Nizar A. Mullani  
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REPLY: We appreciate the careful study of our paper by Mr. Mullani, an experienced and innovative PET researcher. We believe the points raised in his letter do not affect the conclusions drawn in our paper. Each of his points are addressed below.

1. The "resolution frequency" is an ill-defined concept for a blurring function, such as a Gaussian, which tapers off continuously. Thus, we chose not to use that concept in our paper. Instead, we computed the correct integrals exactly and left it to the reader to draw conclusions from the graphical data. The fact that our results are expressed in units of full-width at half maximum (FWHM) does not mean that this measurement was assigned any special significance. Data derived from Mullani's phantom do not refute our conclusions.

2. The frequency-domain characteristics of a bar and a sphere are indeed different. The case of a flat object, such as a myocardial wall lying in the transaxial plane, can be treated by analysis of a "slab" of activity with infinite extent in the transaxial plane and finite axial dimension. Thus, the integral expressions reduce to the simple one-dimensional form. Figure 1 shows a new analysis for this case presented along with the three-dimensional data from our paper. Note that the

3. We agree that the acceptable sampling error depends on the application. That is the reason we presented complete graphical data; the investigator or tomograph designer can choose the appropriate slice spacing according to the imaging situation. Note that variability in the recovery coefficient only falls to zero for infinitely close spacing.

In summary, we believe our principal conclusion, slice spacing should be approximately one-half the full-width at half-maximum, is valid. We believe we are in basic agreement with Mullani. In fact, his great practical experience with tomograph design strengthens our shared opinions.

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Geometric Methods for Determining Left Ventricular Volume

TO THE EDITOR: The article "Left Ventricular Volume Calculation Using a Count-Based Ratio Method Applied to Multigated Radionuclide Angiography" by Massardo et al. (1) adequately delineates the disadvantages of geometric methods for determining left ventricular volume by radiocardiography and describes the limitations of heretofore reported count-proportional nongeometric methods. The authors describe the theory and application of a "count-proportional reference volume" method for determination of left ventricular volumes. They imply that this method avoids the pitfalls of geometric methods and retains the advantages of a nongeometric count proportional technique without the need for blood sampling and attenuation correction.

I suggest that this implication is erroneous. The method described is nothing more than a geometric model employing a sphere and an indirect measurement of its diameter rather than the more sophisticated prolate ellipsoid as described by Dodge et al. (2) for contrast angiography and as applied to radiocardiography by Strauss et al. (3).

Consider the prolate ellipsoid representing the left ventricle (LV) generated by rotation of the ellipse

\[
\frac{x^2}{L^2} + \frac{y^2}{S^2} = 1,
\]

where L and S are the long- and short-axes, respectively.
Since a unique sphere is delineated by the ratio of its volume, \( V \), and diameter, \( D \), the authors use their Equation 4 (as corrected), \( D = \left( \frac{6M^2R}{\pi} \right)^{1/3} \), to calculate \( D \), the diameter (and hence the volume) of a presumed sphere, where \( R \) is obtained from the total counts of the ellipsoid as viewed along the x-axis (LAO projection) and the maximum pixel counts from a reference volume along the long-axis corrected by \( M_z \), the calibration factor for pixel area. An exact equivalent expression necessitating neither total counts nor maximum pixel counts and using the same assumption of a spherical LV may be obtained geometrically as follows:

Let \( P \) = total number of pixels of the circle in the plane of the short-axis, \( S \). Its area \( K_o \), as seen from the LAO projection, is given by:

\[
K_o = PM^2 = \pi \left( \frac{S}{2} \right)^2 \quad \text{Eq. 1}
\]

so that

\[
S = M \left( \frac{P}{\pi} \right)^{1/2} \quad \text{Eq. 2}
\]

Since a sphere is assumed, \( S \) is the diameter, and

\[
V_o = \frac{4}{3} \pi \left( \frac{S}{2} \right)^3 \quad \text{Eq. 3}
\]

\[
V_o = 0.752 \text{M}^3 \text{P}^{1/2} \quad \text{Eq. 4}
\]

As an example, let \( L = 8 \), \( S = 6 \), and \( M = 0.1 \text{ cm} \). Then, the correct volume of the prolate ellipsoid is

\[
V_o = \frac{\pi}{6} LS^2 = 151 \text{ cm}^3.
\]

By the authors' method, if each voxel of volume \( M^3 \) contains one count, then

\[
C_0 = 151,000
\]

and

\[
C_r = 80
\]

\[
R = \frac{151,000}{80} = 1887
\]

and by the authors' Equation 5

\[
V_o = 1.382(0.1)^2(1887)^{1/2} = 113 \text{ cm}^3.
\]

By my method, the area \( K_o = \pi \left( \frac{S}{2} \right)^2 = 28.27 \text{ cm}^2 \) and from Equation 1

\[
P = \frac{28.27}{0.01} = 2827.
\]

Equation 4 yields

\[
V_o = 0.752(0.1)^2(2827)^{1/2} = 113 \text{ cm}^3
\]

identical to the value obtained by the authors' method.

Parenthetically, the resultant error in this example as compared to the volume of the prolate ellipsoid is

\[
\frac{151 - 113}{151} = 25%.
\]

Thus, by knowing the number of pixels, \( P \), and the size of the pixel, \( M \), one may calculate the volume of the sphere without even determining the counts.

Since it can be shown that \( R = \frac{4}{6} \), the authors' Equation 5 and my Equation 4 are exactly equivalent, thus showing that the authors' method is a geometric one. In the method I employ, the area of the LV in the LAO projection is used to find the volume rather than a direct measurement of \( S \), since in practice the projection of the LV is rarely circular. This direct geometric method has the advantage that no assumptions are made regarding either attenuation or the equivalency of the factor \( K \) in the authors' Equations 1 and 2.

It is not surprising that the authors obtained good correlation between their method, a geometric model which considers the LV a sphere (i.e., an ellipsoid of 0 eccentricity) with the contrast angiographic method which geometrically models the LV as a prolate ellipsoid. As the eccentricity of the ellipsoid approaches zero, the authors' assumptions improve. If a geometric method is to be used at all, the standard prolate ellipsoid model should be employed.

The count-based nongeometric methods avoid all assumptions as to the shape of the LV and also give high correlation coefficients with contrast angiographic methods (4); the values obtained are probably more realistic.

REFERENCES


Martin L. Nusynowitz
University of Texas Medical Branch
Galveston, Texas

REPLY: Dr. Nusynowitz is concerned that we have misrepresented our approach to a count-based chamber volume determination as non geometric. He correctly points out the fact that we assume a spherical model of the left ventricle (LV) in the LAO view in order to establish the relationship between counts \( (N_{max}) \) and a reference volume \( (M^3d) \). Given that relationship, we can then calculate the volume of any chamber, regardless of shape and, in fact, the LV volume measurement comes from the counts in the LV at end-diastole and the relationship described above. The reference volume approach requires some calculable volume within the image data to define the counts-to-volume relationship. However, no specific assumptions about the geometry of the chamber to be measured are necessary.
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Martin L. Nusynowitz


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