Re: Validity of Left-Ventricular Ejection Fractions Measured at Rest and Peak Exercise by Equilibrium Radionuclide Angiography Using Short Acquisition Times

I compliment Dr. M. E. Pfisterer and colleagues on their paper relating to short acquisition times in the measurement of left-ventricular ejection fraction (LVEF) (*1*). The only error that is increased by shortening the acquisition time is the statistical error associated with the individual values in the equation:

$$\text{LVEF} = \frac{\text{LV total counts at ED} - \text{LV total counts at ES}}{\text{LV total counts at ED} - \text{background counts}} \quad (1)$$

The importance of the parameter LV total counts at ED (EDCt) is immediately identified. (EDCt = net LV counts + background counts.) LV total counts at ES (ESCt) is a function of the ejection fraction, and a background count is usually derived by any one of a variety of methods (*2*).

The value of the statistical error on LVEF (ΔEF) can readily be ascertained as follows:

$$\frac{\Delta EF}{EF} = \sqrt{\nu_1^2 - \nu_2^2} \quad (2)$$

where ν_1 = relative standard deviation in ED counts − ES counts, and ν_2 = relative standard deviation in ED counts − background counts. ν_1 and ν_2 are given by

$$\nu_1 = \frac{\sqrt{EDCt + ESCt}}{EDCt - ESCt}$$

and

$$\nu_2 = \frac{\sqrt{EDCt + bkgd}}{EDCt - bkgd}$$

where EDCt = LV total counts at ED, ESCt = LV total counts at ES, and bkgd = background counts.

It is therefore possible to plot out the value of the fractional error, $\Delta EF/EF$, as a function of EDCt. This is done in Fig. 1 for an LVEF of 50%. From the error-function graph, the fractional error is 4.5% for typical equilibrium studies where LV counts = 10,000 or EDCt = 22,200. Therefore the error ΔEF (1 s.d.) = $0.045 \times 0.05 = 0.023$.

This value is slightly higher than the value given by Pfisterer et al., who obtained a value of 0.012 for ΔEF. The reason for the discrepancy is that the error in this background contribution has been overlooked in Pfisterer's paper. Similarly, the other statistical errors in LVEF quoted in the paper are too low. The quoted statistical errors and the correct statistical error are given in Table 1.

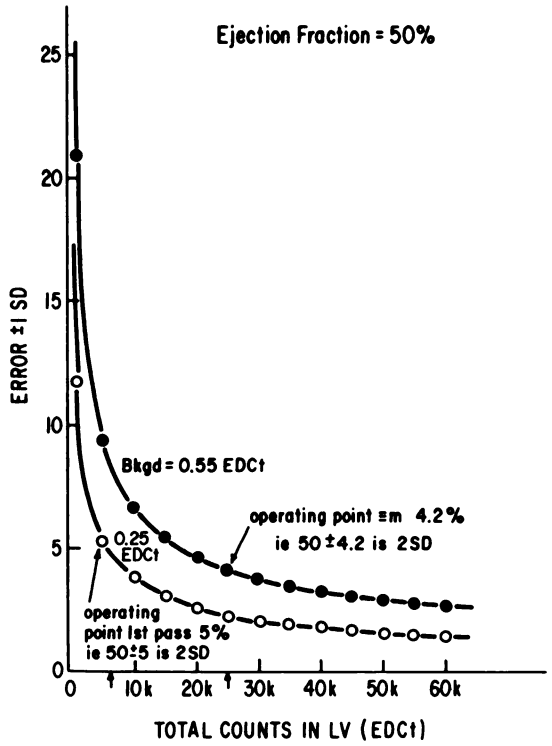

FIG. 1. Plot of error function, $100 \times \Delta EF/EF$, against total counts in LV at end-diastole (EDCt). Two curves are shown for background contributions: a typical equilibrium study, with background 55% of EDCt; and typical first-pass study, with background 25% of EDCt. Typical operating positions for the two types of study are shown.

These new values do not substantially alter the conclusion of Pfisterer et al., that rapid acquisition of equilibrium data should provide adequate precision for LVEF measurement.

The statistical error associated with LVEF measurement and with assessment of regional wall motion is dealt with in detail in another publication (*3*).

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TABLE 1.

Acquisition time	LV counts (net)	LV counts + bkg (EDCt)	Quoted ΔEF (1 s.d.)	Corrected ΔEF (1 s.d.)
5 min	10,000	22,222	0.012	0.023
2 min	4,000	8,888	0.019	0.037
1 min	2,000	4,444	0.033	0.050

REFERENCES

1. PFISTERER ME, RICCI DR, SCHULER G, et al. Validity of left-ventricular ejection fractions measured at rest and peak exercise by equilibrium radionuclide angiography using short acquisition times. *J Nucl Med* 20: 484–490, 1979
2. TAYLOR DN, GARVIE NW, HARRIS D, et al. The effect of various background protocols on the measurement of left ventricular ejection fraction in equilibrium radionuclide angiography. *Br J Radiol* 53: 205–209, 1980
3. TAYLOR DN: Error analysis of radionuclide methods of left ventricular functional assessment. Ph.D. Thesis, University of Southampton, 1980

Reply

We thank Dr. Taylor for his comments and the very useful graph (Fig. 1) depicting the potential random errors associated with ejection-fraction calculations by the first-pass and equilibrium methods. Readers are reminded that the statistical considerations mentioned in our article and by Dr. Taylor pertain to typical counting rates, specified recording times, and in the specific case of a 0.50 ejection fraction (EF); the statistical errors become somewhat worse with lower ejection fractions and less as EF increases. There are other potential sources of error besides random uncertainties associated with low count rates, and these should be considered in the context of the validity of single or serial EF measurements. The most significant factor is the precision with which the LV and noncardiac background regions of interest are assigned. Accordingly, every laboratory should periodically assess its inter- and intraobserver variability using the same recorded data and from data recorded after repositioning the detector, as well as determine accuracy of a single EF value using an agreed upon gold standard.

