

# Enhanced Echocardiography with Indocyanin-Green Solution of Cardiac Wall

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Received January 12 1995; accepted June 23 1995

**Summary.** In a previous study, the authors observed an increase in the echo from the myocardium and endocardium, calling this "enhanced echocardiography." This experiment was conducted to confirm this finding and the mechanism of the enhancement.

Six adult mongrel dogs had their chests opened under general anesthesia, and a minitransducer was sewed onto the epicardium which was perfused by the diagonal branch of the left coronary artery. After confirmation of stabilization of the echocardiogram from the endocardium by the minitransducer, indocyanin green (ICG) dissolved in normal saline was injected into the left ventricle and the effect on the endocardial echo was compared. The effect of repeated administrations of ICG solution on the endocardial echo was examined. At the end of the study, the heart was removed at the timing of the peak enhancement by ICG and the myocardium was examined microscopically.

Immediately after the administration of ICG solution, linear echoes were observed in the myocardium and accentuation of the endocardial echo was observed for 3-5 min (average 4.2 min). The echo returned to the basal level within 15 min. By repeated administration of ICG in three of the six dogs, the accentuation of the endocardial echo was observed for a longer time, the average being 20 min. Microscopic examination revealed no ICG deposit in the myocardium nor microbubbles; instead, massive rouleaus of red blood cells were found in the small vessels.

**Key words**—echocardiography, indocyanin-green, enhancement.

## INTRODUCTION

Indocyanin green (ICG) solution has attracted atten-

tion in the field of cardiology since the study by Gramiak et al.<sup>1)</sup> ICG solution is useful in the accurate determination of the cardiac cavity, shunt-flows, and clear visualization of the endocardium. It is also used in the diagnosis of atrio-septal defects, tricuspid regurgitation and anomalous pulmonary drainage.<sup>2)</sup>

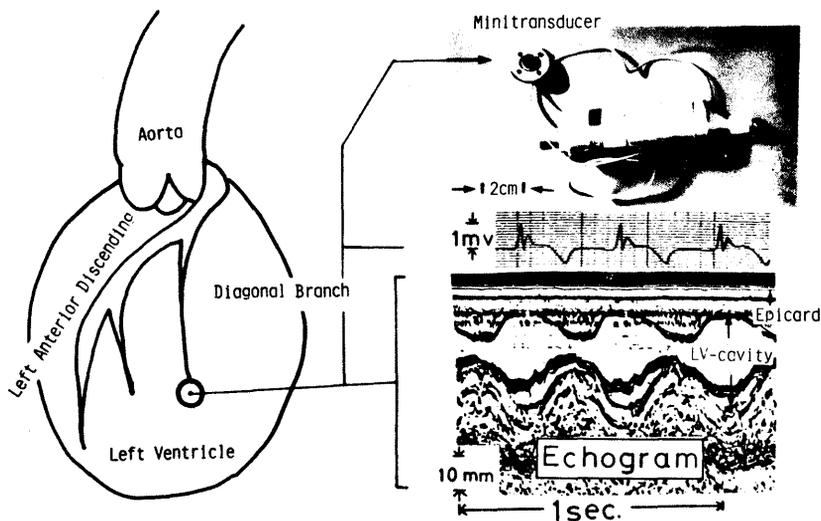
In our previous study, the echo from the endocardium was clearly visualized for 5-10 min when ICG solution was injected into the heart after a minitransducer was placed on the pericardium.<sup>3)</sup> These findings prompted us to conduct the present animal experiment in order to clarify whether the method can be used for the precise examination of changes in the left ventricular endocardium.

## SUBJECTS AND METHODS

Six adult mongrel dogs weighing 10-16 kg were used. The dogs were anesthetized by morphine (1.5 mg/kg), urethane (450 mg/kg) and a-chloralose (45 mg/kg). Respiration was controlled with room air by a Harvard pump through an endotracheal tube. The chest was opened in the 5th or 6th left intercostal space. The pericardium was cut to expose the heart, and a minitransducer (UST-2169-5, vibration frequency of 5 MHz, Aloka Co. Ltd., Japan) was placed onto the pericardium in the perfusion area of the diagonal branch of the left descending coronary artery as shown in Fig. 1. Aloka SSD-110 was used to record the echo from the endocardium of the left ventricle; this was recorded on a strip chart at a paper speed of 100 mm/sec (FR-06A, Honeywell Co. Ltd., U.S.A.). Recording was performed using the following fixed conditions: gain at 40 db, rejection off and 0 db/cm for near suppression.

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## Method



**Fig. 1.** A typical recording of the enhancement of the echo in the left ventricle. On the left, the site of the placement of a minitransducer is shown. In the right upper row, a transducer is shown and in the lower row, the M-mode echogram is shown.

### Administration of ICG solution

Twenty-five mg of ICG was dissolved in 10 ml of normal saline by shaking vigorously, and 3 ml was injected into the left ventricle through an indwelling catheter placed at the apex of the left ventricle.

