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STROKE VOLUME ESTIMATION BY RHEO-ECHOCARDIOGRAPHY DURING ATRIAL FIBRILLATION CONVERTED TO SINUS RHYTHM

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The impedance rheographic and echocardiographic methods were used to investigate changes in the stroke volume (SV) and the cardiac output (CO) in the course of atrial fibrillation and after electroversion. 12 patients were examined. CO increased on average by 11 per cent and 9 per cent after electroversion using respectively rheographic and echocardiographic methods.

1. Introduction

Atrial fibrillation is characterized by arrhytmia, e.g. big fluctuation in time of the cardiac cycle (over 20 per cent) and by the lack of atrial contraction. Atrial fibrillation causes cardiac performance worsening which is manifested in decreasing stroke volume, cardiac output, atrial pressure and time of blood circulation and in increasing central venous pressure, right atrial pressure and arterio-venous difference in the oxygen saturation of blood [1].

Many authors report that lack of sinus rhythm causes a decrease in the cardiac output from 7 do 25 per cent [2, 10]. First of all, it is the result of a loss of effective pumping action of the atrial, but also loss of the rhythm as well as speed up of the cardiac function. A decrease in CO may intensify symptoms, for example, the appearance of latent circulation insufficiency (heart failure) or chest pain of stenocardial effect. Restoration of sinus rhythm improves hemodynamics of the heart.

Thus, it is reasonable to assume that the consequences of sinus rhythm loss depend on the degree of hemodynamic disorders.

The purpose of the study was to investigate changes in stroke volume (SV) and cardiac output (CO) in the course of atrial fibrillation and after electrical cardioversion.

2. Materials and methods

Twelve patients with atrial fibrillation were investigated. The group consisted of 9 males and 4 females, aged from 28 to 52, 47 years on average. Atrial fibrillation persisted from 3 days to 6 months, 44 days on average.

The group investigated (Table I) consisted of:

1. 1 patient with heart failure in course of mitral insufficiency (case 11);
2. 4 patients after commissurotomy (cases 1, 3, 5, 10);
3. 2 patients with double valve replacement (cases 9 and 12);
4. 3 patients with coronary disease and arterial hypertension (cases 7, 8, 9);
5. 2 patients with paroxyzmal atrial flutter (cases 2 and 4).

Before the sinus rhythm was restored, all medicines with possible influence on heart contractility were discontinued (especially digitalis). Two hours prior to cardioversion chinodine (0.4 g) was administered orally to all patients.

Both echographic and rheographic measurements were conducted before and immediately after electrical treatment. Energy applied to the patients was in range of 50 to 300 Ws, depending on the weight as well as condition of patient.

Echographic measurements were made by the *TM* technique, using a UKG-10 device, produced by TECHPAN.

The left ventricular stroke volume (SV) was calculated using the Teichholz formula where:

The end diastolic volume

$$V_d = (DD)^3 \frac{7}{2.4+DD};$$

The end systolic volume

$$V_s = (SD)^3 \frac{7}{2.4+SD},$$

where DD and SD respectively: the diastolic and systolic diameter of the left ventricle (Fig. 1).

The stroke volume

$$SV = V_d - V_s.$$

Rheocardiographic study was performed by the tetrapolar current impedance method developed by T. PAŁKO [6, 7], which is generally based on the Kubicek method.

In that method (Fig. 2), two band electrodes feeding the current are located around the neck and the waist. Through the electrodes there flows the alternating current with a frequency of 60 kHz at the constant amplitude of 1 mA.

