$(1 + (1 - EF) + (1 - EF)^2 + \cdots) \cdot N_o$ = (geometric series) = $(FF/EF) \cdot N_o$. Obviously, if an identical result holds for each part of N_o that enters the ventricle in the succeeding diastoles, then it holds for the sum N_o, too, irrespective of the tempo of indicator ventricular input. The second part of Eq. (*1*) then follows, by observing that the two-pass particles should first regurgitate one time and are then ejected forward, the same reasoning establishes the other parts of Eq. (*1*). The sum of all components N_i equals the total number N_o, as expected: $\sum_1 N_k = N_o \cdot (FF/EF) \cdot \sum_1 (RF/EF)^{k-1} = N_o \cdot (FF/EF) \cdot (EF/FF) = N_o$.

If general requirements of stationary and linear indicator ventricular kinetics are satisfied, it can be shown (*2*) that the area under the indicator ventricle time-number curve (a) equals the product of the total indicator input (N_{tot}) and the mean transit time of indicator particles through ventricular cavity (MTT):

$$a = N_{tot} \cdot MTT. \quad (2)$$

In regurgitation, N_{tot} N_o since each particle renewal is the new count. In terms of the numbers N_i defined above: $N_{tot} = \sum_2 k \cdot N_k$, where the partition coefficient k stands for the number of particle renewals in the ventricle. Summing the above series: $N_{tot} = (FF/EF)\, N_o \sum_1 k \cdot (RF/EF)^{k-1} = (FF/EF) \cdot N_o (\sum_0 r \cdot (RF/EF)^r) \cdot (\sum_0 s \cdot (RF/EF)^s)$ = (geometric series product) = $(EF/FF) \cdot N_o N_o$.

Suppose that the renewal of the particle in the ventricle after each systolic regurgitation is not guaranteed in the succeeding diastole, but on average lasts longer. Then the ventricular radiohistogram could be made up of the components that are successively broader as the number of regurgitations increases. In other words, N_{tot} is partitioned in the following components:

$$\begin{aligned}
C_1 &= \sum_1 N_i = N_o && \text{0th regurgitation} \\
C_2 &= N_o - N_1 = N_o \cdot (RF/EF) && \text{1st regurgitation} \quad (3) \\
C_3 &= N_o - (N_1 + N_2) = N_o \cdot (RF/EF)^2 && \text{2nd regurgitation} \\
&\cdots \\
C_k &= N_o - (N_1 + N_2 + \cdots + N_{k-1}) = N_o \cdot \\
&\quad (RF/EF)^{k-1} && \text{kth regurgitation}
\end{aligned}$$

The first component C_1 is made up of the particles that did not regurgitate yet: it thus comprises the single transit particles and all multiple transit particles during their first transit. The component C_2 consists of the particles that regurgitate for the first time: excluding the single transit particles, it comprises all multiple transit particles during their second transit, or first regurgitation. The succeeding components C_i present the number of indicator particles in the ventricle in higher order regurgitations. The sum of all components C_i must equal the total indicator input N_{tot}: $C_i = N_o (RF/EF)^i = N_o (EF/FF) = N_{tot}$.

Denote by a_i the i^{th} component radiohistogram area. Using the number-area theorem expressed in Eq. (*2*) one finds:

$$a_2/a_1 = RF/EF. \quad (4)$$

This concludes the derivation of the postulate of Philippe et al. (*1*). Alternatively, one may use the total radiohistogram area a to arrive at the same goal:

$$(a - a_1)/a = RF/EF. \quad (5)$$

Equation (5) enables a more accurate RF/EF assessment since it obviates the need for part-by-part fit to determine the area a_2, which is an uncertain procedure at noise levels typical for the first-pass studies (*3*).

2. As documented by Philippe et al. in Figure 2B of their article (*1*), the longer transit time components are present even on the original radiohistogram of insufficient ventricles, and are pronounced on UIR obtained by deconvolution. This implies that avoiding recirculation by replacing the original curves with unimodal models prior the deconvolution, as done by Philippe et al. may have unfavorable results. Still, the deconvolution procedure is exactly valid if recirculation data of both LV and pulmonary curves are taken in account.

I reemphasize that an insufficient ventricle radiohistogram can sustain multimodality subject to quantitation only if the renewal of each regurgitant volume is extended in time. This may be the case in mitral or tricuspid insufficiency when, following rapid ventricular emptying the regurgitant particles dissolve in large, weakly contracting atria. This agrees with the successful demonstration of the method of Philippe et al. in the experimental model where the atria is an elastic balloon of 20-40 ml and the ventricle is the pump of 20 ml in end diastole.

3. In aortic and pulmonary insufficiency the regurgitant flow completely returns to the ventricle in the same cycle, where it mixes with the residual systolic volume and it is not possible to distinguish between an insufficient and competent, but slowly emptying ventricle. It should be appreciated in this context that the data sampling frequency used in the study of Phillipe et al. allow monitoring of the changes from cycle to cycle, not within the cycle.

In conclusion, although Phillipe et al. propose their method for the left side; i.e., mitral and aortic regurgitations, the principles of their methodology can also be derived in the model of mitral and tricuspid regurgitation.

