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.

Normal Adult Circulation

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Range (S)</th>
<th>Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac output (L/min)</td>
<td>6.6</td>
<td>4.4-8.9</td>
<td></td>
</tr>
<tr>
<td>Cardiac index (L/min/m²)</td>
<td>3.5</td>
<td>2.8-4.2</td>
<td></td>
</tr>
<tr>
<td>SVR (dynes sec cm⁻⁵)</td>
<td>1130</td>
<td>952-1308</td>
<td></td>
</tr>
<tr>
<td>IVC sat</td>
<td>83.0</td>
<td>76-88</td>
<td>65-88</td>
</tr>
<tr>
<td>SVC sat</td>
<td>76.8</td>
<td>66-84</td>
<td>67-82</td>
</tr>
<tr>
<td>RA</td>
<td>79.5</td>
<td>72-86</td>
<td>74-84</td>
</tr>
<tr>
<td>RV</td>
<td>78.5</td>
<td>64-84</td>
<td>69-84</td>
</tr>
<tr>
<td>PA</td>
<td>78.4</td>
<td>73-85</td>
<td>75-84</td>
</tr>
<tr>
<td>PAW</td>
<td>98.2</td>
<td>90-100</td>
<td>92-100</td>
</tr>
<tr>
<td>Radial artery</td>
<td>97.3</td>
<td>95-99</td>
<td>95-99</td>
</tr>
</tbody>
</table>

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

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)

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

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

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

<table>
<thead>
<tr>
<th>Level of shunt</th>
<th>Criteria for significant step-up</th>
<th>Approximate minimal ( Q_p/Q_s ) required for detection (assuming SBFI = 3L/min/M²)</th>
<th>Possible causes of step-up</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean of distal chamber samples</td>
<td>Mean of proximal chamber samples</td>
<td>Highest value in distal chamber</td>
</tr>
<tr>
<td></td>
<td>( O_2 %) sat</td>
<td>( O_2 ) vol%</td>
<td>( O_2 %) sat</td>
</tr>
<tr>
<td>Atrial (SVC/IVC to RA)</td>
<td>( \geq 7 )</td>
<td>( \geq 1.3 )</td>
<td>( \geq 11 )</td>
</tr>
<tr>
<td></td>
<td>Partial anomalous pulmonary venous drainage; ruptured sinus of Valsalva; VSD with TR; coronary fistula to RA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ventricular (RA to RV)</td>
<td>( \geq 5 )</td>
<td>( \geq 1.0 )</td>
<td>( \geq 10 )</td>
</tr>
<tr>
<td></td>
<td>VSD; PDA with PR; primum ASD; coronary fistula to RV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Great Vessel (RV to PA)</td>
<td>( \geq 5 )</td>
<td>( \geq 1.0 )</td>
<td>( \geq 5 )</td>
</tr>
<tr>
<td></td>
<td>PDA; aorta-pulmonic window; aberrant coronary artery origin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ANY LEVEL (SVC to PA)</td>
<td>( \geq 7 )</td>
<td>( \geq 1.3 )</td>
<td>( \geq 8 )</td>
</tr>
<tr>
<td></td>
<td>All the above</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.
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%

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)

Calculation of Systemic Blood Flow ($Q_s$)

Use the following equation for systemic blood flow:

$$
Q_s \quad \text{ (L/min)} = \frac{O_2 \text{ consumption (mL/min)}}{\left[ \text{SA } O_2 \text{ content (mL/L)} \right] - \left[ \text{MV } O_2 \text{ content (mL/L)} \right]} \quad (9.2)
$$
<table>
<thead>
<tr>
<th>Location of shunt as determined by site of $O_2$ step-up</th>
<th>Mixed venous sample to use in calculating systemic blood flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Pulmonary artery (e.g., patent ductus arteriosus)</td>
<td>Right ventricle, average of samples obtained during oximetry run</td>
</tr>
<tr>
<td>2. Right ventricle (e.g., ventricular septal defect)</td>
<td>Right atrium, average of all samples during oximetry run</td>
</tr>
<tr>
<td>3. Right atrium (e.g., atrial septal defect)</td>
<td>$\frac{3(\text{SVC } O_2 \text{ content}) + 1(\text{IVC } O_2 \text{ content})}{4}$</td>
</tr>
</tbody>
</table>

**TABLE 9.2.** Calculation of systemic blood flow in the presence of left-to-right shunt
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
- \[0.71*SVC + 0.29*IVC = MVB\]

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

Calculation of Pulmonary Blood Flow ($Q_p$)

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

$$Q_p \quad (L/min) = \frac{O_2 \text{ consumption} \quad (mL/min)}{\left[ PV \ O_2 \text{ content} \quad (mL/L) \right] - \left[ PA \ O_2 \text{ content} \quad (mL/L) \right]} \quad (9.1)$$
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

\[ L \rightarrow R \text{ Shunt} = Q_p - Q_s \quad (9.3) \]