Table 1. Clinical data

No	Initials Sex-Age	Atrial fibrillation SV [cc] Rheo	Atrial fibrillation SV [cc] Echo	Atrial fibrillation CO [l/min] Rheo	Atrial fibrillation CO [l/min] Echo	Atrial fibrillation HR [b/min]	Electroversion SV [cc] Rheo	Electroversion SV [cc] Echo	Electroversion CO [l/min] Rheo	Electroversion CO [l/min] Echo	Electroversion HR [b/min]
1	*NR – M* 50	45	50	5.0	5.6	112	56	63	5.6	6.3	100
2	*DJ – M* 49	33	28	5.9	5.1	180	76	80	6.1	6.4	80
3	*GH – F* 48	54	43	5.6	4.5	102	75	73	6.0	5.9	80
4	*ZJ – M* 48	62	63	5.2	5.3	84	80	78	5.6	5.5	70
5	*GG – F* 30	50	54	6	6.5	120	92	80	6.4	5.6	70
6	*MF – M* 58	62	61	4.8	4.7	77	83	80	5.6	5.5	68
7	*PS – F* 61	62	59	6.6	6.3	106	72	73	6.8	7.0	95
8	*FT – M* 51	58	69	4.7	5.6	81	84	96	5.6	6.5	67
9	*JJ – M* 28	42	46	4.8	5.3	115	72	72	4.8	4.9	67
10	*KM – F* 60	24	47	3.6	7.0	150	48	73	4.8	7.3	100
11	*ŁZ – M* 36	55	67	6	7.4	110	72	70	7.2	7	100
12	*RW – M* 37	50	60	5.2	6.2	104	62	70	5.9	7	100
Average SV and CO		49.75	53.92	5.28	5.79	111.75	72.67	75.67	5.87	6.25	83.08
Standard deviation		11.51	11.22	0.76	0.86	27.86	11.83	7.82	0.68	0.73	14.12

The changes in the impedance ΔZ and first derivative dZ/dt are detected by 2 disc electrodes (instead of band electrodes in the Kubicek method) located above and below the sternum.

The investigation used the impedance rheograph designed by one of us (*T.P.*).

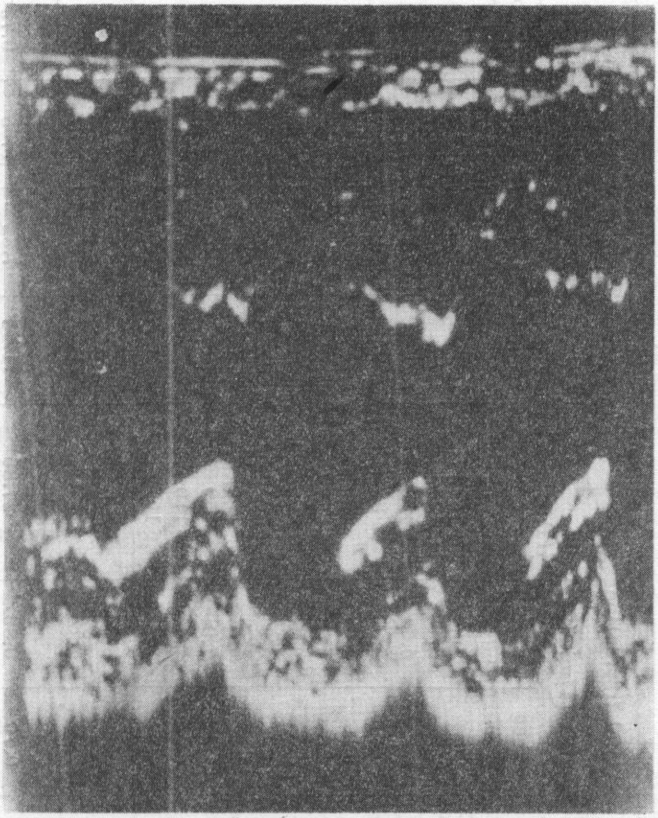

Fig. 1. Measuring method of systole and diastole diameter of the left ventricle by the echocardiographic — *TM* technique

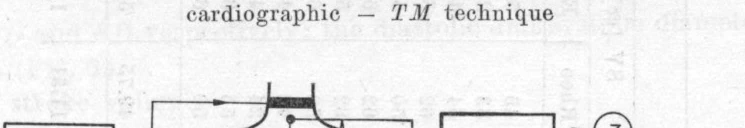

Fig. 2. Principle of the tetrapolar current method for determination of stroke volume

The stroke volume (SV) was calculated using the Kubicek formula:

$$SV = \varrho \frac{L^2}{Z^2} \left| \frac{dZ}{dt} \right| T,$$

where ϱ — resistivity of blood dependent mainly on hematocrite, L — distance between inner electrodes, Z — basis impedance, $|dZ/dt|$ — amplitude of first derivative of impedance change (Fig. 3), T — left ventricle ejection time (Fig. 3).

