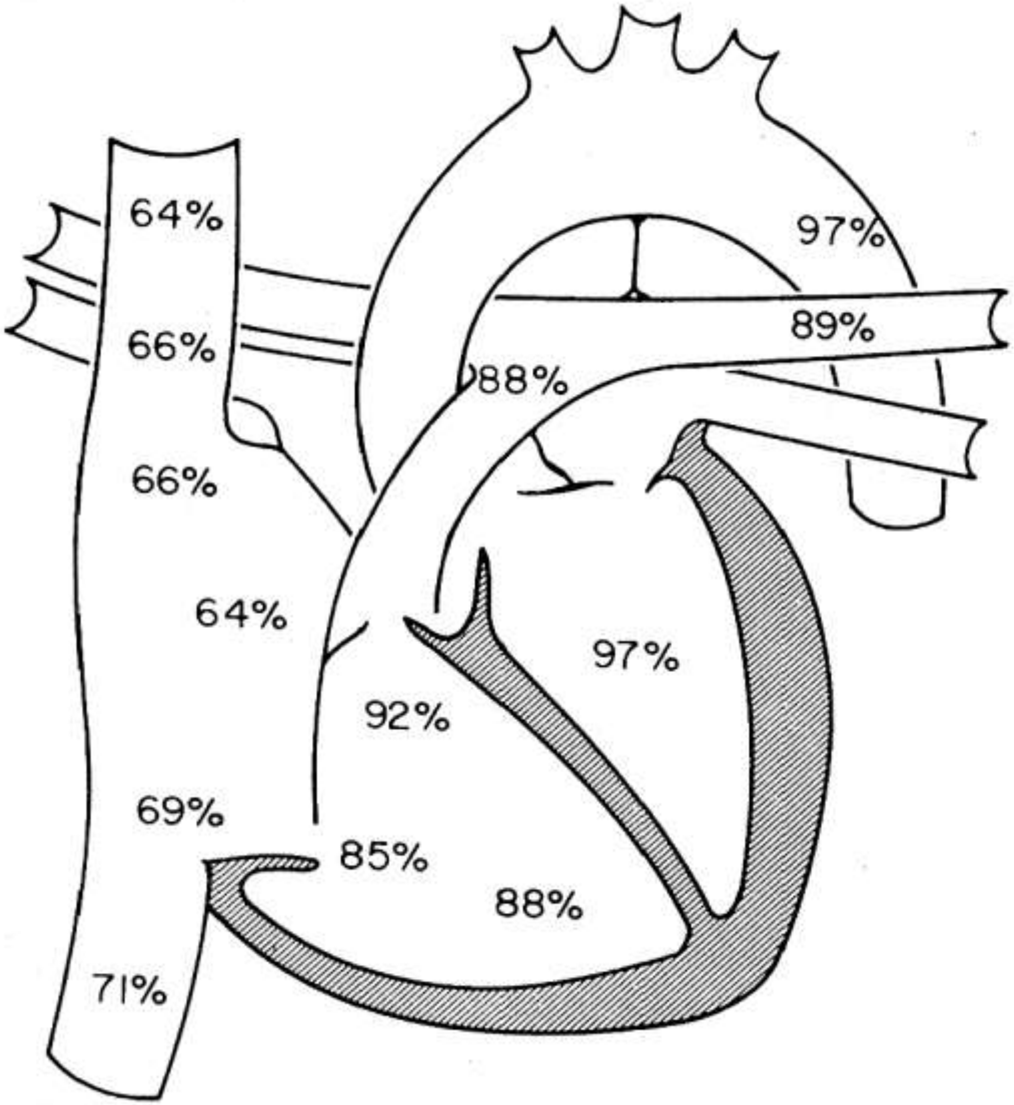
For this calculation, mixed venous O_2 saturation was derived from the formula given in Table 9.2, as 69%. Thus the ratio of Q_p/Q_s in this example is $7.74/4.6 = 1.68$, and the magnitude of the left-to-right shunt is $7.7 - 4.7 = 3$ L/min. This patient has a small-to-moderate-sized atrial septal defect.

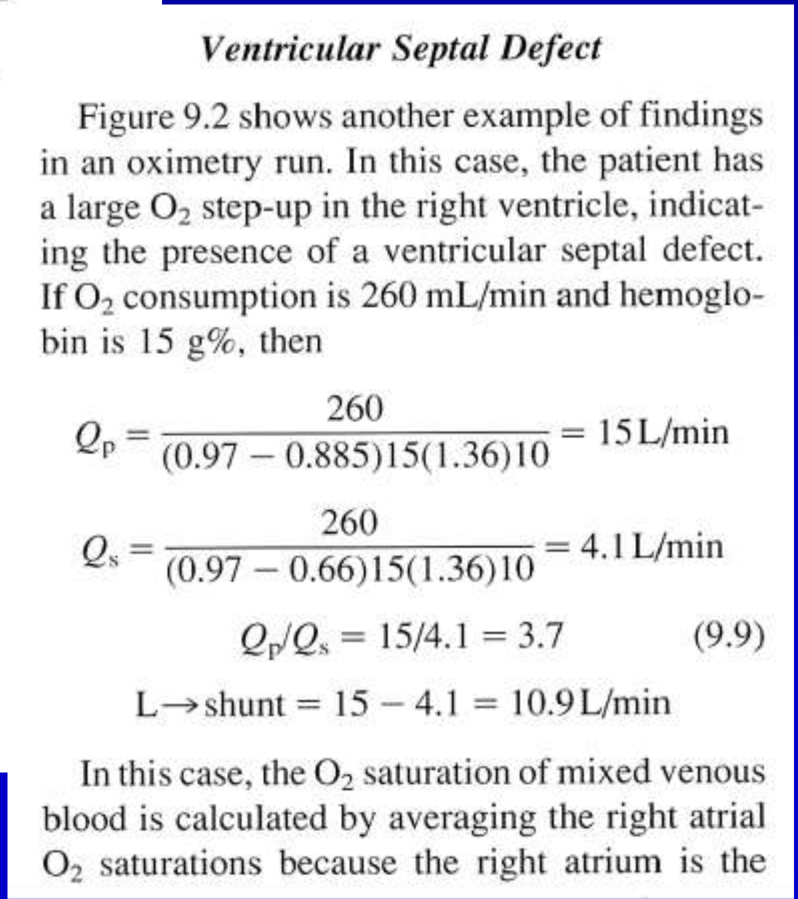
Grossman W. "Shunt detection and quantification" 6th ed. pp. 179-191. 2000.



Example 2

Grossman W. "Shunt detection and quantification" 6th ed. pp. 179-191. 2000.





Ventricular Septal Defect

Figure 9.2 shows another example of findings in an oximetry run. In this case, the patient has a large O_2 step-up in the right ventricle, indicating the presence of a ventricular septal defect. If O_2 consumption is 260 mL/min and hemoglobin is 15 g%, then

$$Q_p = \frac{260}{(0.97 - 0.885)15(1.36)10} = 15\,\text{L/min}$$

$$Q_s = \frac{260}{(0.97 - 0.66)15(1.36)10} = 4.1\,\text{L/min}$$

$$Q_p/Q_s = 15/4.1 = 3.7 \qquad (9.9)$$

$$\text{L} \rightarrow \text{shunt} = 15 - 4.1 = 10.9\,\text{L/min}$$

In this case, the O_2 saturation of mixed venous blood is calculated by averaging the right atrial O_2 saturations because the right atrium is the

Grossman W. “Shunt detection and quantification” 6th ed. pp. 179-191. 2000.

A *simplified formula* for calculation of flow ratio can be derived by combining the equations for systemic and pulmonary blood flow to obtain

$$\frac{Q_p}{Q_s} = \frac{(\text{SA } O_2 - \text{MV } O_2)}{(\text{PV } O_2 - \text{PA } O_2)} \qquad (9.10)$$

where SA O_2, MV O_2, PV O_2, and PA O_2 are systemic arterial, mixed venous, pulmonary venous, and pulmonary arterial blood oxygen saturations, respectively. For the patient illustrated in Fig. 9.1, $Q_p/Q_s = (96\% - 69\%)/(96\% - 80\%) = 1.68$.

Grossman W. "Shunt detection and quantification" 6th ed. pp. 179-191. 2000.

Calculation of Bidirectional Shunts

If there is evidence of a right-to-left shunt, as well as a left-to-right shunt, the formulas in Eq. (9.11) are used (6).

This formula for calculation of bidirectional shunts tends to be too complex for easy use during the procedure. A quick approximation can be obtained by using a hypothetic quantity known as the effective blood flow, the flow that would exist in the absence of any left-to-right or right-to-left shunting:

$$Q_{\text{eff}} = \frac{\text{O}_2 \text{ consumption (mL/min)}}{\begin{bmatrix}\text{PV O}_2\\ \text{content}\\ \text{(mL/L)}\end{bmatrix} - \begin{bmatrix}\text{MV O}_2\\ \text{content}\\ \text{(mL/L)}\end{bmatrix}} \tag{9.12}$$

$$\text{L} \rightarrow \text{R} = \frac{Q_\text{p}\,(\text{MV O}_2 \text{ content} - \text{PA O}_2 \text{ content})}{(\text{MV O}_2 \text{ content} - \text{PV* O}_2 \text{ content})} \tag{9.11}$$

$$\text{R} \rightarrow \text{L} = \frac{Q_\text{p}\,(\text{PV* O}_2 \text{ content} - \text{SA O}_2 \text{ content})(\text{PA O}_2 \text{ content} - \text{PV* O}_2 \text{ content})}{(\text{SA O}_2 \text{ content} - \text{MV O}_2 \text{ content}) \times (\text{MV O}_2 \text{ content} - \text{PV* O}_2 \text{ content})}$$

* If pulmonary vein is not entered, use 98% × O_2 capacity.

Grossman W. "Shunt detection and quantification" 6th ed. pp. 179-191. 2000.

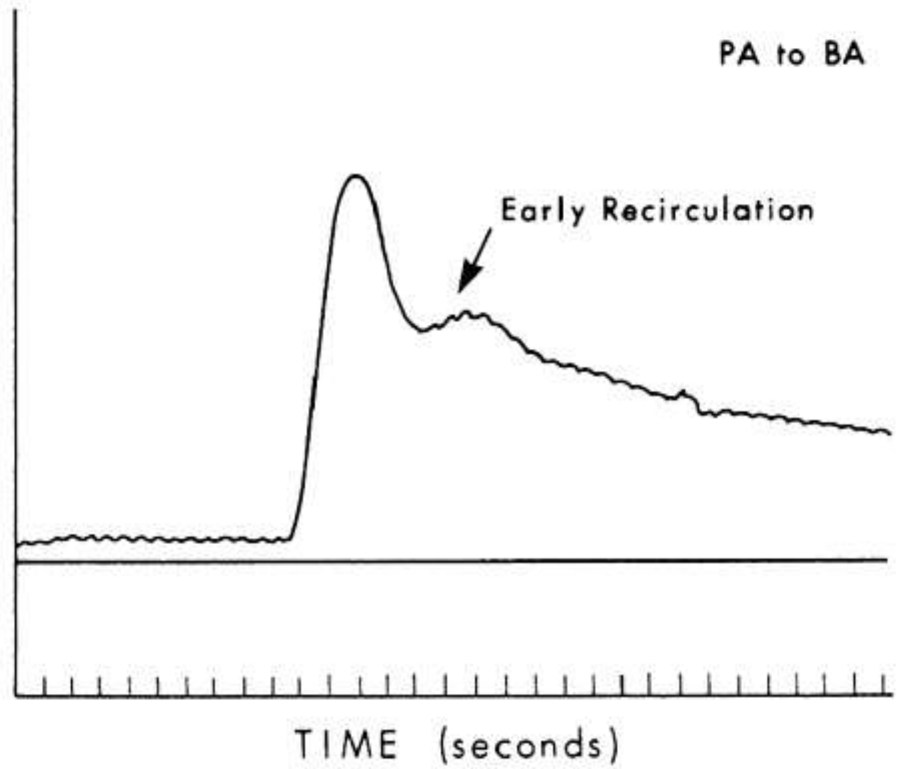


FIG. 9.3. Left-to-right shunt. This indicator dilution curve, performed by injecting indocyanine green into the pulmonary artery with sampling in the brachial artery, demonstrates early recirculation on the downslope, indicating a left-to-right shunt. Injection was at time zero. This technique does not localize the site of the left-to-right shunt.

Grossman W. "Shunt detection and quantification" 6th ed. pp. 179-191. 2000.

TABLE 9.3. *Expected value of O_2 content (volumes percent) for various levels of O_2 step-up and blood hemoglobin concentration**

Increase in O_2 saturation	Hemoglobin Concentration (g/100 mL) 10	12	15
5%	0.68 vol%	0.82 vol%	1.02 vol%
10%	1.36 vol%	1.63 vol%	2.04 vol%
15%	2.04 vol%	2.45 vol%	3.06 vol%
20%	2.72 vol%	3.26 vol%	4.08 vol%

* Modified from Antman EM, Marsh JD, Green LH, Grossman W. Blood oxygen measurements in the assessment of intracardiac left to right shunts: a critical appraisal of methodology. *Am J Cardiol* 1980;46:265, with permission.

Grossman W. "Shunt detection and quantification" 6th ed. pp. 179-191. 2000.

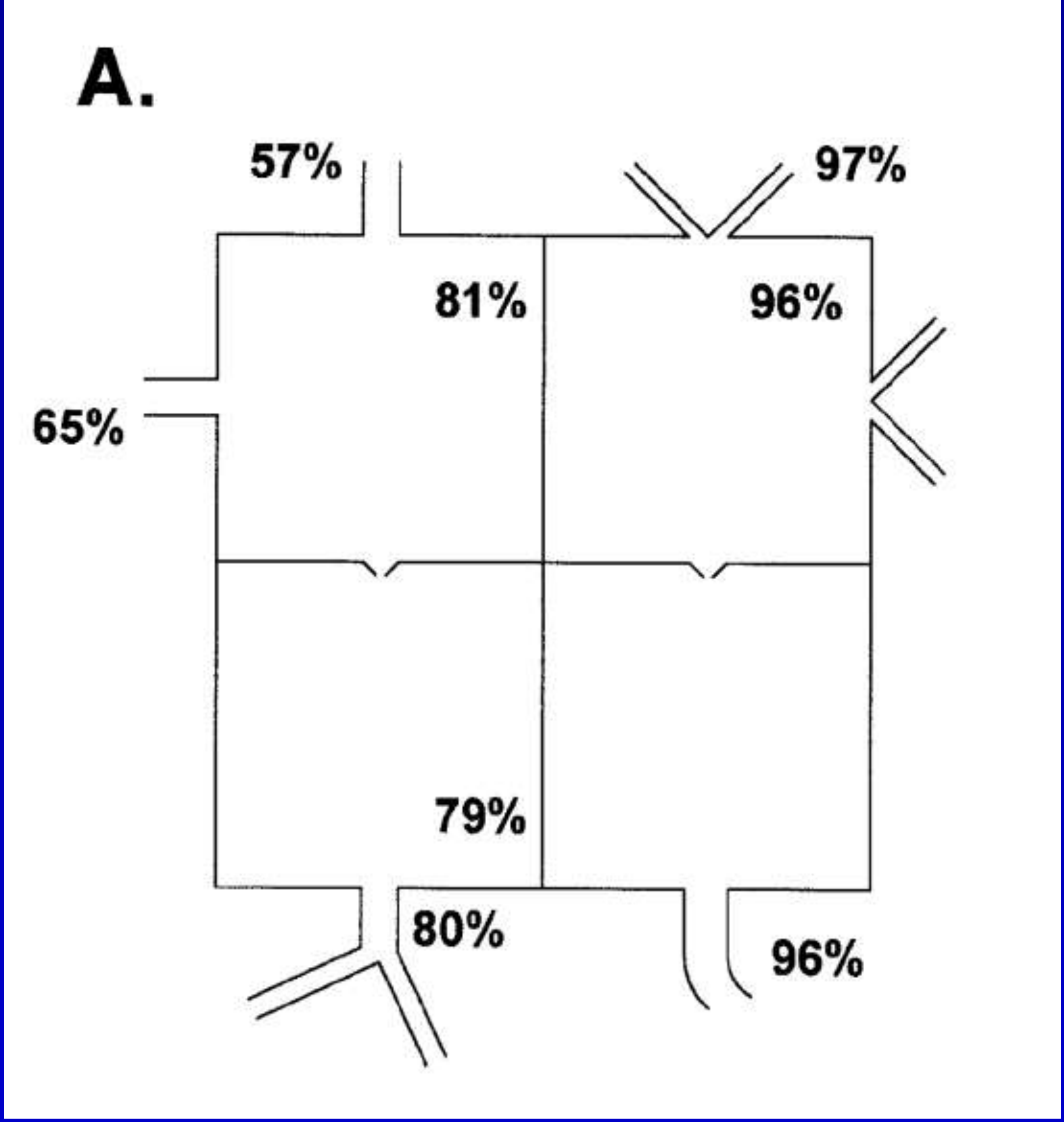
TABLE 9.4. *Guidelines for optimum utilization of oximetric method for shunt detection and quantification**

1. Blood samples at multiple sites should be obtained rapidly.
2. Blood O_2 saturation data rather than O_2 content data are preferable to identify the presence and location of a shunt.
3. Comparison of the mean of all values obtained in the respective chambers is preferable to comparison of highest values in each chamber.
4. Because of the important influence of systemic blood flow on shunt detection, exercise should be used in equivocal cases where a low systemic blood flow is present at rest.

