Radionuclide Angiocardiographic Calculation of the Ratio of Left-to-Right Heart Outputs in a Patient With Unusual Cardiovascular Anatomy: Case Report

J. Anthony Parker, Michael Freed, Donald S. Ahnberg, and S. Treves

Harvard Medical School and The Children's Hospital Medical Center, Boston, Massachusetts

The subject of this case report is an unusual patient whose right lung receives blood from the right heart and whose left lung receives blood from the left heart. Due to this unusual anatomy, it was possible to calculate the ratio of the outputs of the left and right hearts using standard techniques.

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Radionuclides have provided quantitative information about the cardiovascular system for nearly half a century (*1*). Recently we evaluated a child with unusual postsurgical cardiovascular anatomy involving different outputs from the right and left heart. This case report describes the radionuclide technique used to calculate the ratio between these two outputs.

CASE REPORT

A white girl, aged 11 years and 8 months, presented for a followup cardiac evaluation. A murmur had been noted at birth; cyanosis had developed at 3 weeks. At 4 months of age, the patient underwent a modified left Blalock–Taussig procedure, i.e., anastomosis of the left subclavian artery (LSA) and left pulmonary artery (LPA). Since the LPA was very small, the end of the LSA was connected with the end of LPA rather than the usual end-to-side anastomosis. Continued cyanosis led to catheterization at 20 months of age; this showed severe Fallot's tetral-

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For reprints contact: S. Treves, 300 Longwood Ave., Boston, MA 02115.

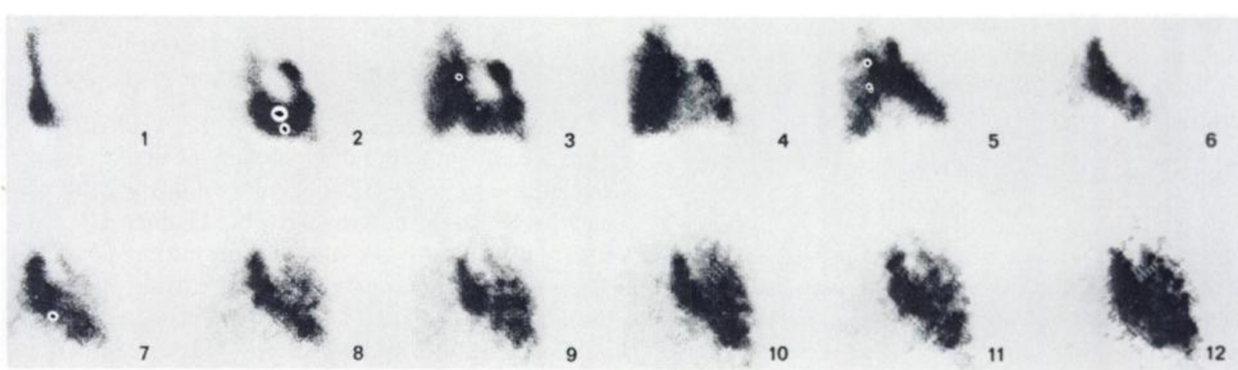

FIG. 1. Sequential image of heart dynamics after bolus injection of tracer (1 sec per frame). Images 1 and 2 show passage of emitter through right atrium, right ventricle, and pulmonary artery. Images 3 and 4 show invasion of right lung. Images 5–7 show levo phase. Images 8–12 show tracer passage from left heart to left lung and body.

ogy with pulmonary atresia, a large ventricular septal defect with right-to-left shunting, and a right aortic arch. A right Blalock–Taussig shunt was performed soon after, with improvement in symptoms. At the age of 10.5 years, she underwent ligation of the right Blalock–Taussig shunt, patch closure of her ventricular septal defect, and placement of a Hancock graft with a porcine aortic heterograft from her right ventricle to the main pulmonary artery (MPA). The left pulmonary artery was hypoplastic from the main pulmonary artery to the junction of the Blalock–Taussig anastomosis. Because of marked scarring and hypoplasia of the LPA proximal to the shunt, it was not possible to establish continuity between the MPA and LPA. Thus, after surgical repair, the right pulmonary artery received all of the systemic venous return, while the left lung received only the arterial circulation from the LSA to the LPA.