(L/min)
Example 1

\[ Q_p = \frac{O_2 \text{ consumption (mL/min)}}{PV \text{ O}_2 \text{ content (mL/L)}} - \frac{PA \text{ O}_2 \text{ content (mL/L)}}{\text{(9.4)}} \]

PV O₂ content was not measured, but left ventricular (LV) and arterial blood O₂ saturation was 96% (effectively ruling out a right-to-left shunt), and therefore it may be assumed that PV blood O₂ saturation was 96%. As described in Chapter 8, oxygen content for PV blood is calculated as follows:

\[ 0.96 \left( \frac{14 \text{ g Hgb}}{100 \text{ mL blood}} \right) \times \left( \frac{1.36 \text{ mL O}_2}{\text{g Hgb}} \right) \]

\[ = 18.3 \text{ mL O}_2/100 \text{ mL blood} \quad (9.5) \]

\[ = 183 \text{ mL O}_2/\text{liter} \]
Similarly, PA $O_2$ content is calculated as

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

Therefore;

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

$$= 7.74 \text{ L/min}$$

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

$$Q_s = \frac{240 \text{ mL } O_2/\text{min}}{\text{[systemic arterial } O_2 \text{ content]} - \text{[mixed venous } O_2 \text{ content]}}$$

$$= \frac{240}{(0.96 - 0.69)14(1.36)10} \quad (9.8)$$

$$= 4.6 \text{ L/min}$$

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 $7.7 - 4.7 = 3 \text{ L/min}$. This patient has a small-to-moderate-sized atrial septal defect.
Example 2

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

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

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

\[ Q_p/Q_s = 15/4.1 = 3.7 \quad (9.9) \]

L→shunt = 15 - 4.1 = 10.9 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
A simplified formula for calculation of flow ratio can be derived by combining the equations for systemic and pulmonary blood flow to obtain

\[
\frac{Q_p}{Q_s} = \frac{(SA \ O_2 - MV \ O_2)}{(PV \ O_2 - PA \ O_2)} \quad (9.10)
\]

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, \(\frac{Q_p}{Q_s} = (96\% - 69\%)/(96\% - 80\%) = 1.68\).
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.

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.

\[
Q_{\text{eff}} = \frac{O_2 \text{ consumption (mL/min)}}{\left[\frac{PV \text{ O}_2 \text{ content}}{mL} - \frac{MV \text{ O}_2 \text{ content}}{mL}\right]}
\]

(9.12)
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.
**TABLE 9.3.** Expected value of $O_2$ content (volumes percent) for various levels of $O_2$ step-up and blood hemoglobin concentration*

<table>
<thead>
<tr>
<th>Increase in $O_2$ saturation</th>
<th>Hemoglobin Concentration (g/100 mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10</td>
</tr>
<tr>
<td>5%</td>
<td>0.68 vol%</td>
</tr>
<tr>
<td>10%</td>
<td>1.36 vol%</td>
</tr>
<tr>
<td>15%</td>
<td>2.04 vol%</td>
</tr>
<tr>
<td>20%</td>
<td>2.72 vol%</td>
</tr>
</tbody>
</table>

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.

Example 3

Example 3

B. From Flamm equation:

\[ \text{MVO}_2 = \frac{3 \text{SVC} + \text{IVC}}{4} = 0.59 \]
\[ \text{Art O}_2 = 0.96 \times 1.36 \times 14.1 \times 10 = 184 \]
\[ \text{MVO}_2 = 0.59 \times 1.36 \times 14.1 \times 10 = 113 \]
\[ \text{PAO}_2 = 0.80 \times 1.36 \times 14.1 \times 10 = 153 \]
\[ \text{PVO}_2 = 0.97 \times 1.36 \times 14.1 \times 10 = 186 \]

\[ \text{QS} = \frac{224.6}{(184 - 113)} = 3.16 \quad \text{QP} = \frac{224.6}{(186 - 153)} = 7.25 \]
\[ = 71 \quad = 31 \]

\[ \text{QP/QS} = \frac{7.25}{3.16} = 2.29/1 \]

or Simplified with Sats:

\[ \text{QP} = \text{Art Sat} - \text{MV Sat} (96 - 59) = 37 \]
\[ \text{QS} = \text{PV Sat} - \text{PA Sat} (97 - 80) = 17 \]
\[ = 2.17/1 \]
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/m² and an Hg level of 12.6 gm/dl, hemodynamic calculations were performed with the patient breathing 23% and 100% inspired O₂ 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% O₂, suggests surgical repair is still an option.
Example

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/m² 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.

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/m² 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.
What is the diagnosis?

6 yo girl
BSA 1.44 m2

O₂ Consumption - 190 ml/min/m²
O₂ Capacity - 162 ml/L (Hb 11.9)

Grossman text, 6th ed, p. 853
What is the diagnosis?