* Based on the data of Antman EM, Marsh JD, Green LH, Grossman W. Blood oxygen measurements in the assessment of intracardiac left to right shunts: a critical appraisal of methodology. *Am J Cardiol* 1980;46:265.

Grossman W. "Shunt detection and quantification" 6th ed. pp. 179-191. 2000.

Example 3



Fox JM et al. Cathet Cardiovasc Intervent. 2003;58:219.

Example 3

B.

Hgb = 14.1

O_2 Consumption = 224.6

From Flamm equation -

$$MVO_2 = \frac{3SVC + IVC}{4} = 0.59$$

$$Art\ O_2 = 0.96 \times 1.36 \times 14.1 \times 10 = 184$$

$$MVO_2 = 0.59 \times 1.36 \times 14.1 \times 10 = 113$$

$$PAO_2 = 0.80 \times 1.36 \times 14.1 \times 10 = 153$$

$$PVO_2 = 0.97 \times 1.36 \times 14.1 \times 10 = 186$$

$$QS = \frac{224.6}{\underset{=71}{(184 - 113)}} = 3.16 \qquad QP = \frac{224.6}{\underset{=31}{(186 - 153)}} = 7.25$$

QP/QS = 2.29/1

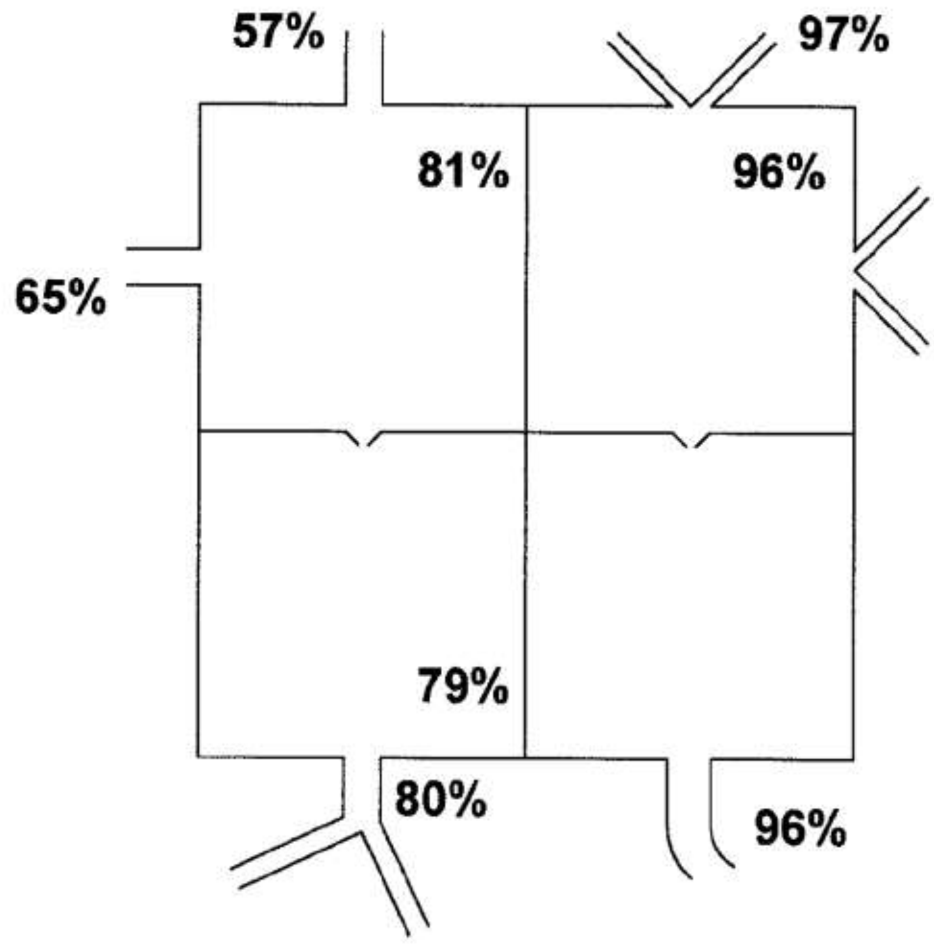
or Simplified with Sats

QP = Art Sat - MV Sat (96 - 59) = 37

QS = PV Sat - PA Sat (97 - 80) = 17

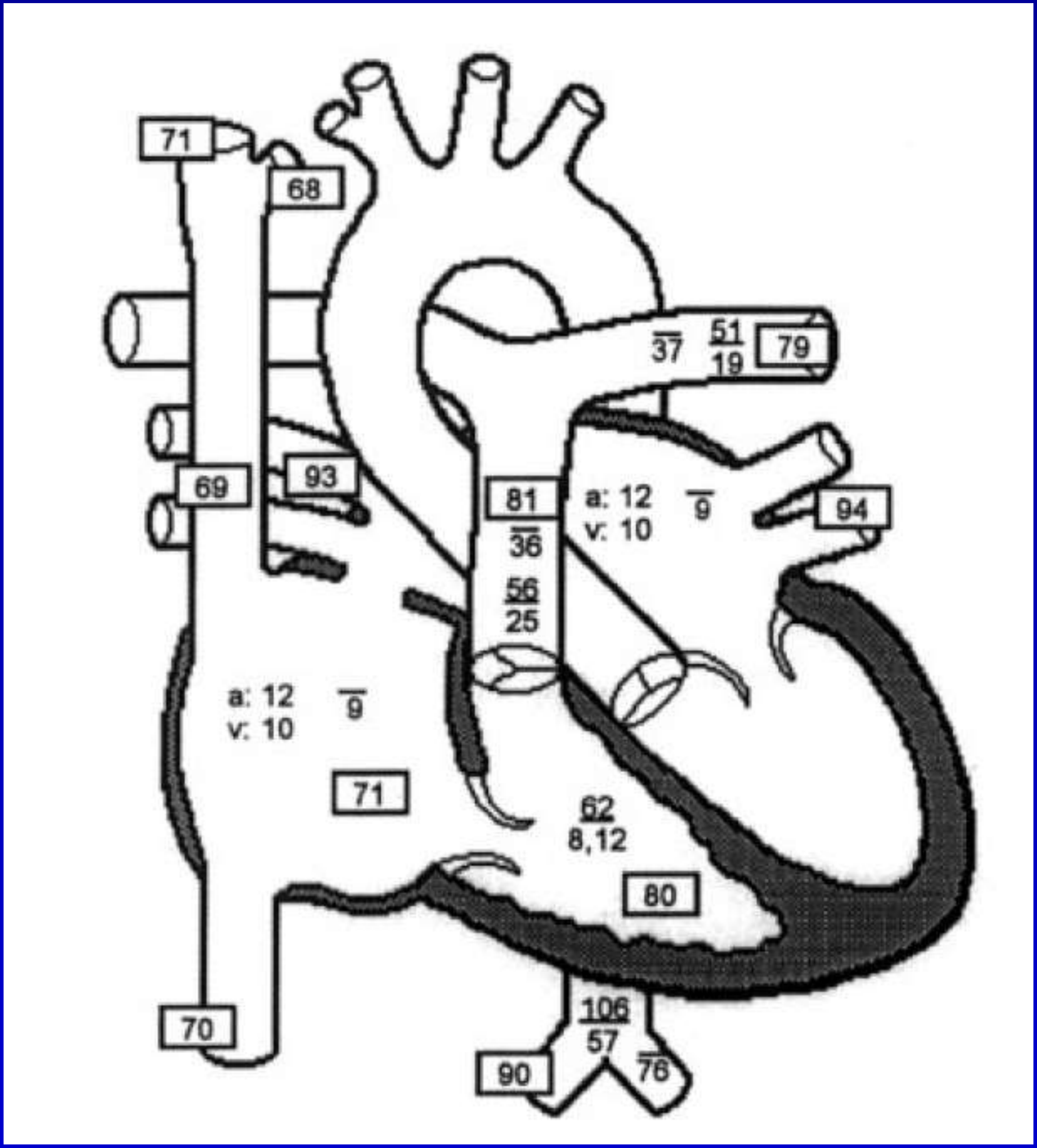
= 2.17/1

A.



Fox JM et al. Cathet Cardiovasc Intervent. 2003;58:219.

Example 4



Fox JM et al. Cathet Cardiovasc Intervent. 2003;58:219.

Example 4

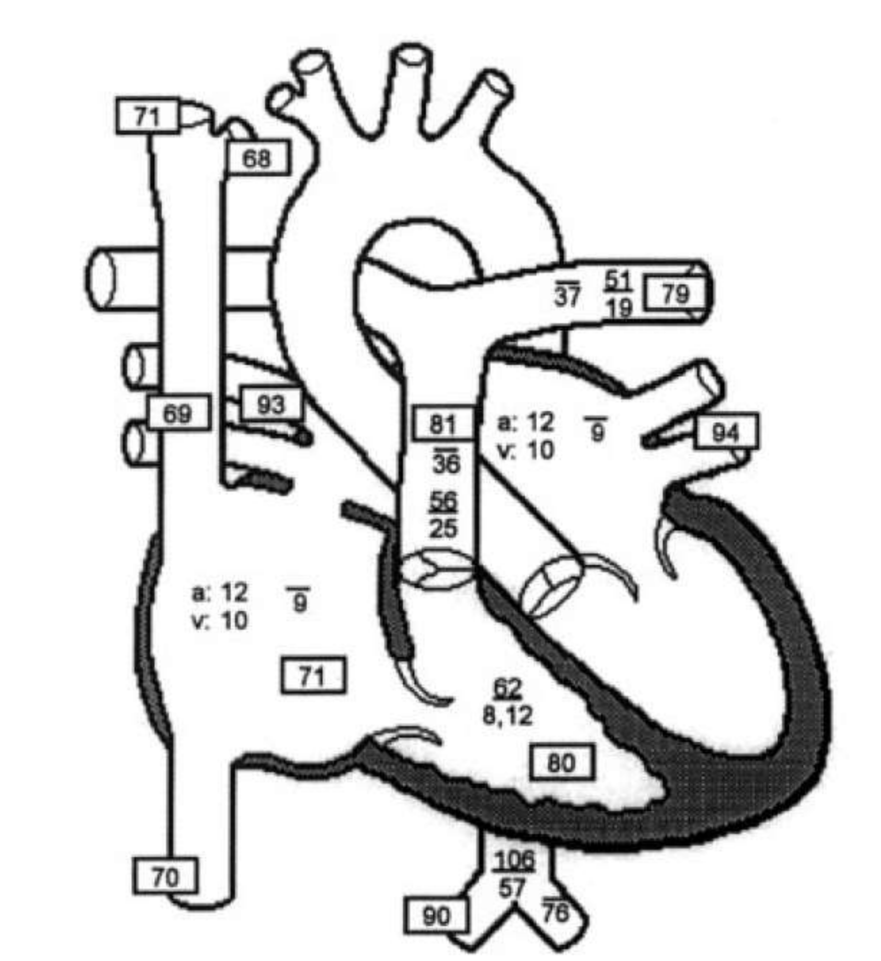
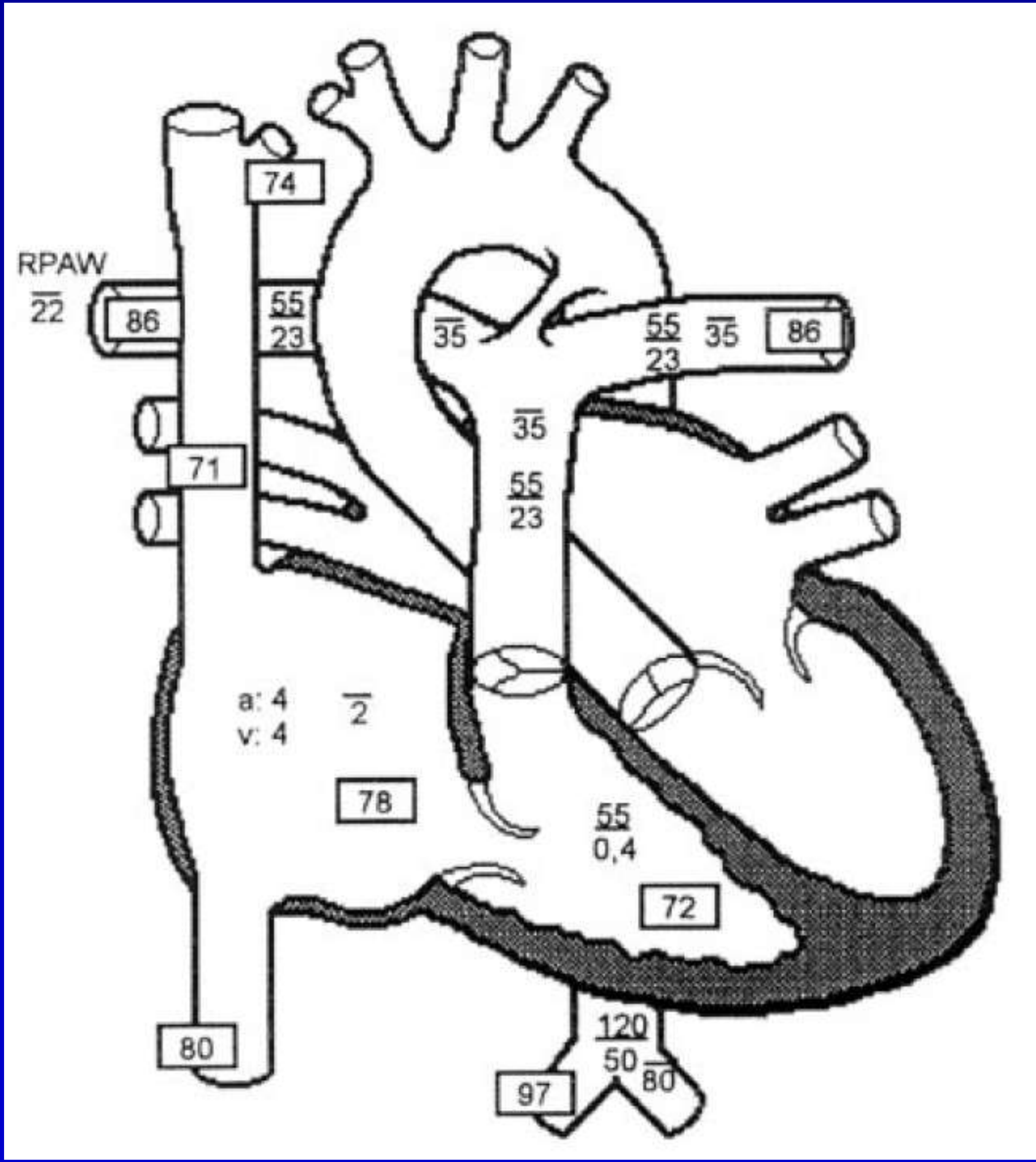


Fig. 2. Diagram of catheterization data obtained from a 44-year-old woman with a secundum ASD. Pressure data listed as fractions and means; saturation data listed in boxes. Note the step-up in oxygen saturation from the superior vena cava of 69% to the main pulmonary artery of 81%, indicating left-to-right shunt at the atrial level. The oxygen saturation of pulmonary veins decreased from 94% to 90% in the femoral artery, indicating right-to-left shunt, also at the atrial level. Using an oxygen consumption of 114 ml/min/m^2 and an Hg level of 12.6 gm/dl, hemodynamic calculations were performed with the patient breathing 23% and 100% inspired O_2 as shown in the accompanying table. Qp, pulmonary blood flow; Qs, systemic blood flow; PVR, pulmonary vascular resistance; SVR, systemic vascular resistance. The significant decrease in the elevated PVR and Rp/Rs to near normal values, while breathing 100% O_2, suggests surgical repair is still an option.

Fox JM et al. Cathet Cardiovasc Intervent. 2003;58:219.

Example 5



Fox JM et al. Cathet Cardiovasc Intervent. 2003;58:219.

