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Measurement of Mean Circumferential Fiber Shortening Rate Using Radionuclide Blood Pool Scan

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= Abstract = Ejection phase indices of left ventricular performance are standard parameters for the evaluation of myocardial contractility. Recently, ejection fraction and ejection rate are easily obtained from radionuclide gated cardiac blood pool scan. No method, however, is available for determining the mean circumferential fiber shortening rate (Vcf) precisely. Velocity indices are relatively independent of alternation in resting filling pressure and volume, and responsive to changes in heart rate. We measured the left ventricular mean circumferential fiber shortening velocity using gamma camera interfaced to a computer after injection of radionuclide to evaluate its significance for detecting left ventricular dysfunction, especially in patients with coronary heart disease. Radionuclide-determined values for mean fiber shortening rate correlated ($r=0.79$) with values for this index obtained from echocardiography. Left ventricular ejection fraction correlated with mean fiber shortening rate. There was a strong relationship between the value of mean fiber shortening rate and the severity of myocardial impairment by the NYHA(New York Heart Association) functional class ($r=0.84$).

In summary, these data indicate that gated cardiac blood pool scan provides a noninvasive, accurate and simple method to measure the mean circumferential fiber shortening rate and it can be utilized in a variety of cardiac disorders.

Key words: ***Mean circumferential fiber shortening rate, radionuclide blood pool scan, coronary artery disease***

INTRODUCTION

It is well known that determination of the left ventricular contractility in the patients with various cardiac diseases is very important for the evaluation of the degree of the cardiac performance and the prognosis, and the left ventricular ejection fraction as an index for the myocardial contractility has proved to be clinically useful. Radionuclide cardiac blood pool scan provides accurate, simple and serial measures of left ventricular ejection fraction using area-length analysis and left ventricular time-activity curve.

But recent investigation has demonstrated that mean circumferential fiber shortening rate (Vcf) is more sensitive than ejection fraction for estimating the left ventricular contractility in patients with coronary disease (Slutsky *et al.* 1980; Peterson *et al.* 1974). The Vcf has been estimated by indicator-dilution techniques (Gorlin *et al.* 1964; Wilcken *et al.* 1965), cardiac cineangiogram (Bristow *et al.* 1970) and echocardiography (Fortuin *et al.* 1972). Indicator-dilution technique and left ventricular angiogram are invasive and technically difficult to perform serial evaluation. Echocardiography has limitation to measure Vcf in cases with regional wall motion abnormality and to measure left ventricular volume and ejection time at the same time with obvious interobserver variation. A first pass radionuclide angiocardiogram for the measurement of Vcf has been reported (Steele *et al.* 1976). This method is simple and useful, but multiple injections of the radionuclide are required to use this method for interventional studies.

A method has been developed for obtaining left ventricular Vcf after injection of radionuclide,

assuming that the Vcf at any time for a given counts is proportional to cube root of the end-diastolic and end-systolic counts. The value of the Vcf using gated cardiac scan was shown to be correlated well with that using X-ray ventriculogram (Bhargava *et al.* 1982). Since the Vcf by radionuclide cardiac blood pool scan is much simpler and non-invasive than ventriculogram, it can be used readily for determination of Vcf as a routine diagnostic purposes.

Accordingly, the present study compares measurements of left ventricular mean circumferential fiber shortening rate using radionuclide cardiac blood pool scan to evaluate its significance in patients with various degrees of left ventricular dysfunction and control subjects with normal left ventricular performance.

MATERIALS AND METHODS

Subject population

Eighty patients (44 men and 36 women) were studied. These subjects had a mean age of 26.8 years (range 8-74 years). Of these 80 patients, 41 subjects (51.3%) had atrial or ventricular septal defect, 29 (36.3%) had valvular heart disease and 10 had other cardiac disease, including 4 cases with patent ductus arteriosus and 2 cases with Tetralogy of Fallot. Twenty-eight subjects (10 men and 18 women) were included for this study as normal control group. These subjects showed no evidence of cardiac disorders or other systemic diseases on physical examination or routine laboratory findings and the average age was 36.7 years, ranged from 15 to 51 years. To compare the results of the radionuclide method, we first examined 18 subjects using echocardiograhy and calculated Vcf. We performed two sequential studies each day in 20 subjects to evaluate reproducibility in measurement of Vcf using radionuclide blood pool scan.

