Amplitude and Time Parameters of Differentiated Impedance Cardiogram in Sympathectomized Rats

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Analysis of amplitude and time parameters of differentiated impedance cardiogram, stroke and minute blood volumes, and heart rate showed that the ascending portion of impedance cardiogram is longer and the descending portion is shorter in rats sympathectomized with guanethidine. This indicates that the cardiac output indices were less affected by sympathetic control.

Key words: *differentiated impedance cardiogram; stroke volume; minute circulation volume; sympathectomy; developing organism*

Impedance cardiography has been successfully used to study the cardiac output indices in a developing organism [1,2,8,9]. The ratio of the amplitude of impedance cardiogram to the fast ejection period allows one to evaluate myocardial contractility [4]. Arterial and venous circulation can be separately assessed using a similar analysis of rheographic parameters [5]. Study of rheographic amplitude-temporal relations is useful in the assessment of cerebral blood flow rates [13]. The method of chemical sympathectomy with guanethidine has been employed as a model to study the sympathetic control in a developing organism, [1,3,10-12,14]. The amplitude and time parameters of differentiated impedance cardiogram (DIC) as well as stroke volume (SV), minute blood volume (MBV), and heart rate (HR) were analyzed in pharmacologically sympathectomized neonatal rats till day 21 and after finishing drug administration until puberty (100 days). Our objectives were to increase informativity of thoracic tertrapolar impedance cardiography more and to reveal possible mechanisms of the cardiac output control.

MATERIALS AND METHODS

Experiments were performed on random-bred albino rats at the age of 3, 7, 14, 21, 30, 42, 49, 70 and 100 days. The animals were sympathectomized with guanethidine since the birth till the day 21. The drug was administrated in a daily dose 25 mg/kg, intracutaneously [11]. Control animals were given physiological saline. The rats were anesthetized with Nembutal (40 mg/kg) and breathed naturally. Recording of DIC was performed by the method of thoracic tertrapolar impedance cardiography using an RPG-204 device [15].

Amplitude and time parameters of DIC were calculated as described previously [4,6]. Temporal parameters of DIC were measured both in absolute (sec) and relative units (%). The ventricular blood ejection period (*tu*) included the fast ejection period (*a*) and the slow ejection period (*b*) (Fig. 1). The *tu* interval was taken as 100%, the parameters *a*% and *b*% were calculated as follows:

$$a\%=a\times 100/tu,\ b\%=b\times 100/tu.$$

Experimental data were statistically processed by Student's *t*-test and correlation analysis.

RESULTS

The DIC amplitudes in 7- and 14-day rats did not differ from the control values (Table 1). On day 21 the, *Ad* in sympathectomized rats was 33.5 mm, which is substantially greater than in the control ($p<0.001$). No difference was found in DIC am-

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plitudes between test and control groups on days 30 and 42. Sympathectomized rats on days 49 and 70 had significantly higher *Ad* than control rats. The amplitude *Ad* in sympathectomized rats growing from day 3 to day 30 increased by 12.9 mm, while from day 30 to day 100 it decreased by 21.7 mm ($p<0.001$).

Ventricular blood ejection period in sympathectomized 3-day-old rats was 0.138 sec (Fig. 2). By day 7, this index decreased. However, no statistically significant difference was found between control and test groups. At all other ages the blood ejection period in sympathectomized rats was considerably greater than in the control. The most significant differencies were observed in 14-, 21- and 30-day old rats.

The DIC ascending portion in sympathectomized rats on days 14 and 21 was shorter than in the control (Fig. 2). Sympathectomy changed considerably parameter *a%* on day 21, when it was equal 31% in the test and 43% in the control group. On days 30, 42, 49 and 70, the DIC ascending portion in sympathectomized rats was significantly shorter than in the control. According to our results, the DIC descending portion (*b%*) is always longer than the ascending portion. The DIC descending portion in sympathectomized 14- and 21-day-old rats was longer than in the control. The greatest differencies were observed on day 21, when *b%* was equal to 69% in sympathectomized rats and 57% in the control.

