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# Study of atrial contraction in sick sinus syndrome using conventional and esophageal echocardiography

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**Summary**

To evaluate the active systolic function of both atria in sick sinus syndrome (SSS), conventional and esophageal echocardiograms were recorded in 22 normal subjects (Normal), 5 patients (pts) with sinus bradycardia (Group I), 9 with sinoatrial block or sinus arrest (Group II), 10 with bradycardia-tachycardia syndrome (BTS, Group III) and 6 with transient atrial fibrillation (Group IV). Two pts in Group II and 8 in Group III had a history of syncope.

Atrial filling fraction obtained by the left ventricular echogram (AFF by LV echo) and posterior wall excursion of the aorta during atrial contraction (Ea) were determined by the conventional echocardiogram. The excursion of the interatrial septum during atrial contraction (Eb) and the dimensional

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shortening of the right atrium during atrial contraction (Ec) were determined by the esophageal echocardiogram.

Results were as follows:

1) AFF was almost the same in Normal, and Group I, II and IV, but it was significantly lower in Group III. AFF was also decreased in 2 pts in Group II who had a history of syncope.

2) Both Ea and Eb in Group III were significantly lower than those in the other groups.

3) Ec was not significantly different among all groups, although one patient in Group III had markedly decreased Ec.

4) There was a significant correlation between Ea and AFF ($r=0.638$, $p<0.001$).

We conclude that in a number of cases with SSS, especially BTS, left atrial active contraction is significantly impaired in addition to the electrophysiological abnormality.

**Key words**

Sick sinus syndrome  Atrial filling fraction  Echocardiography  Active atrial contraction

Many investigators have reported that sick sinus syndrome (SSS) is related to pathological lesions not only in the sinus node but also in the atrial muscle[1~4]. However, there have been no systematic studies on the biatrial dynamics and function in patients with SSS.

We previously reported that atrial filling fraction obtained by the left ventricular echogram (AFF by LV echo) is a useful index for estimating booster pump function of the left atrium[5]. Esophageal echocardiography devised by our laboratory[6] can demonstrate echograms of the right atrial free wall, interatrial septum and left atrial posterior wall simultaneously, and permits the noninvasive determination of internal dimensions of both atria[7~10].

We recorded conventional and esophageal echocardiograms in normal subjects and in patients with various types of SSS, and examined the relationship between clinical symptoms or electrophysiological findings and right or left atrial systolic function.

