Radionuclide First Transit and R-Wave Synchronized Imaging: Correlation of Three Methods of Determining Left Ventricular Ejection Fraction with Contrast Angiography

Gordon E. Wynant

Harrisburg Hospital, Harrisburg, Pennsylvania

Left ventricular ejection fractions in 25 patients, as determined by first transit and R-wave synchronized imaging, were compared with contrast angiography. The ejection fraction obtained by first transit and R-wave synchronized images using a varying region of interest correlated well with the contrast angiography (r = 0.96; r = 0.99 respectively). Use of a fixed end-diastolic region of interest consistently underestimated the ejection fraction (r = 0.92).

Left ventricular performance is commonly determined by contrast angiography. Radionuclide angiocardiography is rapidly becoming a diagnostic tool in the evaluation of heart disease. The left ventricular ejection fraction (LVEF) determined by first transit and equilibrium techniques has been shown to be accurate (*1–15*). Current R-wave synchronized imaging has also proved an accurate and reproducible method for determining left ventricular performance (*16–23*). This study compares the accuracy of LVEF determinations from: (a) first transit data, (b) R-wave synchronized images using an operator-defined, fixed end-diastolic region of interest, and (c) computer-defined regions of interest that track the left ventricular border through systole.

Methods

Twenty-five patients undergoing cardiac catheterization also had radionuclide first transit and R-wave synchronized blood pool imaging. Contrast angiography was performed in the 30° right anterior oblique projection after 40–60 ml of Renografin was injected into the left ventricle. Cineradiography images were recorded and the LVEF was calculated by conventional single plane area length method (*24*).

Method 1: First Transit End-Diastolic Area of Interest

Radionuclide first transit imaging was performed with the patient supine in the anterior projection using a 10 in. single crystal Picker camera equipped with a high sensitivity collimator. A 20 gauge intravenous angiocatheter was inserted into the medial antecubital vein. The patient received a rapid bolus injection of 20–30 mCi of Tc-99m HSA (human serum albumin) followed by a 10–15-ml saline flush. First transit scintillation data were recorded in a dedicated computer (ADAC) in a 32×32 byte mode matrix with a framing rate of 0.05 sec/image and stored on magnetic disc. A left ventricular end-diastolic frame was chosen. An operator-defined left ventricular region of interest and a left paraventricular background region of interest were created with a lightpen. A background-

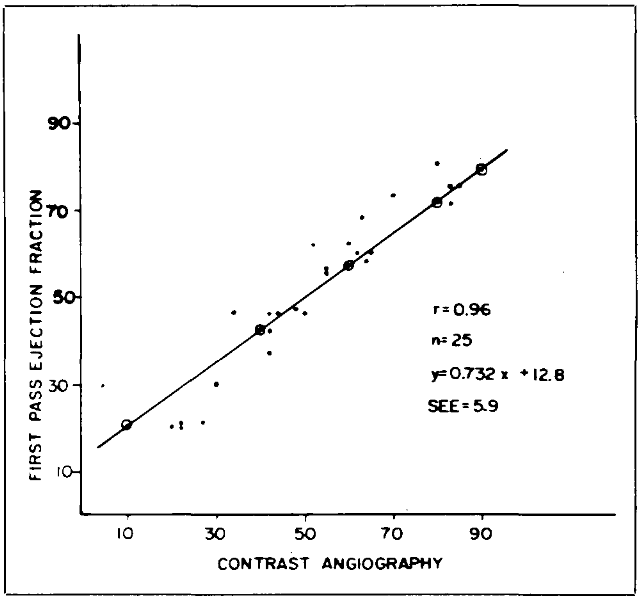

FIG. 1. Comparison of ejection fraction determined by first transit and contrast angiography.

For reprints contact: Gordon E. Wynant, Harrisburg Hospital, Section of Nuclear Medicine, Harrisburg, PA 17101.

subtracted, time-activity data curve was generated and the ejection fraction was calculated by identifying with the lightpen end-diastolic and end-systolic count data.