6 yo girl
BSA 1.44 m²
O₂ cap 1.36

O₂ Consumption - 190 ml/min/m²
O₂ Capacity - 162 ml/L (Hb 11.9)

Text answer:

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?

O₂ Consumption - 131 ml/min/m²
O₂ Capacity - 173 ml/L (Hb 12.7)

Grossman text, 6th ed, p. 855
What is the diagnosis?

O₂ Consumption - 131 ml/min/m²
O₂ Capacity - 173 ml/L (Hb 12.7)

MPAP/MAoP = 0.69

Qₚ/Qₛ = 3.4
Rₛ/Rₚ = 6.2

Grossman text, 6th ed, p. 855
What is the diagnosis?

O₂ Consumption - 109 ml/min/m²
O₂ Capacity - 118 ml/L

Grossman text, 6th ed, p. 865
What is the diagnosis?

O₂ Consumption - 109 ml/min/m²
O₂ Capacity - 118 ml/L

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

\[
R_P (mmHg/L/min/M^2) = \frac{(10-95)}{2.43} = 2.06
\]

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

\[
R_S (mmHg/L/min/M^2) = \frac{(80-4)}{5.77} = 13.2
\]
What is the diagnosis?

O₂ Consumption - 150 ml/min/m²
O₂ Capacity - 300 ml/L

Grossman text, 6th ed, p. 867
What is the diagnosis?

L-R shunt: \( Q_P - Q_{\text{eff}} = 10.0 - 1.02 = 9.0 \)
R-L shunt: \( Q_S - Q_{\text{eff}} = 2.27 - 1.02 = 1.25 \)
\( Q_{\text{eff}} = 150/[300(0.99 - .50)] = 1.02 \)

\[ \begin{align*}
Q_P (L/min/M^2) &= 150/[300(0.99-0.94)] = 10.0 \\
R_P (mmHg/L/min/M^2) &= (12-4)/10 = 0.80 \\
Q_S (L/min/M^2) &= 150/[300(0.72-0.50)] = 2.27 \\
R_S (mmHg/L/min/M^2) &= (70-4)/2.27 = 29.1
\end{align*} \]

\( Q_P/Q_S = 4.4 \)
\( R_S/R_P = 36.4 \)
\( Q_{\text{eff}} = 1.02 \)

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

O₂ Consumption - 150 ml/min/m²
O₂ Capacity - 300 ml/L (Hb 22)
What is the diagnosis?

O₂ Consumption - 150 ml/min/m²
O₂ Capacity - 300 ml/L (Hb 22)

L-R shunt: $Q_P - Q_{eff} = 10.0 - 1.02 = 9.0$
R-L shunt: $Q_S - Q_{eff} = 2.27 - 1.02 = 1.25$

$Q_{eff} = 150/[300(0.99 - .50)] = 1.02$

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

$Q_P (L/min/M^2) = 150/[300(0.99 - 0.94)] = 10.0$
$R_P (mmHg/L/min/M^2) = (12 - 4)/10 = 0.80$

$Q_S (L/min/M^2) = 150/[300(0.72 - 0.50)] = 2.27$
$R_S (mmHg/L/min/M^2) = (70 - 4)/2.27 = 29.1$
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.

What is the diagnosis?

[Diagram with various measurements and percentages marked on a cardiovascular system diagram.]
VSD

130/82
m100
80%

35/15
m22

5

134/13

PAW 13

55%

97%

60%

82%
What is the diagnosis?
CHF, likely left heart failure, ?MR

**Diagram**

- **SVC**: Superior Vena Cava
- **RVC**: Right Vena Cava
- **RPV**: Right Pulmonary Vein
- **PA**: Pulmonary Artery
- **LV**: Left Ventricle
- **RA**: Right Atrium
- **LA**: Left Atrium
- **PAW**: Pulmonary Artery Wedge

**Pressure Measurements**

- **98/81**: Aorta (93%)
- **55/36**: PA (48%)
- **100/20-30**: RV (92%)
- **57/10-15**: LV (50%)
- **50%**: IVC

**Flow Rates**

- **47%**: 12
- **48%**: RV
- **48%**: IVC
- **45%**: SVC

**Other Notes**

- PAW: 32
What is the diagnosis?

[Diagram showing various measurements and percentages around the heart and vascular system.]
Ebstein’s Anomaly
What is the Diagnosis?

Diagram with various percentages and blood pressure readings.
PDA with Eisenmenger’s Physiology

Diagram showing blood flow and pressures in the heart and circulation, with various percentages and blood pressure readings indicated.
Diagnosis?
ASD  Qp/Qs = 3:1  (98-83)/(98-93)
What is the diagnosis?

[Diagram of the heart with annotated pressures and values]

- Mean 7
- A 10
- V 8
- 106/62
- 26/7
- 106/0-11
- 50/0-10
- PAW 8
Pulmonic stenosis

Mean 7
A 10
V 8

26/7

106/0-11

50/0-10

106/62

PAW 8
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/m² 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.