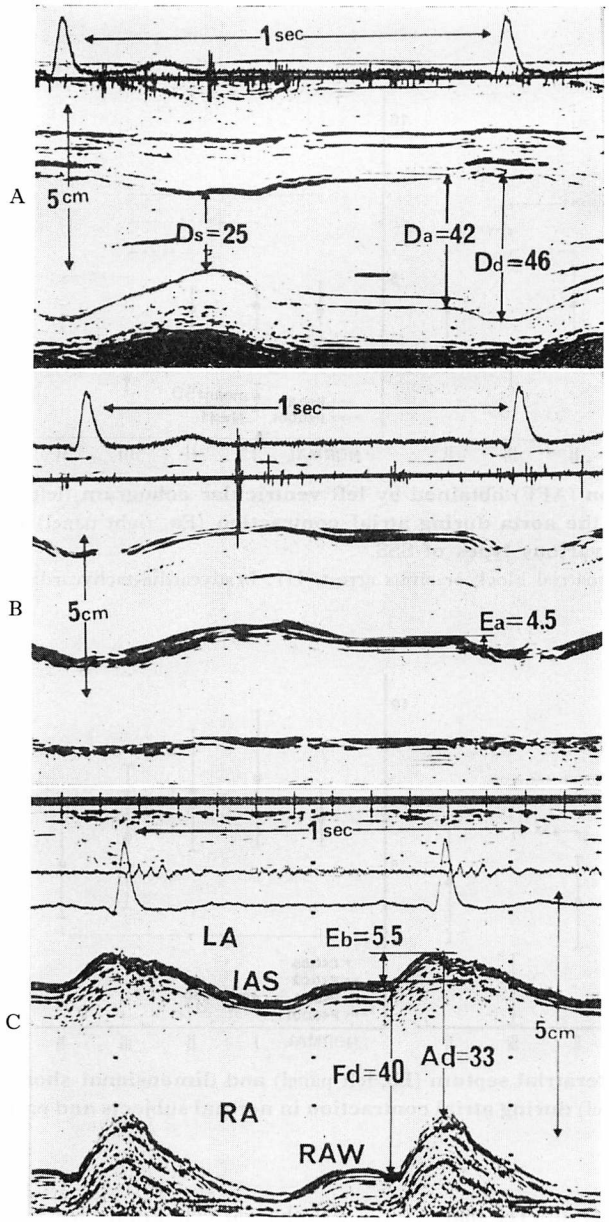
## Materials and methods

Echocardiograms were obtained from 22 normal subjects (Normal), 24 patients with SSS diagnosed by clinical and electrophysiological data and 6 patients with transient atrial fibrillation. Thirty-one were male and 21 were female, aged from 22 to 73 years old. All patients had regular sinus rhythm when echocardiography was performed. The group of SSS composed of 5 patients with sinus bradycardia (Group I), 9 with sinoatrial block or sinus arrest (Group II) and 10 with bradycardia-tachycardia syndrome (BTS, Group III). Patients with transient atrial fibrillation were included in Group IV in this study. Two

**Table 1. Subjects**

| | Normal | I | II | III | IV | Total |
|---|---|---|---|---|---|---|
| Sex Male | 17 | 4 | 3 | 3 | 4 | 52 |
| Female | 5 | 1 | 6 | 7 | 2 | |
| Age (yrs) | 22~59 | 29~64 | 36~68 | 55~73 | 30~54 | 22~73 |
| Conventional echo | 11 | 5 | 9 | 10 | 6 | 41 |
| Esophageal echo | 11 | 3 | 6 | 7 | 5 | 32 |
| History of syncope | 0 | 0 | 2 | 8 | 0 | 10 |

I: sinus bradycardia, II: sinoatrial block or sinus arrest, III: bradycardia-tachycardia syndrome, IV: transient atrial fibrillation. echo=echocardiogram.




AFF by LV echo

$$= \frac{DdV - DaV}{DdV - DsV} \times 100$$

$= 24\%$

Esophageal echo

Ec = Fd − Ad

= 7

**Fig. 1. Left ventricular** (panel A)**, and aortic-left atrial echograms** (panel B) **obtained by conventional echocardiography and atrial echogram obtained by esophageal echocardiography** (panel C) **in a normal man** (56-year-old).

Dd=left ventricular end-diastolic dimension; Ds=left ventricular end-systolic dimension; Da=left ventricular dimension at the beginning of atrial contraction; DdV=left ventricular end-diastolic volume using Teichholz's method; DsV=left ventricular end-systolic volume using Teichholz's method; DaV=left ventricular volume at the beginning of atrial contraction using Teichholz's method; Ea=posterior wall excursion of the aorta during atrial contraction; Eb=excursion of the interatrial septum during atrial contraction; Fd=right atrial dimension at the beginning of atrial contraction; Ad=right atrial end-systolic dimension; Ec=dimensional shortening of the right atrium during atrial contraction, LA=left atrium; IAS=interatrial septum; RA=right atrium; RAW =right atrial free wall. Panel A: AFF by LV echo=100 (DdV−DaV) / (DdV−DsV)=24%. Panel C: Ec=Fd−Ad=7 mm.

