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Assessment of left ventricular function using solid-state gamma camera equipped with a highly-sensitive collimator

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Purpose: The solid-state gamma camera 2020tc Imager^{TM} (Digirad, CA) is now commercially available and has been clinically applied. The present study evaluates the feasibility of equilibrium radionuclide ventriculography (ERNV) within a 3 min period using this camera equipped with a highly sensitive collimator. ***Materials and Methods:*** ERNV was performed from the best septal position (left anterior oblique view) in 20 patients with cardiac disease using a single detector anger-type gamma camera equipped with a low-energy, high-resolution collimator. Immediately thereafter, we performed a second ERNV using the solid-state gamma camera equipped with a highly sensitive collimator. Acquisition periods were 10 and 3 min, respectively. ***Results:*** Significantly more counts were collected from over the left ventricle with the solid-state gamma camera over 3 min than those with the anger-type gamma camera over 10 min (817.1 ± 387.8 k counts vs. 668.2 ± 327.4 k counts, $p < 0.01$). The left ventricular ejection fraction obtained from ERNV data using the solid-state gamma camera correlated closely with those acquired by the anger-type gamma camera ($r = 0.94$, $p < 0.0001$, SEE = 5.93%). ***Conclusion:*** The results showed that the solid-state gamma camera could assess left ventricular function with excellent data collection efficiency and high reliability.

Key words: left ventricular ejection fraction, solid-state gamma camera, equilibrium radionuclide ventriculography, highly sensitive collimator

INTRODUCTION

A COMMERCIALLY available solid-state gamma camera, 2020tc Imager^{TM} (Digirad, CA) that does not require vacuum (photomultiplier) tubes, has been clinically applied.[1,2] The solid-state gamma camera uses CsI(Tl) as the scintillant and a Silicon photodiode. Because CsI(Tl) has a higher density and atomic number than NaI(Tl), it detects gamma rays with higher sensitivity. This camera has a field-of-view of 20.8 × 20.8 cm, which provides the basis for a compact, lightweight (approximately 160 kg) and portable system.

The present study evaluated the validity of left ventricular function analyzed by short-time equilibrium radionuclide ventriculography (ERNV) using the 2020tc Imager equipped with a highly sensitive collimator.

MATERIALS AND METHODS

Patient Population

Twenty-two consecutive patients (15 men and 7 women; mean age, 62 ± 16 years) were referred to our laboratory for evaluation of left ventricular function by means of ERNV. The patients had been diagnosed with the following conditions: myocardial infarction (6), angina pectoris (4), dilated cardiomyopathy (3), hypertrophic cardiomyopathy (3), valvular disease (3) and other cardiac diseases (3). Patients were excluded from the study if they had

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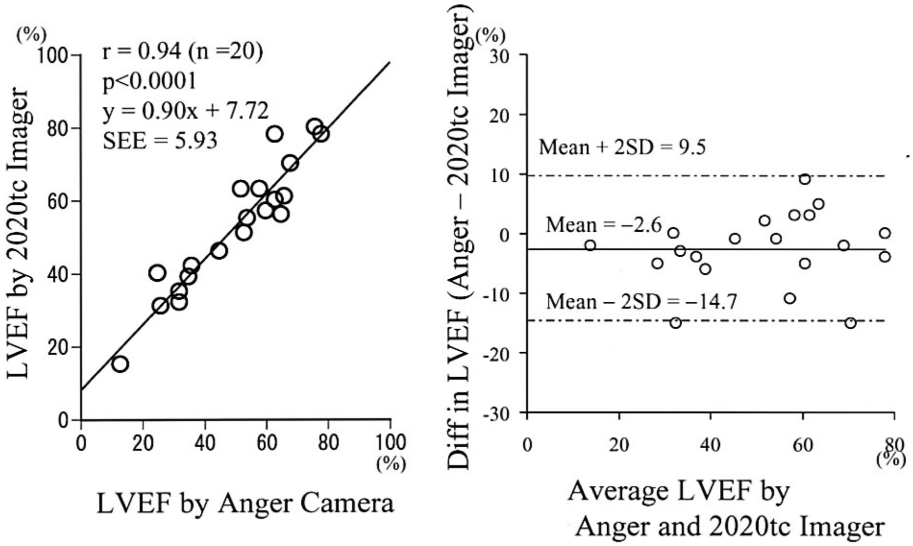

Fig. 1 Comparison of left ventricular ejection fraction obtained from equilibrium radionuclide ventriculography with anger-type and solid-state gamma cameras.

non-sinus rhythm or severe arrhythmias. After receiving an explanation of the study, all patients provided written informed consent to participate.