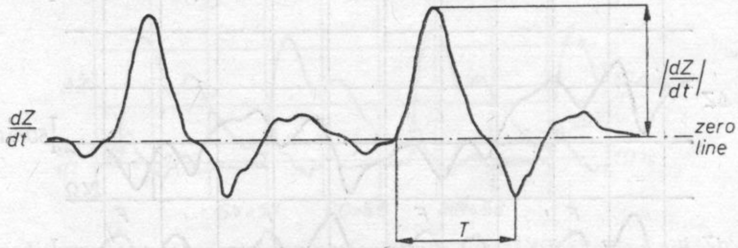

Fig. 3. Principle of dZ/dt amplitude and T - ejection time assessment from rheocardiographic dZ/dt signal

The reliability of this method for computing SV was verified [8] by comparison with the invasive computerized termodilution method. For healthy subjects the results obtained by the two methods differ less than 15 per cent. The impedance method proved to be very useful for change trend observation.

3. Results

Examples of rheocardiographic recordings and the calculated stroke volume (SV) and the cardiac output (CO) for 2 patients with atrial fibrillation (FA) (Figs. 4 and 5) and a patient with atrial flutter (VA) (Fig. 6) are shown in Figs. 4-6.

The results indicate that SV during atrial fibrillation in rest changes very distinctly. It depends not only on the ventricular filling time. We suggest that the influence of the atrial activation conducted to the ventricular activation changing electromechanical effect should be considered. In this situation the CO, measured during over 1 min. is almost constant in spite of the very large beat-to-beat SV changes. Immediately after synchronized electrical atrial defibrillation SV and CO appeared virtually stable. The CO value after cardioversion is usually distinctly higher than that during atrial fibrillation.

The results of SV and CO obtained by the methods from the examination of patients with atrial fibrillation (FA) are shown in Table I and a diagram (Fig. 7).

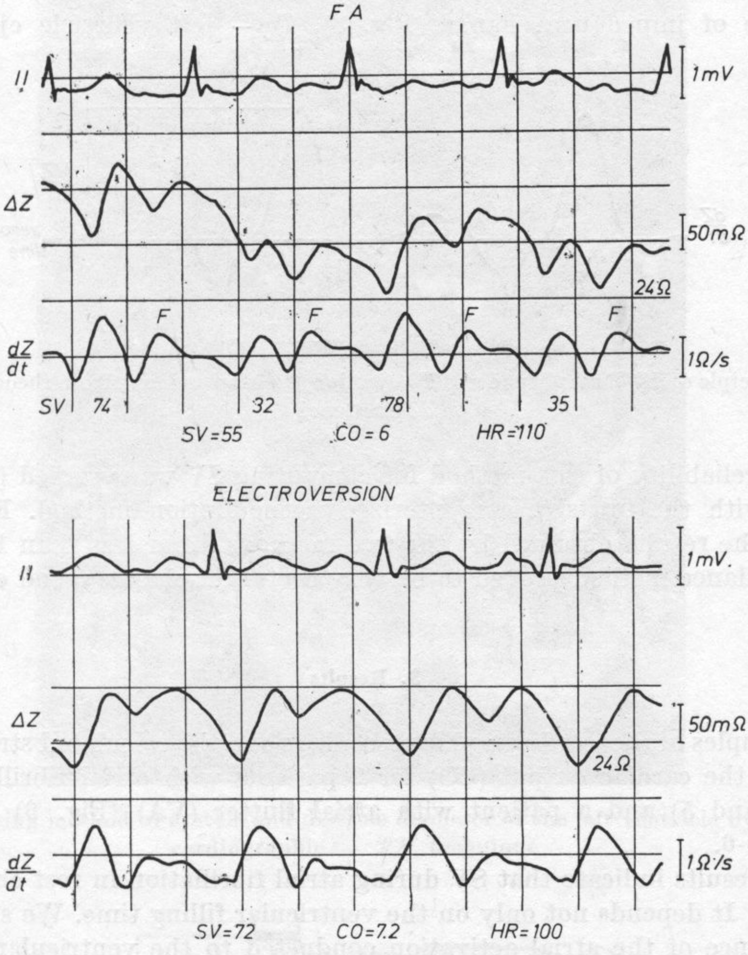

Fig. 4. Rheocardiographic recordings for patient with atrial fibrillation with fast ventricle rate and after electroversion. Signs of mitral insufficiency evident (big *F* wave)