Example 5

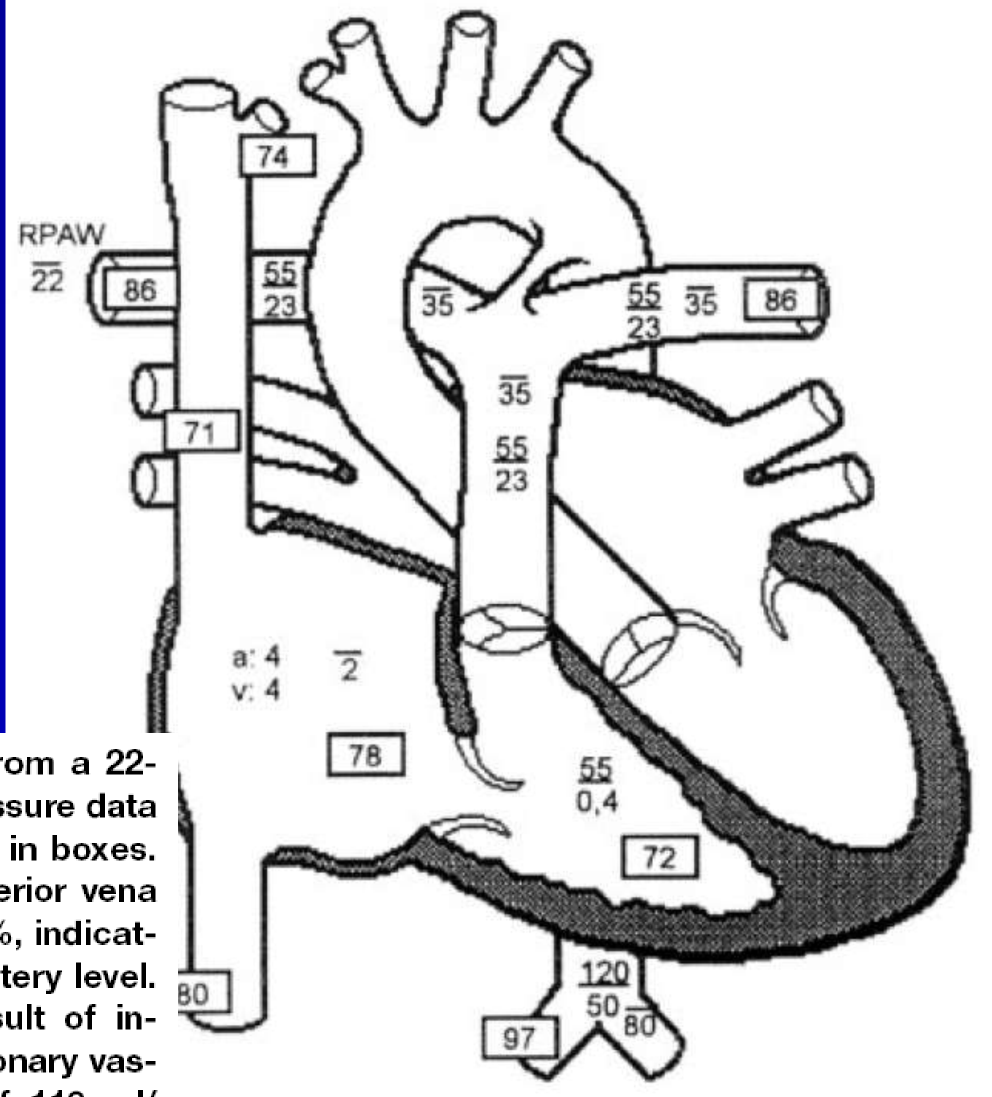
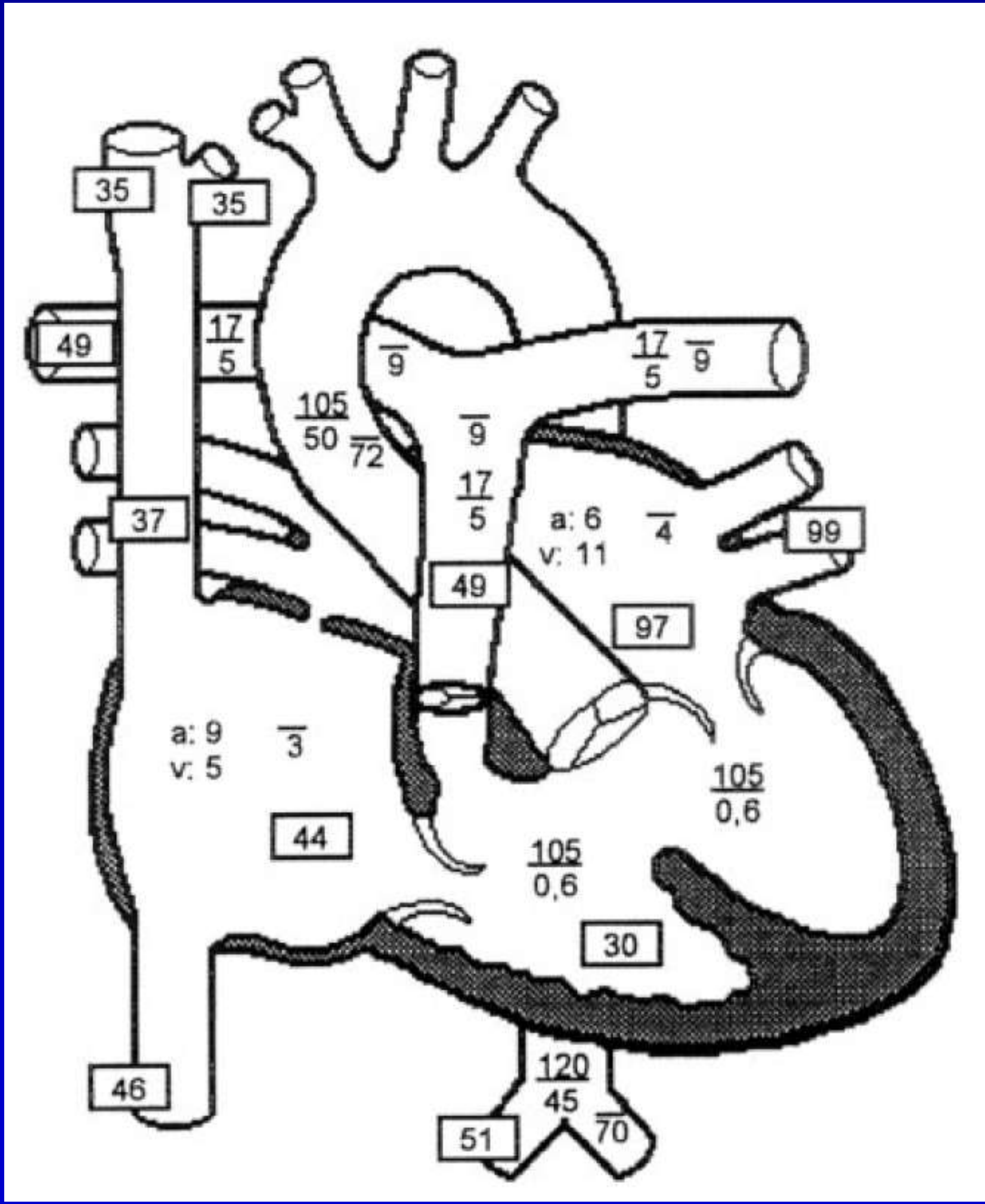


Fig. 3. Diagram of catheterization data obtained from a 22-year-old woman with a patent ductus arteriosus. Pressure data listed as fractions and means; saturation data listed in boxes. Note the step-up in oxygen saturation from the superior vena cava of 71% to the branch pulmonary arteries of 86%, indicating significant left-to-right shunt at the pulmonary artery level. The elevated pulmonary artery pressure is the result of increased pulmonary blood flow, not elevation in pulmonary vascular resistance. Using an oxygen consumption of 118 ml/min/m^2 and a hemoglobin level of 13.1 gm/dl, the Qp = 6.0, Qs = 2.5, Qp/Qs = 2.4, and the pulmonary vascular resistance = 2.2. The patent ductus arteriosus was coil-occluded successfully during the same catheterization.

Fox JM et al. Cathet Cardiovasc Intervent. 2003;58:219.

Example 6



Fox JM et al. Cathet Cardiovasc Intervent. 2003;58:219.

Example 6

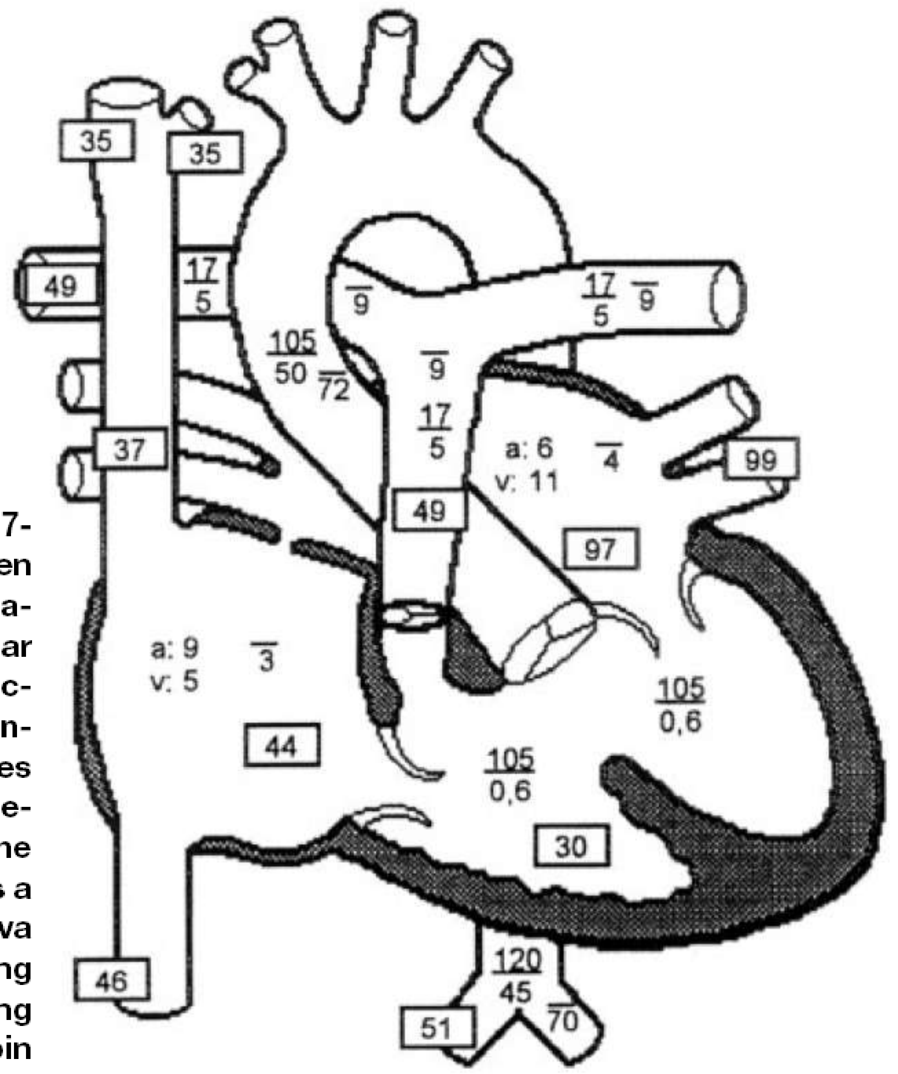
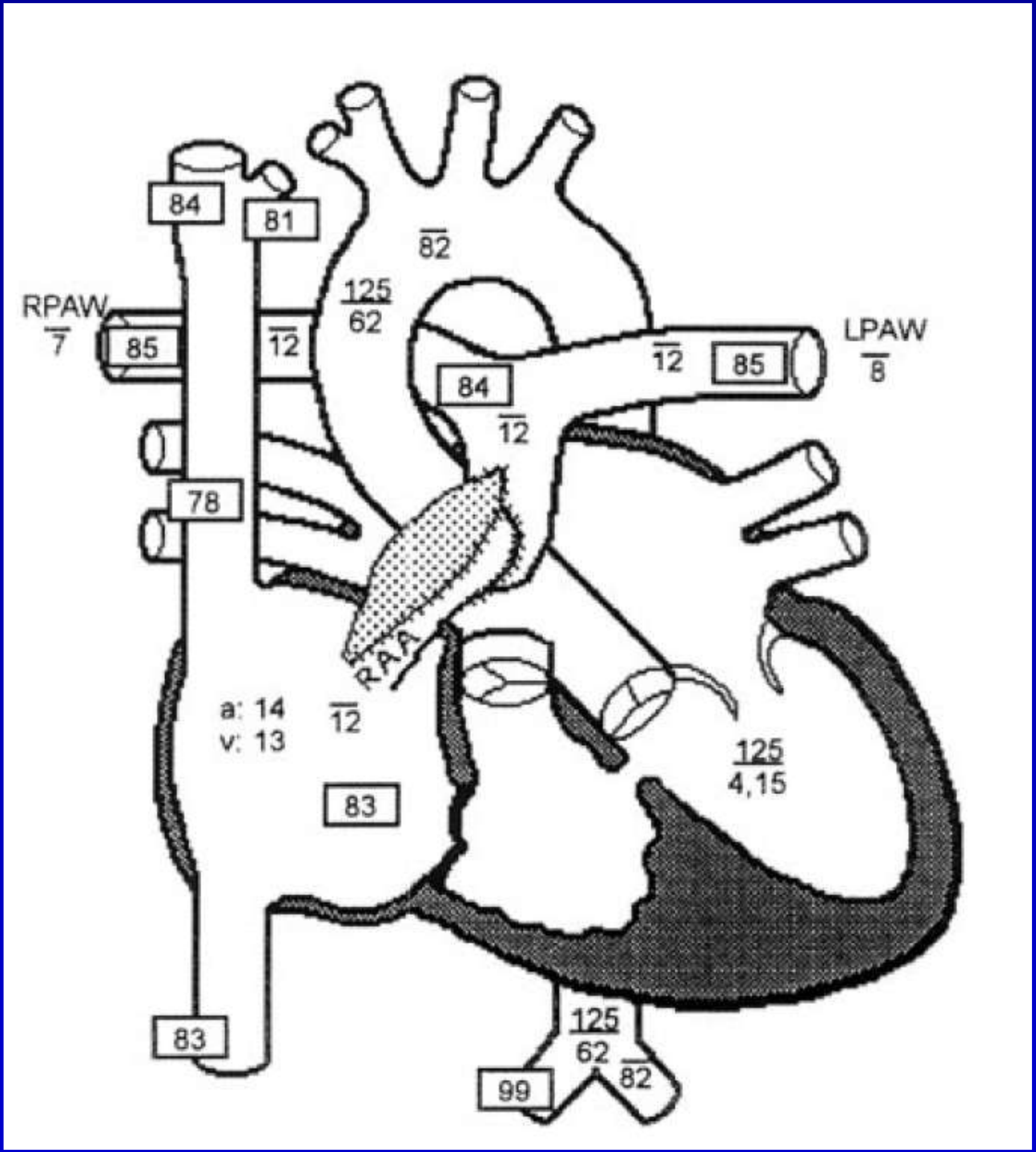


Fig. 7. Diagram of catheterization data obtained from a 57-year-old woman with tetralogy of Fallot and a patent foramen ovale. Pressure data are listed as fractions and means; saturation data are listed in boxes. The right and left ventricular systolic pressures are equal, indicating a nonrestrictive ventricular septal defect. The severe obstruction across the right ventricular outflow tract limits pulmonary blood flow and produces significant right-to-left shunt through the ventricular septal defect. This is indicated by the decrease in saturation from the pulmonary veins of 99% to 51% in the femoral artery. There is a slight step-up in oxygen saturation from the superior vena cava of 37% to the branch pulmonary arteries of 49%, indicating minimal left-to-right shunt, again at the ventricular level. Using an oxygen consumption of 118 ml/min/m^2 and a hemoglobin level of 13.5 gm/dl, the Qp = 1.3, Qs = 4.6, Qp/Qs = 0.3, the left-to-right shunt = 0.3, and the right-to-left shunt = 3.6. The pulmonary vascular resistance = 4.6. The patient underwent palliative systemic-to-pulmonary artery shunt placement to increase systemic oxygen saturation.

Fox JM et al. Cathet Cardiovasc Intervent. 2003;58:219.

Example 7



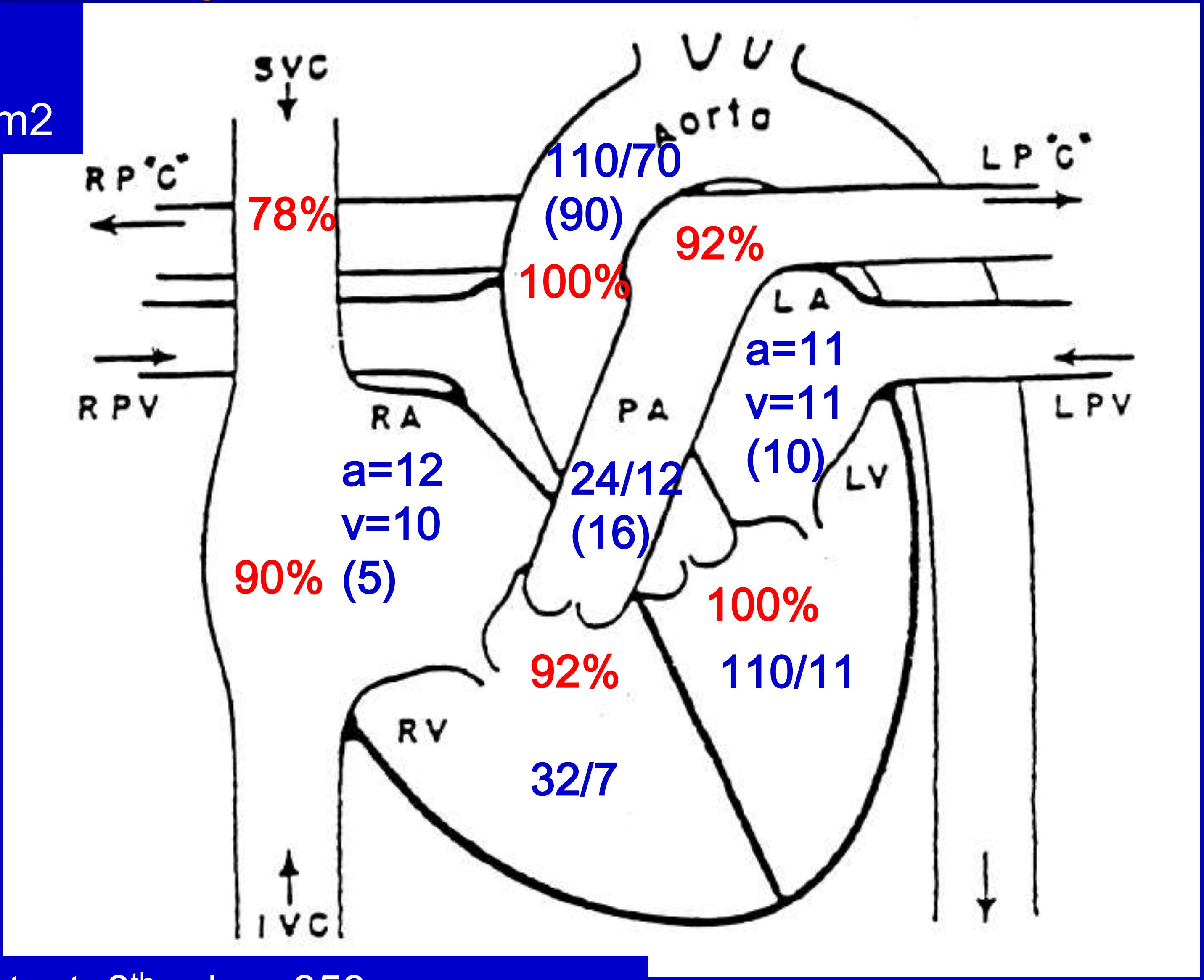
Fox JM et al. Cathet Cardiovasc Intervent. 2003;58:219.

