Chronotropic and Dromotropic Components of Cardiac Reflexes in the Cat

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The relationship between dromotropic and chronotropic components of various cardiac reflexes was studied in cats. Intravenous infusion of blood was mainly accompanied by unidirectional negative chronotropic and dromotropic effects, but the dynamics of these effects was different. Clumping of the carotid arteries in most animals induced unidirectional negative chronotropic and dromotropic effects. Their dynamics was also different and differed from that observed during intravenous blood infusion. Pulsatile increase in blood pressure in the carotid artery was accompanied by a unidirectional negative effect in the majority of animals. The opposite chronotropic and dromotropic effects with similar temporal dynamics were revealed in $^1/_3$ animals. The ratio of positive and negative effects was similar during clumping of the abdominal aorta ($^1/_3$ unidirectional, $^1/_3$ opposite, and $^1/_3$ isolated chronotropic and dromotropic effects). Aschner test was characterized by the prevalence of isolated chronotropic effect (negative effect in the majority of animals; positive effect in $^1/_3$ animals). Hence, different cardiac reflexes are characterized by different ratio between chronotropic and dromotropic components.

Key Words: *chronotropic influences; dromotropic influences; heart; nervous regulation*

The directionality and degree of cardiac reflexes are estimated by changes in HR, *i.e.*, chronotropic component of the response. At the same time, dromotropic, inotropic, and lusitropic effects are poorly studied. The ratio between various components of cardiac reflexes was estimated only in few studies [1-4].

Here we evaluated the ratio between chronotropic and dromotropic components of various cardiac reflexes in cats.

MATERIALS AND METHODS

Experiments were performed on 21 adult male and female cats under pentobarbital anesthesia (nembutal, 60 mg/kg intraperitoneally). ECG was recorded. Reference points of the *P* wave and *QRS* complex were automatically recognized to construct histograms of *RR* and *AV* intervals. Blood pressure in the brachial artery was measured using an Elema-Schonander transducer. More precise estimation of *AV* interval in 16 cats included recording of atrial (EGa) and ventricular electrograms (EGv) with tantalum hook electrodes applied to the atrium and ventricle. The method for preparation, recording, and selection of reference points was described elsewhere [3]. We used the following reflexogenic stimulations: 1) stream intravenous infusion of 10-20 ml blood from the same animal with rheopolyglucin; 2) bilateral clumping of the carotid arteries; 3) pulsatile unilateral increase in carotid artery pressure synchronized with natural systolic increase in blood pressure induced at a certain time interval

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TABLE 1. Chronotropic and Dromotropic Components of Cardiac Reflexes: Relative Frequency of the Effect (%*)

Component of reflex; effect	Stimulation				Aschner's reflex
	intravenous infusion of blood	CA clumping	pulsatile increase in CA pressure	abdominal aortic clumping	
Chronotropic					
negative	89.2	81.6	71.4	44.6	55.0
positive	7.2	10.5	28.6	44.6	37.5
uncertain	3.6	7.9	—	10.7	7.5
Dromotropic					
negative	80.0	65.8	57.1	32.2	15.0
positive	2.7	18.4	37.1	35.2	30.0
uncertain	7.3	15.8	5.8	32.7	55.0

Note. *Percentage of all reactions. CA: carotid artery.

from the *R* wave (a T-tube was connected to a pulsatile pressure system via an Elema-Schonander transducer and inserted into the carotid artery); 4) clumping of the abdominal aorta with a loop applied through a small cut in the abdominal wall (1.5-2.0 cm); and (5) eyeball pressing for 1 min (Aschner's reflex). All signals (ECG, EGa, EGv, and brachial artery pressure) were transduced to an amplifier of a 12-bit 8-channel analog-to-digital converter (sampling rate 1 kHz) and to a computer. The magnitude of chronotropic and dromotropic components was estimated from the number of stimulation-induced positive, negative, and uncertain reactions of *RR* and *AV* intervals and ratio of the mean *RR* or *AV* interval during stimulation to the mean baseline interval. The relationship between these components was evaluated from the following parameters: 1) number of unidirectional and opposite responses of *RR* and *AV* intervals, as well as the number of responses accompanied by insignificant changes in one of these intervals; 2) dromochronotropic ratio, *i.e.*, ratio of changes in *AV* interval (msec) to changes in *RR* interval (msec); and 3) absolute correlation coefficient between *RR* and *AV* interval histograms for the ratio between temporal dynamics of variations in *RR* and *AV* intervals. Interval histograms were averaged with a 10-point window to exclude occasional and respiratory variations. Only the trends caused by reflex responses were analyzed.

