PHYSIOLOGY

Frequency Parameters of Feline Left Ventricular Pressure under Various Experimental Conditions

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Cardiac frequency-domain parameters of the left ventricular pressure were studied in acute experiments on cats under conditions of reflex and load stimulation and during maximum inotropic stimulation with epinephrine. A strict correlation was revealed between the upper threshold of the frequency range and the maximum value of pressure first derivative. Without epinephrine infusion, the maximum value of pressure first derivative and the upper threshold of the frequency range attained 9840 mm Hg/sec and 98.4 Hz, correspondingly. During epinephrine infusion, the corresponding values were 12911 mm Hg/sec and 145 Hz. Left ventricular pressure in cats is characterized by high-frequency parameters, which can be measured by special catheter microtransducers and only in some cases by routine pressure gauges.

Key Words: *heart; contractile indices; intraventricular pressure; spectrum analysis*

Analysis of cardiac inotropic function is an important tasks of experimental cardiology. To this end, the contractile indices are widely used. The overwhelming majority of these indices are so-called isovolumic parameters calculated from the curve of intraventricular pressure during the phase of isovolumic contraction [2,4,5]. Since this phase in the left ventricle is characterized by extremely rapid pressure changes, some methodic requirements should be met, the most important of them is correspondence of frequency parameters of instrumental system for measuring blood pressure and other signals. However, such frequency parameters are rarely tested in experimental studies. Among pressure gauges, only catheter-micromanometers (a miniature pressure transducers fixed on the tip of a catheter) provide adequate recording of the pressure signal from the left ventricle [3,6]. Widely used routine liquid-filled catheters connected to a manometer often distort the pressure signal, if the system is not carefully tailored [3,6]. In experimental animals, the frequency parameters of the pressure signal from the left ventricle were examined only in few studies carried out in 1970s. These studies were predominantly performed on dogs and under limited variety of experimental conditions. Thus, in many cases the choice of adequate measuring system and correct interpretation of contractile indices (specifically, the maximum value of the first derivative of intraventricular pressure increment during the phase of isovolumic contraction dP/dt_{max}) remain very problematic. In this paper, we examined frequency parameters of the left ventricular pressure in feline heart under various modes of cardiac function, different reflex stimulation, and maximum inotropic stimulation.

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MATERIALS AND METHODS

The study was carried out on mature cats (n=25) of both sex narcotized with nembutal (30-40 mg/kg intraperitoneally). The chest was opened and artificial pulmonary ventilation (APV) was established. Blood pressure in the left ventricle was measured with a ca-

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theter passed via the heart apex and connected to a Statham P34XL pressure transducer. Natural frequency of this ventricular pressure measuring system was not less than 300 Hz. This parameter was measured before and after each experiment. The following stimuli inducing cardiac reflexes and modifying activity of the heart were used: intravenous blood infusion (10-20 ml); intraarterial blood infusion (10-20 ml); increase in afterload by ligation of the abdominal artery with a preliminary applied snare; bilateral clamping of the carotid arteries with preliminary applied snares; transitory dosed cooling of the vagus nerves, which blocked parasympathetic and reflectory enhanced sympathetic input to the heart [1]; electrical stimulation of the proximal ends of the vagus nerves reducing sympathetic influences to the heart; eyeball pressing for 1 min (Aschner reflex); transitory (30-60 sec) APV arrest; electrical stimulation of the heart at a rate slightly surpassing the natural heart rate. Maximum inotropic stimulation was attained by intravenous infusion of epinephrine at a rate of 3 μg/kg/min. The signals were processed using a 10-bit digitizer and fed to 8-bit PK-8001 computer (Korvet) or IBM PC at a sampling rates of 300-500 or 1000 Hz, respectively. Spectrum analysis of left ventricular pressure for 8-sec epochs was performed by fast Fourier transform using Statistica for Windows software with preliminary subtraction of the mean pressure, elimination of the trend, and implementation of Hamming window including 5 points. The frequency of the most high-frequency harmonics with the power density surpassing 100 mm Hg^2 (f_{100}) was taken for the upper limit of the frequency range. Contribution of higher harmonics to the total spectrum power was below 1% (Fig. 1). Other statistical parameters were calculated using Statistica for Windows software.

RESULTS

The maximum value of pressure first derivative $(dP/dt)_{max}$ is the most important index of cardiac activity directly related to the frequency parameters of intraventricular pressure. First, this value is most popular contraction index; second, it is used for calculation of many other types of contraction indices [2,4,5]; third, it is an indirect measure of intraventricular pressure frequency parameters (the higher is the rate of signal measuring, the higher harmonic frequencies it is characterized). Therefore, we carried out a correlation analysis between f_{100} and $(dP/dt)_{max}$ for the left ventricle. This correlation proved to be strong (r=0.93) and was described by the following linear regression equation: $f_{100}=6.18+0.0089\times(dP/dt)_{max}$ (Fig. 2). This equation was valid under all conditions including all reflex, load, and pharmacological (epinephrine) stimulations.

