Deglutition-Induced Tachycardia and Spectral Analysis of the Heart Rate

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In healthy subjects at rest, swallowing is accompanied by a tachycardiac or tachycardiac-bradycardiac reaction, during which the heart rate can be accelerated by as much as 20 beats/min. The duration of these reactions is comparable to the period of regular low-frequency heart rate oscillations, thereby their occurrence during ECG recordings for heart rate spectral analysis leads to overestimation of low-frequency oscillation power. Using a special method of smoothing of single tachycardia waves, we found that in young healthy subjects the mean contribution of deglutition-induced tachycardia waves to the power of low-frequency heart rate oscillations is 42%.

Key Words: *heart rate; spectral analysis; low-frequency oscillations; swallowing; single waves of tachycardia*

Spectral analysis of heart rate (HR) oscillations is widely used in clinical examinations for quantitative estimation of chronotropic effects of the parasympathetic and sympathetic nervous systems on cardiac activity [2,3,8]. However, these estimates are correct only when the mean HR oscillations are close to periodic throughout recording (usually 5 min). We found that periodic HR oscillations are occasionally interrupted by relatively high-amplitude single tachycardia waves. These irregular oscillations can significantly distort evaluation of the power of periodic oscillations by spectral analysis and lead to erroneous conclusions about the intensity of sympathetic and parasympathetic chronotropic effects. Some of these irregular waves can be caused by swallowing of saliva [1,7,10].

To test this assumption we determined the range of HR periodic oscillations affected by single waves of tachycardia and evaluated the contribution of these waves.

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MATERIALS AND METHODS

The study involved healthy subjects (n=6) aged from 22 to 37. The ECG was recorded for 5-6 min in the lying position after 10-min rest. All 11 recordings were performed in the morning on an empty stomach. Signals were inputted into a computer through an ECG amplifying system with a BIOLA 12-bit analog-to-digital convertor and processed using specially developed software [2].

Single tachycardia waves caused by a single swallow can be identified by characteristic deglutition-related changes in the breathing pattern. About 80% of deglutitions are performed during expiration which becomes more prolonged and followed by a short (1-2 sec) apnea (deglutition apnea). In the next cycle, the respiratory volume increases [11,12]. These phenomena can be traced by cyclic changes in the amplitude of the *QRS* complex. These changes are determined by the phasic nature of respiration [6] and can be used to delimit the consecutive respiratory cycles, determine their duration, and compare their amplitudes. Sudden shifts in the breathing pattern are easily revealed in the plot of *QRS* current amplitude. Finally, the frequency ranges of HR oscillations which are affected by re-

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spiratory movements can be clearly defined by plotting the frequency spectrum of *QRS* amplitude variations as a function of time and comparing this plot with the corresponding plot for *RR* intervals or their inverse values, "instantaneous" HR.

To obtain the *QRS* amplitude curve in addition to the *RR* curve, the ECG signals were recorded in the McPhi-Parungao corrected system of orthogonal leads. The values of consecutive *QRS* amplitudes in X, Y, and Z leads were used to plot three curves. The most informative of them selected by visual inspection (as a rule, Z-curve) was taken as an indicator of respiratory movements.

The *RR* intervals were determined as the periods between the points where the modulus of a spatial vector of the myocardial depolarization rate (at consecutive sinus systoles) reached its maximum. Instantaneous HR were calculated from these *RR* intervals to plot a cardiotachogram, which was displayed on the screen together with the selected *QRS* amplitude curve. If the single wave of tachycardia coincided with the respiratory cycle of the above-described type, the wave was considered to be induced by deglutition. In addition, the subjects were asked to signal their swallowings by hand-waving, and the corresponding points were marked on the plot.

The power spectra for HR and *QRS* amplitude oscillations were calculated by the method of Welch's periodograms: the series of consecutive values of instantaneous HR or *QRS* amplitudes was divided into 100-sec sections overlapping by 50% and analyzed by fast Fourier transform [2]. The total power of oscillations was determined for the following frequency ranges: 0.005-0.05 Hz (very slow oscillations), 0.05-0.15 Hz (slow or low-frequency oscillations, LF), and 0.15-0.40 Hz (high-frequency or respiratory oscillations, HF) as the area under the correspondending spectral wave.

The contribution of single tachycardia waves to the spectral power of the HR oscillations was estimated for each frequency range. The ECG signals around the wave were carefully analyzed on the screen to ensure their sinus origin. The total power in the three frequency ranges were calculated from the initial cardiotachogram containing irregular waves, and after their elimination (smoothing), the difference between HR oscillation power for each interval was referred to the initial value and expressed in percents. The results were averaged. Statistical analysis of the differences between the power values before and after smoothing was performed using paired Student's *t* test. Smoothing did not eliminate high-frequency (respiratory) oscillations of *RR* intervals and preserved their general changes (linear trend).