What is the diagnosis?

O_2 Consumption - 190 ml/min/m^2
O_2 Capacity - 162 ml/L (Hb 11.9)

6 yo girl

BSA 1.44 m2



Grossman text, 6th ed, p. 853

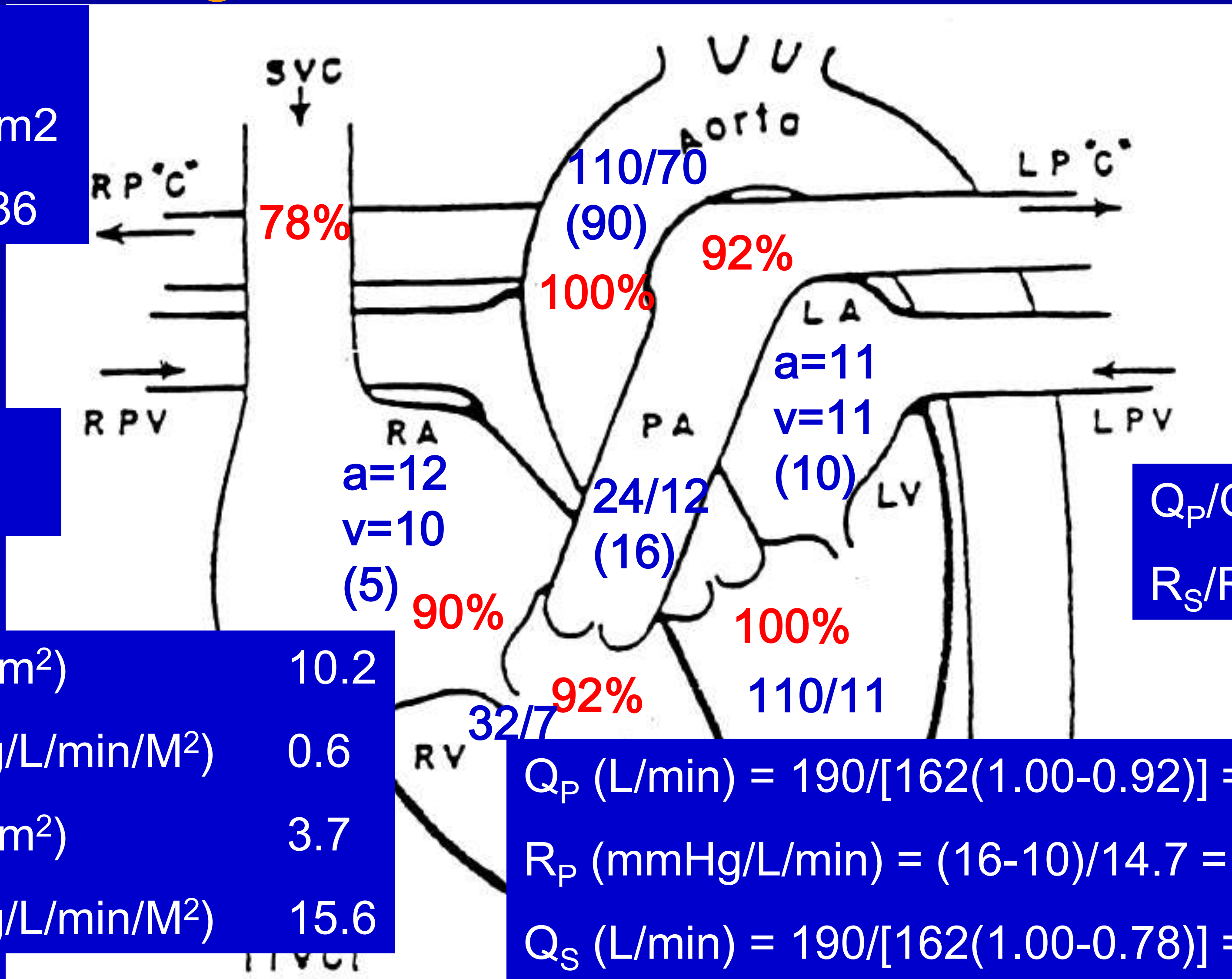
What is the diagnosis?

O_2 Consumption - 190 ml/min/m^2
O_2 Capacity - 162 ml/L (Hb 11.9)

6 yo girl

BSA 1.44 m2

O2 cap 1.36



Text answer:

$Q_P/Q_S = 2.76$

$R_S/R_P = 38.9$

Q_P (L/min/m^2)	10.2
R_P (mmHg/L/min/M^2)	0.6
Q_S (L/min/m^2)	3.7
R_S (mmHg/L/min/M^2)	15.6

Q_P (L/min) = 190/[162(1.00-0.92)] = 14.7

R_P (mmHg/L/min) = (16-10)/14.7 = 0.41

Q_S (L/min) = 190/[162(1.00-0.78)] = 5.33

R_S (mmHg/L/min) = (90-5)/5.33 = 15.95

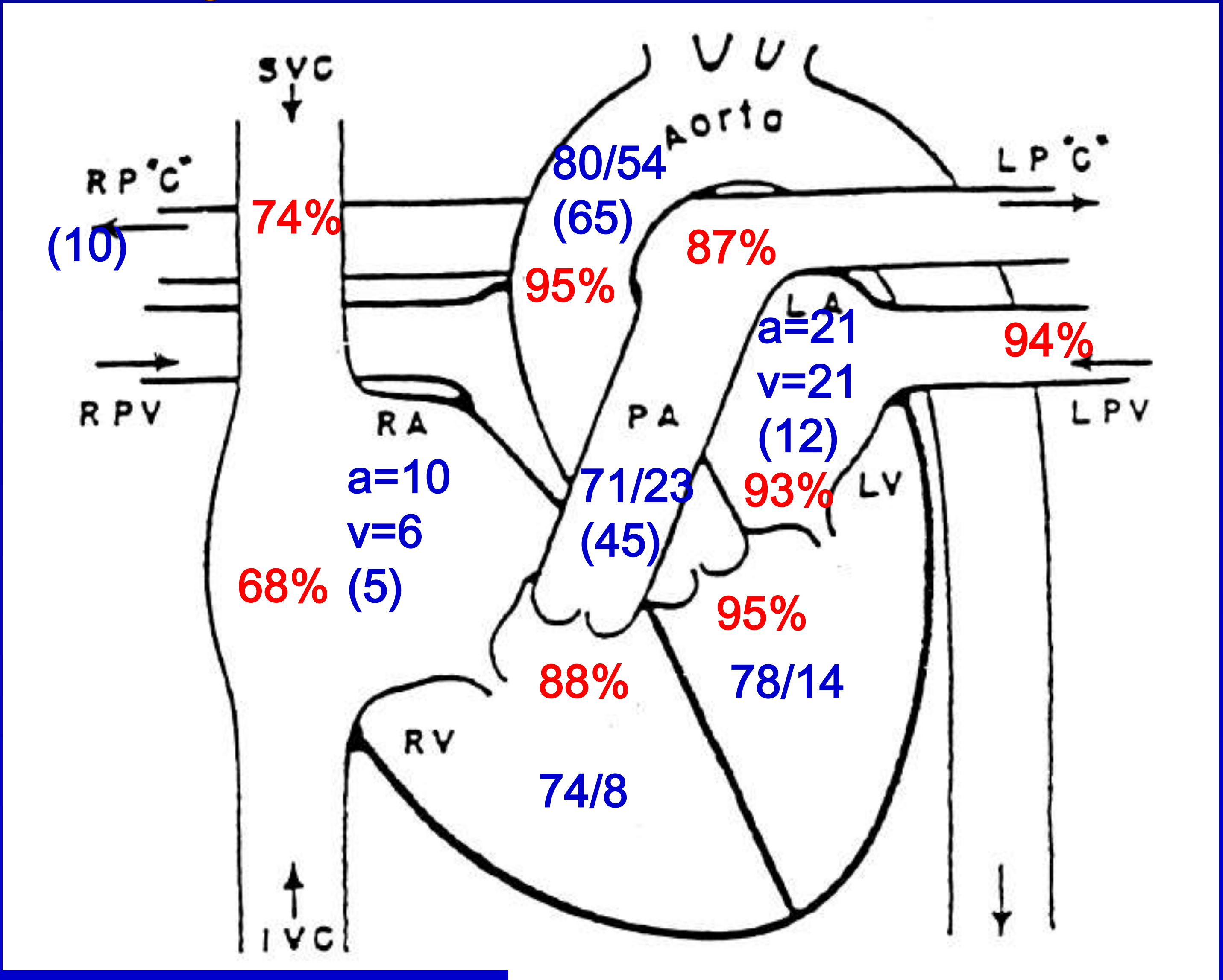
Grossman text, 6th ed, p. 853

Indexing

- Cardiac index = C.O./BSA
- Resistance index ≠ (Delta P/ C.O.)/BSA
- Resistance index = Delta P/ C.I.

What is the diagnosis?

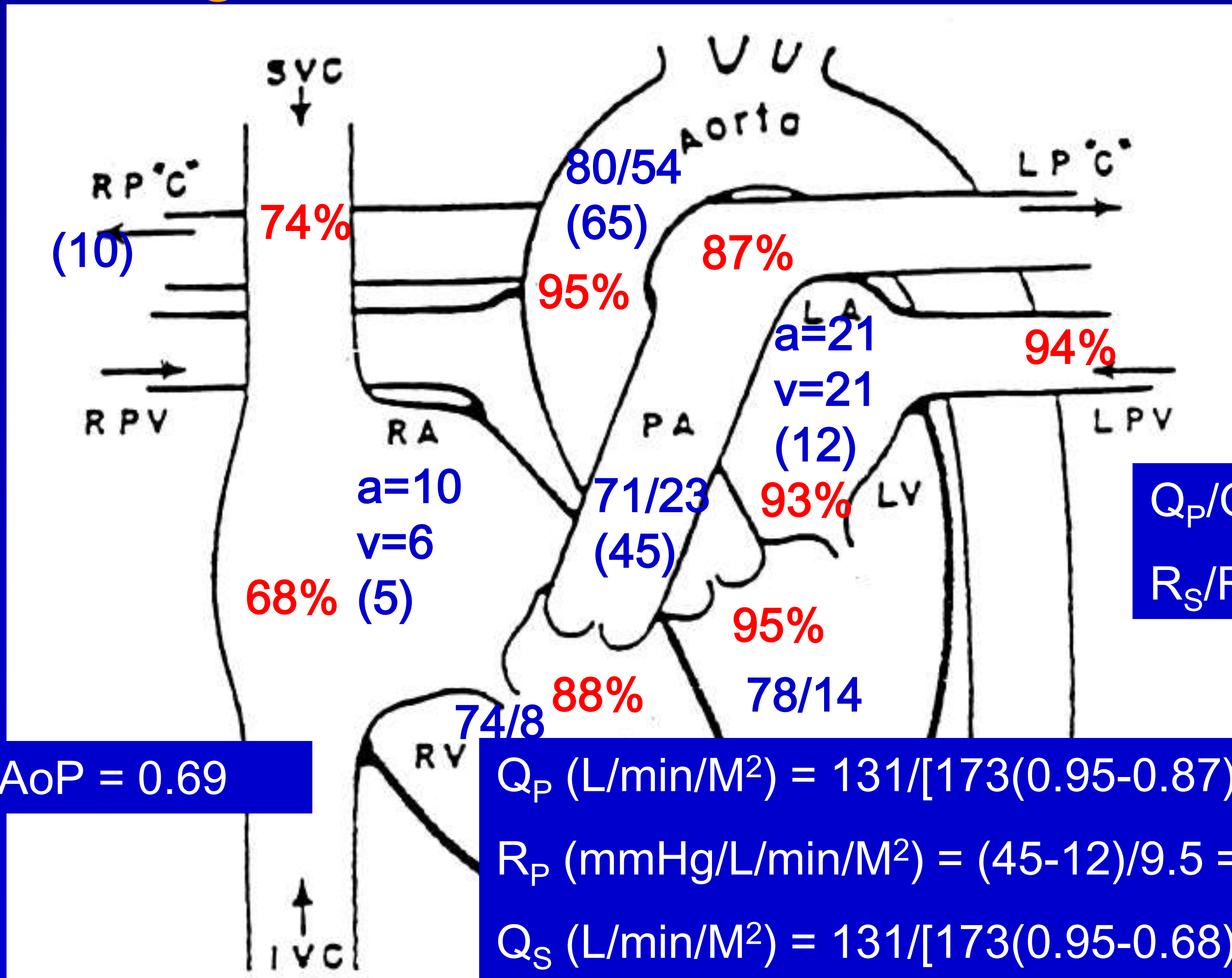
O_2 Consumption - 131 ml/min/m^2
O_2 Capacity - 173 ml/L (Hb 12.7)



Grossman text, 6th ed, p. 855

What is the diagnosis?

O_2 Consumption - 131 ml/min/m^2
O_2 Capacity - 173 ml/L (Hb 12.7)



Q_P/Q_S = 3.4

R_S/R_P = 6.2

MPAP/MAoP = 0.69

Q_P (L/min/M^2) = 131/[173(0.95-0.87)] = 9.5

R_P (mmHg/L/min/M^2) = (45-12)/9.5 = 3.47

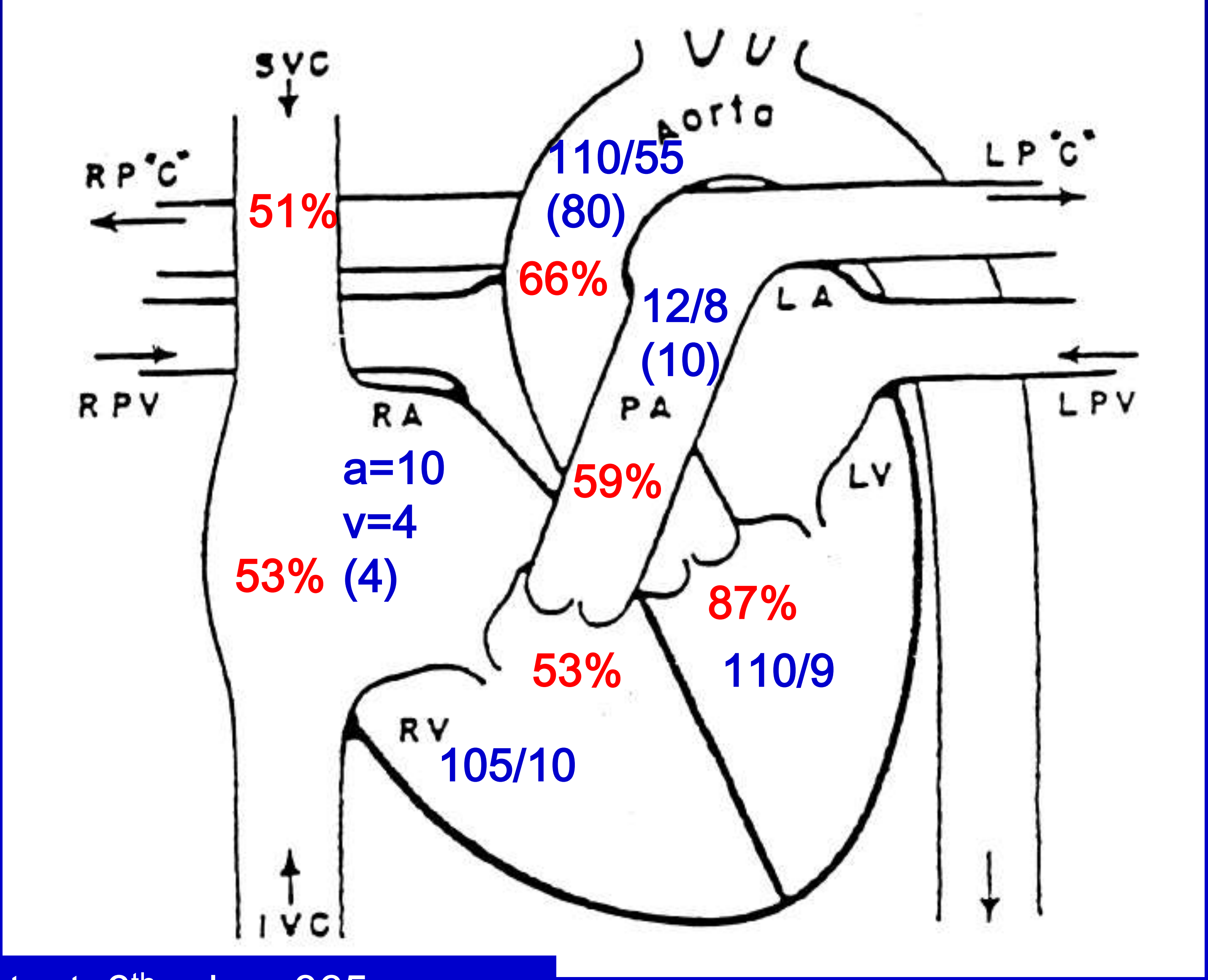
Q_S (L/min/M^2) = 131/[173(0.95-0.68)] = 2.80

R_S (mmHg/L/min/M^2) = (65-5)/2.80 = 21.4

Grossman text, 6th ed, p. 855

What is the diagnosis?