As shown, ejection fraction equals:

$$\frac{\text{ED Counts - ES Counts}}{\text{ED Counts}}.$$

After a 10-min equilibration period, R-wave synchronized images were acquired in the anterior and left anterior oblique projections. The cardiac cycle was divided into 16 image segments and stored directly in core memory (ADAC) as consecutive images in a 64 × 64 byte mode matrix. Upon completion of the equilibrium study, the images were transferred to magnetic disk. An algorithm developed by Bell et al. was used to discriminate arrhythmic cycles (*25*). The LVEF was calculated using two different methods.

Method 2: Operator-Defined End-Diastolic Fixed Region of Interest

A single left ventricular region of interest was defined by the operator using a left anterior oblique end-diastolic image. A background region of interest was also created. A time-activity curve of the cardiac cycle using only one ventricular area of interest was generated and corrected for background. The ejection fraction was calculated from end-diastolic and end-systolic count data.

Method 3: Computer-Defined Varying Regions of Interest

Nine point spatial smoothing with background subtraction was performed on each image in the cardiac cycle. An automated computer program then:

1. determines the left ventricle region of interest for each image of the cardiac cycle (the program permits operator intervention to modify the region of interest);
2. determines a background region of interest;
3. generates a time-activity curve representative of counts obtained from each region of interest; and
4. calculates the ejection fraction from end-diastolic and end-systolic count data.

Results

All three methods were successfully performed with each of the 25 patients. The processing time for the first transit method was 10–15 min. Processing time for the end-diastolic fixed region of interest was 10 min. The automatic computer-defined regions-of-interest method rarely worked in a totally automatic fashion. It was necessary for the operator to edit the regions of interest in 80% of the patients to assure that each region corresponded to visually acceptable ventricular borders. This intervention was greater when there was considerable change in the left ventricle size.

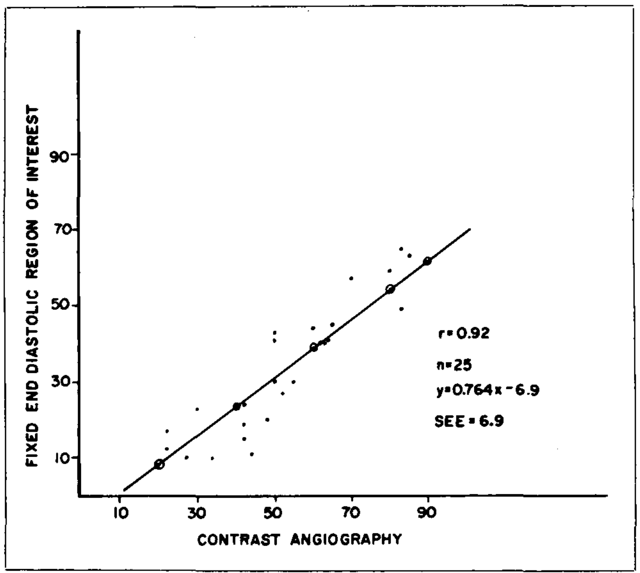

FIG. 2. Comparison of R-wave synchronized blood pool radionuclide method using fixed end-diastolic region of interest (method 2) to contrast angiography.

Regression plots for each method are shown in Figs. 1, 2, and 3. The fixed region-of-interest method underestimated the ejection fraction as compared to the varying region-of-interest method (Fig. 4).

Conclusion

The first transit and R-wave synchronized imagings differ markedly in their methodology but both techniques