At followup catheterization 1 year after repair, right ventricular pressure was 40/5, right pulmonary artery pressure 25/10 (mean 15 mm Hg), right capillary wedge pressure 7, and right pulmonary resistance 1.8. The Blalock–Taussig shunt was patent, with left pulmonary artery pressure 10/5 and oxygen saturation 95%. Flow to the right lung (3.2 liter/min-m^2) and systemic flow (2.8 liter/min-m^2) were calculated by the Fick method. Angiography showed a small residual ventricular septal defect with a right-lung-to-systemic flow ratio of 1.2. Left ventricular volumes were calculated from the levo phase of a right ventricular angiogram using Simpson's rule. Stroke volume was determined by subtracting the end-systolic volume from end-diastolic volume, and the left ventricular output (4.7 liter/min-m^2) was calculated by multiplying the stroke volume by the heart rate. Flow to the left lung (1.9 liter/min-m^2) was equal to the left ventricular output minus the systemic blood flow. The ratio of the left heart output to that of the right heart was therefore 4.7/2.8 = 1.7.

TECHNIQUE

Donato et al (*2*) have shown that, given an independent measurement of total blood volume (TBV), cardiac output (CO) can be calculated with the formula

$$CO = \frac{TBV \times e}{A},$$

where A is the area under the time–activity curve of the first transit of an intravascular radionuclide through a region of interest and e is the equilibrium count rate in that same region. The region of interest may include any or many portions of the cardiovascular system, and the result is independent of the counting efficiencies for each portion since the equilibrium count rate normalizes the area A for these several counting efficiencies. However, tracer mixing must occur before entry into the region of interest, and no additional unmixed blood may enter the system in the region of interest. These restrictions are usually met for a region overlying the lung. The first transit of nuclide may be distinguished from recirculation by fitting the upslope and the initial downslope prior to recirculation wiht a gamma-variate function (*3*). In our work with shunt calculation, this function has been a good model of first transit when the injected tracer bolus was sharp (*4*).

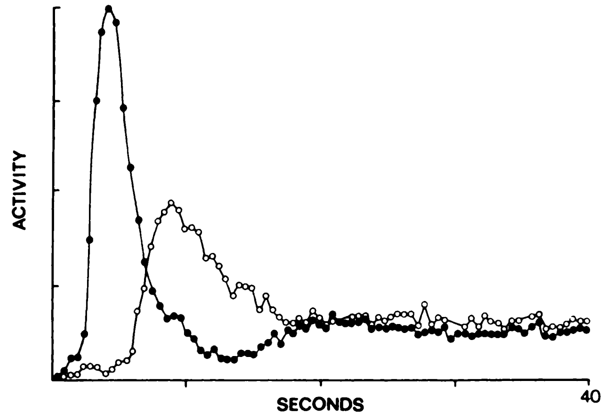

FIG. 2. Right (●) and left (○) lung activity curves during first 40 sec after intravenous administration of pertechnetate bolus.

In the present case, an area of interest over the right lung detects activity after mixing in the right heart. After intravenous injection, the right cardiac output CO_R can be calculated from this region. All of the activity then goes to the left heart, where it mixes with unlabeled blood from the left lung. A portion of this blood then returns to the left lung. On the same injection, the left cardiac output CO_L can be calculated from a region of interest overlying the left lung. The ratio of these outputs is independent of the measurement of total blood volume:

$$\frac{CO_L}{CO_R} = \frac{\left(\dfrac{TBV \times e_L}{A_L}\right)}{\left(\dfrac{TBV \times e_R}{A_R}\right)} = \frac{(e_L/A_L)}{(e_R/A_R)}.$$