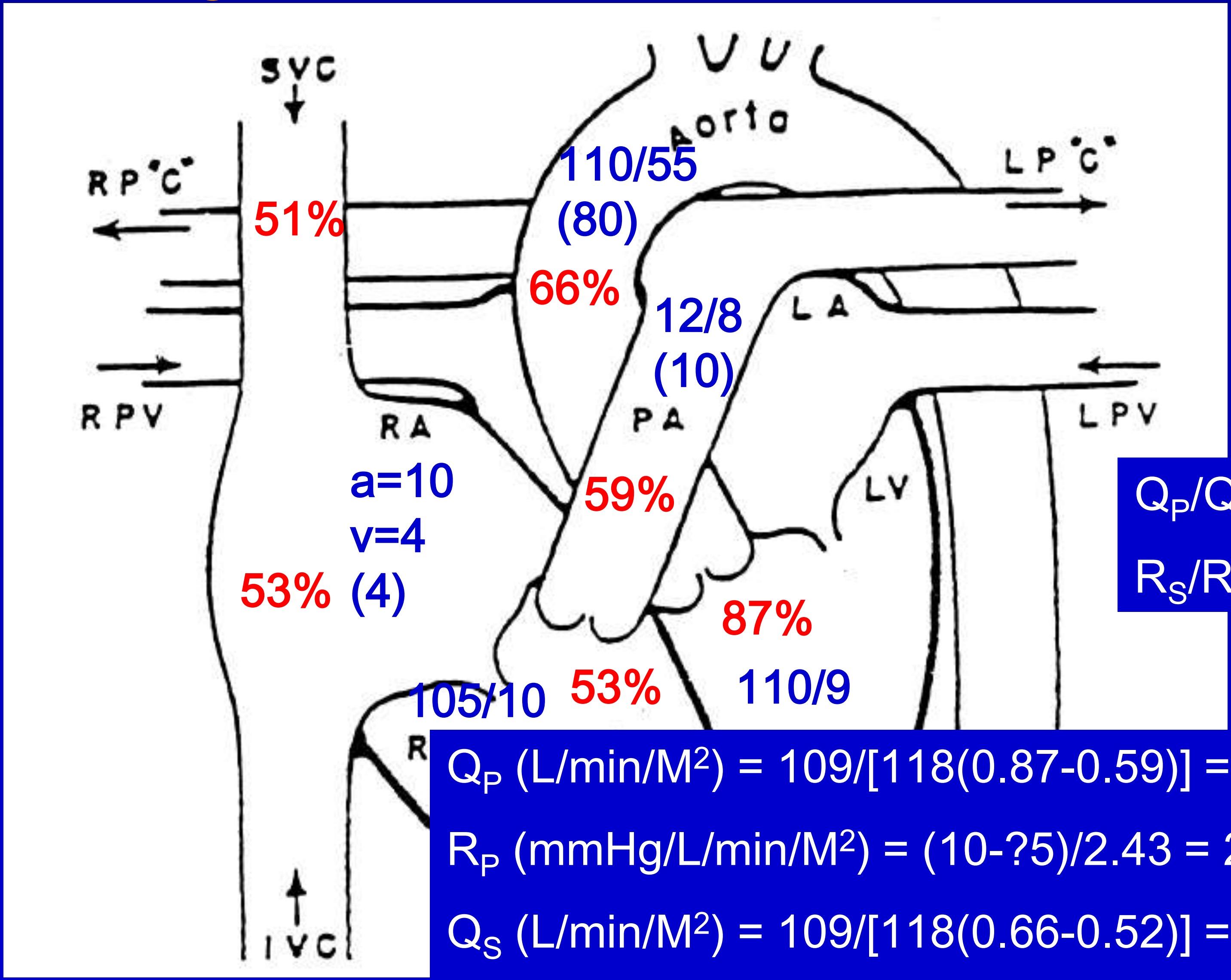
O_2 Consumption - 109 ml/min/m^2
O_2 Capacity - 118 ml/L



Grossman text, 6th ed, p. 865

What is the diagnosis?

O_2 Consumption - 109 ml/min/m^2
O_2 Capacity - 118 ml/L



$Q_P/Q_S = 0.42$

$R_S/R_P = 6.41$

Q_P (L/min/M^2) = 109/[118(0.87-0.59)] = 2.43

R_P (mmHg/L/min/M^2) = (10-?5)/2.43 = 2.06

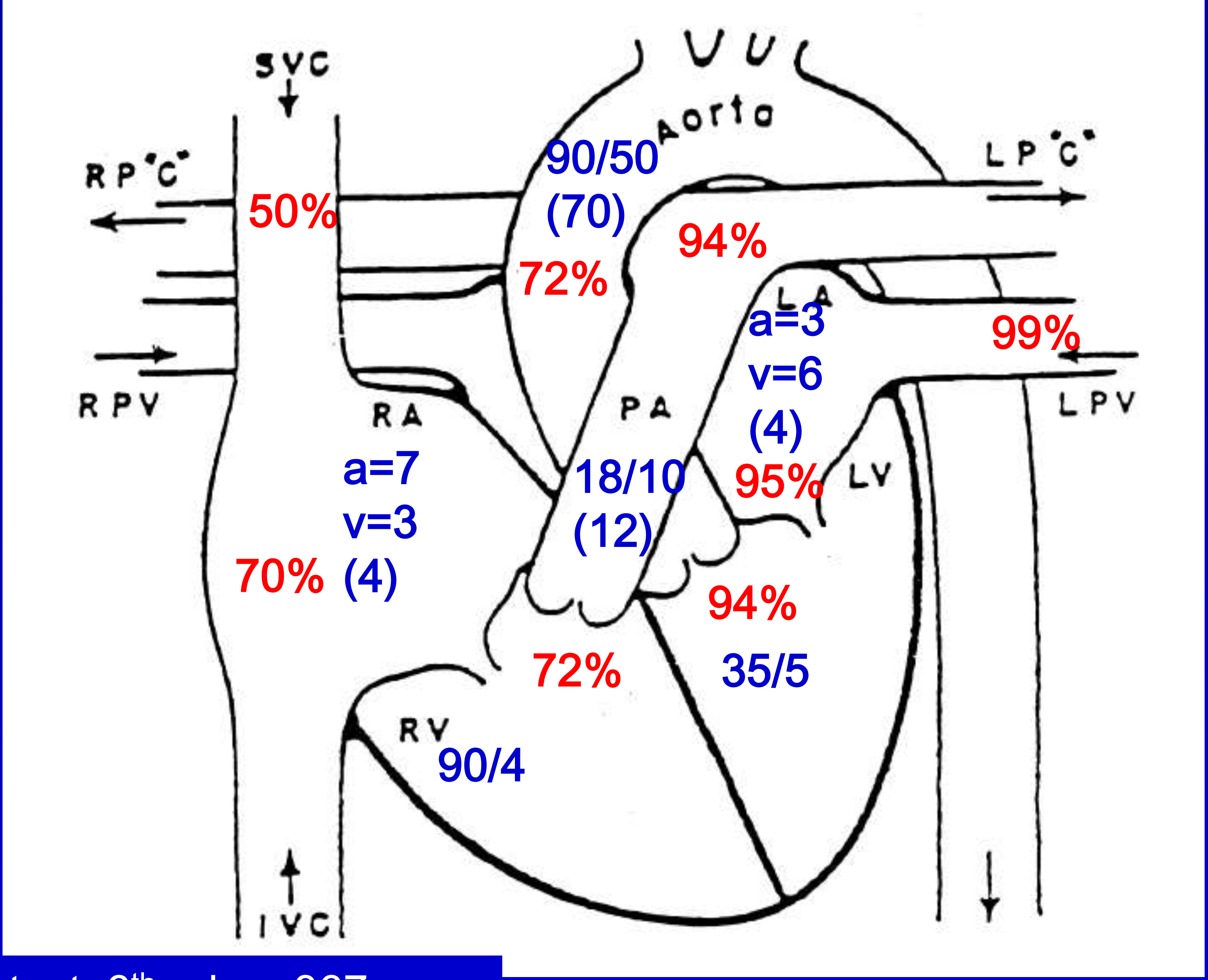
Q_S (L/min/M^2) = 109/[118(0.66-0.52)] = 5.77

R_S (mmHg/L/min/M^2) = (80-4)/5.77 = 13.2

Grossman text, 6th ed, p. 865

What is the diagnosis?

O_2 Consumption - 150 ml/min/m^2
O_2 Capacity - 300 ml/L

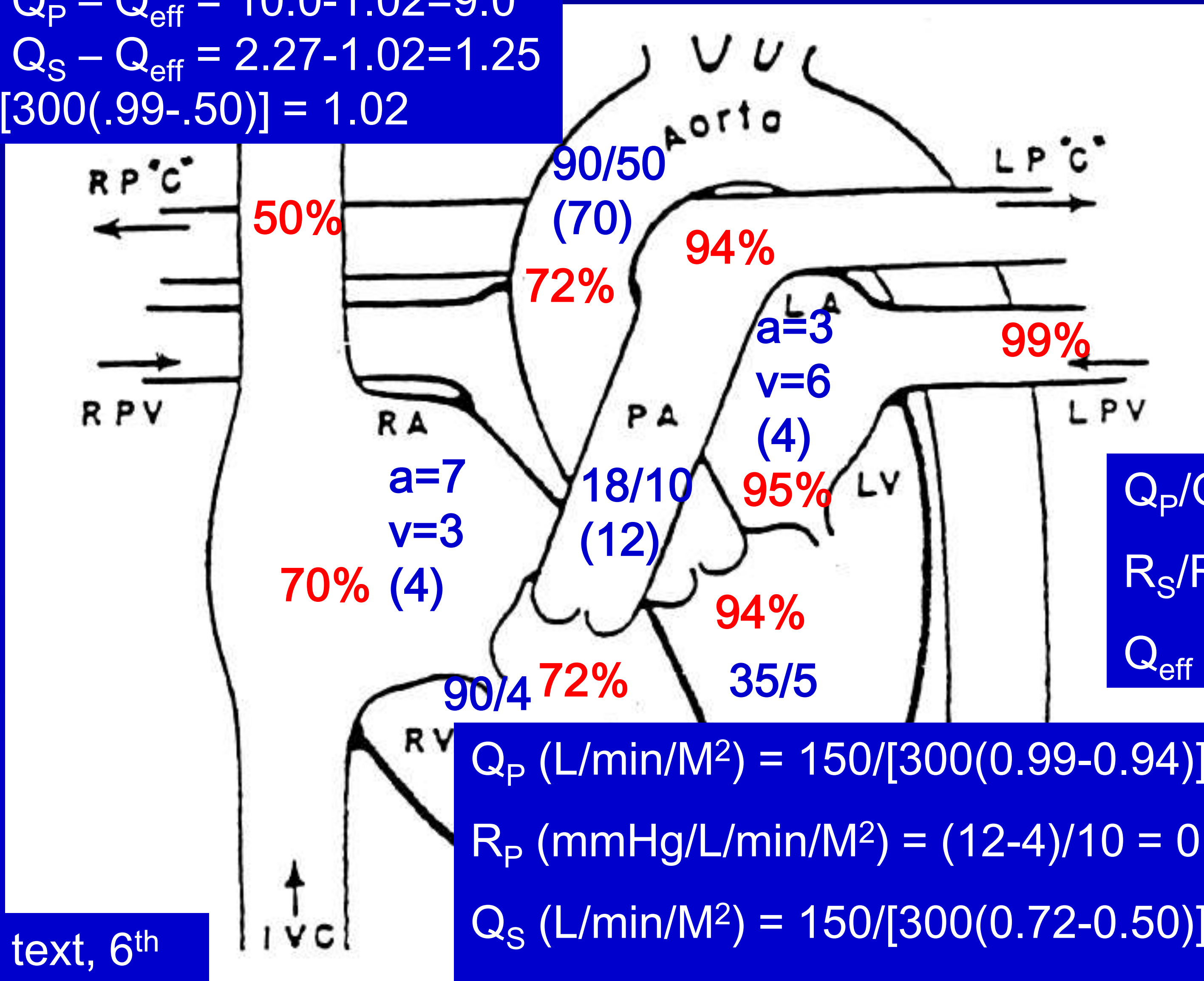


Grossman text, 6th ed, p. 867

What is the diagnosis?

O_2 Consumption - 150 ml/min/m^2
O_2 Capacity - 300 ml/L (Hb 22)

L-R shunt: $Q_P - Q_{eff}$ = 10.0-1.02=9.0
R-L shunt: $Q_S - Q_{eff}$ = 2.27-1.02=1.25
Q_{eff} = 150/[300(.99-.50)] = 1.02



Q_P/Q_S = 4.4

R_S/R_P = 36.4

Q_{eff} = 1.02

Q_P (L/min/M^2) = 150/[300(0.99-0.94)] = 10.0

R_P (mmHg/L/min/M^2) = (12-4)/10 = 0.80

Q_S (L/min/M^2) = 150/[300(0.72-0.50)] = 2.27

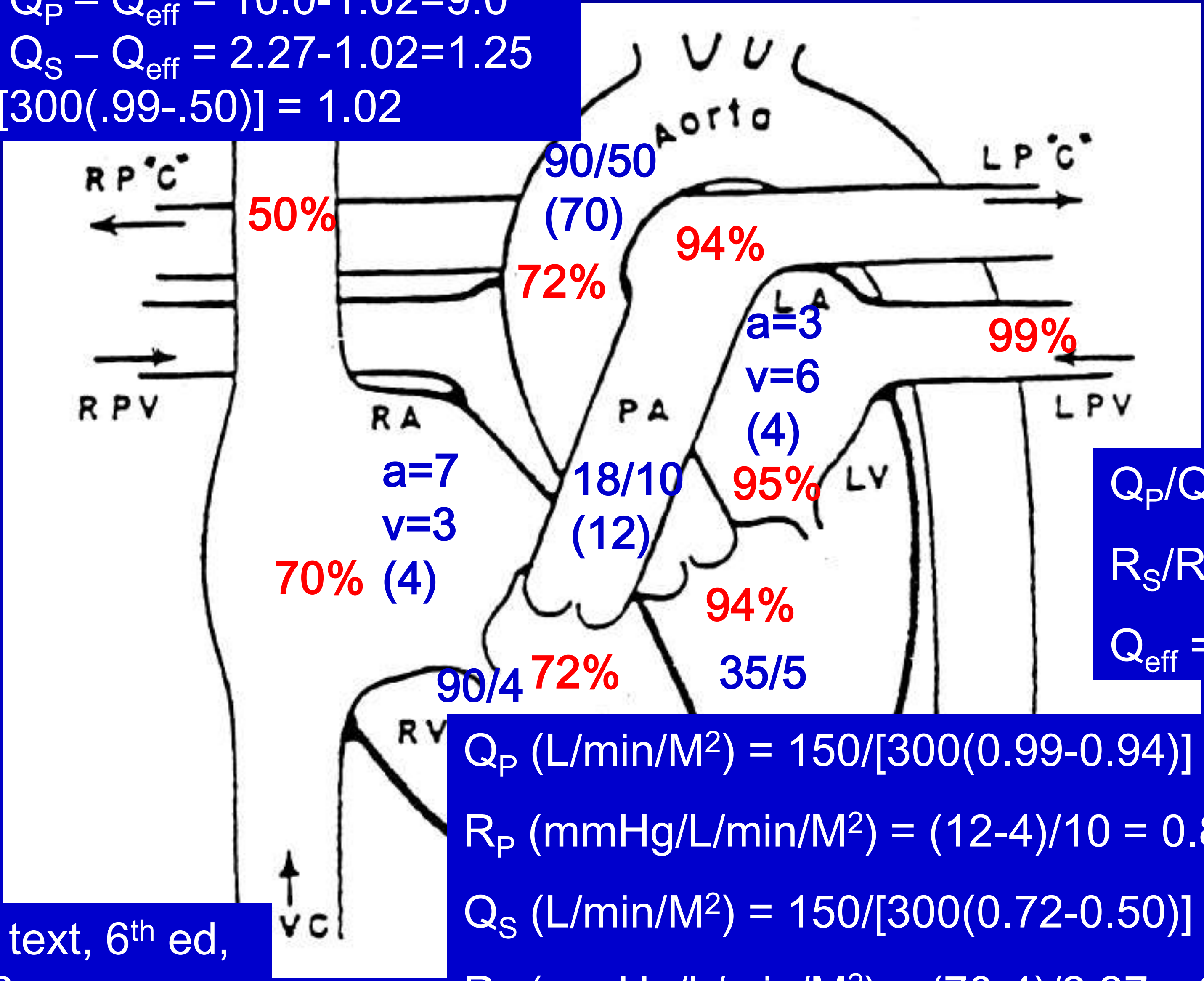
R_S (mmHg/L/min/M^2) = (70-4)/2.27 = 29.1

Grossman text, 6th ed, p. 867, 186

What is the diagnosis?