RESULTS

In the cardiotachogram of subject A (Fig. 1), the episodes of swallowings are marked by arrows. The subject was asked to swallow 3 or 4 times. Each swallowing was accompanied by tachycardia, when the peak HR surpassed the mean value for the preceding 20-30 sec by 22, 28 and 20 beats/min, respectively. The first tachycardiac episode was followed by bradicardia when the peak HR was by 18 beats/min lower than the mean value before this episode (75.5 beats/min). This finding is in line with observations made more than 100 years ago [10], which showed that "heart beats are accelerated with each swallow", that their rate increases with shortening the intervals between single acts, and that bradicardia can occur after cessation of swallowing. These observations were later confirmed by ECG recordings, and the deglutition-induced increase in HR was termed a pharyngeocardiac reflex [1]. Swallowing of fluid or food or even

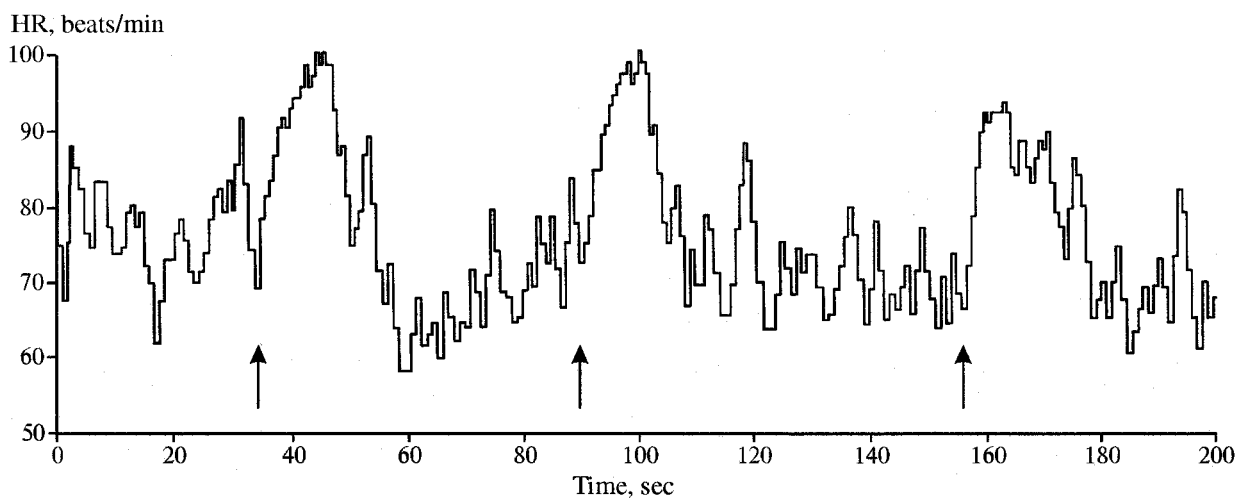

Fig. 1. Deglutition-cardiac reflex in subject A.

their presence in the oral cavity are not necessary for tachycardia development [9]. It is sufficient to voluntarily contract the muscles stretching the palatopharyngeal arches and lifting the soft palate and palatine uvula muscle to increase HR by 5-30 beats/min. Deglutition reflex (unconditioned) is initiated by excitation of pharyngeal mechanoreceptors located primarily in the posterior arches and wall of the throat [13].

It is important that tachycardia occurs already with a single swallow, i. e. swallowing of accumulated saliva. Thus, in subject E (Fig. 2, *a*), HR after a single swallow surpassed the mean HR for the preceding 20 sec by 21 beats/min. The following decline of HR was delayed, so that the total duration of this wave of tachicardia approached 12-15 sec. Approximately the same time lasted the tachycardiac-bradycardiac reaction (16±5.5 beats/min) in subject M (Fig. 2, *b*). Therefore, the duration of tachycardiac or tachycardiac-bradycardiac shifts in HR after a single swallowing act, corresponds to the period of spontaneous low-frequency HR oscillations (10-sec oscillations). As seen from the *QRS* amplitude curves on Figure 2, tachicardia is preceded by expiratory apnea and the following inspiration is somewhat deeper than before deglutition.