Data Acquisition from Equilibrium Radionuclide Ventriculography

Approximately 10 min after receiving an injection of ^{99m}Tc-human serum albumin-DTPA (740 MBq), patients underwent ERNV using a conventional anger-type gamma camera (GCA 602A, Toshiba, Tokyo), equipped with a low-energy, high-resolution collimator interfaced with a minicomputer (GMS 550U, Toshiba, Tokyo). Twenty-five frames per cardiac cycle were acquired in the left anterior oblique projection that optimally displayed the ventricular septum (approximately 40°) with 5 to 10° of caudal angulation. Data were collected in a 64 × 64 byte mode using an R-wave gate over 10 min. Immediately thereafter, patients underwent a second ERNV using the 2020tc Imager equipped with a low-energy, highly sensitive, parallel-hole collimator interfaced with a workstation (Digirad, CA). Twenty-four frames per cardiac cycle were acquired in the left anterior oblique projection, which was the same angle at which the first set of data was acquired. Data were collected in a 64 × 64 byte mode using an R-wave gate over 3 min.

Calculation of Left Ventricular Ejection Fraction and Collection Counts

For the ERNV data with the anger-type gamma camera, a semiautomatic program generates left ventricular regions of interest in each frame of the cardiac cycle by an experienced observer. Left ventricular ejection fraction (LVEF, %) was calculated in the usual manner from the background-corrected time-activity curve using the commercial package, New GMS (Toshiba, Tokyo).[3] For the data with the solid-state gamma camera, LVEF was determined from standard counts and an automatic algorithm, using the commercially available program Mirage (Segami, MD)[4–6] installed on the Digirad workstation, to define the borders of the left ventricle.

Collection counts over the left ventricle were calculated by drawing a left ventricular region of interest (ROI) to compare the efficiency of 3 and 10 min ERNV data.

Statistical Analysis

All data are expressed as means ± one standard deviation. The paired Student's t-test determined differences between proportions. Linear regression analysis and Bland-Altman plots characterized relationships between left ventricular ejection fraction determined by the anger-type camera and the solid-state gamma camera. A p value of <0.05 was considered significant.

RESULTS

Automatic segmentation was achieved and the left ventricle of 20 of 22 patients (91%) was accurately contoured when the Mirage program was used to analyze ERNV data from the solid-state gamma camera. Insufficient separation of the biventricle prevented analyses of ERNV data from two patients (with dilated cardiomyopathy and valvular disease), who were excluded from further analysis.

The average heart rates during ERNV data acquisition with the anger-type (68.4 ± 12.7 bpm) and the solid-state gamma camera (73.1 ± 18.5 bpm) did not statistically differ.

