Right ventricular ejection fraction: Comparison of technetium-99m first pass technique and ECG-gated steady state krypton-81m angiography

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Abstract. Right ventricular ejection fraction (RVEF) calculated from ECG-gated steady-state 81mKr angiography and from 99mTc first-pass studies were compared in 30 patients using a digital, single crystal, gamma-camera. Despite the two entirely different approaches RVEF values obtained by the two methods were comparable (r = 0.97): the mean absolute difference between the two techniques was 2.5% +/- 1.5% and the largest observed absolute difference was 5%. In the absence of an accepted reference method for measuring RVEF, this close correlation provides indirect validation of both techniques. The choice of method will therefore depend on several factors, including radiotracer availability, the characteristics of the gamma-camera and the protocol of clinical investigation.

Key words: Right ventricular ejection fraction – Steady state 81mKr – First-pass 99mTc

The study of the right ventricle by means of contrast angiography and echocardiography has been hampered by the complex anatomical configuration of the cavity, precluding the use of a simple geometric hypothesis for the calculation of volume and ejection fraction.

Radionuclide methods are particularly attractive for measuring RVEF as they are virtually independent of the shape of the cavity. Two methods, the first pass technique (Steele et al. 1976; Tobinick et al. 1978; Berger et al. 1978) and 81mKr steady state angiography (Knapp et al. 1980; Sugrue et al. 1983; Ham et al. 1983) have been shown to provide accurate measurement of RVEF in a variety of clinical settings. Indeed, both techniques allow selective imaging of the right ventricular cavity. The first pass technique provide temporal separation of the cardiac chambers; while krypton has the unique characteristic of being almost completely cleared from the blood pool during its first pulmonary transit. Using 81mKr, the study of the RV can therefore be performed in the right anterior oblique projection, allowing optimal separation between the right atrium and ventricle.

Besides this similarity however, the techniques differ in many aspects including acquisition procedures, number of cardiac beats available for the calculation of ejection fraction, count densities and background.

The aim of this study was to compare RVEF calculated from 99mTc first pass and ECG gated steady state 81mKr studies performed in the same patients using a digital, single crystal, gamma camera.

Materials and methods

Patient population

30 patients (19 males and 11 females; mean age 57 years, range 39 years to 76 years) with chronic obstructive pulmonary disease were investigated at 2 day intervals to compare first pass 99mTc and steady state 81mKr techniques for measuring RVEF. All patients were clinically stable and usual drug administration was continued during this period. Informed consent was obtained from each patient.

ECG gated 81mKr steady state ventriculography

The detailed procedure of the ECG gated 81mKr steady state study of the right ventricle has been described previously (Ham et al. 1986). 81mKr was produced by continuous elution of a sterile, commercially available, 12 mCi 81Rb-81mKr generator and was perfused into the right basilic vein. Patients were studied supine, in the 30° right anterior oblique projection using a large field, digital, single crystal, gamma camera connected to a mini-computer (Apex Line, Elscint Company) and equipped with a high sensitivity, medium energy, parallel hole collimator (APC 56). Sixteen ECG gated frames were acquired on a 64 x 64 matrix with a software zoom of 2 and a preset time of 600 s. Background activity, mainly pulmonary, was corrected by using 99mTc-MAA lung perfusion scintigraphy acquired in the same position immediately following completion of the gated study. Corrected activity in the nth pixel of a given frame (A'n) was given by

\[ A'n = A'n - (A'n, Tc) (R, Kr/R, Tc) \]

where \( A'n \) was the activity of the pixel on the MAA image; \( R, Tc \) the activity in a reference zone delineated on a well perfused lung area, and \( R, Kr \) the activity in that reference zone on the 81mKr image.

End-diastolic (ED) and end-systolic (ES) RV regions of interest (ROI) were then carefully delineated on the background corrected images taking into account isocount lines and the phase and amplitude images of the first and second Fourier harmonics which were constructed from the original gated data. For the tricuspid valve plane, the ED ROI...
was delineated by taking into account (1) the isocount lines separating the right atrium and the right ventricle on the ED frame, (2) the left border of the hypoamplitude area between the atrium and the ventricle shown on the first harmonic amplitude image and, (3) the second harmonic amplitude and phase images. The ES ROI was delineated on the ES image using the same method but by referring to the right border of the hypoamplitude area of the first harmonic image. For the pulmonary valve plane, the ED and ES ROI were drawn from the first harmonic phase and amplitude images. The free border of the RV was delineated following isocount lines on the ED and ES count density images. RVEF was then calculated using the count density ratio.

