Left Ventricular Ejection Fractions Using a Multicrystal Scintillation Camera

Kathryn Wilkins and Lionel Reese

St. Joseph's Hospital and University of Western Ontario, London, Ontario, Canada

Left ventricular ejection fractions (LVEF) were measured after injection of a bolus of Tc-99m gluconate. These ejection fractions were then compared to values obtained by contrast angiography. The importance of such parameters as delivery of the bolus, collimation, projection used, and parameters chosen for subsequent data analysis were evaluated. We found that results were most critically dependent upon delivery of radioactive bolus and background selection. Correlation of LVEF obtained in the LAO-20° view to values obtained at the time of catheterization provides a statistically significant relationship.

The need for a reliable, noninvasive method to serially determine left ventricular function is apparent. With experimentation, we have developed an acceptable method of calculating left ventricular ejection fraction (LVEF), using the first pass of a radioactive bolus through the heart.

As in studies performed by Schad *(1)*, we used the Baird System "70" multicrystal camera, which is computerized and programmed for ejection fraction calculation, for all our studies. Two series of experiments were carried out to find a technique that would best provide accurate, reproducible measurements of LVEF.

Materials and Methods

Patients referred for cardiac angiography were also, with their consent, referred to the nuclear medicine department for radionuclide evaluation of LVEF. A second radioisotope measurement, either on the same or the following day, was performed on selected patients.

Patients were positioned under the detector and injected with a radioactive bolus of Tc-99m gluconate. We used this radioisotope because it is cleared rapidly by the kidneys and, therefore, results in minimal background for sequential examinations. The site of the injection was always the medial basilic vein of the right arm. The distribution of radioactivity over the chest was recorded for 1 min as 600 100-msec frames.

A serial display was produced to follow the path of the bolus through the chambers of the heart. The area of the superior vena cava was flagged and a histogram produced at 0.5-sec intervals. A FWHM of the peak of less than 2 sec was accepted as representing a discreet bolus. When we were satisfied that both the position and the bolus were acceptable, the needle was removed and the patient was dismissed. If we were not satisfied with either of these parameters, the necessary changes were made, i.e., a background frame was collected and another injection given.

The LVEF is calculated according to the following equation:

$$\frac{\Sigma(ED_i - BGD) - \Sigma(ES_i - BGD)}{\Sigma(ED_i - BGD)} \times 100, \qquad (1)$$

where BGD represents the counts in a background frame chosen by the operator to represent the activity in the underlying structures, such as lung and right ventricle; ED_i represents the counts in a frame that corresponds to the ith peak; ES_i represents the counts in a frame that correspond to the ith trough; and Σ represents the sum of all peak frames or trough frames.

In order to obtain these parameters, the left ventricle was flagged and a histogram produced, which consisted of peaks and troughs corresponding to each diastole and systole. The diastolic peaks chosen were 80% of maximum and above. The frame numbers at which the chosen peaks and corresponding troughs occurred were then entered into the computer along with a background frame obtained from the same histogram. The computer then calculated the ejection fraction. The number of peaks chosen varied from patient to patient, depending on the patient's heart rate, with the average number of peaks chosen being four.

Patients were studied using two different protocols; this allowed us to determine the importance of different collimation, in relation to injected dose, delivery of bolus, and projection used. In addition, we systematically changed the selection of the background frame to determine its importance to the calculation. The first series consisted of eight patients in LAO 45° and anterior projections.

A 1½-in. collimator was used and a 30-mCi bolus was injected using an 18-gage needle with attached stopcock and thin anaesthesia extension tubing (approximately 1-mm i.d.). Twenty cubic centimeters of normal saline were used to flush the bolus.