Statistical treatment of data involved Student's *t* test and Pearson's test.

RESULTS

Intravenous blood infusion was accompanied by negative chronotropic and dromotropic effects in most animals (Table 1). The mean changes in *RR* and *AV* intervals were 10.6 and 2.2 msec, respectively. These effects were pronounced. The mean change in *RR* and *AV* intervals for the reactions with the negative chronotropic and dromotropic effects was 12.8 and 3.0 msec, respectively (Fig. 1, *a*). The chronotropic and dromotropic effects were co-directed in most animals (74.1%); the dromochronotropic ratio was high (0.23) and *RR*-*AV*

TABLE 2. Relative Frequency (%) of Unidirectional, Opposite, and Isolated Chronotropic and Dromotropic Effects

Stimulation	Effects			
	chronotropic and dromotropic		isolated	
	unidirectional	opposite	chronotropic	dromotropic
Intravenous infusion of blood	74.1	18.5	5.6	1.9
Carotid artery clumping	66.7	19.4	11.1	2.8
Pulsatile increase in carotid artery pressure	60.0	34.3	5.7	—
Abdominal aortic clumping	30.4	26.8	32.1	10.7
Aschner's reflex	21.1	21.1	52.6	5.3

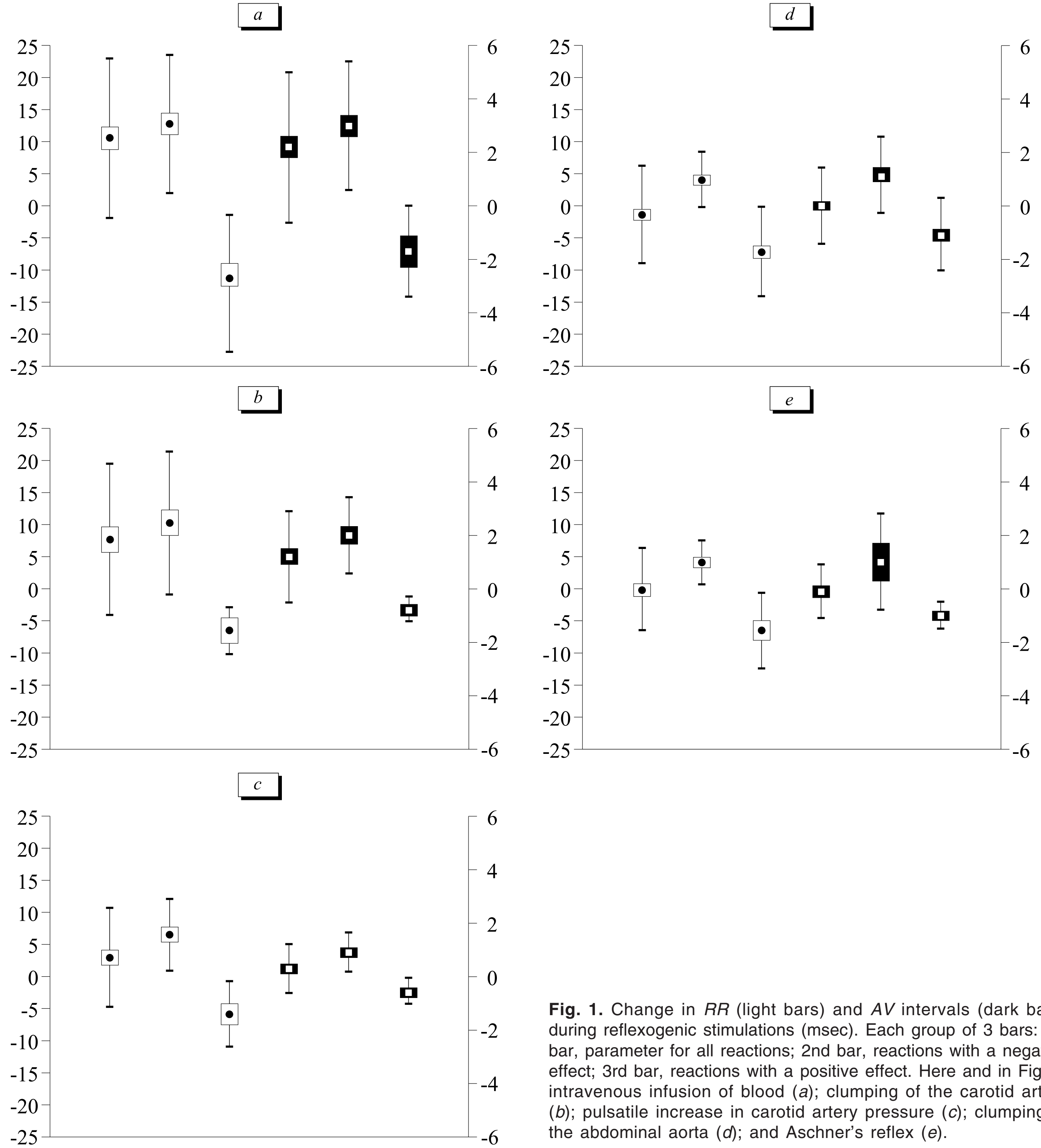

Fig. 1. Change in *RR* (light bars) and *AV* intervals (dark bars) during reflexogenic stimulations (msec). Each group of 3 bars: 1st bar, parameter for all reactions; 2nd bar, reactions with a negative effect; 3rd bar, reactions with a positive effect. Here and in Fig. 2: intravenous infusion of blood (*a*); clumping of the carotid artery (*b*); pulsatile increase in carotid artery pressure (*c*); clumping of the abdominal aorta (*d*); and Aschner's reflex (*e*).

correlation coefficient was relatively high (0.49; Table 2, Fig. 2, *a*). However, differences were revealed in the temporal dynamics of these effects. In 60% animals, *RR* interval increased to a certain level and remained unchanged for a long time. *AV* interval increased, but rapidly returned to normal in the follow-up period (Fig. 3, *a*). *RR-AV* correlation coefficient was very high (0.77) in phase 1 of this reaction (before *AV* interval attained its maximum).

Clumping of the carotid artery was also followed by negative chronotropic and dromotropic effects in most animals. The mean change in *RR* and *AV* intervals was 7.7 and 1.2 msec, respectively. These effects were significant (10.3 and 2.0 msec for reactions with negative chronotropic and dromotropic effects, respectively; Fig. 1, *b*, Table 1). The percentage of unidirectional reactions (Table 2) and dromochronotropic ratio (0.24) were as high as in blood infusion (Fig. 2, *b*). However, *RR-AV* correlation coefficient was relatively low (0.36), which can be explained by significant differences in the dynamics of the chronotropic and dromotropic effects. *RR* interval tended to increase, but was characterized by polyphasic variations. *AV* interval also increased. However, changes in *AV* interval were less pronounced and did not coincide with polyphasic variations in *RR* interval (Fig. 3, *b*).