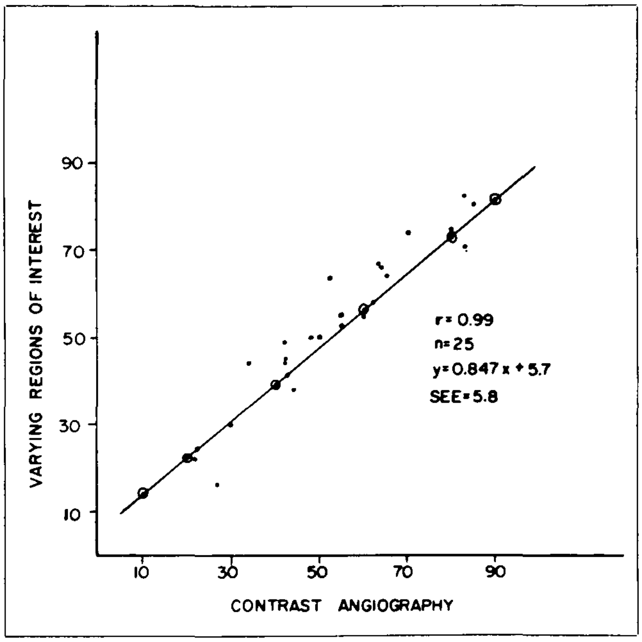

FIG. 3. Comparison of R-wave synchronized blood pool radionuclide method using varying region of interest (method 3) to contrast angiography.

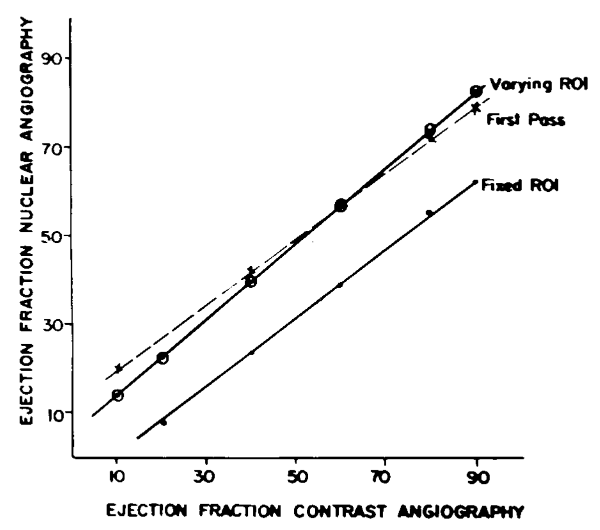

FIG. 4. Comparison of radionuclide ejection fraction by first transit, fixed end-diastolic and varying regions of interest methods to contrast angiography. Underestimation of ejection fraction using fixed region-of-interest method is apparent.

provide a reliable means of assessing global left ventricular performance. A region of interest that remains fixed throughout the cardiac cycle (method 2) will record data that may not be representative of the left ventricle during systole. This causes the systole count to be overestimated, which in turn reduces the apparent ejection fraction. This underestimation of the ejection fraction can be eliminated if the region of interest becomes smaller with systole.

The ejection fraction determined by first transit and R-wave synchronized images using a varying region of interest throughout the cardiac cycle correlated well with contrast angiography (r=0.96; r=0.99, respectively). The fixed end-diastolic, region-of-interest method consistently underestimated the ejection fraction (r = 0.92).

References

1. Weber PM, dos Remedios LV, Jasko IA: Quantitative radioisotopic angiocardiography. *J Nucl Med* 13: 815–822, 1972

2. Steele PP, Van Dyke D, Trow RS, et al: Simple and safe bedside method for serial measurement of left ventricular ejection fraction, cardiac output, and pulmonary blood volume. *Br Heart J* 36: 122–131, 1974

3. Steele P, Kirch D, Matthews M, et al: Measurement of left heart ejection fraction and end-diastolic volume by a computerized, scintigraphic technique using a wedged pulmonary artery catheter. *Am J Cardiol* 34: 179–186, 1974

4. Berndt T, Alderman EL, Wasnich, et al: Evaluation of portable radionuclide method for measurement of left ventricular ejection fraction and cardiac output. *J Nucl Med* 16: 289–292, 1975

5. Ashburn WL, Kostuk WJ, Karliner JS, et al: Left ventricular volume and ejection fraction determination by radionuclide angiography. *Semin Nucl Med* 3: 165–176, 1973

6. Van Dyke D, Anger HO, Sullivan RW, et al: Cardiac evaluation from radioisotope dynamics. *J Nucl Med* 13: 585–592, 1972

7. Schelbert HR, Verba JW, Johnson AD, et al: Nontraumatic determination of left ventricular ejection fraction by radionuclide angiocardiography. *Circulation* 51: 902–909, 1975