O_2 Consumption - 150 ml/min/m^2
O_2 Capacity - 300 ml/L (Hb 22)

L-R shunt: $Q_P - Q_{eff} = 10.0-1.02=9.0$
R-L shunt: $Q_S - Q_{eff} = 2.27-1.02=1.25$
$Q_{eff} = 150/[300(.99-.50)] = 1.02$



$Q_P/Q_S = 4.4$

$R_S/R_P = 36.4$

$Q_{eff} = 1.02$

Q_P (L/min/M^2) = 150/[300(0.99-0.94)] = 10.0

R_P (mmHg/L/min/M^2) = (12-4)/10 = 0.80

Q_S (L/min/M^2) = 150/[300(0.72-0.50)] = 2.27

R_S (mmHg/L/min/M^2) = (70-4)/2.27 = 29.1

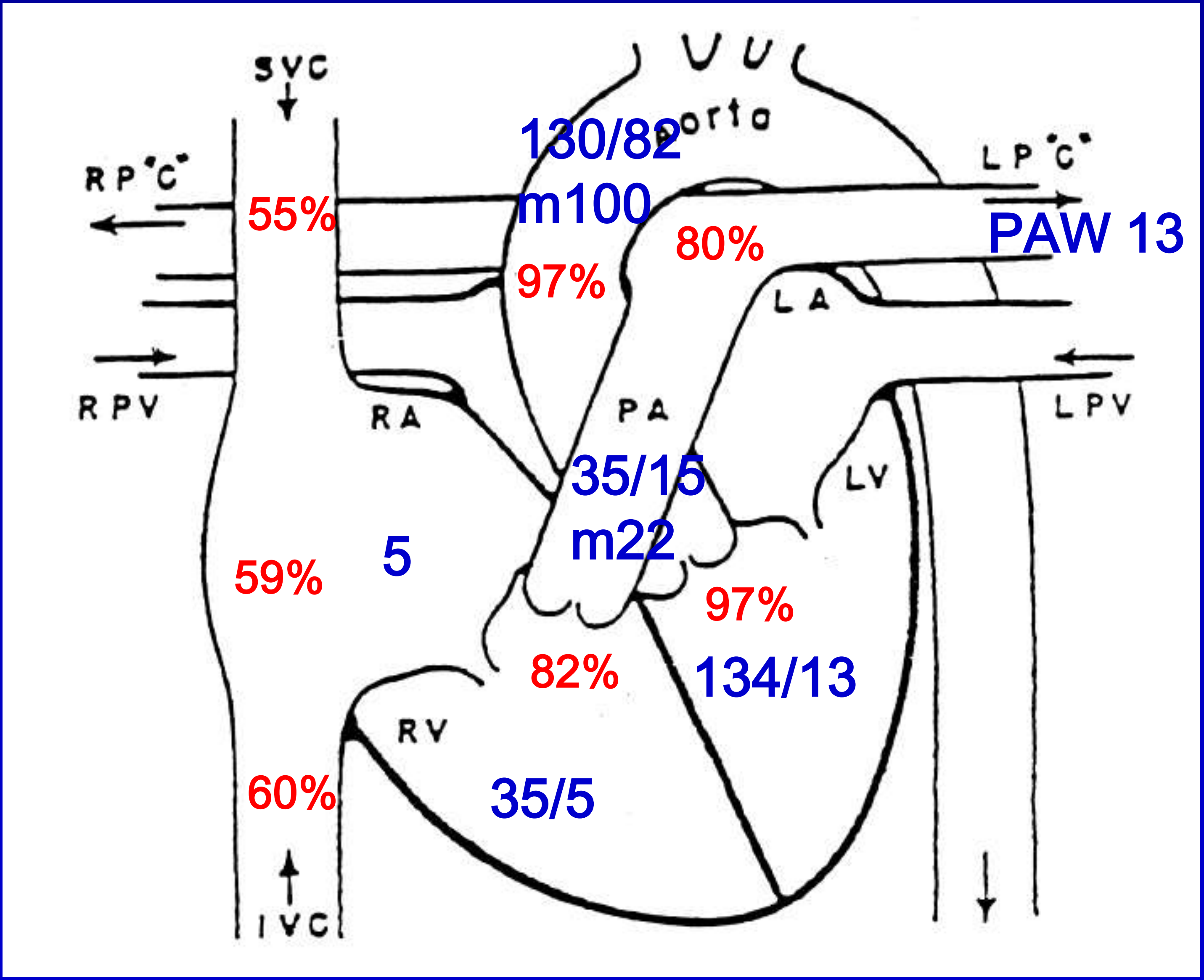
Grossman text, 6th ed, p. 867, 186

Guidelines for Optimum Utilization of Oximetry in Shunt Detection

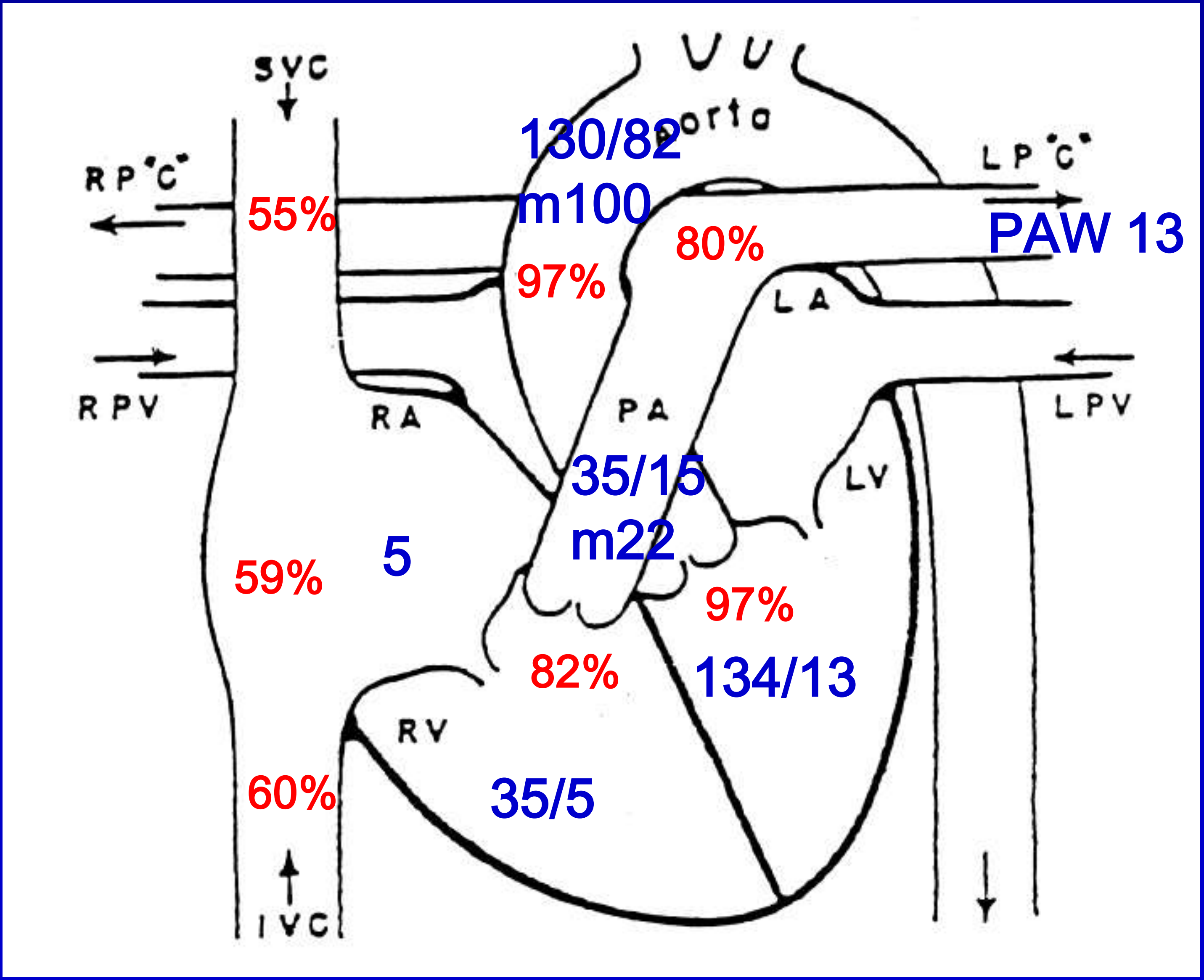
- Blood samples at multiple sites should be obtained rapidly.
- Blood O_2 saturation data rather than O_2 content data are preferable to identify the presence and location of a shunt.
- Comparison of the mean of all values obtained in the respective chambers is preferable to comparison of highest values in each chamber.
- Because of the important influence of systemic blood flow on shunt detection, exercise should be used in equivocal cases where a low systemic blood flow is present at rest.

Grossman text, 6th ed, p. 187; from Antman EM et al. Am J Cardiol.

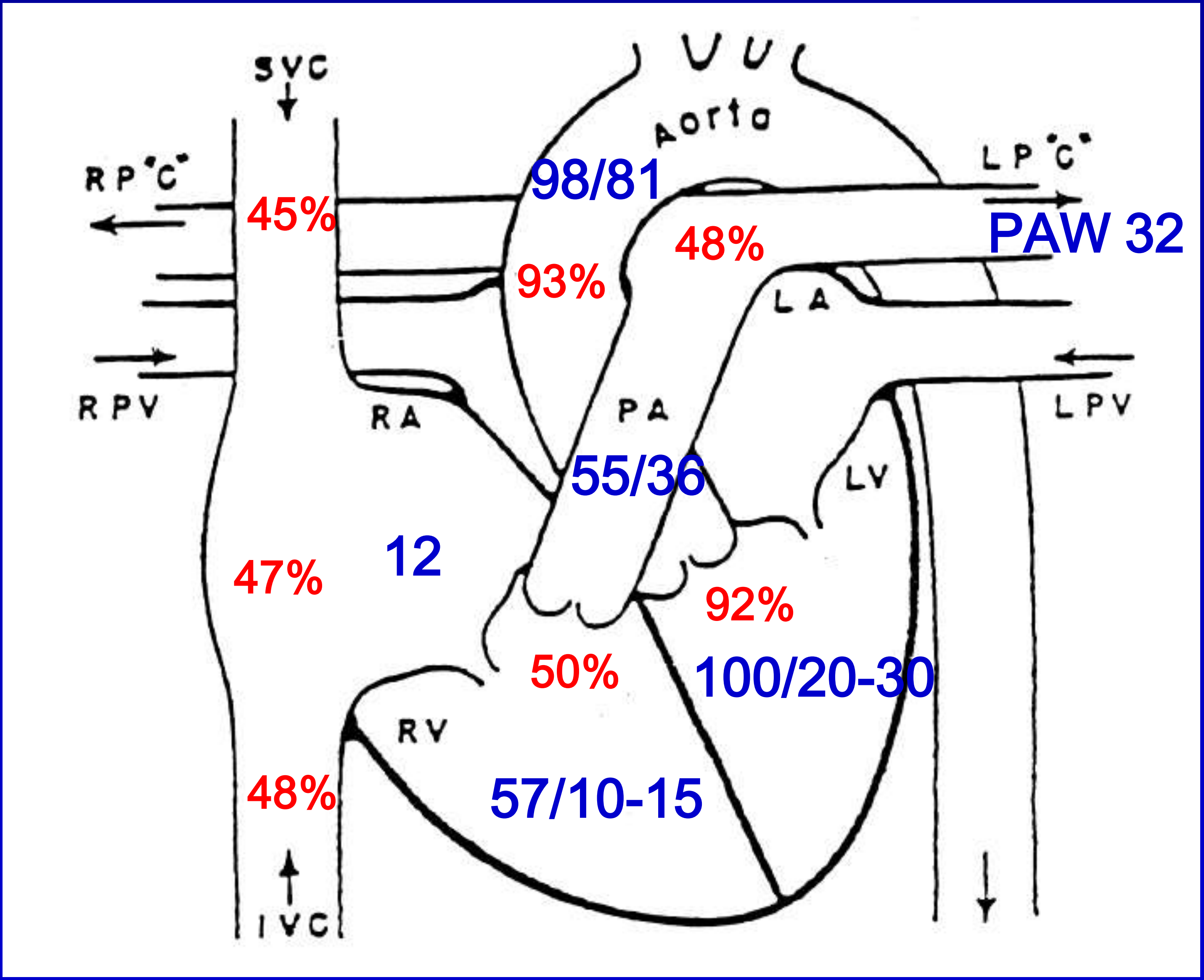
What is the diagnosis?



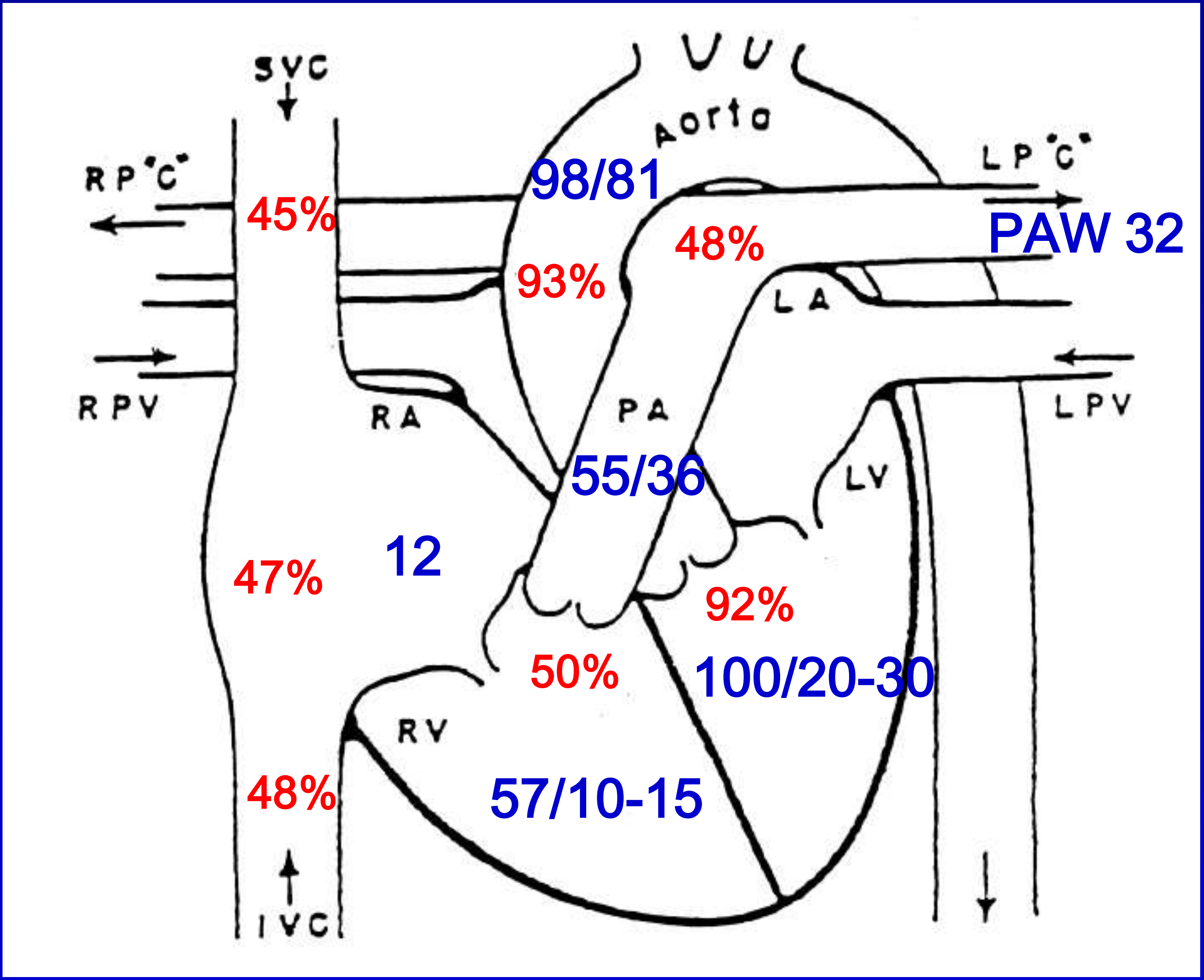
VSD


SVC
Aorta
130/82
m100
RP "C"
LP "C"
55%
80%
97%
PAW 13
LA
RPV
RA
PA
LPV
35/15
m22
LV
5
59%
97%
82%
134/13
RV
60%
35/5
IVC