First pass $^{99m}Tc$ technique

Twenty millicuries of $^{99m}Tc$ bound to human serum albumin were injected as a bolus in a right antecubital vein and rapidly flushed with 20 ml of normal saline. Patients were studied supine, in the 30° right anterior oblique projection using a very high sensitivity, low energy, collimator (APC 1). Data were collected in frame mode (25 frames/s) on a $32 \times 32$ matrix with a software zoom of 2.

Measurement of first pass RVEF involved the following steps: approximate ROIs were first drawn over the superior vena-cava and the RV. Bolus integrity was assessed from the caval mean transit time (MTT) measured as the interval between 36.9% of the peak in the upslope and the downslope of the caval time-activity curve (TAC). Studies with caval MTT greater than 4 s were rejected (Jengo et al. 1978). The right heart phase was determined from the approximate RV-TAC. A representative right ventricular cardiac cycle was then constructed from three or four beats selected on the descending portion of the RV-TAC using the ECG signals recorded during acquisition. Extra beats were rejected. After spatial and temporal smoothing of the gated series, first and second harmonic phase and amplitude images were constructed. ED and ES-RV ROIs were then carefully delineated applying the same rules as described for the steady state krypton study. No background correction was performed.

Results

RVEF calculated from ECG gated $^{81m}Kr$ steady state data (EF-Kr)

Acquisition count rate averaged 5.2 Kcts/s (range 4 Kcts/s–9 Kcts/s). Data from 600 to 1,100 cardiac cycles, depending on heart rate, were summed for 10 min. Right ventricular mean count density in the end diastolic image was 48,916 (range 25,979 to 80,163) and averaged 31,102 in the end systolic image (range 14,796 to 54,639). The ratio of background activity to total end diastolic count rate was found to be 3.71% to 30.9%. Examples of background corrected ED and ES images are displayed in Fig. 1. RVEF calculated with this technique ranged from 12% to 63%.

RVEF calculated from $^{99m}Tc$ first pass data (EF-Tc)

During the first transit of the radioactive bolus through the cardiac chambers, maximal count rate reached 80 Kcts/s–120 Kcts/s. The maximal activity detected in a right ventricular end diastolic frame averaged 2,472 counts (range 1,520 to 3,190). Three cardiac cycles were usually added up to create a representative cardiac cycle in which right ventricular ED and ES count densities averaged respectively 6,484 and 3,183 counts. Selected ED and ES images are displayed in Fig. 2. RVEF determined using this technique ranged from 11% to 64%.

Comparison of RVEF calculated from data obtained with both techniques

Right ventricular ejection fractions calculated from $^{99m}Tc$ first pass and from $^{81m}Kr$ steady state data are displayed in Fig. 3. The coefficient of the linear correlation between the two methods was 0.97. The equation of the linear regression analysis between EF-Kr and EF-Tc was $\text{EF-Kr} = 0.97 \text{EF-Tc} + 1.7$ and, between EF-Tc and EF-Kr, $\text{EF-Tc} = \text{EF-Kr}$. 

![Fig. 1. ECG-gated $^{81m}Kr$ steady state angiocardiography study before processing (upper left) and $^{99m}Tc$-MAA lung perfusion scintigraphy performed in the same position (upper right). Selected end diastolic (left) and end systolic (right) images after background subtraction. The superior vena-cava, right atrium, right ventricle and the common pulmonary artery are clearly identifiable. Separate regions of interest have been delineated. Note the important displacement of the atrio-ventricular valve plane induced by heart contraction. Right ventricular ejection fraction was 33%](image1)

![Fig. 2. ECG-gated $^{99m}Tc$ first pass angiocardiographic study performed in the same patient as Fig. 1. Selected end diastolic (left) and end systolic (right) images of the gated representative cycle. No background correction was performed. Regions of interest were delineated using the same rules as those utilized for krypton studies. Ejection fraction was 35%](image2)