The second series consisted of 17 patients evaluated in the LAO-20° projection. A 1-in. collimator was used and the injected dose reduced to 15 mCi. We demonstrated at

For reprints contact: Kathryn Wilkins, Dept. of Nuclear Medicine, St. Joseph's Hospital, London, Ontario, Canada N6A 4V2

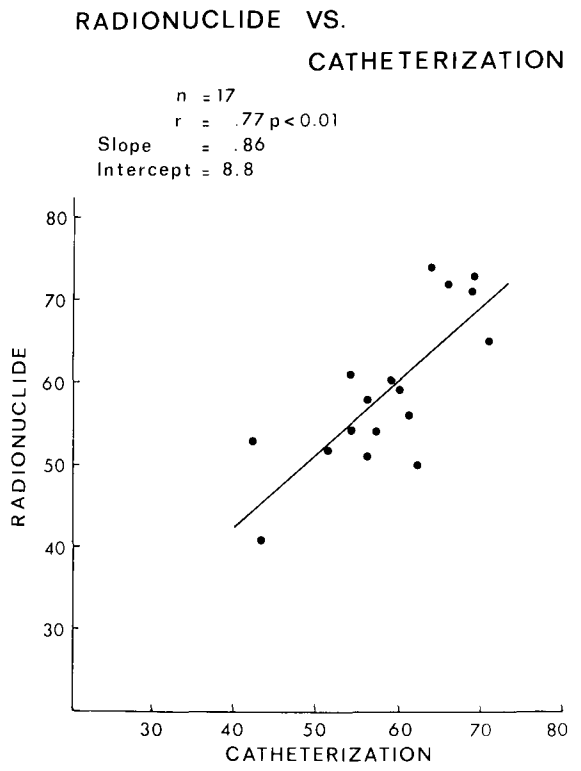

FIG. 1. Correlation of LVEF calculated by the radionuclide method compared with those calculated by contrast angiography.

this time that the amount of radioactivity lost in the stopcock apparatus was very dependent upon the injected volume. For example, when we used a tuberculin syringe in conjunction with stopcock, flushing apparatus, and injected volume of 0.4 ml, approximately 30% of the activity was left in the syringe, stopcock, tubing, and needle. When we used the same dose of gluconate in a standardized volume of 0.5 ml, the loss of activity in the apparatus was approximately 20%. Therefore, all doses of gluconate were standardized to a volume of 0.5 ml. Also, small air bubbles were introduced before and after the bolus immediately prior to injection. Thin extenstion tubing was replaced with thicker tubing (approximately 3.2-mm i.d.), and an 18-gage hypodermic needle replaced with an 18-gage angiocath.

Results

In the first series, the radionuclide assessment of LVEF did not correlate significantly with the values obtained from contrast angiography. On examination, we found that overall counting rates were low, resulting in considerable uncertainty in the calculated value of LVEF. This appeared to occur as a result of loss of activity in the stopcock apparatus and the dispersal of the bolus in the thin extension tubing.

In the second series, we obtained much better results. The correlation of LVEF obtained during catheterization to those obtained with our present technique was moderately good ($r = 0.77$; $p < 0.01$), as shown in Fig. 1. In this series the bolus was markedly improved over the first series (FWHM), presumably because of the defining air bubbles, standarized volume, and enlarged tubing. The first series resulted in a FWHM of 2–4 sec, while the second series resulted in a FWHM of 1–2 sec. Overall counting rates were also improved even though the injected dose was reduced, probably because of reduced collimation, as well as improvement in the quality of the bolus. Figure 2 graphically shows the excellent correlation between repeat studies on the same patient ($r = 0.97$, $p < 0.01$). In 60% of the cases the patients were not moved between studies and there was a time interval of approximately 10 min between injections. In 40% of the cases the patients had their studies done at least 24 hr apart.

The critical importance of the background frame selection (Eq. 1) became apparent in this second investigation. We found that reproducibility and correlation to contrast angiography were markedly reduced if the background frame was not taken just prior to the first trough (Fig. 3B). In the first series, the area used for background selection was found not to represent the total amount of background (Fig. 3A). At that point in time, the bolus had not yet reached the left atrium and, therefore, did not compensate for activity contributed by the left atrium.