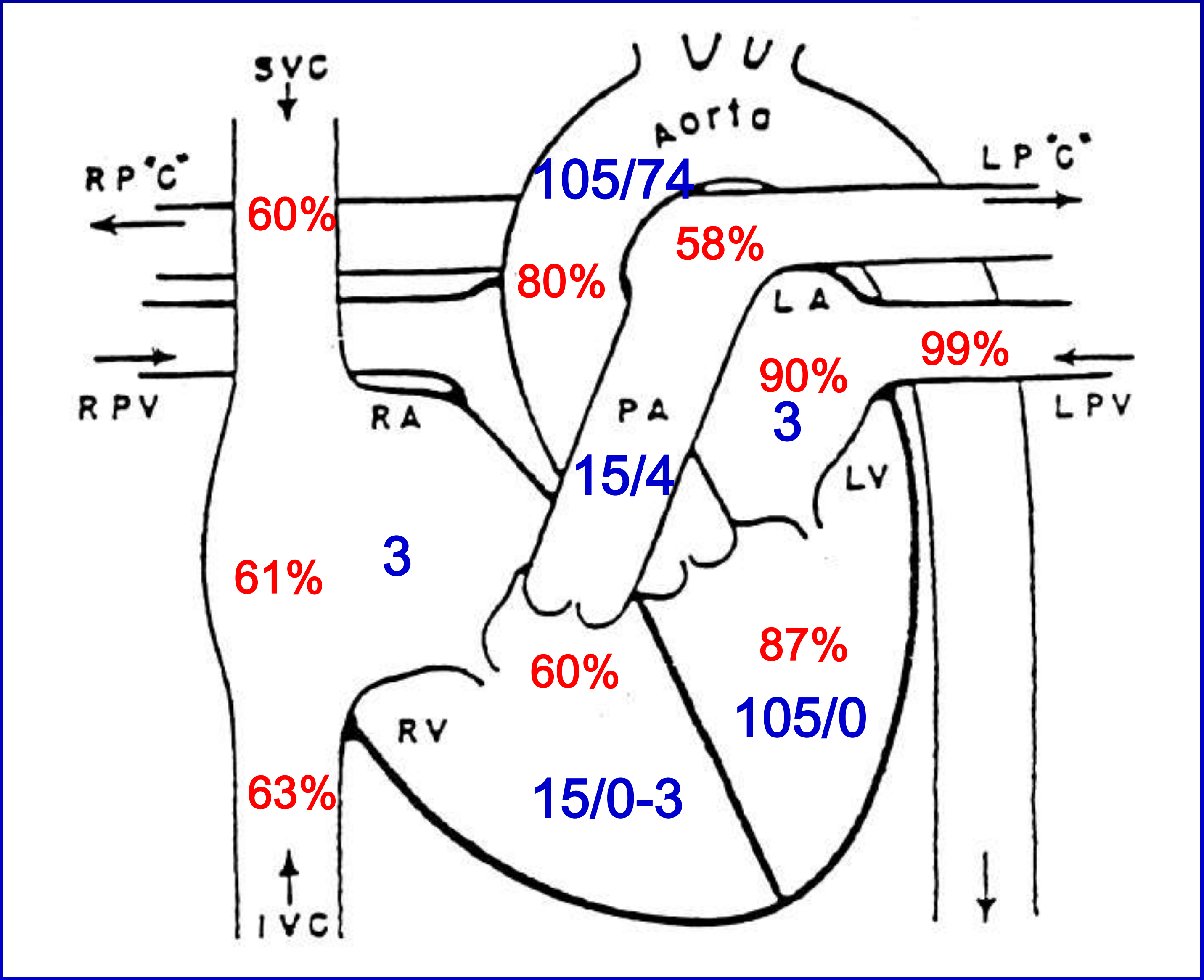
What is the diagnosis?



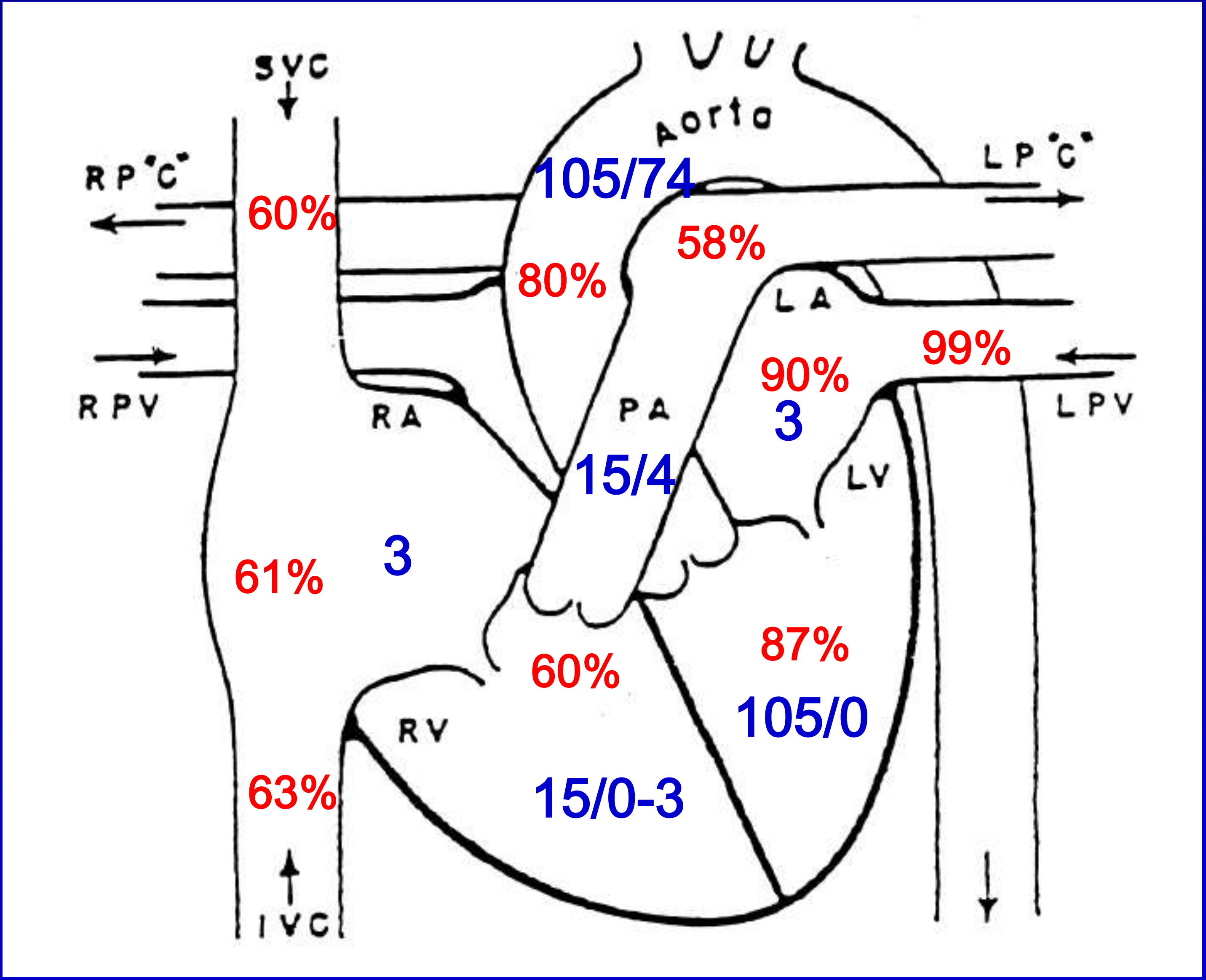
CHF, likely left heart failure, ?MR



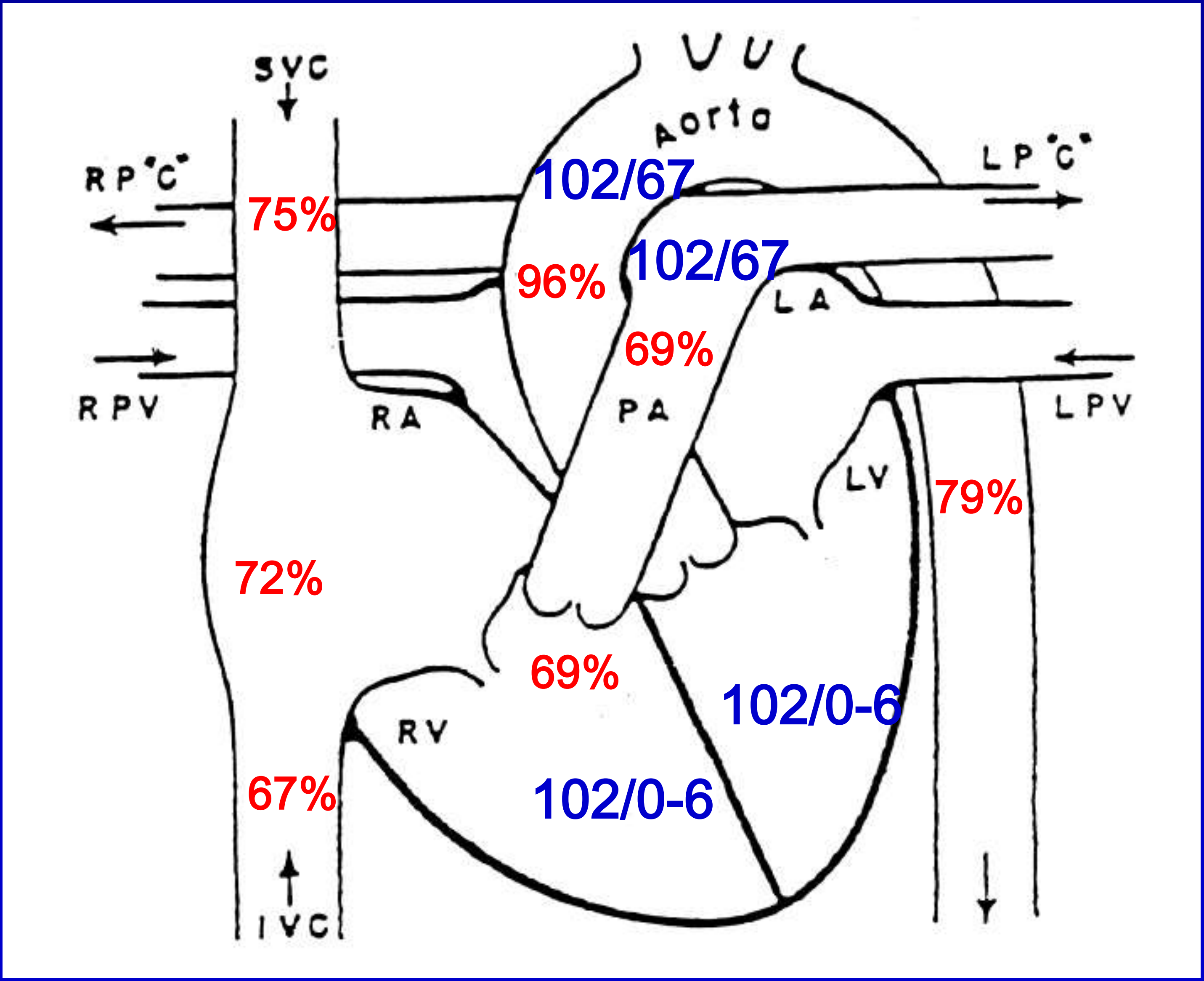
What is the diagnosis?



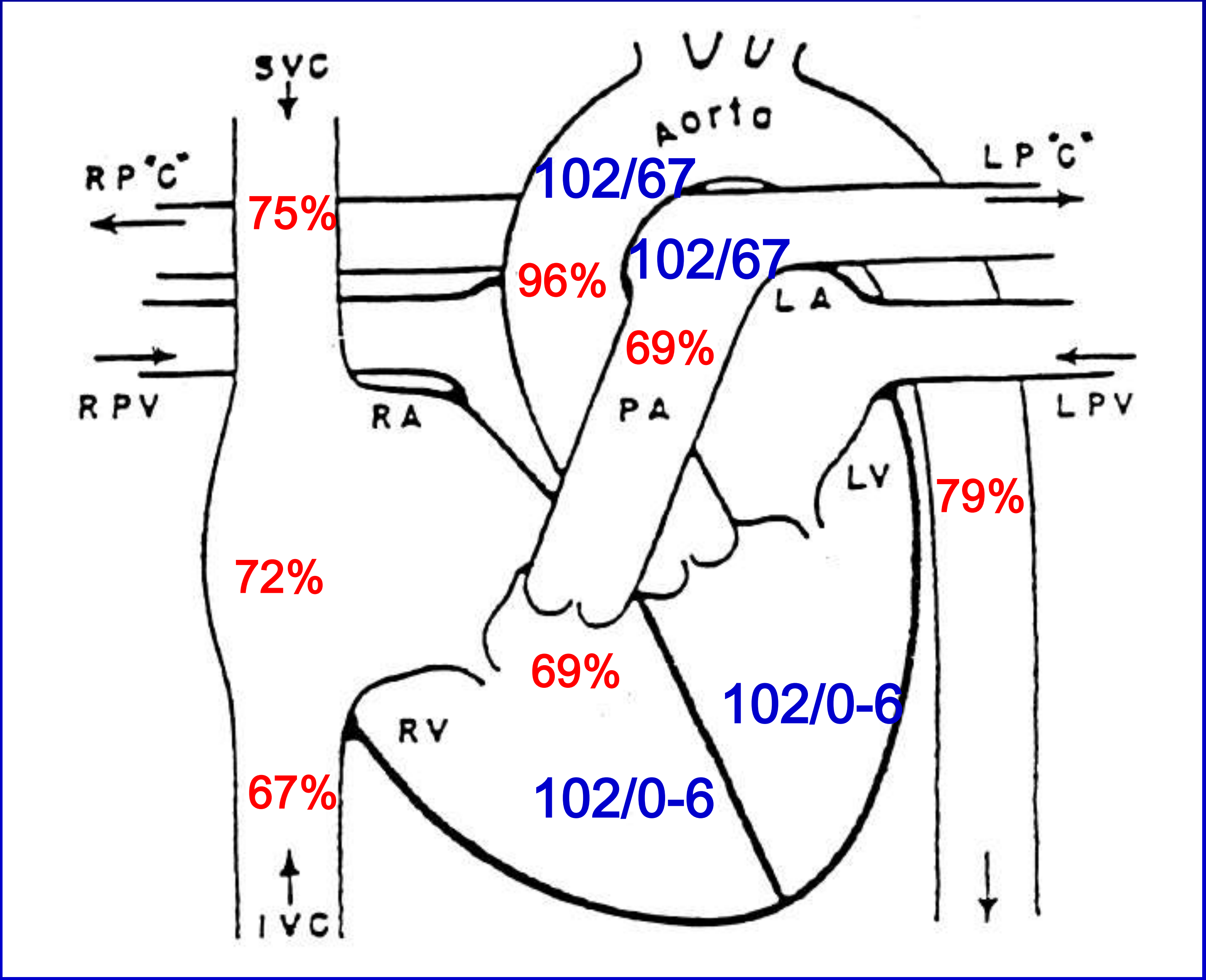
Ebstein's Anomaly



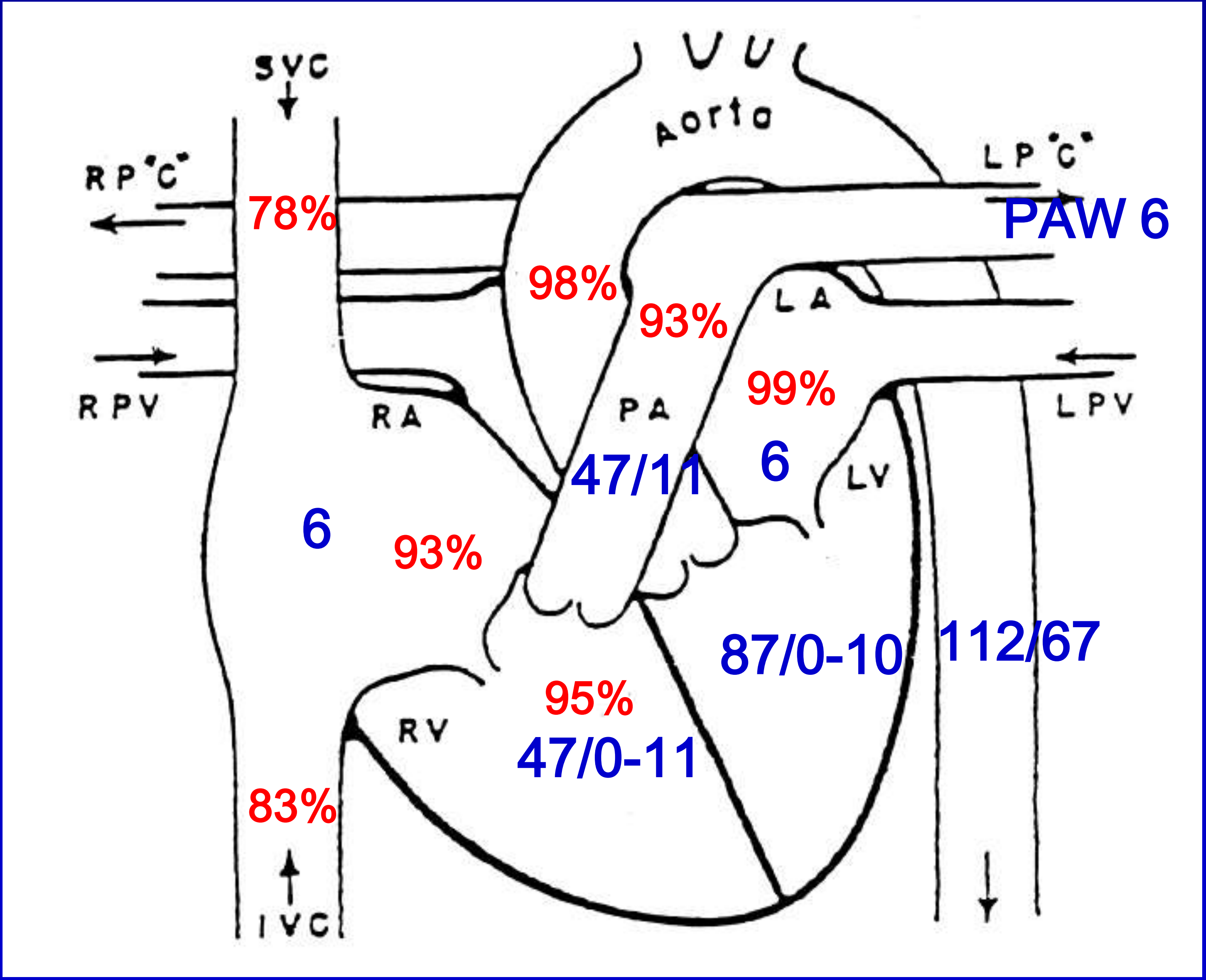
What is the Diagnosis?