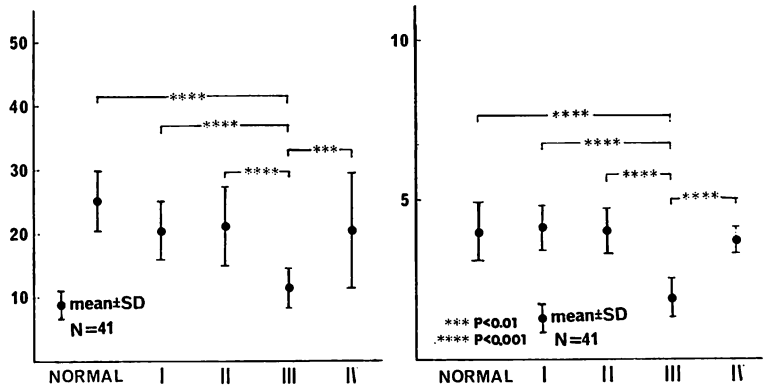



**Fig. 2. Atrial filling fraction** (AFF) **obtained by left ventricular echogram** (left panel) **and posterior wall excursion of the aorta during atrial contraction** (**Ea**, right panel) **in normal subjects and patients with various types of SSS.**

I: sinus bradycardia, II: sinoatrial block or sinus arrest, III: bradycardia-tachycardia syndrome, IV: transient atrial fibrillation.

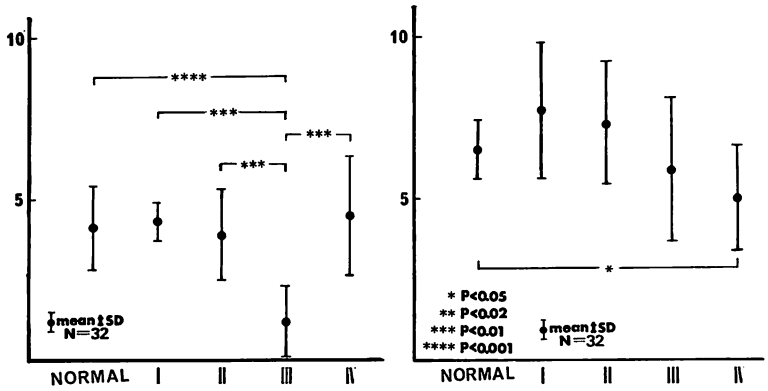



**Fig. 3. Excursion of the interatrial septum** (**Eb**, left panel) **and dimensional shortening the of right atrium** (**Ec**, right panel) **during atrial contraction in normal subjects and patients with various types of SSS.**

patients in Group II and 8 in Group III had a history of syncope (**Table 1**).

Conventional echograms were obtained using a Toshiba SSH-11A or Aloka SSD-110S simultaneously with electrocardiogram (lead II) and phonocardiogram at a paper speed of 100 mm/sec. Left ventricular and aortic root echograms were recorded in supine or left decubitus position with the transducer placed in the third or fourth intercostal space at the left sternal border.

Esophageal echograms were obtained simultaneously with an electrocardiogram (lead II), esophageal electrocardiogram and phonocardiogram at a paper speed of 100 mm/sec. The instrument, procedure for inserting the esophageal transducer, and identification of both atrial echograms were reported previously[6~10].

In **Fig. 1**, representative example of left ventricular (panel A), and aortic-left atrial (panel B) echograms and atrial echogram obtained by esophageal echocardiography (lower panel:

C) in a normal subject are shown From the left ventricular echogram, left ventricular end-diastolic and end-systolic dimensions (Dd and Ds), and left ventricular dimension at the beginning of atrial contraction (Da) were measured. Left ventricular end-diastolic and end-systolic volumes (DdV and DsV), and left ventricular volume at the beginning of atrial contraction (DaV) were calculated by Teichholz's formula. Then, atrial filling fraction, AFF, was determined by the formula: (AFF by LV echo (%)=(DdV−DaV) / (DdV−DsV) ×100). From the aortic-left atrial echogram, posterior wall excursion of the aorta during atrial contraction (Ea) was measured. From the esophageal echogram, excursion of the inter-atrial septum during atrial contraction (Eb), left atrial dimension at the beginning of atrial contraction, right atrial dimension at the begin ning of atrial contraction (Fd) and right atrial end-systolic dimension (Ad) were measured. Dimensional shortening of the right atrium during atrial contraction (Ec) was determined by Fd-Ad. In the case shown in **Fig. 1**, for example, AFF by LV echo was 24%, Ea was 4.5 mm, Eb was 5.5 mm and Ec was 7 mm.