The rate of spontaneous deglutitions increases under conditions of emotional excitation. In 3 groups of 17-28-year-old subjects (n=38) with a low, medium and high emotional tone created by special methods, the mean number of deglutitions for 30 min was 8, 16 and 34, respectively [5]. In our experiments, the number of deglutitions for 5 min varied from 1 to 5 (the mean value=3).

Cardiotachogram of subject M. displayed respiratory waves (high-frequency HR oscillations) of regular amplitude that allowed to reveal two high-amplitude waves of tachycardia (Fig. 3 *a*, *I*). The peak HR of the first and second waves surpassed the mean for the preceding 40 sec by 13 and 15 beats/min, respectively.

The initial spectra of adjacent fragments, one of which included a tachycardia wave differed at frequencies below 0.15 Hz (Fig. 3, *b*, *c*). After smoothing, these difference became insignificant. Spectral estimations for 5-min ECG fragments showed that elimination of slow waves decreased the power of respiratory oscillations by only 1.8%, while the power of low-frequency oscillations decreased by 49.8% (Fig. 3, *b*, *c*).

Single deglutition-induced waves increased the power of low-frequency oscillations by 42% and that of high-frequency oscillations by 3% (Table 1). Each deglutition added from 0.14 to 1.7 (beats/min)^2 (average 0.6±0.1 (beats/min)^2) to the spectral power in the low-frequency range. This "addition" (about 16% of the mean value) seems to be not so high. However, it should be taken into consideration that the wave-inducing acts are repeated, being especially frequent under conditions of emotional stress [5] typical of patients with paroxysmal arrhythmias. Their contribution, therefore, can be several times greater. This dis-

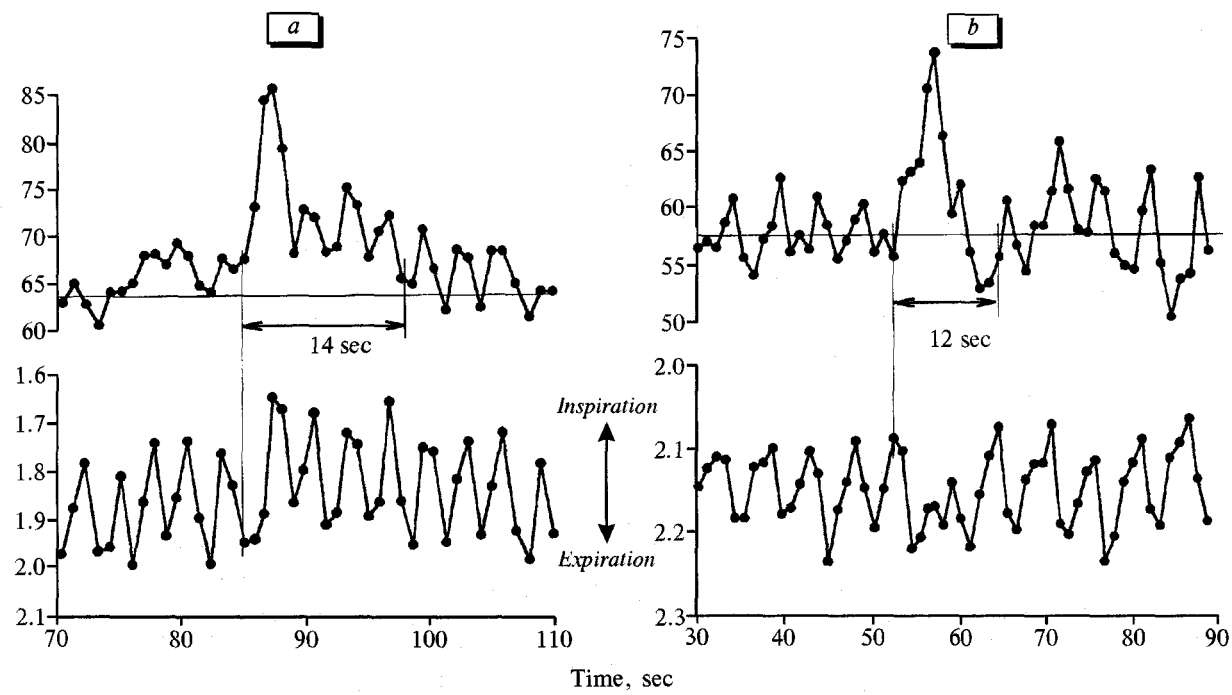

Fig. 2. Changes in HR and respiratory cycles during single swallowings of saliva in subjects E (*a*) and M (*b*). Upper plots: cardiotachograms (beats/min), lower plots: current *QRS* amplitude (mV). Thin horizontal lines in the upper plots show the mean value of HR. Changes in HR caused by deglutition of accumulated saliva are marked by arrowheads . The duration of these changes corresponds to the period of regular low-frequency HR oscillations.