Radionuclide blood pool scan and data analysis

After injection of 15 mCi of technetium-99m human serum albumin, equilibrium multiple gated acquisition studies using scintillation gamma camera (Ohio Nuclear Model 420) were performed in the 30 to 40 degree left anterior oblique projection with the angle varying from patient to patient in order to give the best visualization of the interventricular septum. Using a low-energy, general-purpose, parallel-hole collimator, the energy window was centered at 140 KeV and the window was usually set

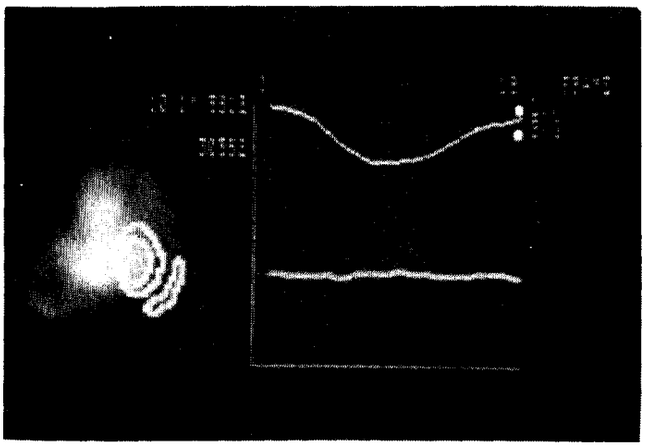

Fig. 1. Time-activity curve obtained from the left ventricular area of interest.

at 20 percent. A standard computer system (PDP 11/34) collected data from approximately 400-600 heart beats and placed the data sequentially into each of 24 frames using the R wave to initiate the sequence and 64 × 64 byte mode matrix. A left ventricular time-activity curve was generated for each patient using a computer and a semiautomatic edge detection system determined the boundaries of the left ventricle in each frame. The end-diastolic counts were defined as the count in the frame that had the largest volume and the end-systolic counts was defined as the count in the frame with the smallest volume (Fig. 1). A computer assigned region of interest adjacent to that of the left lower border of the left ventricle was used to correct for noncardiac activity.

Assuming that the ventricular circumference is proportional to the cube root of the volume or count, the calculation of circumferential fiber shortening rate (Vcf) and fractional shortening (FS) in circumference were calculated from the following equation:

$$FS = \frac{(\sqrt[3]{EDC} - \sqrt[3]{ESC}) \times 2\pi}{\sqrt[3]{EDC} \times 2\pi} \quad Vcf = \frac{FS}{ET}$$

where EDC =counts at end-diastole (initial highest point of the time-activity curve), ESC=counts at end-systole (nadir of the curve), and ET=time between end-diastole frame and end-systole frame.

Correlation coefficients using standard formulas were calculated by Spearman's rank test and the various means were compared by Student's t test.

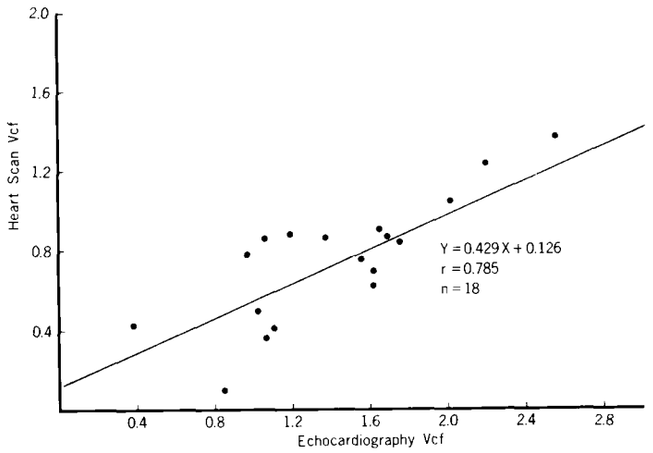

Fig. 2. Correlation of mean circumferential fiber shortening rate derived from radionucilde scan and echocardiography.

Table 1. The values of ejection fraction(EF) and mean circumferential lfiber shortening rate (Vcf) according to NYHA functional class

NYHA functional class	EF	Vcf
I (n=28)	62.5± 8.8	0.87±0.19
II (n=38)	57.3±10.8	0.75±0.23
III (n=10)	51.0±10.1	0.65±0.19
IV (n= 4)	40.6±21.8	0.40±0.21
Normal control (n=28)	64.2± 9.6	0.88±0.37

(Mean±S.D)

RESULTS

Eighteen patients were studies for the evaluation of correlation between Vcf value derived from gated cardiac blood pool scan and that from echocrdiography (Fig. 2). The correlation coefficient was 0.785 and the regression equation was y=0.43x+0.126.

