Third, a gamma variate was used to fit the left ventricular curve. This function routinely underestimates curve areas and overestimates flow (*5*) compared to the more widely accepted technique of monoexponential extrapolation (*6*), which they appropriately employed for their reference method based on arterial sampling. For consistency, they could have used the same fitting function for both their test and reference methods. Again, one assumes that this reflected availability of software.

Fourth, the gamma variate fit was terminated at the time when recirculation was felt to occur. This is an extremely subjective decision, and in the vast majority of cases such a point can never be clearly ascertained, regardless of whether the data is plotted on a linear, semilogarithmic, or any other kind of scale. A monoexponential fit, customarily carried to a lower point on the descending portion of the left ventricular curve, would appropriately include first flow activity in other structures (e.g. aorta, chest wall, etc.) that also contribute to the equilibrium count rate. Exclusion of flow from these structures reduces the area under the curve and raises flow calculated by Eq. (1).

Thus each of the four difficulties mentioned above result in a relative overestimation of cardiac output by the technique that the authors employed. As a result, they found that lowering the equilibrium count rate by subtracting background tended to correct for other sources of overestimation.

Empirically, the authors found their approach useful, but it cannot be recommended in general. Difficulties could arise if one were to employ their approach with other cameras, other collimators, other doses of radionuclide, or alternative software for curve analysis. One could obtain very different results, and background correction as employed by the authors would not be appropriate. Methods for determining cardiac output using radionuclides should be carefully evaluated in each institution in which they are employed. Such quantitative methods should not be employed in the absence of appropriate software.

References

1. Kelbaek H, Hartling OJ, Skagen K, et al. First-pass radionuclide determination of cardiac output: an improved gamma camera method. *J Nucl Med* 1987; 28:1330–1334.
2. Glass EC, Rahimian J, Hines HH. Effect of region of interest selection on first-pass radionuclide cardiac output determination. *J Nucl Med* 1986; 27:1282–1292.
3. Glass EC, Cohen HA, Berens SC, et al. Functional evaluation of left heart by first-pass deconvolution analysis. *J Nucl Med* 1982; 23:P79.
4. Adams R, Hine GJ, Zimmerman CD. Deadtime measurements in scintillation cameras under conditions simulating quantitative nuclear cardiography. *J Nucl Med* 1978; 19:538–544.
5. Thompson HK, Starmer CF, Whalen RE, et al. Indicator transit time considered as a gamma variate. *Circ Res* 1964; 14:502-515.
6. Hamilton WF, Moore JW, Kinsman JM, et al. Studies on the circulation. IV. Further analysis of the injection method, and of changes in the hemodynamics under physiological and pathological conditions. *Am J Physiol* 1932; 99:534–551.

Edwin C. Glass
Saint John's Hospital and Health Center
Santa Monica, California

REPLY: We appreciate Dr. Glass's interest in our paper (*1*), and we agree that radionuclide first-pass techniques have been underutilized. The following comments are offered to clarify the questions raised by Dr. Glass.

Using the Siemens mobile cardiac camera equipped with a low-energy, all purpose collimator, deadtime losses are undetectable in the field below 2×10^6 cpm. From 555 MBq technetium-99m in vitro labeled red blood cells we usually record peak left ventricular activities below 2×10^5 cpm.

Compton scatter from other sources than the left ventricle should be corrected for during first-pass by exclusion of the right ventricular scatter and during equilibrium by subtracting background activity as described. Alternative procedures for background subtraction may be usable, such as subtraction of the first-pass activity in an identical background area as that used at equilibrium (*1*). Gamma variate fitting of the first-pass, time-activity curve is a widely accepted technique for curve area calculation that gives reliable results (*2,3*).

Assessment of the point of recirculation is not a sensitive factor in the first-pass radionuclide determination of cardiac output. This is ascribed to the nature of the gamma variate fit function, and suggests further that this technique be employed for area calculation.

Glass et al. recently described a swift and elegant first-pass technique for cardiac output determination (*4*). Great caution should be exercised, however, in the clinical application of this method, that does not consider background activity after complete mixing of the tracer, a crucial point of the first-pass technique (*5–7*). By estimating the blood volume of cardiac patients from height and weight predicted values of healthy subjects, relatively small distribution volumes of the tracer may counterbalance the overestimated equilibrium activity. A thorough evaluation of any technique for measurement of cardiac output should be evaluated on location as stressed by Dr. Glass.

References

1. Kelbaek H, Hartling OJ, Skagen K, et al. First-pass radionuclide determination of cardiac output: an improved gamma camera method. *J Nucl Med* 1987; 28:1330–1334.
2. Thompson HK, Starmer CF, Whalen RE, et al. Indicator transit time considered as a gamma variate. *Circ Res* 1964; 14:502–515.
3. Starmer CF, Clark DO. Computer computations of cardiac output using the gamma function. *J Appl Physiol* 1970; 28:219–220.
4. Glass EC, Rahimian J, Hines HH. Effect of region of interest selection on first-pass radionuclide cardiac output determination. *J Nucl Med* 1986; 27:1282–1292.
5. Donato L. Basic concepts of radiocardiography. *Semin Nucl Med* 1973; 3:111–130.
6. Kuikka J. In-113m radiocardiographic measurements of cardiopulmonary parameters in healthy subjects and in cardiac patients. University of Jyvaeskylae, Finland, 1976.
7. Lassen NA, Perl W. Volume, flow or mass, flux ratio (mean transit time): bolus injection. In: *Tracer kinetic methods in medical physiology.* New York: Raven Press, 1979:76–101.

Henning Kelbaek
Ole J. Hartling
Ole Munck
Herlev Hospital
DK-2730 Herlev
Denmark