The data were expressed as a mean plus or minus one standard deviation (mean±SD) and statistical analyses were made by unpaired t test.

## Results

### 1. AFF by LV echo, Ea, Eb and Ec in each group

AFF by LV echo was 25.1±4.6% in Normal, 20.8±4.2% in Group I, 20.8±6.0% in Group II, 11.1±2.7% in Group III and 20.3±9.0% in Group IV. AFF in Group III was significantly lower than than in the other groups (left panel in **Fig. 2**). Ea was 4.0±0.9 mm in Normal, 4.1±0.7 mm in Group I, 4.0±0.7 mm in Group II, 1.9±0.6 mm in Group III and 3.7±0.4 mm in Group IV. Ea in Group III was significantly lower than that in the other groups (right panel in **Fig. 2**).

As shown in **Fig. 3**, Eb was 4.1±1.3 mm in Normal, 4.3±0.6 mm in Group I, 3.9±1.4 mm in Group II, 1.2±1.1 mm in Group III and 4.5±1.8 mm in Group IV. Eb in Group III was also significantly lower than that in the other groups (left panel in **Fig. 3**). Ec was 6.5±0.9 mm in Normal, 7.7±2.1 mm in Group I, 7.3±1.9 mm in Group II, 5.9±2.2 mm in Group III and 5.0±1.6 mm in Group IV. There was no significant difference of Ec among the patient groups (right panel in **Fig. 3**).

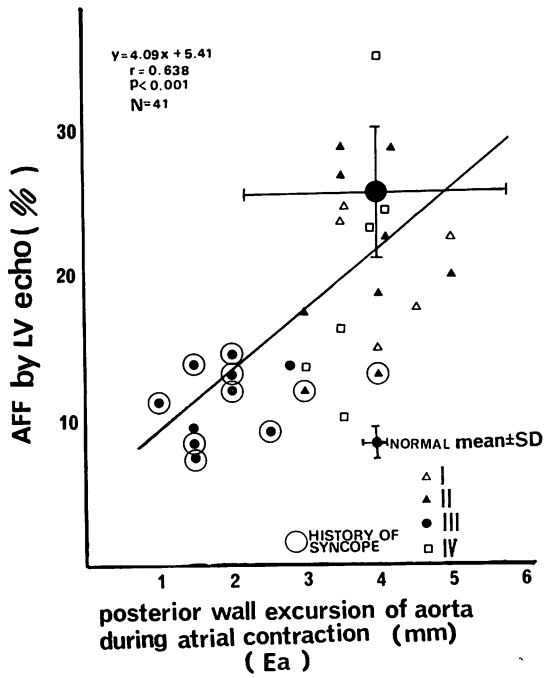



**Fig. 4. Relationship between posterior wall excursion of the aorta during atrial contraction (Ea) and atrial filling fraction (AFF) by LV echo in normal subjects and patients with various types of SSS.**

### 2. Relationship between Ea and AFF by LV echo

There was a correlation between Ea and AFF by LV echo with the correlation coefficient of 0.638 ($p<0.001$) as shown in **Fig. 4**. AFF in 2 patients in Group II who had a history of syncope was markedly decreased compared with that of the other patients in the same group.