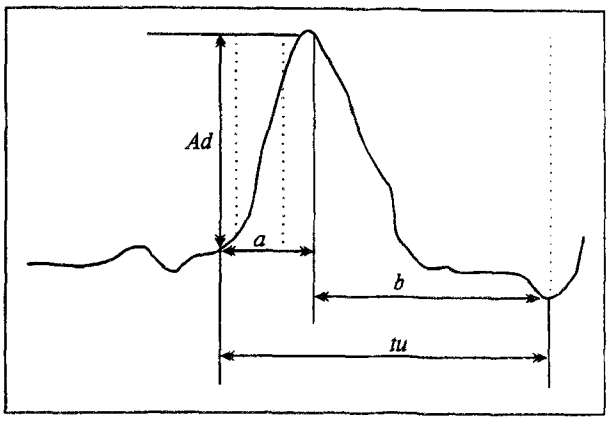

Fig. 1. Measuring of main amplitude and time parameters of the differentiated impedance cardiogram (DIC). *Ad*) amplitude of DIC, mm; *tu*) blood ejection time, sec; *a*) fast ejection time (ascending portion), sec; *b*) slow ejection time (descending portion), sec.

After guanethidine administration had been stopped, i.e., on days 30, 42, 49 and 70, parameter *b%* remained at a high level.

It should be noted that during of sympathectomy, i.e. till day 21, changes in parameters *a%* and *b%* were opposite to changes observed in the control group. While increasing in the control, the DIC ascending portion decreased in test rats from day 7 through day 21. The DIC descending portion decreased in the control, and increased under sympathectomy. The effect of guanethidine, which consisted

TABLE 1. Amplitude and Time Parameters of DIC in Developing Sympathectomized Rats (*M±m*)

Age, days	Group	N	*Ad*, mm	*a*, sec	*b*, sec
3	Test	10	26.3±1.6	0.089±0.030	0.083±0.010
7	Test	32	30.3±0.8	0.042±0.001	0.083±0.002**
	Control	10	30.2±2.5	0.038±0.002	0.082±0.010
14	Test	19	28.1±1.2	0.043±0.001**	0.092±0.002***
	Control	16	25.2±1.8	0.032±0.001	0.058±0.002
21	Test	29	33.5±2.0***	0.040±0.001**	0.091±0.001***
	Control	14	24.7±0.9	0.031±0.001	0.041±0.001
30	Test	19	39.2±1.1	0.042±0.001***	0.063±0.002*
	Control	10	35.9±2.5	0.034±0.001	0.045±0.001
42	Test	19	32.6±1.5	0.036±0.001	0.058±0.001***
	Control	22	34.0±1.9	0.036±0.001	0.058±0.001***
49	Test	18	33.3±0.9***	0.037±0.001	0.060±0.002***
	Control	14	25.9±1.4	0.036±0.001	0.050±0.001
70	Test	12	23.9±1.0***	0.039±0.001*	0.062±0.002***
	Control	10	19.7±0.9	0.035±0.001*	0.062±0.002***
100	Test	9	17.5±0.6	0.039±0.003	0.060±0.001***
	Control	10	17.3±0.5	0.033±0.001	0.050±0.001

Note. Here and in Table 2: *p<0.05, **p<0.01, ***p<0.001 compared with control.

