Beat-to-beat Changes of Right Ventricular Contraction in Clinical Cases*

HARUO TOMODA, SHUNNOSUKE HANADA, TAKANORI OGINO, HAJIME HIROSE,
TOSHIO SEKIMOTO, TOSHIYUKI OHASI, KAZUHIKO KATAYAMA, AND
HIROSHI SASAMOTO

Beat-to-beat changes of right ventricular contraction were analysed in clinical cases with atrial fibrillation. In some cases right ventricular myocardial contraction was recorded by trans-catheter method. Changes in the right ventricular myocardial contraction thus measured and changes in the right ventricular, left atrial, or left ventricular pressure due to beat-to-beat changes in the preceding R-R interval were studied. Some dissociations among these parameters were pointed out and discussed.

IN STUDYING beat-to-beat changes of cardiac performance in clinical cases, patients with atrial fibrillation offer several opportunities for observation, as already shown by other authors.^{1,2}

The purpose of this paper is to study beat-to-beat changes of the right ventricle in clinical cases with atrial fibrillation, using recently developed methods, especially measuring myocardial contraction by trans-catheter method.

METHODS

Studies have been performed in a total of 24 patients with atrial fibrillation. The majority of the patients had mitral valvular diseases and ranged in age from 20 to 59 years, as shown in Table I.

Some subjects were, and some were not, receiving digitalis at the time of these studies. The patients were not anesthetized but premedicated with sedatives (pethidine hydrochloride 35–70 mg intramuscularly or diazepam 5 mg orally).

Right heart catheterization was performed on all subjects. Left heart catheterization by trans-septal method was also performed simultaneously with the right heart catheterization in 14 of 24 cases.

Pressure was recorded through cardiac catheters by means of Statham P23Db strain gauge pressure transducers.

Furthermore, in 8 of 24 cases right ventricular myocardial contraction (at the free wall near the apex) was recorded by inserting a pair of prongs equipped with strain gauges into the subendocardial muscles through the catheter (after BING et al.)³ (Fig. 1)

Only one-directional myocardial contraction can be measured by this method and the direction of the prongs to the muscle fibers cannot be known.

Thus, the myocardial contraction may apparently vary according to the variations of the direction.

But this limitation of the method is not important in studying beat-to-beat changes of the myocardial contraction in cases of atrial fibrillation.

The myocardial contraction was expressed as per cent shortening, i.e., ratio of the myocardial contraction to end-diastolic fiber length; the shortening velocity as per cent per second; and the end-diastolic fiber length as per cent representing ratio of spacing of the prongs to the spacing of the fully opened prongs.

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Department of Internal Medicine, School of Medicine, Keio University, Tokyo (Director: Prof. H. Sasamoto)

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TABLE I

No. of Cases	Patient	Age	Sex	Diagnosis	Heart Rate beats/min	R.A.	R.V.	P.A.
						(m)	S/D	(m)
1	M.U.	29	F	Mitral Steno-insufficiency	84	1	45/0	27
2	U.H.	48	M	Mitral Stenosis	68	6	56/8	23
3	K.S.	52	M	Myocardial Infarction	72	2	22/3	16
4	T.M.	50	M	Hypertension	78	0.5	39/0	20
5	T.S.	22	M	Mitral Stenosis	64	6	40/6	
6	M.U.	43	M	Aortic Insufficiency with Mitral Stenosis	71	5.5	39/1.5	27
7	I.S.	22	M	Mitral Steno-insufficiency	118	7	50/3	36
8	S.S.	49	M	Aortic Insufficiency	110	-2	27/0	14
9	I.S.	47	F	Mitral Stenosis	72	6	35/8	28
10	T.K.	27	M	Idiopathic Myocardiopathy	80	18	42/20	32
11	G.Y.	53	M	Mitral Stenosis	70	5	63/7.5	30
12	I.I.	33	F	Mitral Stenosis	70	7.5	80/8	55
13	K.S.	33	M	Mitral Stenosis	90	15	58/15.5	46
14	H.O.	42	F	Mitral Stenosis	64	16	66/20	46
15	H.I.	32	F	Mitral Steno-insufficiency	74	6	39/8	28
16	K.K.	48	F	Mitral Insufficiency	106	6	45/7	30.5
17	J.H.	59	M	Chronic Pulmonary Emphysema	100	-2	30/2.6	27
18	M.M.	20	F	Mitral Insufficiency	88	4.5	37/5	
19	Y.Y.	25	F	Mitral Steno-insufficiency	78	2.5	27/3	15.5
20	Y.Y.	20	M	Mitral Insufficiency	91	6	50/1	28
21	K.F.	37	M	Mitral Stenosis	52	0	47/0	41
22	M.W.	39	M	Mitral Stenosis	76	2	51/1.5	26
23	S.S.	32	M	Mitral Steno-insufficiency	64	5	40.5/6	20
24	K.K.	24	M	Mitral Stenosis	100	2	60/4	46