The collection counts over the left ventricle were

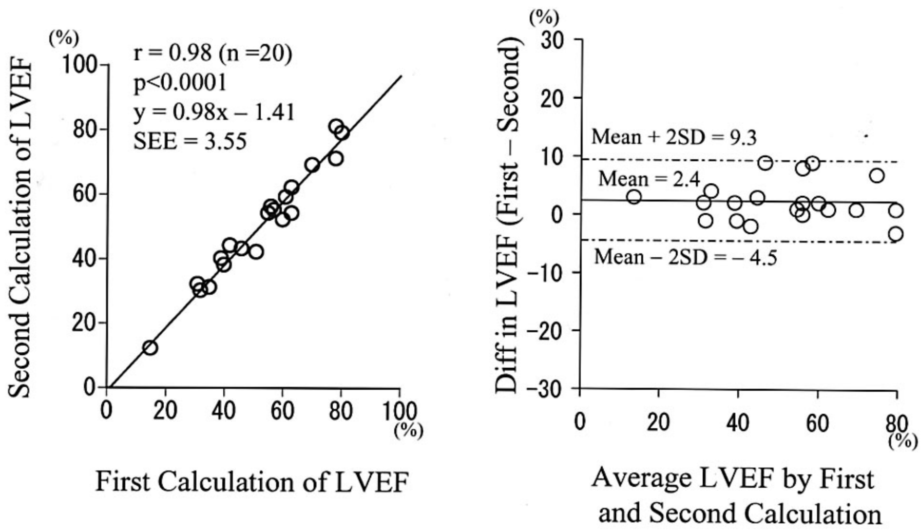

Fig. 2 The interobserver variability in calculation of left ventricular ejection fraction with the solid-state gamma camera.

significantly higher with the solid-state gamma camera over 3 min than with the anger-type gamma camera over 10 min (817.1 ± 387.8 k counts vs. 668.2 ± 327.4 k counts, $p < 0.01$). As expected, left ventricular collection counts per minute were significantly higher with the solid-state (272.4 ± 129.3 k counts/min), than with the anger-type gamma camera (66.8 ± 32.7 k counts/min, $p < 0.0001$).

Figure 1 shows that the LVEF values generated from ERNV data using both types of gamma camera closely correlated ($r = 0.94$, $p < 0.0001$, SEE = 5.93%) and the mean difference was small (–2.6 ± 6.1%).

The interobserver variability in calculation of LVEF values with the solid-state gamma camera has been evaluated by repeat processing of 20 cases by two observers. An excellent correlation was obtained between the twice processing ($r = 0.98$, $p < 0.0001$, SEE = 3.55%), and the mean absolute variability was extremely small (2.4 ± 3.5%) as shown in Figure 2.

DISCUSSION

In the present study, count collection was efficient using the solid-state gamma camera equipped with a highly sensitive collimator. Although there is a difference in the calculation algorithm, LVEF values obtained from ERNV data using the solid-state and the anger-type gamma camera closely correlated. These results indicated that ERNV over 3 min is clinically feasible with a highly sensitive collimator and the 2020tc Imager.

Characteristics of the Solid-State Gamma Camera

The 2020tc Imager is constructed from an array of modules that are tiled together to form the detector head. Each module is partitioned into 4,096 individual elements of 3.2 × 3.2 mm in area. Each detector element has its own signal processing chain and can address individual photon events. This results in images with outstanding spatial resolution and contrast.

As described above, the lightweight and compact design of the solid-state gamma camera allows mobility of the unit among departments and floors. This type of movable camera[7–9] can therefore be used under emergency conditions in coronary care and/or intensive care units.

Clinical Application of Equilibrium Radionuclide Ventriculography with the Solid-State Gamma Camera

ERNV is useful in the evaluation of patients with heart failure since measurements of LVEF[10–12] and left ventricular volume[13,14] can objectively document the appropriate parameters. The potential response to medical therapy can also be evaluated using left ventricular functional measurements in ERNV.[15,16] Furthermore, ERNV could be helpful in the medical management and follow-up of patients with heart failure.

ERNV performed using the sold-state gamma camera provides left ventricular function to be determined at the bedside in coronary care unit. The mobility and excellent count collection efficiency of the solid-state camera allow serial assessment of left ventricular function under drug administration (including norepinephrine, dopamine, dobutamine and olprinone) because data can be acquired over a very short period. Though it was not mentioned in this study, also regional wall motion change could be evaluated in addition to global functional assessment. In cases with therapeutic dobutamine infusion, wall motion changes in the myocardium with coronary arterial stenosis are induced according to the dosage of the administration. Even if global function can be improved, regional wall motion abnormalities such as a worsening or biphasic response can be caused by myocardial ischemia.[17,18] From this viewpoint, regional wall motion[19,20] should be assessed during the administration of medical therapy. Bedside ERNV should be favorable for assessing therapeutic effects in patients with left ventricular dysfunction.

CONCLUSION

We confirmed that count collection was highly efficient and that left ventricular function was able to be analyzed in a very short period with equilibrium radionuclide ventriculography using the solid-state gamma camera. This technique would be useful for assessing left ventricular function under emergency conditions.

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