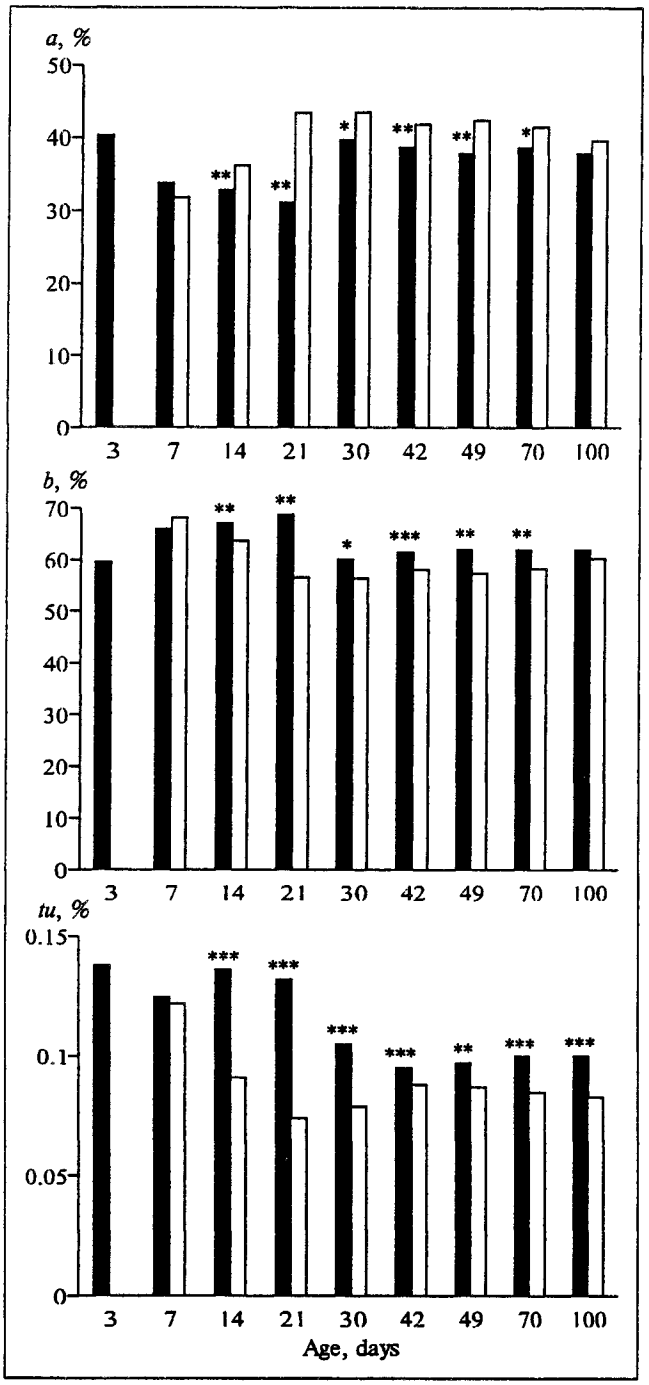

Fig. 2. Ventricular blood ejection period and its components in developing sympathectomized rats. Here and in the Fig. 3: black columns: sympathectomy, white columns: control; *$p<0.05$, **$p<0.01$, ***$p<0.001$ compared with control.

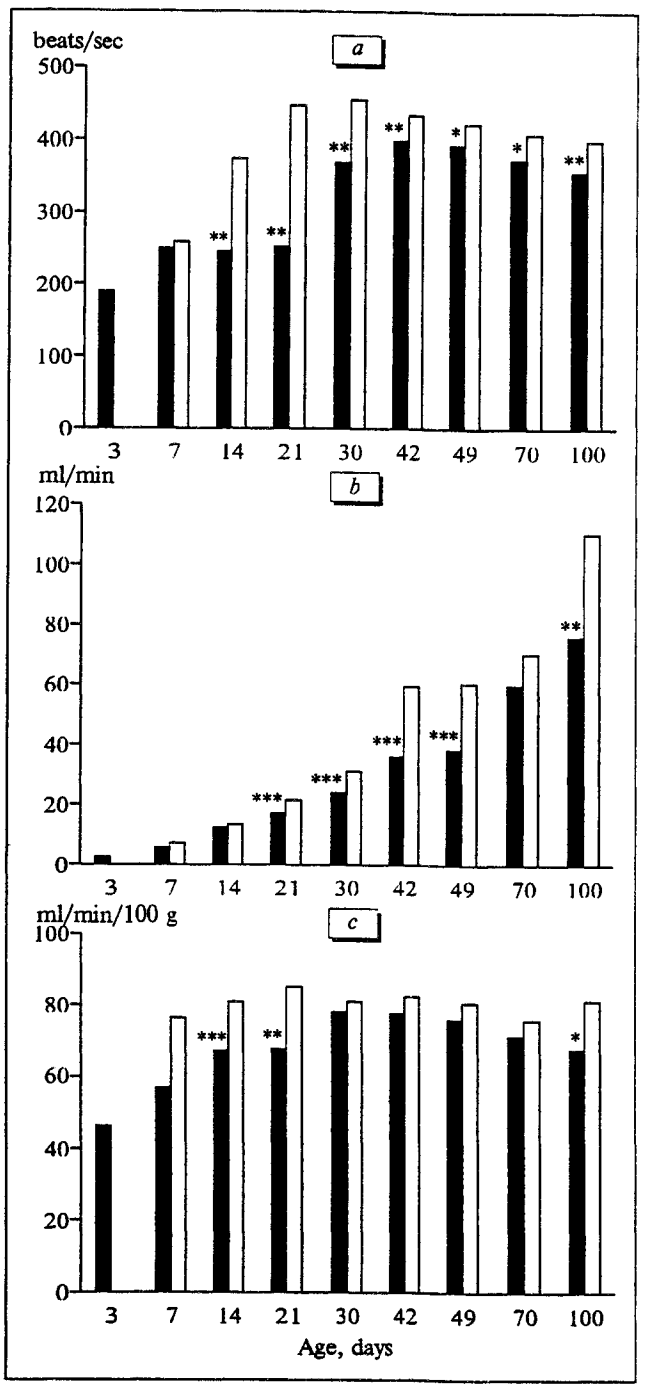

Fig. 3. Heart rate (*a*) and minute blood volume (*b,c*) in developing rats sympathectomized by Guanethidine.

in destroying adrenergic nerve endings as well as neurones, is most pronounced on day 30, when about 0.5% of neurones survive [11]. After completion of drug administration, the compensatory processes developed in a sympathectomized organism. The longer the period of Guanethidine administration, the shorter the ascending and the longer the descending portion of DIC. It is worth to note that after the end of guanethidine injection *b%* remains longer and *a%* shorter than in the control. These results suggest that longer descending and shorter ascending portion of DIC are associated with reduced sympathetic control.