R.A. = right atrium; R.V. = right ventricle; P.A. = pulmonary artery; P.C. = pulmonary capillary;

Pressure		R. V. Myocardial Contraction			R. V. pressure, R-R interval relation	R. V. per cent shortening, R-R interval relation	L. V. Pressure, R-R interval relation
L.A. (P.C.) (m)	L.V. S/D	B.A. S/D	Per cent shortening	Maximal shortening velocity			
mmHg			%	%/sec			
(15)		106/74			Ascending		
20		110/88			Descending		
		100/70			Ascending		
8		152/90			Ascending		
17		98/60			Descending		
19.5		130/90			Ascending		
27		120/70			Ascending		
7		114/40			Ascending		
20		130/82			Descending		
(23)		108/62	20.5	144	Indefinite	Indefinite	
		134/74	8.2	97	Descending	Ascending	
(32)		110/70	14.7	111	Ascending	Ascending	
(25)		150/84	12.7	124	Ascending	Ascending	
(25.5)		90/58	18.7	117	Descending	Ascending	
(30)		102/62	13.2	111	Ascending	Ascending	
(19.5)		128/78	7.1	78	Ascending	Ascending	
(3)		142/90	8.7	89	Ascending	Ascending	
13	110/10	112/68			Ascending		Ascending
13	105/1.5	106/68			Intermediate		Ascending
20	112/12	120/68			Ascending		Ascending
16	130/7	138/72			Descending		Ascending
20	106/6	114/88			Intermediate		Ascending
6	100/1	110/80			Ascending		Ascending
26	110/12	118/90			Ascending		Ascending

L.A. = left atrium; L.V. = left ventricle; B.A. = brachial artery; (m) = mean pressure; S/D = systolic/diastolic

Fig. 1. A pair of prongs equipped with strain gauges.

Fig. 2. Recordings of case 17 (59 years old, male, chronic pulmonary emphysema). From top to bottom, PCG, ECG, right ventricular myocardial contraction and right ventricular pressure are shown.

All measurements were done during end-expirium so as to exclude the effects of respiratory fluctuations. One of the recordings thus obtained is shown in Fig. 2.

RESULTS

The relation between the duration of the preceding R-R interval and the right ventricular systolic pressure was studied. As can be seen in Table I, the right ventricular systolic pressure bears a direct relation to the duration of the preceding R-R interval (described as "ascending" in the Table) in 15 of 24 cases. But in 6 of 24 cases inverse relation was observed between the right ventricular systolic pressure and length of the preceding R-R interval (described as "descending" in the Table).

Three cases were of an "intermediate" (parallel to abscissa, case 19 and 22) or "indefinite"

Fig. 3. The relation between right ventricular systolic pressure and the preceding R-R interval.

MS: mitral stenosis,
MI: mitral insufficiency,
CPE: chronic pulmonary emphysema.

Fig. 4. The relation between per cent shortening of right ventricular myocardial fibers and the preceding R-R interval. Same cases as in Fig. 3.

Fig. 5. The relation between right ventricular systolic pressure and the preceding R-R interval (above), and the relation between per cent shortening of the right ventricular myocardial fibers and the preceding R-R interval (below). Case 16 (48 years old, female, mitral insufficiency)

Fig. 6. The relation between maximal shortening velocity and per cent shortening of right ventricular myocardial fibers (above), and the relation between the per cent shortening of the cardiac fibers and end-diastolic fiber length (below). Same case as in Fig. 5.

type (case 10).

These relations are shown for 5 typical cases in Fig. 3. Three of them show a direct relation (ascending) and two an inverse relation (descending).

On the other hand, in the same 5 cases a direct relation can be seen between the right ventricular myocardial shortening (per cent shortening of cardiac fibers) measured by the method mentioned above and the duration of the preceding R-R interval (Fig. 4).

Further details are explained in the followings on cases 16 and 11. In case 16 (mitral insufficiency) the right ventricular systolic pressure and the per cent shortening of cardiac fibers are related to the preceding R-R interval (Fig. 5). There was also a direct relation between the maximal shortening velocity of cardiac fibers and the per cent shortening, as well as between per cent shortening of cardiac fibers and the end-diastolic fiber length

(Fig. 6).