### Data analysis

After the stabilization of the endocardial echo, 3 ml of ICG solution was twice administered into the left ventricle at intervals of 30 sec. The M-mode echocardiogram was serially recorded and the effect on the echoes from the myocardium and endocardium was determined. In one dog, the heart was removed at the time of the peak effect of the ICG solution on the echo and the myocardium was examined microscopically.

## RESULTS

### 1) ICG-induced echocardiogram of the cardiac wall

As shown in Fig. 2, the M-mode showed a clear echo from the posterior wall, but the endocardial echo from the anterior wall was not clear in a control state.

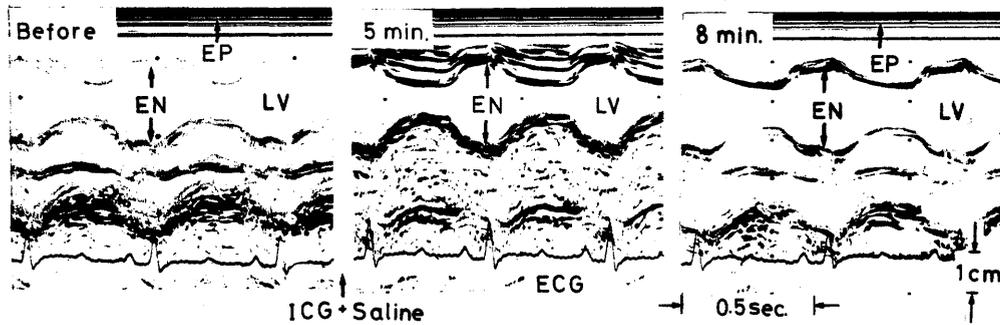
At 5 min after the administration of ICG, the echo was most accentuated both in the anterior and posterior wall. Several thick echo lines were observed in the myocardium after ICG administration. The ICG-induced echo of the myocardium disappeared within 8 min but the enhanced echo of the posterior endocardium was observed for a longer time: it returned to the baseline level 15 min after administration of ICG. The peak accentuation of the echo was observed at 1-5 min after ICG administration; the mean was 3 min in the six dogs and the effect disappeared within 15 min. The echo of the myocardium disappeared more rapidly: within 3-5 min, averaging 4.2 min.

### 2) Effects of repeated administration of ICG

After three successive administrations of ICG, the accentuation of the echo from the endocardium lasted for a longer time as shown in Fig. 3 and a clear echo could be obtained 30 min after administration of ICG.

### 3) Microscopic examination

In the myocardium, deposition of ICG was not observed but the massive rouleau formation of red blood cells was observed within the small arteries.



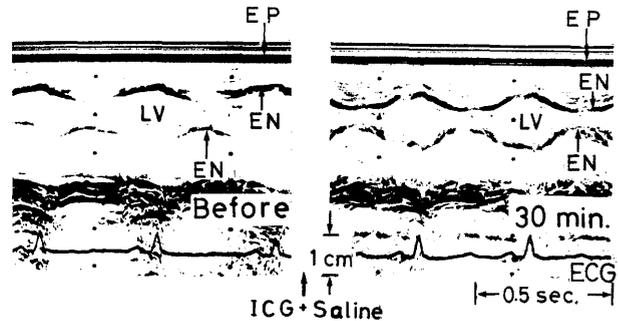
**Fig. 2.** M-mode cardiac echograms before and after administration of the ICG solution. The endocardial echo is poorly delineated in the anterior wall, but is accentuated after ICG administration into the left ventricle. The peak effect can be observed at 5 min, returning to the baseline level within 15 min. Several thick lines of echos are observed soon after the administration of ICG solution, but disappear relatively rapidly compared to endocardial echoes. EP: epicardium, EN: endocardium, LV: left ventricle.

## DISCUSSION

ICG solution might be used in the diagnosis of cardiac diseases mainly to visualize the right side of the heart.<sup>2)</sup> However, the administration of ICG solution directly into the left ventricle has rarely been performed since the study of Gramiak in the diagnosis of mitral regurgitation.<sup>1)</sup> The present authors investigated changes in the left ventricular diameter by a minitransducer placed onto the pericardium, but the clear visualization of the endocardial echo simultaneously from the anterior and posterior wall was difficult.<sup>3)</sup>

In the present study, contrast echocardiography was attempted in this canine experiment. After injection of ICG into the left ventricle, several echo lines were observed in the myocardium. The echo from the endocardium was accentuated and precise measurement of the internal dimensions of the left ventricle was facilitated. As the administration of ICG was repeated, clear visualization of the echo from the endocardium lasted for a longer time.

For the accentuated echoes from the cardiac wall, several mechanisms might be involved. Since ICG was dissolved in normal saline with vigorous shaking, microbubbles might adhere to vessel walls as well as on the endocardium. Microscopic examination disclosed no deposition of ICG, nor microbubbles on the vessel walls; in contrast, massive rouleau formations were observed in the vessels of the myocardium. The latter finding might be potentially dangerous. Further studies are needed, before the clinical application of ICG in the contrast echocardiography of the left ventricle.



**Fig. 3.** M-mode echocardiogram. The echocardiogram in a control state (left). Endocardial echoes can be clearly visualized 30 min after three successive administration of ICG solution (right).

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