### 3. Right and left atrial dimensions

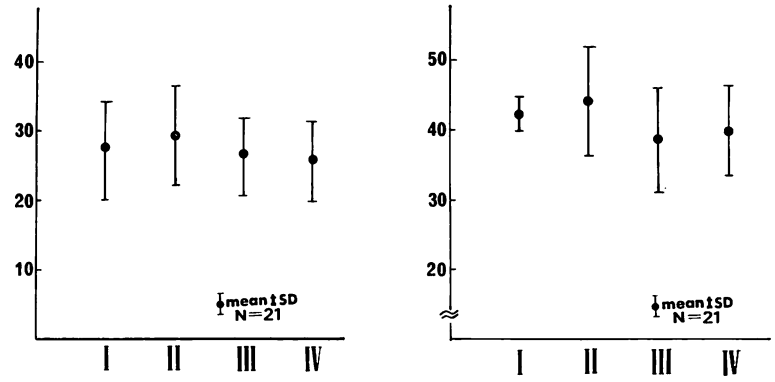



**Fig. 5. Left atrial** (left panel) **and right atrial** (right panel) **dimensions at the beginning of atrial contraction obtained by esophageal echograms in patients with various types of SSS.**

Both atrial dimensions obtained by esophageal echograms are shown in **Fig. 5**. Among patient groups I–IV, there were no significant differences of left atrial dimension (LAD) and right atrial dimension (RAD) at the beginning of atrial contraction.

**4. Echocardiograms of patients with bradycardia-tachycardia syndrome**

The representative echograms of 2 patients in Group III are shown in **Fig. 6** (Case 1) and **Fig. 7** (Case 2). The patients have suffered from typical BTS which consisted of paroxysmal atrial fibrillation followed by a transient sinus arrest, resulting in Adams-Stokes attack. Echocardiography was performed during regular sinus rhythm.

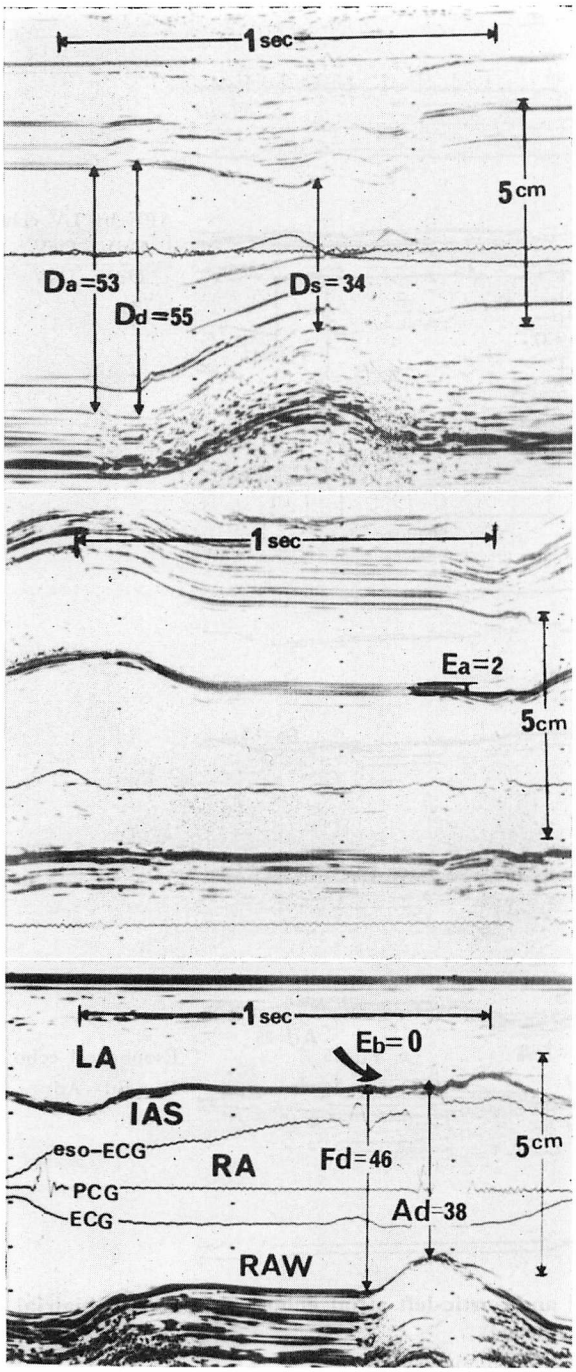
In Case 1, AFF by LV echo (12%) and Ea (2 mm) were markedly decreased, and no leftward displacement of the interatrial septum was seen during atrial contraction (lower panel: C). However, Ec was within the normal range. Most of the patients with BTS exhibited similar echocardiographic findings.