Eighty patients with various cardiac diseases were classified into four groups according to the NYHA(New York Heart Association) functional class. As shown in Table 1 and Fig. 3, there was a strong relationship between degree of NYHA functional impairment and value of Vcf by gated cardiac blood pool scan. Spearman's rank correlation coefficient (r) between Vcf value and functional class was 0.84 which revealed a statistically significant ($p<0.01$). The average value for mean cir-

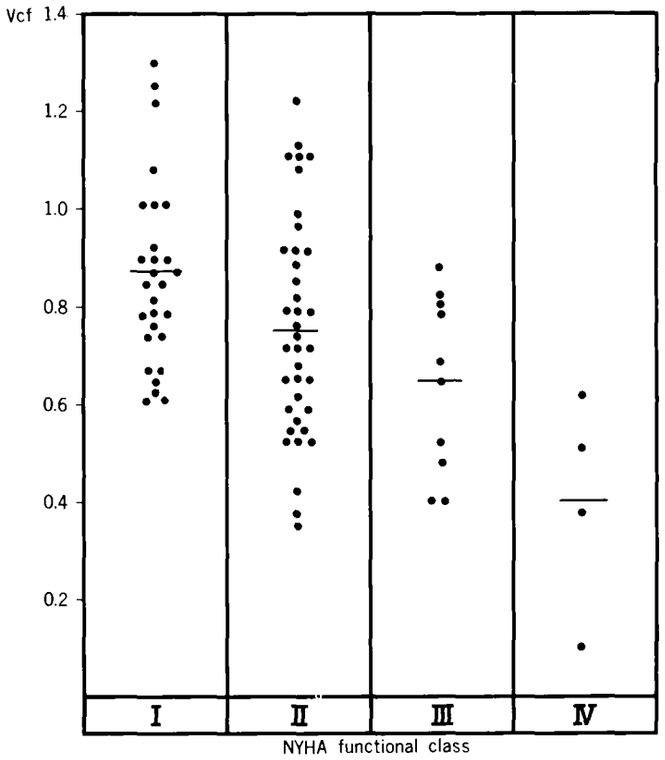

Fig. 3. Correlation of mean circumferential fiber shortening rate and grading of NYHA functional class.

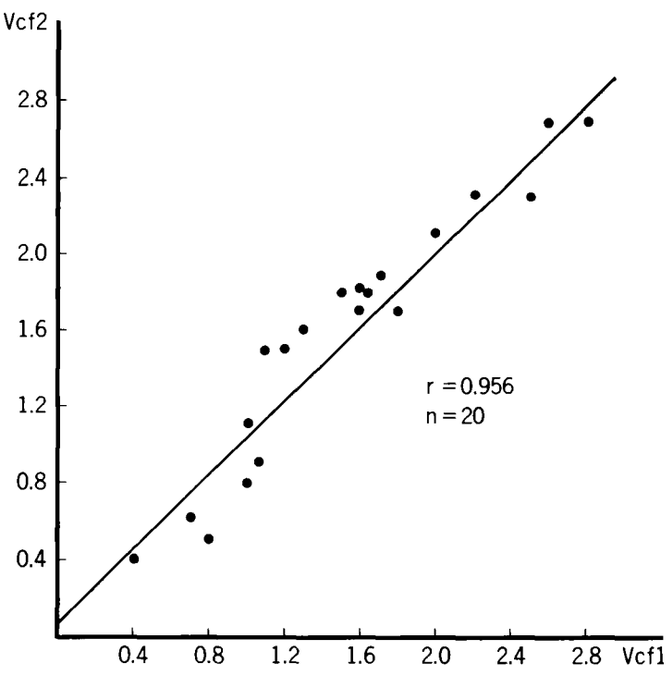

Fig. 4. Reproducibility in measurement of mean circumferential fiber shortening rate (Vcf) using radionuclide blood pool scan.

cumferential fiber shortening rate in the 28 normal control subjects was 0.88±0.37 (mean±SD). The Vcf values in the NYHA functional class I, class II, class III and class IV were 0.87 ±0.19, 0.75± 0.23, 0.65±0.19 and 0.40±0.21 respectively.

Left ventricular ejection fraction (EF) in these subjects was demonstrated in Table 1. Ejection fraction was also correlated well with the value of Vcf.

To etablish reproducibility of this method, intraobserver correlations for same observer were determined by regression analysis of the values from the two sequential studies in 20 subjects. The correlation coefficient was 0.956 and mean variability of sequential studies was low (Fig. 3).