PDA with Eisenmenger's Physiology

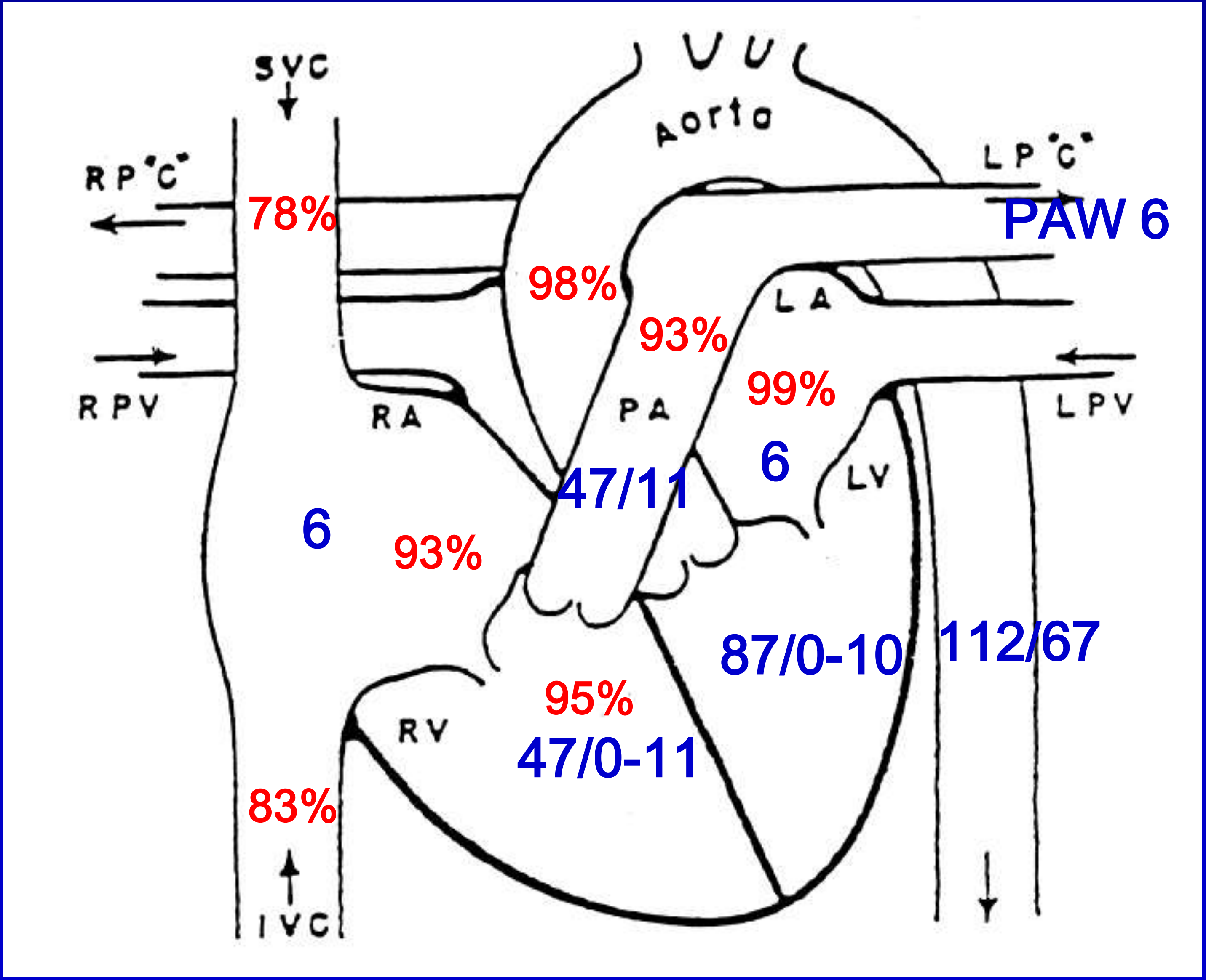


Diagnosis?

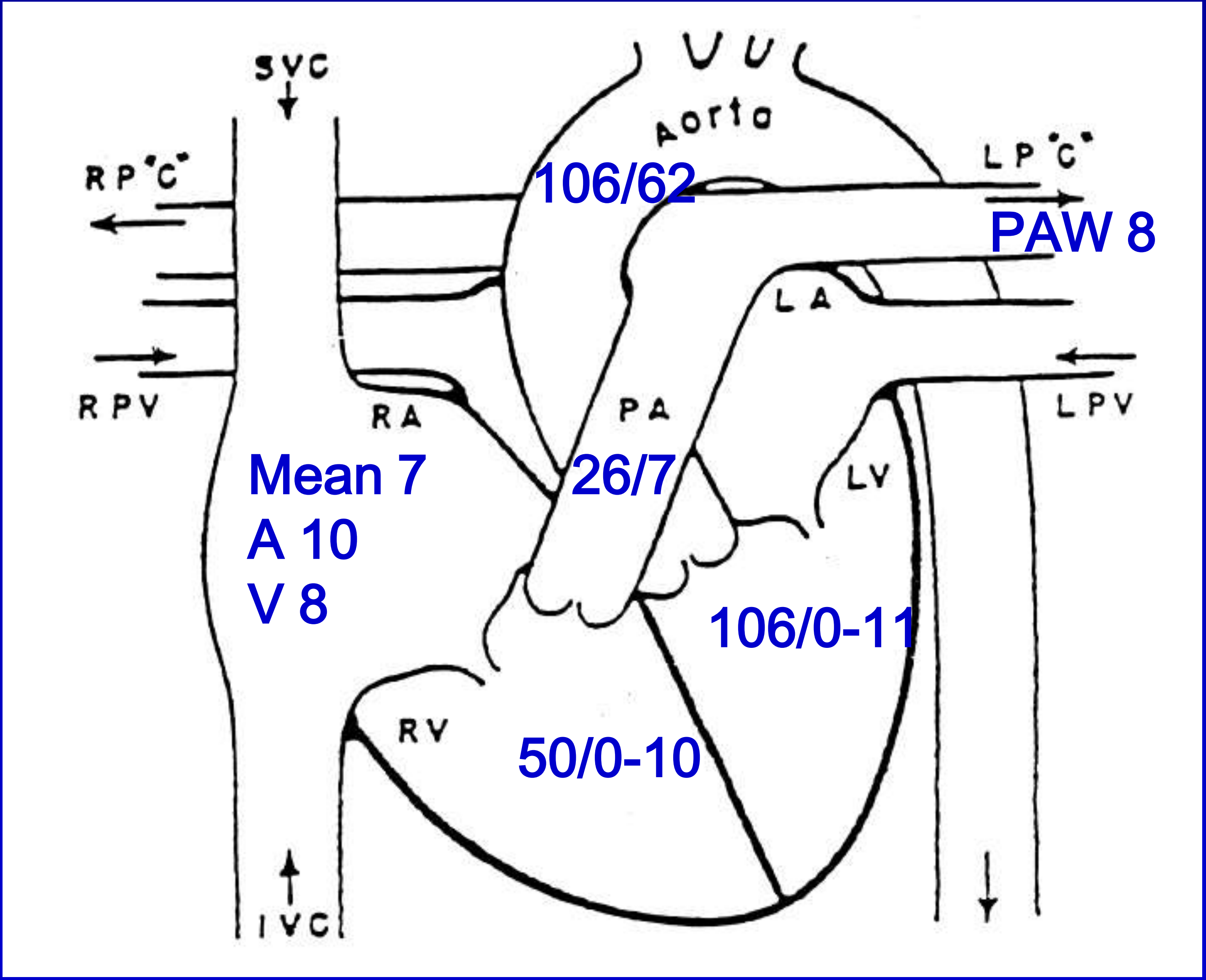


SVC
Aorta
RP "C"
LP "C"
PAW 6
78%
98%
93%
LA
99%
RPV
RA
PA
LPV
47/11
6
LV
6
93%
87/0-10
112/67
RV
95%
47/0-11
83%
IVC

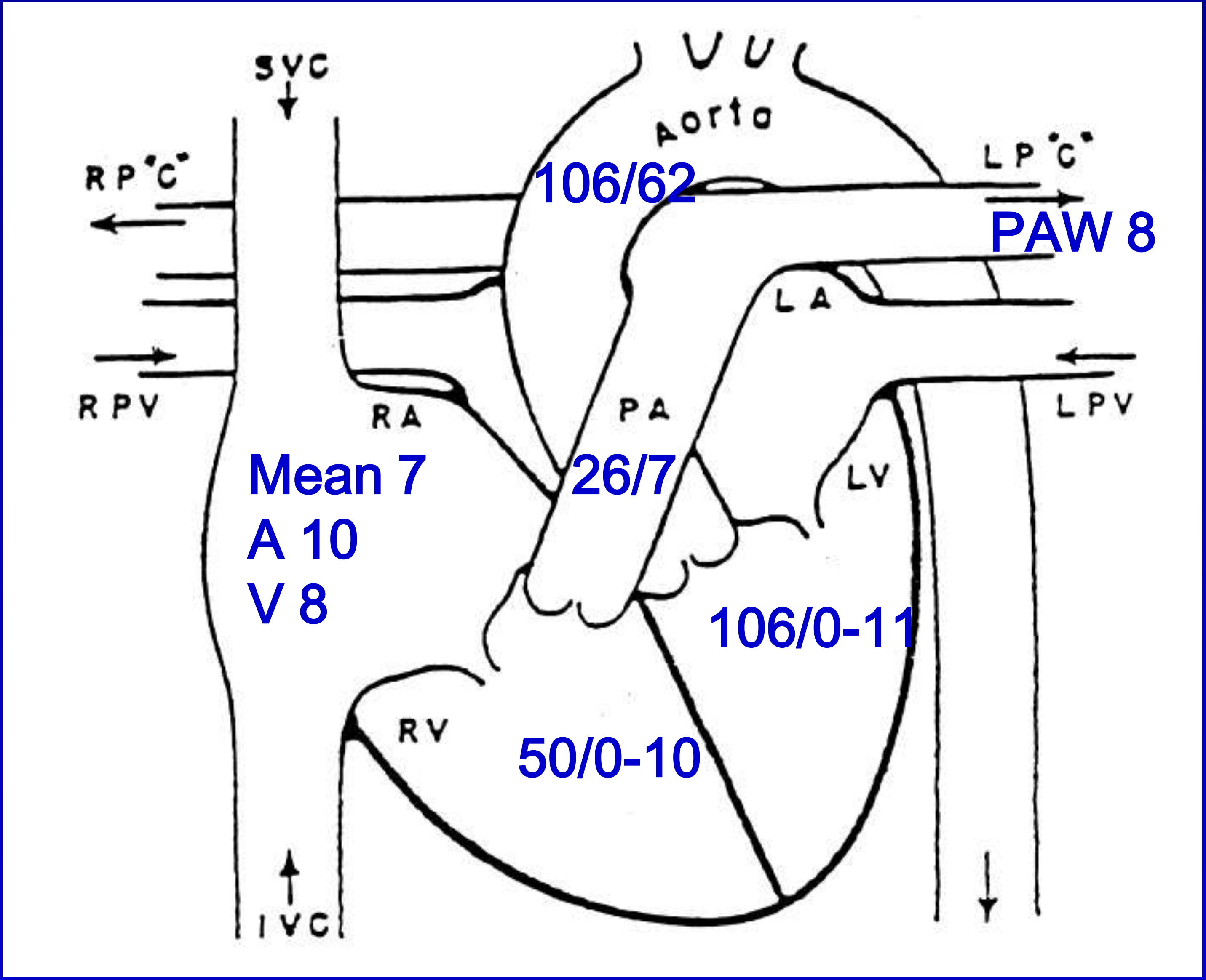
ASD Qp/Qs = 3:1 (98-83)/(98-93)



What is the diagnosis?



Pulmonic stenosis



Example 7

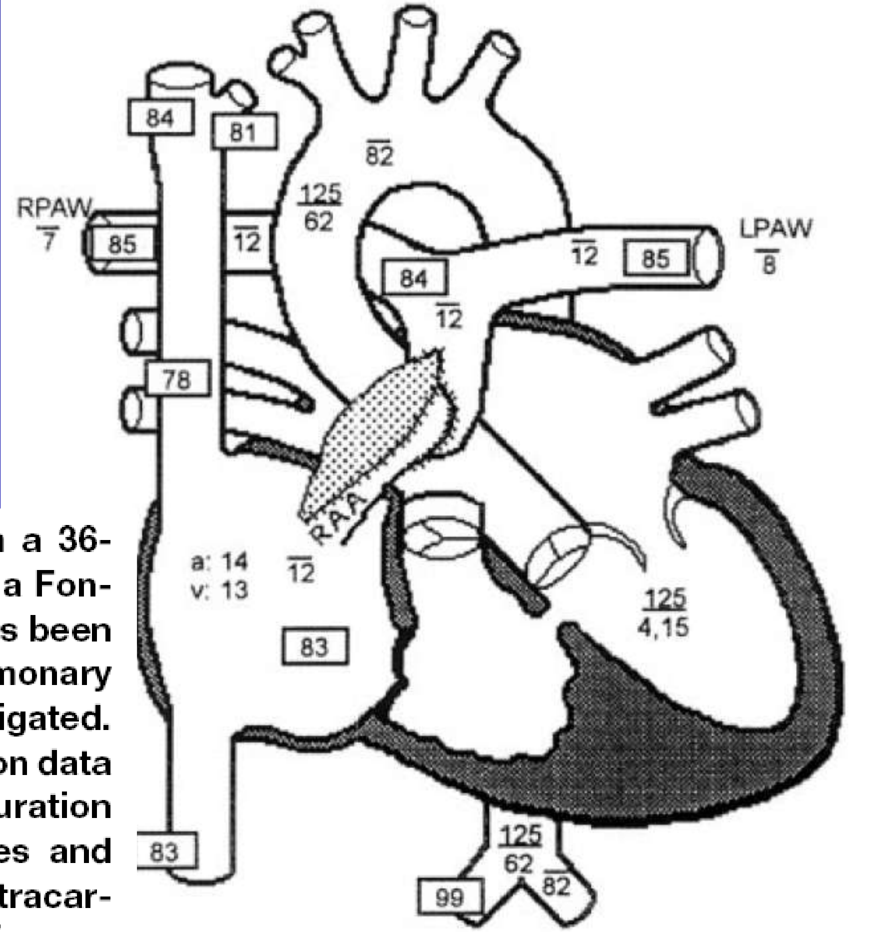


Fig. 8. Diagram of catheterization data obtained from a 36-year-old man with tricuspid atresia who has undergone a Fontan procedure where the right atrial appendage (RAA) has been used as a conduit and anastomosed to the main pulmonary artery. The proximal main pulmonary artery has been ligated. Pressure data are listed as fractions and means; saturation data are listed in boxes. There is no step-up in oxygen saturation from the superior vena cava to the pulmonary arteries and femoral artery blood is fully saturated, indicating no intracardiac shunt. The right atrial-to-pulmonary artery connection appears unobstructed with mean pressures of 12 mm Hg in the right atrium and throughout the branch pulmonary arteries. Flow of blood through the pulmonary arteries is relatively passive and usually represented solely as mean pressures. Using an oxygen consumption of 126 ml/min/m^2 and a hemoglobin level of 16.9 gm/dl, the Qp = 3.7, Qs = 3.7, Qp/Qs = 1.0, and the pulmonary vascular resistance = 1.1.

Fox JM et al. Cathet Cardiovasc Intervent. 2003;58:219.