In Case 2 (**Fig. 7**), AFF by LV echo (7%), Ea (1.5 mm) and Eb (2.5 mm) were significantly decreased. Additionally, the dimensional shortening of the right atrium during atrial contraction was not observed. In all patients with BTS except this one, Ec was within the normal range.

## Discussion

Recently, pathological basis for sick sinus syndrome has been reported. Kaplan et al[1] observed pathological changes in both sinoatrial and atrioventricular nodes and atria in 2 cases with BTS, and suggested that the term " sick sinus syndrome " was an inaccurate and inappropriate synonym for BTS. Thery et al[2] reported that chronic sinoatrial block was associated with extensive lesions of the sinus node and BTS was associated in most cases with lesions of the sinoatrial node and atrial muscle. There have been additional reports in which SSS was related to pathological lesions not only in the sinus node but also to the atrial muscle[3,4]. However, to the best of our knowledge, no reports have been published on the biatrial dynamics and function in patients with SSS.

To evaluate active pump function of atria in patients with SSS, we examined AFF by LV echo and dimensional shortening of both atria during atrial contraction (Ea, Eb, Ec) using conventional and esophageal echograms. The relationships among these indices, the types of SSS and its severity were also studied. We found that left atrial dimensional shortening during the atrial contraction obtained by both methods, and AFF by LV echo were significantly decreased in BTS comparing with those