In the patient under discussion, 6 mCi of $^{99m}TcO_4^-$ was injected into the right jugular vein while she was under a Searle Radiographics Pho/Gamma HP scintillation camera in the anterior projection (Fig. 1). The regions of interest were selected with the use of the Gamma-11 PDP-11/20 computer system (Digital Equipment Corp., Maynard, Mass.). Since pertechnetate is a poor vascular label, the equilibrium values of e_R and e_L were established by a simple linear extrapolation of the later 20 sec of the curves

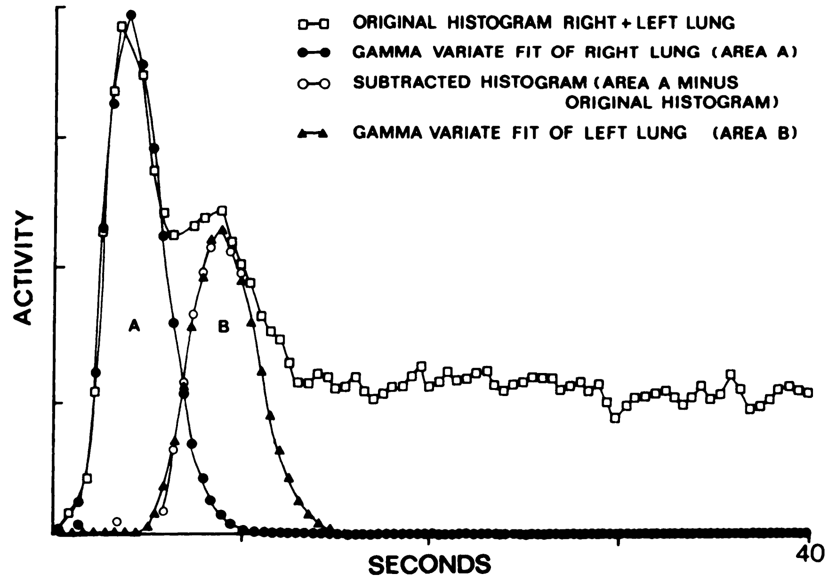

FIG. 3. Gamma-variate fits to right and left lung areas of interest.

back to time zero. These equilibrium values e_R and e_L include contributions from the chest wall vasculature which the fitted first-transit areas A_R and, to a lesser extent, A_L do not contain. This patient's relative pulmonary overcirculation tends to reduce the magnitude of this error. Since the inaccuracies in the calculation of e_R and e_L are similar, the error will be less severe in the ratio. The cardiac output ratio is used to derive the percent of left heart output going to the left lung: $1 - (CO_R/CO_L)$.

RESULTS

Curves from regions of interest overlying the right and left lungs (excluding the region of the heart) are shown in Fig. 2. Gamma-variate fits (*4*) from 10% of the peak on the upslope to 70% of the peak on the downslope (Fig. 3) gave left-lung A_L and right-lung A_R areas of 3805 and 3059 counts, respectively. Back-extrapolated equilibrium values e_L and e_R were 187 and 255 counts per second, respectively. (For statistical considerations, it should be noted that these values are obtained from fitting 20 points.) The left-to-right heart output ratio is therefore 1.7, in excellent agreement with the calculations from catheterization. The percentage of left heart output going to the left lung is 40%.

DISCUSSION

This case is presented as a novel application of a standard tracer technique to an unusual problem. The patient has very interesting physiology in that the left lung receives fully oxygenated blood under normal pressure and the right lung receives all the normal cardiac output at low pressure. This technique will be useful in noninvasively measuring changes in the ratio of right-to-left perfusion.

REFERENCES

1. Blumgart HL, Weiss S: Studies on the velocity of blood flow. VII: The pulmonary circulation of time in normal resting individuals. *J Clin Invest* 4: 399–425, 1927

2. Donato L, Giunlini C, Lewis ML, et al: Quantitative radiocardiography. I. Theoretical considerations. *Circulation* 26: 174–182, 1962

3. Thompson HK, Starmer CF, Whalen RE, et al: Indicator transit time considered as a gamma variate. *Circ Res* 14: 502–515, 1964

4. Maltz D, Treves S: Quantitative radionuclide angiocardiography: Determination of Qp:Qs in children. *Circulation* 47: 1049–1056, 1973