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REPLY: We thank Eterović for his interest in our work. We appreciate his comments and the elegant mathematic derivation of the regurgitation quantitation formula.

In his comments, RF does not represent the regurgitant fraction but the regurgitant ejection fraction: the usual definition for RF is the ratio of the regurgitant stroke volume by the total stroke volume.

We do not, however, see the purpose of the formula 5

$(a - a_1/a = RF/EF)$. Furthermore, the UIR is not a noisy curve and therefore gamma fitting of the UIR components is not a problem. Indeed, when the UIR is obtained after lagged normal deconvolution, the unit impulse response (constrained to be a non negative sum of lagged normal curves) is well suited for gamma fitting (*1,2*). Theoretically, we agree with Eterović about the fitting before deconvolution, but in real life things are not always so mathematically obvious. We think that pulmonary and LV curve fitting are necessary, because the ends of the curves are noisy and the activity probably does not originate only from recirculation in the concerned compartment.

Finally, we would like to point out that although Eterović demonstrates that this model is better suited for mitral and tricuspid regurgitation, we only used it in mitral and aortic insufficiency: in our series, we studied four patients with pure aortic insufficiency, and correlation with contrast ventriculography was excellent (Patients 19, 20, 23, 24). It should be of interest to test this model in tricuspid regurgitation, as suggested by Eterović, but in this case, gamma curve fitting and deconvolution would probably not be necessary, because of the good curve quality and to the absence of dilution of the radionuclide bolus in the right heart.

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Thallium-201 SPECT in Coronary Artery Disease Patients with Left Bundle Branch Block

TO THE EDITOR: After having finished interpreting 13 thallium stress tests on a busy Monday in our nuclear imaging department, it was with great interest that I read DePuey's article "Thallium-201 SPECT in Coronary Artery Disease Patients with Left Bundle Branch Block," (*J Nucl Med* 1988; 29:1479–1485). On this given day, six patients were studied with single photon emission computed tomography (SPECT) imaging using the bulls-eye program that DePuey et al. discuss and three of these patients had left bundle branch block. Unfortunately, after reading their article on thallium-201 SPECT in patients with LBBB, I really have no further insight into the problem with false-positive studies than I had prior to reading this publication. The major problem I have with this article is the fact that the study population is so small (n = 14). This is an extremely small population of patients from which to generalize major comments regarding the utility of SPECT thallium imaging in patients with LBBB. The kind of information that practicing physicians need to know is what percentage of patients with LBBB will have false-positive thallium studies. This information cannot be reliably obtained when the sample size is so small.

One additional problem I had with the manuscript is that from reading the Methods section, it seems the interpretation of a positive study is based solely on reading bulls-eye polar coordinate maps. While my experience with thallium SPECT scanning using the bulls-eye polar coordinate maps is not extensive (SPECT Tl-201, n = 300; Planar Tl-201, n = 13,000), I have often found myself in a difficult situation where the tomographic sections appear to be normal, while the bulls-eye polar coordinate map is abnormal. Since it is well known that multiple factors can cause false-positive polar coordinate maps, I am reluctant to call an examination positive only in the basis of the polar coordinate map. From DePuey's article it seems that the tomographic sections themselves were not interpreted as part of the study, but that the authors only used bulls-eye information. If this is true, it would be helpful for me to know what percentage of the bulls-eye polar coordinate maps yielded information different from visual interpretation of the tomographic section.

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REPLY: We appreciate Dr. Winzelberg's comments regarding our investigation. When interpreting thallium-201 single photon emission computed tomography (^{201}Tl SPECT) studies, it is absolutely critical to inspect both oblique slices and polar coordinate maps. In our laboratory, in which now over 15,000 patients have been studied with ^{201}Tl SPECT, the 32 planar acquisitions are first viewed in "rotating" cinematic format to detect patient motion, excessive lung activity, tracer-avid visceral structures overlying the myocardium, and soft tissue attenuators. Next, oblique short axis, verticle long axis, and horizontal long axis slices for stress and then delayed images are viewed systematically. Only after a preliminary interpretation is drawn from oblique slice review do we inspect the bulls-eye plots, which aid in assimilation of the complex three-dimensional tomographic data. Finally, standard deviation plots in which patient data are compared to gender-matched normal files are reviewed. With increasing experience and awareness of the many causes of SPECT scan artifacts, very seldom is there discrepancy between interpretations from oblique slice and bullseye plot reviews. In our article only the quantitative analysis of lateral-to-septal myocardial ratios was performed on the bullseye plots alone.

Since for many years the literature has cautioned us of the nonspecificity of regional septal wall motion abnormalities, decreases in ejection fraction during exercise, and septal perfusion defects in patients with left bundle branch block (LBBB), we have discouraged referral of patients with LBBB for equilibrium radionuclide angiocardiography and ^{201}Tl imaging for the diagnosis of coronary artery disease. This is a major reason for our small patient population with cath correlation. We are sometimes referred patients with LBBB who have a low pretest likelihood of coronary disease. If ^{201}Tl SPECT demonstrates only a septal perfusion defect, patients usually do not undergo diagnostic catheterization.

When our manuscript was initially submitted for review, we included an additional ten asymptomatic patients who