AFF by LV echo

$$= \frac{DdV - DaV}{DdV - DsV} \times 100$$

$= 12\%$

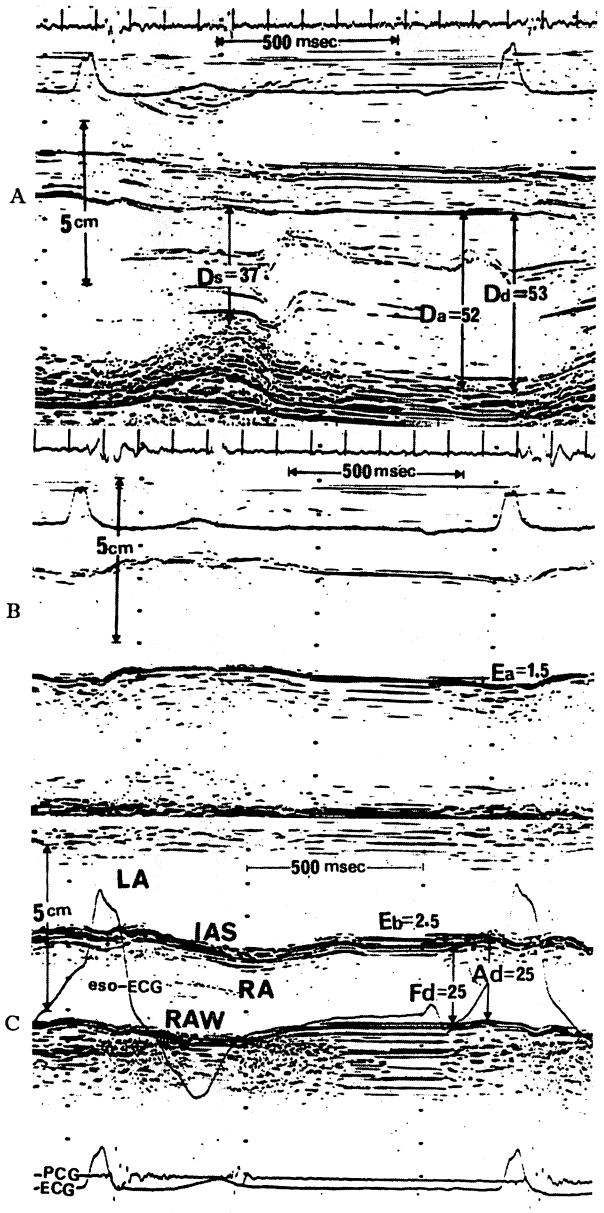
Esophageal echo

$Ec = Fd - Ad$

$= 8$

**Fig. 6. Left ventricular** (panel A) **and aortic-left atrial echograms** (panel B) **and biatrial echograms** (panel C) **in a man with BTS** (59-year-old).

Panel A: AFF=12%, panel C: Ec=8 mm.




AFF by LV echo

$$= \frac{DdV - DaV}{DdV - DsV} \times 100$$

$= 7\%$

Esophageal echo

$Ec = Fd - Ad$

$= 0$

**Fig. 7. Left ventricular** (A) **and aortic-left atrial echograms** (B) **and biatrial echograms** (C) **in a man with BTS** (70-year-old).

Panel A: AFF=7%, panel C: Ec=0 mm.

of Normal and the other types of SSS. Among patient groups I–IV, there were no significant differences of both atrial dimensions. These echocardiographic findings suggest that there is an impairment of left atrial contraction in BTS. This finding is supported by the pathological changes of atrial muscle in patients with BTS[1,2]. However, further studies are necessary regarding the effect of several factors such as loading conditions on atrial contraction, and neuro-humoral mediation or ventricular compliance on active atrial systolic performance.

Many observations that atrial fibrillation is related to lesions in the sinoatrial node[11,12] have been reported. According to Davis and Pomerance[12], there was a difference between long-term and short-term atrial fibrillation, and the sino atrial node was normal in short-term fibrillation, whereas there was a reduced percentage of the intact fibers in a long-term fibrillation. In our study, atrial pump function in patients with a history of transient atrial fibrillation was not disturbed and this finding is supported by Davis' observation.

AFF was markedly decreased in 2 patients in Group II who had a history of syncope and permanent right ventricular pacing. However, the average AFF value of all patients in Group II was not different compared to that in Normal. This suggests that the severity of impairment of left atrial contraction tends to coincide with that of clinical symptom. A statistically significant correlation between Ea and AFF by LV echo which was considered to be an exact measure of AFF of LV suggested that Ea might be a useful index for evaluating active systolic function of the left atrium.

Consequently, our data suggest that in a number of cases with SSS, especially in patients with BTS, impairment of left atrial contraction is present.

## 洞機能不全症候群の心房動態：経胸壁および経食道心エコー図による検討

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洞機能不全症候群 (SSS) における心房収縮機能評価の目的で，経胸壁および経食道心エコー図法を施行した．左室心エコー図上求めた atrial filling fraction (AFF)，心房収縮期大動脈後壁振幅 (Ea)，食道心エコー図上の心房収縮期心房中隔振幅 (Eb)，および右房短縮径 (Ec) を測定し，SSS の病型やその重症度との関係について検討した．

対象は正常 22 例，洞徐脈 (I 群) 5 例，洞房ブロックないし洞停止 (II 群) 9 例，徐脈・頻脈症候群 (BTS, III 群) 10 例，一過性心房細動(便宜上 IV 群とした) 6 例の計 52 例で，心エコー図は全例洞調律時に記録した．失神歴は II 群の 2 例，III 群の 8 例に認められた．

AFF は正常群(25.1±4.6%)に比し，I, II, IV 群では有意差はなかったが，III 群(11.1±2.7%)では有意な低下を認めた．また，II 群のうち失神歴のある 2 例での AFF は有意に低下していた．Ea および Eb ともに，正常群に比し，III 群でのみ有意に低下していたが，Ec は各疾患群間に有意差はなかった．

これらの結果より，SSS 重症例，特に BTS 例では，電気生理学的異常に加えて，左房の収縮機能の有意な低下が存在することが，示唆された．

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