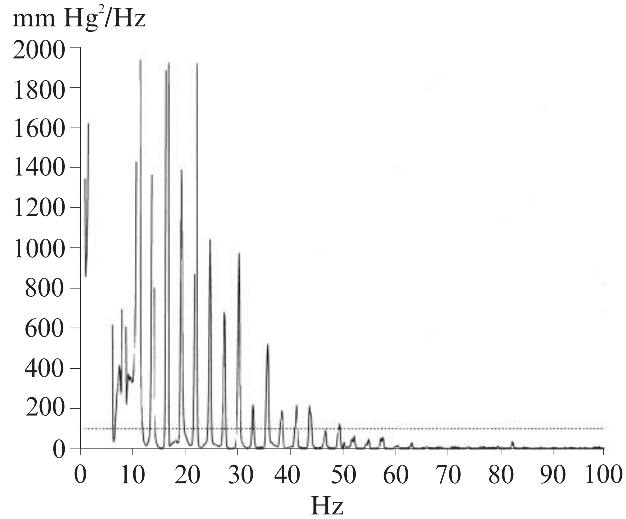

Fig. 1. Power spectrum of cardiac intraventricular pressure. Abscissa: frequency harminics; ordinate: power spectrum. Only the harmonics with a power density below 2000 are shown; the low-frequency harmonics had greater power. Specifically, this is true for the harmonic with the frequency equal to the heart rate. Dashed line corresponds to spectral power of 100 mm Hg^2.

The mean baseline value of $(dP/dt)_{max}$ was 5184.4±2170.3 mm Hg/sec, which corresponded to f_{100}=46-60 Hz. Without epinephrine infusion the maximum values of these indices were 9840 mm Hg/sec and 98.4 Hz. During epinephrine infusion, the highest value of $(dP/dt)_{max}$ was 12911 mm Hg/sec, which corresponded to f_{100}=145 Hz.

Thus, left ventricular pressure in cats is characterized by very high rate indices. For evaluation of the effects of load and reflex influences on contractility of feline heart (at least under conditions of narcosis and thoracotomy) the researchers should use measuring systems with flat amplitude-frequency characteristic in

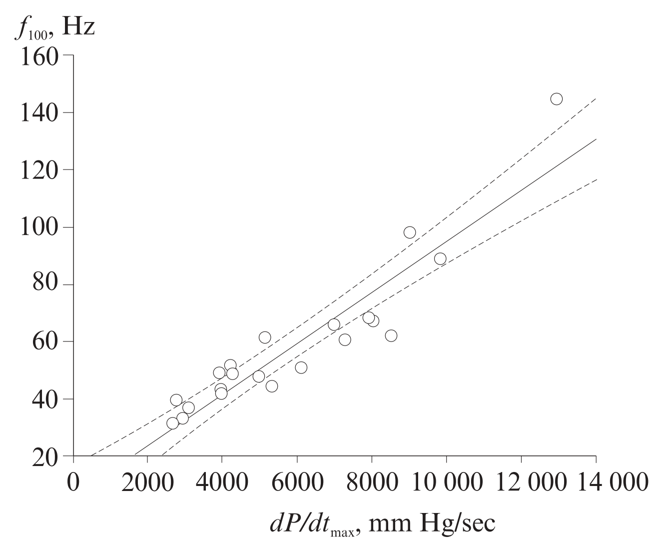

Fig. 2. Regression curve for f_{100} and $(dP/dt)_{max}$. Dashed lines show 95%confidence interval.

a range up to 100 Hz, which should be specially tested. The experiments with maximum inotropic stimulations need even higher frequency range of the measuring system with flat amplitude-frequency characteristic in a range up to 150 Hz. These requirements are met by the catheters supplied with tip micromanometer, and only occasionally by the routine liquid-filled catheters [3,6].

REFERENCES

1. N. N. Alipov, I. M. Izrail'tyan, and T. E. Kuznetsova, *Usp. Fiziol. Nauk*, **25**, No. 1, 35-36 (1994).
2. N. N. Alipov, A. V. Sokolov, L. V. Trubetskaya, and T. E. Kuznetsova, *Byull. Eksp. Biol. Med.*, **132**, No. 12, 616-620 (2001).
3. C. J. Davidson and R. O. Bonow, in: *Heart Disease*, Eds. E. Braunwald, *et al.*, Philadelphia (2001).
4. W. Grossman, in: *Grossman's Cardiac Catheterization, Angiography and Intervention*, Eds. W. Grossman and D. S. Baim, Philadelphia (2000).
5. W. C. Little, in: *Heart Disease*, Eds. E. Braunwald, *et al.*, Philadelphia (2001).
6. T. Sharir, A. Marmor, C. T. Ting, *et al.*, *Hypertension,* **21**, No. 1, 74-82 (1993).