Key words ; impedance, impulse, coronary artery disease, ejection fraction

Cardiac impulse index by thoracic impedance compared with left ventricular ejection fraction in coronary artery disease patients after coronary bypass grafting

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The kinetic energy of the heart is usually ignored in clinical practice compared to pressure energy of the heart. The cardiac impulse index determined by the thoracic impedance was compared with left ventricular ejection fraction before and after coronary artery bypass grafting : where, the cardiac index was $dZ/dt_{(max)}/Zo^2 *$ EC : which is the maximum of the first derivative of the heart-synchronus impedance signal normalized by the mean thoracic impedance of Zo, and the time interval between the beginning of ejection to the peak of ejection on ICG. In 23 patients, the cardiac impulse index decreased postoperatively ($p<0.01$), but the left ventricular ejection fraction was shown any significant changes following cardiac catherization. In 15 normal subjects, the cardiac impulse index was 16.7 ± 6.3 $\Omega/cm/\Omega^{2} * 10^{-5}$. In 13 age-matched group patients of 23, cardiac impulse index decreased ($p<0.05$). After bypass grafting, their cardiac impulse index of 23 patients decreased ($p<0.01$) but the left ventricular ejection fraction remained unchanged.

In conclusion, the cardiac impulse index appears to be more sensitive index of cardiac function than left ventricular ejection fraction.

Introduction

The kinetic energy of the right heart has been exsamined by right heart cathetrization and angiogragograpy[1]. Concering the left ventricle, the velocity of shortuning of the contractile elements at maximum wall tension has been descrived[2]. However the indices of pressure energy of the left ventricle has been widely used clinically[3].

Data obtained from impedance cardiography can be used to calculate cardiac contractility indices and to calculate the stroke volume[4]. Regarding the former, the decreased magnitude of the first derivative of heart-synchronous impedance signal of ΔZ (dZ/dt) was observed with long term continued paroxysmal supraventricular tachycardia compared with the short term continued supraventricular tachycardia[5]. Then, the cardiac impulse index (CII)

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was proposed as an index of the kinetic energy of the heart, where dZ/dt is multiplied by the interval of the beginning of ejection to the peak of ventricular ejection. Using this index, patients with coronary disease were investigated, and the index was compared with left ventriculer ejection fraction.

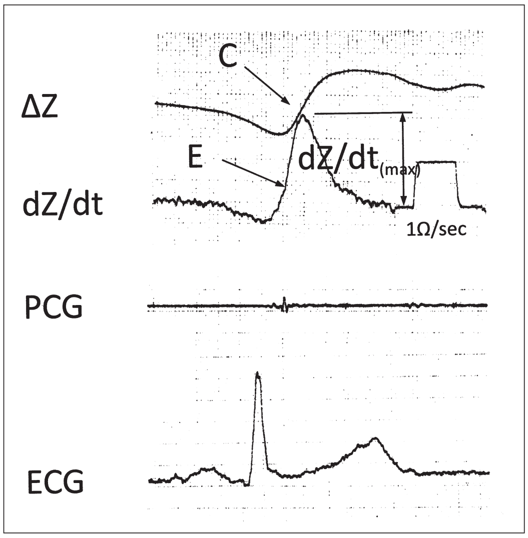
Methods

Group A included 23 patients, and their ages were 64 + −9. The underlying diseases in the patients were angina pectoris in 9, and myocardial infarction in 13. They included 1 patient with single vessel disease, 5 with disease in two vessels, and 17 with the disease in three vessels. All of these patients underwent impedance cardiography and left heart catheterization before and after surgery. Thirteen patients out of group A were age-matched group with normal groups. The underlying diseases in these patients were 4 patients with angina pectoris and 9 patients with myocardial infarction. These patients included the one with single vessel disease, four with disease in 2 vessels, and eight with 3 vessels. As a control group, 15 healthy subjects constituted of aged 49 to 59 years underwent impedance cardiography.

Cardiograph (MDL 304 ; A) was done using the four electrode method, as described by Kubicek[6]. The recordings were made using Mingograf 804 (Siemens-Elema) with a paper speed of 10 cm/sec. The cardiac impulse index was calculated as follows ;

$$dZ/dt_{(max)}/Zo^2 * EC$$

where, $dZ/dt_{(max)}/Zo^2$ is the maximum of first derivaritve of the heart-synchonus impedance signal normalized by the mean thoracic impedance of Zo (see the Appendix), and EC is the time interval between the beginning of ejection to the peak of ejection on ICG. The E point was determined at the steepest point or the corner on the ascending line of the dZ/dt waveform that occurred soon after the B point, referring to the vibrations of the first heart sound[7] (Fig. 1).



(Figure 1) Normal man of 54 year-old.

Cardiac catheterization was performed, and the left ventricular end-diastolic volume (LVEDV) and left ventricular ejection fraction (LVEF) were measured using ventriculographic video records at 30 frames per second in 30 degrees right anterior projection using Cardio 500 instrument (Kontron Electric) using Simpson' rule method[8]. Cardiac cathetization and impedance cardiography after surgery were performed 4-6 weeks after the operation with an interval of 1 week between examinations. None of the patients in either group complained of angina at the time of angina study and none of the patients had heart failure during the study. The tests were performed in 1998 to 2004.

The study protocol was approved by the Hospital Regulatory Board before the study began, and the study was conducted with the Board's permission. Written informed consent was obtained from all participants.

Statistical analysis

To compare the means of the indices between groups, unpaired t test was used. The correlation coefficient was calculated. A probability of <0.05 was considered to be statistically significant.