Pulsatile increase in carotid artery pressure was mainly accompanied by negative chronotropic and dromotropic effects (Table 1). A positive effect was observed in $^1/_3$ animals. The mean change in *RR* and *AV* intervals was 2.90 and 0.29 msec, respectively. These data attest to the prevalence of the negative effect. The chronotropic and dromotropic effects were less pronounced as compared to those in the 1st and 2nd stimulation (6.5 and 0.9 msec for reactions with the negative chronotropic and dromotropic effects, respectively; -5.9 and -0.6 msec for reactions with the positive chronotropic and dromotropic effects, respectively; Fig. 1, *c*). The chronotropic and dromotropic effects were unidirectional in 60% animals. However, 34.3% animals exhibited opposite chronotropic and dromotropic effects (Table 2). The dromochronotropic ratio was 0.06. The dromotropic effect was uncertain only in 5.8% reactions (Table 1). Hence, the percentage of such reactions was lower compared to that in other treatments. We conclude that these features are related to high ratio of opposite reactions, but not to low value of the dromotropic component. However, *RR-AV* correlation coefficient exceeded that in other treatments (0.53). The chronotropic and dromotropic effects had the same temporal dynamics. Unidirectional reactions were accompanied by simultaneous changes in *RR* and *AV* intervals. However, mirror changes in *RR* and *AV* intervals were revealed in opposite reactions (Fig. 3, *c*, *d*).

Clumping of the abdominal aorta was accompanied by equal ratio of positive and negative chronotropic effects (Table 1), the same was true for positive (32.2%) and negative (35.2%) dromotropic effects (Table 1). Changes in *RR* and *AV* intervals approached zero (-1.4 and 0.0 msec, respectively), which reflected equal ratio of positive and negative effects. The chronotropic and dromotropic effects were minor (4.0 and 1.1 msec for reactions with the negative chronotropic and dromotropic effects, respectively; -7.2 and -1.1 msec for reactions with the positive chronotropic and dromotropic effects, respectively; Fig. 1, *d*). These effects were unidirectional only in 30.4% animals; 26.8% animals exhibit opposite effects. The isolated chronotropic (no changes in *AV* interval) and dromo-