On the other hand, in case 11 (mitral stenosis) there was an inverse correlation between the right ventricular systolic pressure and the preceding R-R interval, although the right ventricular myocardial shortening related directly to the preceding R-R interval (Fig. 7).

Furthermore, the left ventricular systolic pressure related to the preceding R-R interval in all cases examined. For example, in case 21 (mitral stenosis) the right ventricular systolic pressure related inversely to the preceding R-R interval, though the left ventricular systolic pressure related directly to the preceding R-R interval.

Finally, all cases which showed the descending or intermediate curves had mitral stenosis, and no cases without mitral stenosis showed these curves.

DISCUSSION

The right ventricular systolic pressure and the

Fig. 7. The relation between right ventricular systolic pressure and the preceding R-R interval (above), and the relation between per cent shortening of of the right ventricular myocardial fibers and the preceding R-R interval. Case 11 (53 years old, male, mitral stenosis)

duration of the immediately preceding R-R interval showed a direct relation in 15 of 24 cases.

But in 6 of 24 cases this relation was inverse. Quite the same study has already been reported.⁴ In that report also, the right ventricular systolic pressure does not always show a direct relation to the preceding R-R interval but in some cases showed an almost inverse correlation. The author points out that the heart rate is the major factor which determines the relation; that is, after longer diastole the right ventricle cannot be filled any more, and the curves become flat or rather downward in the cases with slower heart rate.

In fact in our cases too, those that show ascending curves have an average heart rate of 88 (64–118) and those that show flat or descending curves a rate of 68 (52–78).

But the right ventricular myocardial contraction and the duration of the preceding R-R interval of the same cases always revealed a direct relation. The myocardial contraction, the shortening velocity and the end-diastolic fiber length also

showed direct relations. In one case the left ventricular pressure was related to the preceding R-R interval, although an inverse relation was encountered for the right ventricle.

In addition to these facts, all 6 cases with descending curves had mitral stenosis. It is evident that all these facts could not be explained by differences in the heart rate only. BRAUNWALD et al.⁵ have already reported that in patients with mitral stenosis and atrial fibrillation, the magnitude of the left atrioventricular pressure gradient at the end of diastole varies inversely with the duration of the preceding diastole.

In our cases with mitral stenosis also an inverse relation was found between the magnitude of the left atrioventricular pressure gradient and the duration of the preceding diastole.

From these facts the following speculations are made; in cases with mitral stenosis, the longer preceding R-R interval permits more complete emptying of the left atrium through the stenosed mitral orifice, and this leads to a decrease of the left atrial pressure, allowing the right ventricle to contract more sufficiently under lower pressure generation.

The reasons the right ventricles in cases of mitral stenosis do not always reveal the same reaction (some cases show ascending curves, some descending curves, and other cases show intermediate curves) seem to depend on complicated effects of heart rate, grade of mitral valvular or pulmonary vascular changes, and right ventricular function itself.

In our cases, however, there were no clear differences in pulmonary blood volume or calculated pulmonary vascular resistance.

In case 13 and 14 the elevation of the central venous pressure (15 mmHg and 16 mmHg, respectively), as well as clinical signs, shows classical right heart failure, but the right ventricular myocardial contraction related directly to the preceding R-R interval. This fact indicates that even in the state of so-called right heart failure, right ventricular myocardial fibers contract in the same way as those of cases without such findings.

Finally, case 10 with idiopathic myocardio-pathy showed “indefinite” curves both in pressure and myocardial fiber shortening. This may be due to changed contractility of the heart muscles.

SUMMARY

Beat-to-beat changes of right ventricular contraction in 24 clinical cases with atrial fibrillation

were studied. Right ventricular myocardial contraction in 8 of the cases was measured by inserting a pair of prongs into the heart muscles through cardiac catheters.

In 15 of the 24 cases the right ventricular systolic pressure related directly to the duration of the preceding R-R interval, but in 6 cases with mitral stenosis an inverse relation was encountered. However, the right ventricular myocardial contraction, maximal shortening velocity and left ventricular systolic pressure related directly to the preceding R-R interval in these cases.

From these facts the following speculations are made; in some cases with mitral stenosis, a longer preceding R-R interval permits more complete emptying of the left atrium through the stenosed mitral orifice, and this leads to a decrease in the left atrial pressure and its backward effects, allowing the right ventricle to contract more sufficiently under lower pressure generation.

It was also observed, in two cases with elevated central venous pressure and clinical signs of classical right heart failure, that the right ventricular myocardial fibers contracted in the same way as those of cases without such findings.

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