Results

In group A, the CII decreased after surgery ($p<0.01$), but the CII was not correlated with the LVEDV or LVEF. There were two dZ/dt peakes in 2 patients which was measured the higher one, and postoperative normalization of the dZ/dt waveform was observed in both patients. The QRS duration was decreased to 0.101 ± 0.024 sec to 0.089 ± 0.018 sec. In two patients with biphasic pattern, the QRS duration decreased after surgery.

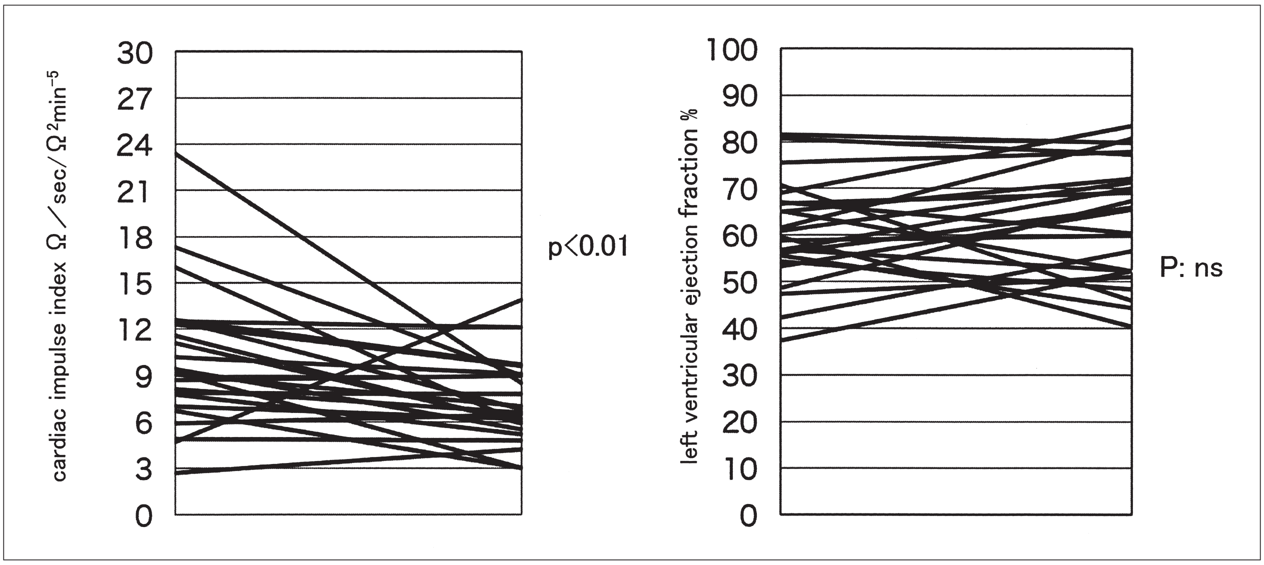
In group B, the CII in 13 patients before operation was decreased than normals ($p<0.05$), and there was no biphasic dZ/dt waveform. The CII of 23 patients decreased after operation ($p<0.01$), but the LVEDV and LVEF remained the same.

Discussion

The product of force and time is the impulse. The initial ventricular impulse is defined as the net force acting over the time from the beginning of ejection to the attainment of the peak flow rate[9]. I observed, during the recovery period from heart failure, that there was delayed but large increase in the magnitude of the first derivative of heart-synchronous impedance of ΔZ on ICG in heart failure patients with long-term, continuous, paroxysmal supra-ventricular tachycardia compared with short-term, continuous, paroxysmal tachycardia[10]. Based on this observation, the CII was proposed as a measure of the ejection force of the heart.

There are 2 peaks of the dZ/dt in 2 patents of group A. This means discrepancy of the both ventricular ejections. However, the disappearance of two peaks of dZ/dt did not correlated with QRS duration and the CII. In group B, there was no case of 2 peak of the dZ/dt. The CII in group A was decreased than in normal group ($p<0.05$). This means that there was a significant decrease in the cardiac function in the same-age group of normal patients though LVEF wound be normal. In Groups A and B, the CII was decreased after surgery without change in the LVEDV or LVEF. This appears to indicate the significance of the CIl, though the CII is an index of biventricular ejection.

In conclusion, in groups A, the CII decreased without any decrease in the LVEF. This suggests that the CII could be a more sensitive index of the cardiac function than the LVEF, and appears to be useful for estimation of cardiac function.



(Figure 2) The change of cardiac impulse index and the left ventricular ejction fraction after coronary bypass grafting in 23 patients with coronary artery disease.

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Appendix

Assuming that stroke volume accumulates in the aorta with L, the cross-sectional area of the aorta changes as

$\Delta V/L$ (1)

Also, $Y=(1/Z)$ and,

$\Delta Y=(\sigma \Delta V/L)/L$ (2)

where, Y is the admittance, Z is the basal thoracic impedance Zo, and σ is the conductivity of blood.

$\Delta V=L^2 \Delta Y/\sigma$ (3)

ΔY changes with time, as

$\Delta Y=dY_{(max)}$□T (4)

where, T is the ejection time.

$dY/dt_{(max)}=d(1/Z)/dt_{(max)}=dZ\text{-}1/dZ$□$dZ/dt_{(max)}=-Z^{-2}$□$d\ Z/dt_{(max)}=-dZ/dt_{(max)}/Z^2$

索引用語：インパルス，冠動脈疾患，躯出率

冠動脈疾患のバイパス術前後における心インパルスインデクスと左心躯出率の比較

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Ｎ＝23 について心インパルスインデックスと左心躯出率を比較した。心インパルスインデクスは減少したが左心躯出率は有意な変化をしめさなかった。心インパルスインデクスは心機能の評価に有用であると思われる。