Table 2. Stroke Volume Parameters in Developing Sympathectomized Rats (*M±m*)

Age, days	Group	Number	Body weight, g	SV, ml	SV/100 g
3	Test	10	6.1±0.3,	0.014±0.001	0.24±0.04
7	Test	32	10.1±0.3	0.025±0.001	0.24±0.01
	Control	10	10.9±1.3	0.026±0.003	0.22±0.001
14	Test	19	17.8±0.4	0.049±0.002***	0.26±0.001
	Control	16	17.6±1.5	0.035±0.001	0.23±0.02
21	Test	29	24.5±0.6	0.063±0.004*	0.25±0.02
	Control	14	22.6±1.6	0.049±0.003	0.23±0.02
30	Test	19	29.4±0.9**	0.068±0.003	0.23±0.01
	Control	10	42.8±3.6	0.066±0.003	0.22±0.01
42	Test	19	49.3±2.0***	0.092±0.003***	0.20±0.01
	Control	22	70.8±4.2	0.126±0.010	0.21±0.01
49	Test	18	51.3±2.6***	0.098±0.010**	0.20±0.01
	Control	14	78.7±5.5	0.142±0.010	0.21±0.02
70	Test	12	83.0±2.0*	0.158±0.010	0.19±0.01
	Control	10	103.7±9.2	0.182±0.020	0.20±0.01
100	Test	9	128.6±3.2***	0.200±0.020	0.19±0.02

Concerning SV, in 14- and 21-day-old sympathectomized rats it was considerably greater than in the control (Table 2). On days 42 and 49, SV was smaller than in the control. No differences were found for other ages between test and control groups. There was no discrepancy in SV per 100 g body weight between control and sympathectomized rats at the same age. However, this index had a tendency to gradually decrease with age.

Heart rates in 7-day-old sympathectomized rats were 149.5 beats/sec, being of the same value as in the control group (Fig. 3, *a*). A pronounced increase in heart rate occurred in the control group by day 14 and 21, while sympathectomy suppressed it. After guanethidine injections had been finished, heart rate in sympathectomized rats rose and reached the maximum on day 42. By the 100th day, heart rate decreased in both groups, with lower rates in sympathectomized rats.

Minute blood volume in 7- and 14-day-old sympathectomized rats did not differ from that in the control group (Fig. 3, *b*). On days 21 and 30, MBV in sympathectomized rats was less than in the control by 4.5 and 7.1 ml/min, respectively ($p<0.001$). Sympathectomy had the strongest effect on MBV elevation on days 42 and 49, when the difference compared with the control was 23.4 and 22.1 ml/min, respectively ($p<0.001$). In pubertal (100-day) sympathectomized rats MBV was 34.3 ml/min lesser than in the control ($p<0.01$). In sympathectomized rats above 21 day, the index of circulation (MBV/100 g body weight) was lesser than in the control. The differences on days 14 and 21 were 13.8 and 17.4, respectively. There were no differences between the indices of MBV/100 g in test and control rats at the ages of 30, 42, 49, and 72 days. Compared with control, in 100-day-old sympathectomized rats this index decreased by 13.6 ml/min/100 g ($p<0.05$).

Statistically significant positive correlations between SV, age, body mass and MBV were found for sympathectomized rats ($r=0.99$-0.95). The fast ventricular blood ejection period (*a%*) strongly correlated with SV in sympathectomized rats ($r=-0.80$). Heart rate correlated with ventricular ejection period ($r=-0.93$) and the length of descending portion of DIC ($r=0.95$).

The ascending portion of DIC (*a%*) in sympathectomized rats was shorter than in the control. The descending portion of DIC (*b%*) in test rats was longer than in the control. Therefore, the degree of sympathetic influence on the cardiac output indices can be evaluated from the duration of ascending and descending portions of DIC. Daily injections of Guanethidine to rats for 3 weeks during neonatal period, markedly diminish the rates of the increase in heart rate and MBV. Stroke volume in 14- and 21-day-old sympathectomized rats was greater than in the control. The increased amplitude of DIC and the shorter ascending portion (*a%*) were also charateristic.

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