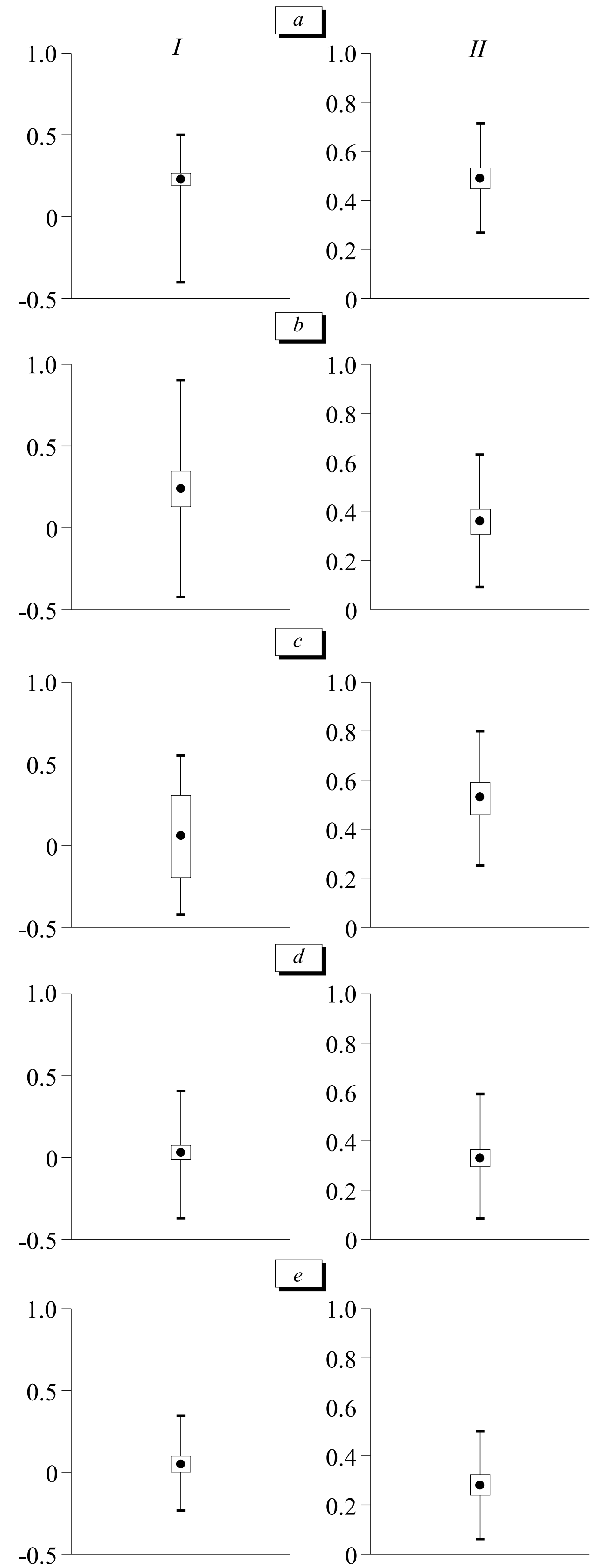

Fig. 2. Dromochronotropic ratio (*I*) and absolute correlation coefficient of *RR* and *AV* interval histograms (*II*).