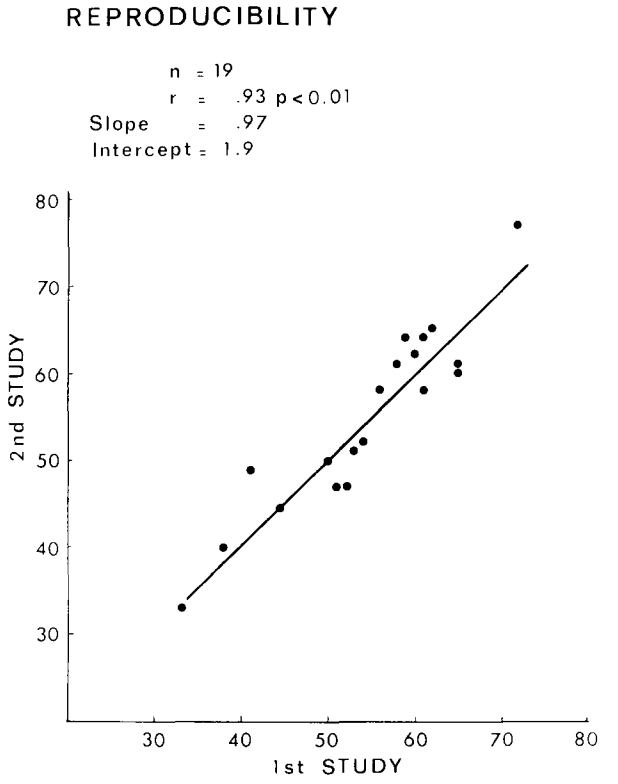

FIG. 2. Correlation of LVEF, calculated by the radionuclide method, and performed at two different times on the same patient.

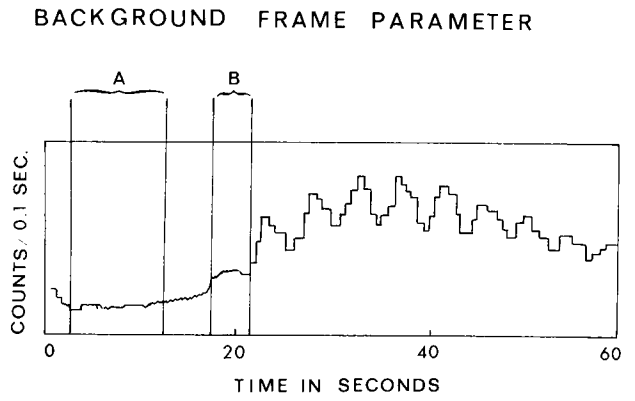

FIG. 3. Time-activity curves showing the area (A), which was used for background subtraction in series 1, and area (B), which was used in series 2.

Discussion

These results indicate that with the use of proper technique, left ventricular ejection fractions can be accurately measured noninvasively. Utilization of the background-subtraction mode permits serial examinations to be carried out to determine changes in LVEF following treatment or stress. In fact, Fig. 2 supports the validity of such sequential examinations. Additionally, when contrast angiography is performed, values for ejection fractions often cannot be obtained because the invasive nature of the procedure can cause premature ventricular contractions. Of the 26 patients investigated in this study, 30% could not be assessed by catheterization methods due to these premature ventricular contractions. In such cases, the ventricle contracts prematurely and never fills to its maximum, thereby resulting in an erroneous end diastolic image. No such measurement failures occurred using our radionuclide technique.

The remarkable reproducibility of repeat studies (Fig. 2) not only suggests that there is little error in the determination of LVEF, but also suggests the validity of the single-pass technique as a true representation of the average cardiac cycle.

It should be pointed out that LVEF measured by our technique did not correlate highly to those measured radiographically. This does not imply though that our estimation of this parameter has a large error associated with it, since a large portion of this difference is probably related to the imprecise radiographic technique. Therefore, the observed correlation ($r = 0.77$) is probably as good as is to be expected, and, in fact, others have obtained similar values (*2*).

Acknowledgments

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References

1. Schad N: Nontraumatic assessment of left ventricular wall motion and regional stroke volume after myocardial infarction. *J Nucl Med* 18: 333–341, 1977

2. Groch MW, Gottlieb S, Mallon SM, et al: A new dual-probe system for the rapid bedside assessment of left ventricular function. *J Nucl Med* 17: 930–936, 1976