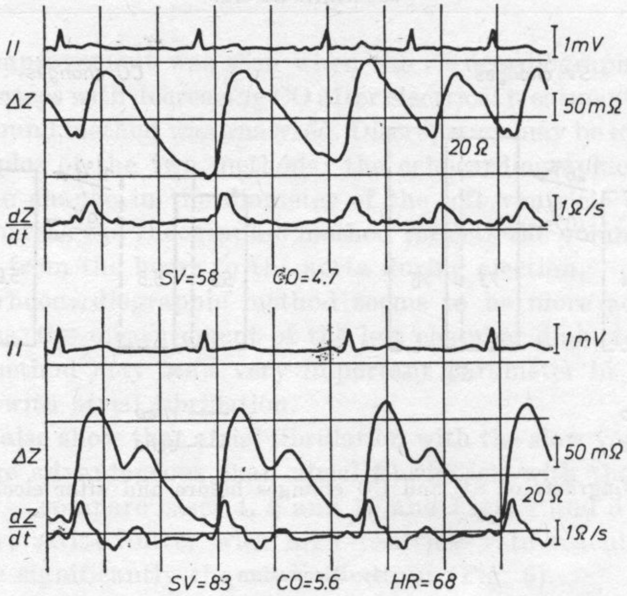

Fig. 5. Rheocardiographic recordings for patient with atrial fibrillation with slow ventricle rate and after electroversion

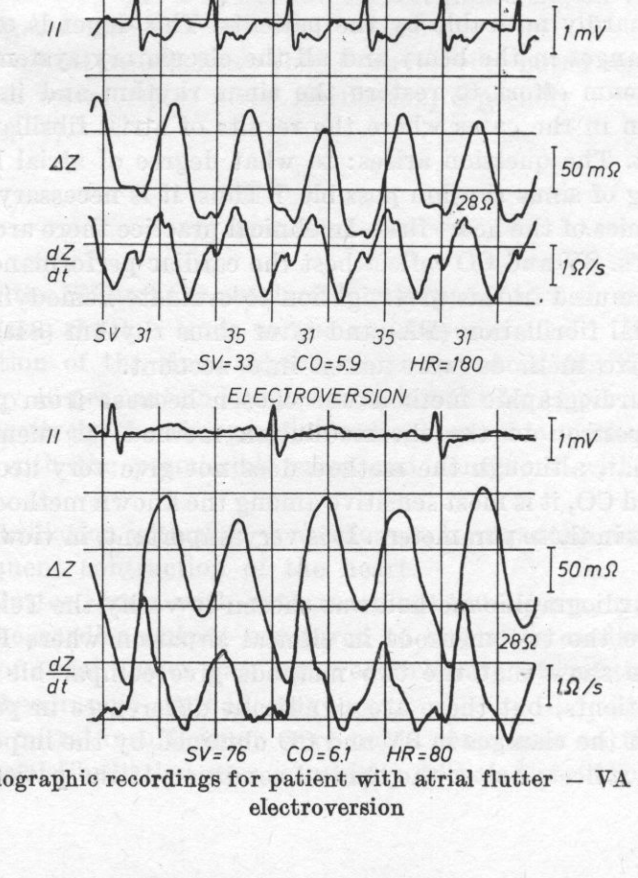

Fig. 6. Rheocardiographic recordings for patient with atrial flutter — VA and directly after electroversion

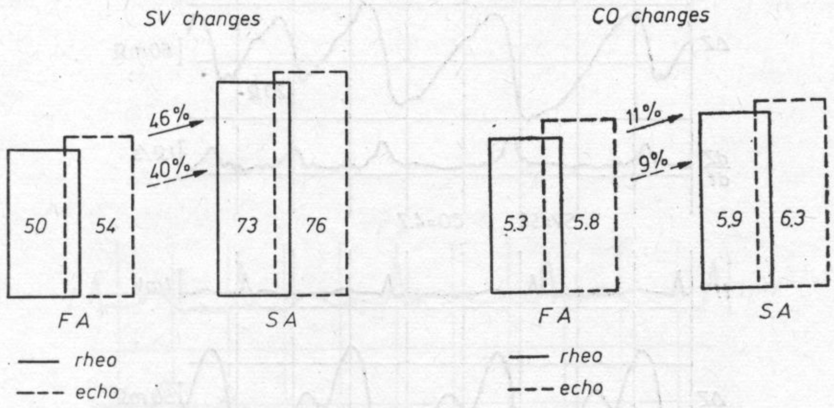

Fig. 7. Diagrams of SV and CO changes before and after electroversion

4. Discussion

Atrial fibrillation causes different degrees of hemodynamic disorders. In some cases they are very heavy and lead to edema or acute brain ischemia and the MAS syndrom. In other cases, clinical symptoms are so insignificant that they are hardly noticable by the patients. This depends on the origin of the disease, changes in the heart and all the circulatory system.