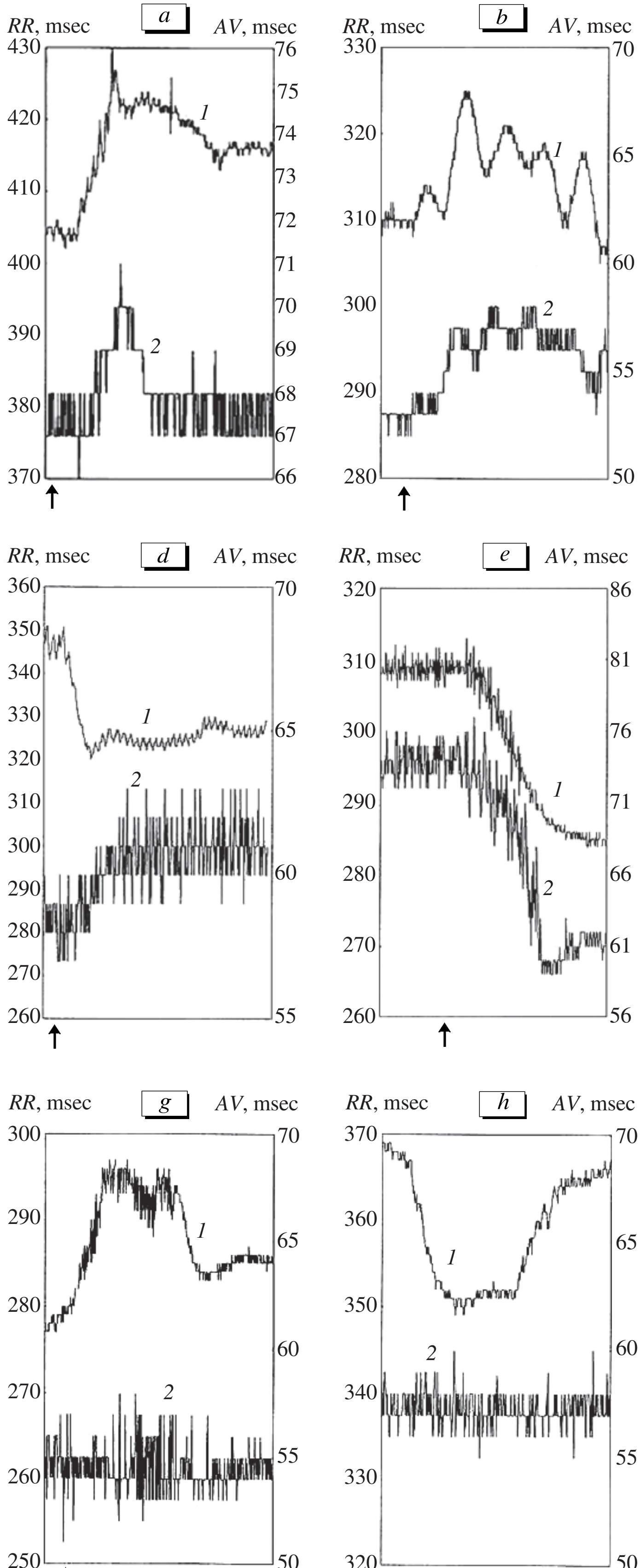

Fig. 3. *RR* (*1*) and *AV* interval histograms (*2*) during various cardiac reflexes. Arrows: moment of stimulation. Intravenous infusion of blood (*a*); clumping of the carotid artery (*b*); pulsatile increase in carotid artery pressure, unidirectional chronotropic and dromotropic effects (*c*); pulsatile increase in carotid artery pressure, opposite effects (*d*); clumping of the abdominal aorta, unidirectional effects (*e*); clumping of the abdominal aorta, opposite effects (*f*); Aschner's reflex, isolated negative chronotropic effect (*g*); and Aschner's reflex, isolated positive chronotropic effect (*h*).

tropic effects were revealed in 32.1 and 10.7% animals, respectively (Table 2). Hence, the dromochronotropic ratio was low (0.03; Fig. 2, *d*). *RR-AV* correlation coefficient was 0.33, which results from high incidence of isolated effects. Synchronous chronotropic and dromotropic effects were accompanied by simultaneous (unidirectional reactions) or mirror (opposite reactions) histograms of *RR* and *AV* intervals (Fig. 3, *e*, *f*).

Eyeball pressing was accompanied by most significant differences in the chronotropic and dromotropic effects (Table 1). Similarly to the previous series, the mean change in *RR* and *AV* intervals approached zero (-0.2 and -0.1 msec, respectively). As regards the chronotropic effect, these features were related to a similar incidence of positive and negative reactions. However, the dromotropic effect was associated with high incidence of uncertain reactions. The following chronotropic and dromotropic effects were estimated: 4.1 and 1.0 msec for reactions with the negative chronotropic and dromotropic effects, respectively; and -6.5 and -1.0 msec for reactions with the positive chronotropic and dromotropic effects, respectively (Fig. 1, *e*). The ratio of unidirectional and opposite effects was similar. The isolated chronotropic effect prevailed under these conditions (Table 2). These data explain low values of the dromochronotropic ratio (0.05) and *RR-AV* correlation coefficient (0.28; Fig. 2, *e*; Fig. 3, *g-h*).

Similar results were obtained during direct recording of EGa and EGv. These data allow us to exclude artifacts due to inaccurate estimation of reference points from surface ECG.

Our results show that the ratio between chronotropic and dromotropic components differs in various cardiac reflexes. These components may be unidirectional (intravenous blood infusion carotid artery clumping), unidirectional and opposite (abdominal aortic clumping), or isolated (Aschner's reflex). Even when various reflexes are characterized by the same relative frequency of unidirectional reactions, the quantitative ratio between chronotropic and dromotropic effect (dromochronotropic ratio) and temporal dynamics of these effects can differ significantly. Moreover, stable and highly reproducible ratio between chronotropic and dromotropic components is typical of several reflexes. These data illustrate coordination of chronotropic influences, which is probably realized via the nervous system. It is doubtful that directionality of cardiac reflexes can be estimated only from the chronotropic component.

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