DISCUSSION

Ejection phase indices of left ventricular performance are standard parameters for the evaluation of myocardial contractility. Velocity indices are relatively independent of alteration in resting end-diastolic filling pressure and volume, and responsive to alteration in heart rate. Therefore, velocity indices may be more sensitive than ejection fraction or fractional shortening for detecting left ventricular dysfunction, especially in patients with coronary heart disease (Mahler *et al.* 1974; DeMaria *et al.* 1979; Ricci *et al.* 1979; Slutsky *et al.* 1979). Mean circumferential fiber shortening rate (Vcf) has been shown to be one of important and useful parameters as velocity indices of left ventricular systolic performance. There are few published studies of the mean rate of fiber shortening in man. Those in which indicator-dilution techniques were employed, were based on a spheroidal left ventricular model which may underestimate the extent and velocity of shortening of most of the cardiac fibers in the normal ventricle (Gorlin *et al.* 1964; Wilcken 1965). Vcf has been measured from cineangiographic data by measuring the fractional change in the minor axis at end-diastole and end-systole and dividing the result by the ejection time (Bristow *et al.* 1970). But the need for catheterization makes serial evaluations following interventions impractical. While echocardiography can be used to calculate these indices for serial evaluations, it is inaccurate in the presence of segmental contraction abnormalities (Fortuin *et al.* 1972).

Radionuclide gated cardiac blood pool scan evaluates global and regional function by assessing changes in counts, thus obviating mathematical assumptions of ventricular geometry. It has been proven that Vcf may be obtained from gated blood pool images using cube root estimates of end-diastolic and end-systolic radii with a high degree of correlation with the standard contrast ventriculographic technique and it can be used as a simple and useful index of left ventricular systolic performance in the patients with coronary artery disease (Bhargava *et al.* 1982). Futhermore, this method is an alternative radionuclide technique well-suited to serial intervention studies. A single-pass radionuclide angiocardiography for the measurement of circumferential fiber shortening rate has been also reported (Steele *et al.* 1976). This technique is useful, but it requires that the first-pass program be executed with a specific region of interest; a diameter of the left ventricle at the mid-point of the end-diastolic long axis and multiple injections of the radionuclide are required to use this method for intervention study. With use of radionuclide techniques these indices can be obtained just as easily without left heart catheterization.

In this study, we hoped to show the capability of radionuclide angiocardiography in defining the systolic performance of the left ventricle in normal controls and subjects with coronary heart disorders. The calculation of left Vcf from radionuclide technique showed similar to those developed for echocardiography ($r=0.79$) and there was a strong relationship between the value of Vcf and the severity of myocardial impairment which was determined by the New York Heart Association functional class ($r=0.84$). Unfortunately we could not compare the results with those from the contrast cineangiocardiography. Mean ejection rate correlated quite closely with ejection fraction. This finding has previously (Peterson *et al.* 1974) been noted and is not surprising since these measurements differ by only the ejection time. No patient with a normal Vcf had a diminished ejection fraction. And this was useful in the presence of both coronary and non-coronary heart diseases. An advantage of this method is the higher count rate obtained from the left ventricular area of interest and this high count rate allows formation of a time-activity curve from an area of interest coincident with the left ventricular minor axis, and a radionuclide method for estimating Vcf has been developed. Another advantages are: it does not require repeated injections of radionuclide for intervention studied and it can be produced on any reliable gated blood pool scan

program with good reproducibility.

We have reported a method for evaluating mean circumferential fiber shortening rate from gated cardiac blood pool scan which is accurate, reproducible and simple to perform. It is concluded that this technique may be utilized in a variety of cardiac disorders without undue concern that segmental contraction abnormalities will invalidate the results.

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= 국문초록 =

방사성동위원소 심혈관촬영술을 이용한 평균원주단축율 측정에 관한 연구

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방사성동위원소 심혈관촬영술에서 분석한 좌심실 수축기능 지표인 평균원주단축율의 측정 및 유용도를 알아보고자 28명의 정상대조군 및 80명의 심질환환자를 대상으로 방사성동위원소 심장풀스캔을 시행하고 평형상태에서 gated스캔상의 계측치를 컴퓨터에 입력후 좌심실 용적계수로 평균원주단축율을 측정하여 다음과 같은 결과를 얻었다.

좌심실 구출분획율은 평균원주단축율과 매우 좋은 상관관계를 나타내었으며, 방사성동위원소법에 의한 평균원주단축율을 심에코도상 측정한 단축율과 비교한 결과 상관계수 0.79의 상관관계를 보였다.

평균원주단축율과 NYHA(New York Heart Association)에 의한 심장 기능정도의 분류에 따른 각 군과의 관계에서서는 상관계수 0.84로서 심장기능 정도를 반영함을 관찰하였다.

이 검사법에 의한 평균원주단축율 측정의 재현성을 알아보고자 20명의 환자를 대상으로 2회 측정한 결과 r=0.956으로 우수한 재현성을 나타내었다. 이상의 성적에서 방사성동위원소 심혈관촬영술은 평균원주단축율 평가에 비관혈적이고 간단하며 정확한 방법임을 알았고 관산동맥혈질환 등의 여러 심장질환에서 유용함을 밝혔다.