The maximum effort to restore the sinus rhythm and its consolidation should be taken in the cases where the results of atrial fibrillation are heavy and permanent. The question arises: to what degree of atrial hypertrophy is the maintaining of sinus rhythm possible ? Thus, it is necessary to investigate the hemodynamics of the heart first. In clinical practice there are several hemodynamic indexes. SV and CO reflect best the cardiac performance. Thus, these parameters were used in this investigation to evaluate hemodynamic disorders in cases of atrial fibrillation (FA) and after sinus rhythm (SR) was restored. Only noninvasive methods were taken into account.

The rheocardiographic method was chosen because from previous verification in comparison to the thermodilution method (as mentioned above), it is evident that, although the method does not give very accurate absolute values of SV and CO, it is most sensitive among the known methods to determine relative changes in these parameters. It is very important, in view of the purpose of this study.

The echocardiographic method was chosen to verify the Teichholz formula and to compare the two methods in clinical situation where FA occurs.

The results show that the two methods give comparable results in our group of 12 patients, but there are significant differences in particular cases.

Analyses of the changes in SV and CO obtained by the impedance method prove that this reflects better the clinical condition of the patient. In all cases hemodynamic improvement was seen when the rheocardiographic method was used, whereas 3 cases with decreasing CO after electrical treatment were observed when the ultrasound method was analysed. Discrepancy may be explained by the different principles of the two methods: the echocardiographic method takes into account the change in the diameter of the left ventricle only in systole and diastole, whereas the rheographic method reflects the volume of the blood that is expelled from the heart to the aorta during ejection.

Thus, the rheocardiographic method seems to be more adequate.

Nevertheless, the measurement of the left chamber diameter in the echocardiographic method may be a very important parameter in the evaluation of the patients with atrial fibrillation.

The results also show that atrial fibrillation with the slow ventricle contraction rate is more advantageous than atrial fibrillation with the fast ventricle action (Table I — compare cases 4, 6 and 10 and Figs. 4 and 5).

Surprisingly, atrial flutter with high ventricle rate reaching 180 b/min. does not change significantly the cardiac output (Fig. 6).

Analysis of the findings leads us into 2 additional resolutions, essentially not connected with the purpose of this work, namely:

1. During atrial fibrilation and atrial flutter with high ventricle rate, alternating phenomena may occur and it can be recognized by the rheocardiographic method (Figs. 4 and 6).

2. Signs of mitral insufficiency (big *F* wave) were noted sometimes on the heocardiographic waveform of atrial fibrillation, especially with fast ventricle contraction (Fig. 4).

5. Conclusions

Analysis of the SV and CO obtained for the patients with atrial fibrillation converted to sinus rhythm leads to the conclusions:

1. Restoration of the sinus rhythm from the atrial fibrillation increases stroke volume by 46 per cent and 40 per cent, but CO by 11 per cent and 9 per cent using respectively the rheographic and echographic methods; the results are consistent with the permissible error and consistent with the literature [1, 10].

2. Atrial fibrillation with slow ventricle rate is advantageous to fibrillation with more frequent contraction of the heart.

3. Atrial flutter, even with rate reaching 180 b/min., practically does not diminish the cardiac output compared to one after cardioversion.

4. In case of atrial flutter with high ventricle rate, alternating pulse-recognized by the rheographic method may occur.

5. Signs of mitral insufficiency were noted sometimes on the rheographic waveform of atrial fibrillation case, especially with fast ventricle contraction.

6. Final conclusion

Sinus rhythm should be restored in the consideration of the hemodynamic improvement, especially for patients with a long history of heart failure, as well as fatal thrombogenesis. It has to be taken into account that restoration of sinus rhythm may cause embolism, as a result of moving thrombus produced earlier during long-term atrial fibrillation.

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