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Early Multiprojectional Hepatic Imaging in Tc-99m PIPIDA Cholescintigraphy

Brown et al. (*1*) have recently reported a favorable comparison between Tc-99m sulfur colloid (TcSC) and the Tc-99m iminodiacetic acid (IDA) derivatives in hepatic scintigraphy. They conclude, however, "IDA will not be a replacement for TcSC scintigraphy because of the difficulty of doing multiple projections. . . ." For several months we have routinely imaged the liver in multiple projections (anterior, posterior, right lateral, RAO, LAO) as the initial phase of hepatocholescintigraphy, beginning at 5 min after i.v. injection of 7 mCi of Tc-99m (*p*-isopropyl acetanilide) iminodiacetic acid (PIPIDA). This procedure takes approximately 15 min and coincides with the hepatocyte phase. It is followed by scanning of the biliary tree and its drainage at 20, 30, 40, 50, and 60 min, and beyond if indicated.

We wish to present two cases illustrating the utility and feasibility of obtaining these additional views. Case 1 is that of a 70-year-old man admitted with a fever of unknown origin. Chest and abdominal radiographs revealed the presence of multiple lucencies in the right upper abdominal quadrant, suggesting the possibility of an abscess, perhaps secondary to perforation of the gallbladder. PIPIDA hepatocholescintigraphy (Fig. 1) revealed a large photopenic space-occupying lesion at the dome of the right hepatic lobe, and early presence of tracer in the transverse colon. Surgery confirmed the perforation of the gallbladder, a large hepatic abscess, and a cholecystocolonic fistula.

Case 2 is that of a 56-year-old man who developed fever and right upper quadrant pain and tenderness, with persistent drainage from a T-tube in the common bile duct, placed after cholecystectomy and common duct exploration. Because of the clinical suspicion of subphrenic and/or hepatic abscess as well as the possibility of bile leak, the radiologist recommended both a liver-lung scan and a PIPIDA scan. With Tc-99m microspheres and PIPIDA rather than TcSC, it was possible to perform both examinations at the same sitting. There was no evidence of abscess or bile leak (Fig. 2). There was no drainage of the common bile duct into the small bowel, and repeat surgery showed that this obstruction was on a neoplastic rather than an inflammatory basis.

Over the past several years, much has been written on hepatobiliary imaging using several IDA derivatives, initially the dimethyl (HIDA) and *p*-isopropyl (PIPIDA) congeners (*2–4*), and most recently the di-isopropyl (DISIDA) (*5*). A review of the literature indicates that most authors obtain only anterior and right lateral views, some beginning as early as 5 min after injection, others not until 15 min after. Weissman et al. (*6*) described the additional information that may be gained during the hepatocyte phase, although they do not specify what views were obtained. Brown et al. (*1*) do not explain why they find it difficult to image the liver in multiple projections.

We have experienced no difficulty in obtaining views of the liver in multiple projections, nor have these hindered the cholescintigraphic examination, which continues on from 20 min after injection. The drawbacks are possible failure of imaging of the tracer due to hyperbilirubinemia or hepatocyte dysfunction, and the lack of imaging of the spleen and bone marrow, as with TcSC. Nonetheless, we feel that this minor change of protocol has many advantages and, in selected cases, may obviate the need for a TcSC liver scan, with resulting decreased radiation exposure to the pa-

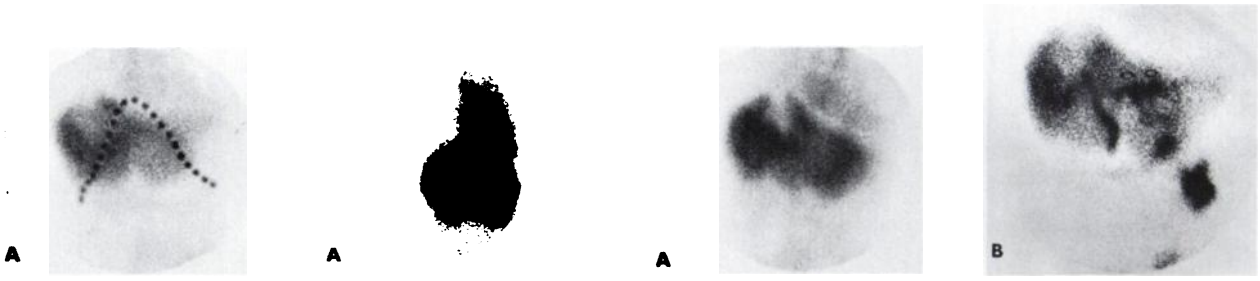

FIG. 1. (A) Case 1. Scintiphotos of liver obtained at 5–20 min after injection of 7 mCi of Tc-99m PIPIDA, showing photopenic area in right hepatic lobe. Left anterior, middle—right lateral, and right—right anterior oblique. (B) Scintiphoto of right upper quadrant in same patient at 30 min, demonstrating cholecystocolonic fistula (arrowheads).