8. Jengo JA, Mena I, Blaufuss A, et al: Single pass technique for bedside determination of left ventricular (LV) ejection fraction (EF) and segmental wall motion (SWM). *Am J Cardiol* 39: 285, 1977 (abst)

9. Strauss HW, Zaret BL, Hurley PJ, et al: A scintiphotographic method for measuring left ventricular ejection fraction in man without cardiac catheterization. *Am J Cardiol* 28: 575–580, 1971

10. Secker-Walker RH, Resnick L, Kunz H, et al: Measurement of left ventricular ejection fraction. *J Nucl Med* 14: 798–802, 1973

11. Berman DS, Salel AF, DeNardo GL, et al: Clinical assessment of left ventricular regional contraction patterns and ejection fraction by high-resolution gated scintigraphy. *J Nucl Med* 16: 865–874, 1975

12. Drew D, Botvinick E, Shames D, et al: Radioisotope ventriculography is equivalent to the invasive contrast technique. *Circulation* 54 (2): (Suppl) 109, 1976 (abst)

13. Green MV, Brody WR, Douglas MA, et al: Count rate measurement of left ventricular ejection fraction from gated scintigraphic images. *J Nucl Med* 17: 557, 1976

14. Weaver WD, Hamilton GW, Williams DL, et al: Reproducibility of the ejection fraction measured by first transit radionuclide studies. *J Nucl Med* 17: 556, 1976 (abst)

15. Hamilton GW, Weaver WD, Williams DL, et al: Calculation of ejection fraction from first transit radionuclide data: A comparison of several methods with contrast angiography. *J Nucl Med* 17: 556, 1976 (abst)

16. Strauss HW, Singleton R, Burow R, et al: Multiple gated acquisition (MUGA): An improved noninvasive technique for evaluation of regional wall motion (RWM) and left ventricular function (LVF). *Am J Cardiol* 39: 284, 1977 (abst)

17. Borer JS, Bacharach SL, Green MV, et al: Realtime radionuclide cineangiography in the noninvasive evaluation of global and regional left ventricular function at rest and during exercise in patients with coronary-artery disease. *New Engl J Med* 296: 839–844, 1977

18. Burow RD, Strauss HW, Singleton R, et al: Analysis of left ventricular function from multiple gated acquisition cardiac blood pool imaging. Comparison to contrast angiography. *Circulation* 56: 1024–1028, 1977

19. Folland ED, Hamilton GW, Larson SM, et al: The radionuclide ejection fraction: A comparison of three radionuclide techniques with contrast angiography. *J Nucl Med* 18: 1159–1166, 1977

20. Robertson MC, Coleman AR, Cheng CH, et al: R-wave synchronized blood pool imaging: Reproducibility of ejection fraction measurements. In *Proceedings of the Society of Nuclear Medicine 2nd Annual Western Regional Meeting, Las Vegas, Navada, Oct 21-23, 197/8* (in press)

21. Trobaugh GB, Kennedy JW, Hamilton GW, et al: Reproducibility of ventricular function measurements by angiographic and radionuclide angiography. *Am J Cardiol* 41: 439, 1978 (abst)

22. Williams DL, Hamilton GW: The effect of errors in determining left ventricular ejection fraction from radionuclide counting data. In *Proceedings of the Symposium on Selected Computer Aspects of Nuclear Cardiology*. New York, Society of Nuclear Medicine, 1978, pp 107–117

23. Green MV, Brody WR, Douglas MA, et al: Ejection fraction by count rate from gated images. *J Nucl Med* 19: 880–883, 1978

24. Dodge HT: Determination of left ventricular volume and mass. *Radiol Clin N Am* 9: 459–467, 1971

25. Bell GB, Spade BW, Scheibe PO, et al: Cyclically gated cardiac studies with R-R interval-dependent window widths. *Proceedings of the Symposium on Nuclear Cardiology: Selected Computer Aspects.* New York, Society of Nuclear Medicine, 1978, pp 63–73