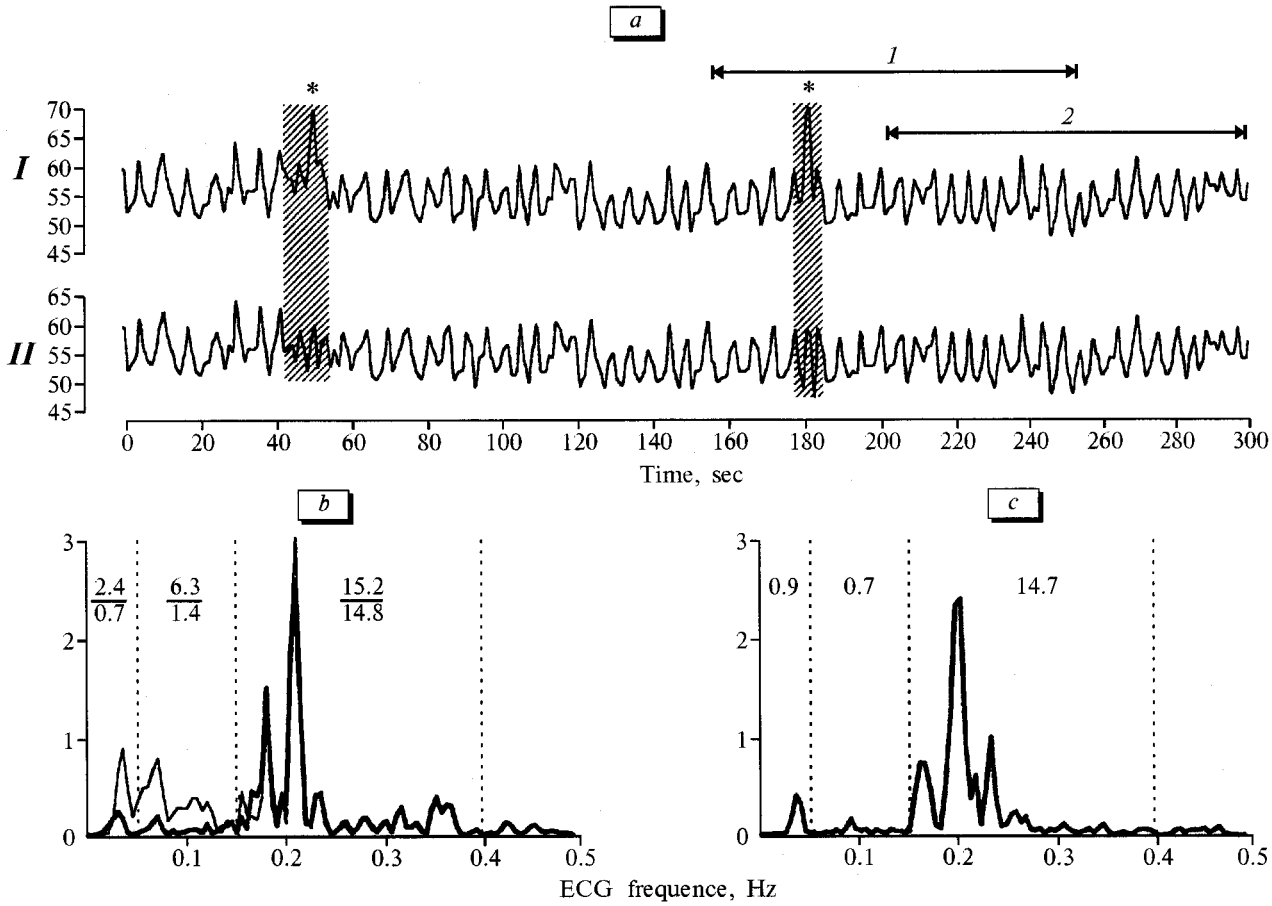

Fig. 3. An example of editing the cardiotachogram for elimination of single tachycardia waves. *a)* cardiotachogram before (*I*) and after (*II*) editing. The waves of deglutition-induced tachycarida are marked by asterisks; the shadowed fragments were edited. *b* and *c*) HR spectra for 100-sec cardiotachogram fragments indicated by lines *1* and *2*, respectively. Fragment *1* includes the episode of swallowing which is reflected in significant slow waves in the spectrogram (*b*, fine line); the same fragment after smoothing is shown by solid line. Figures: power of HR oscillations within the standard ranges before (numerator) and after editing (denominator). Ordinates: *a*) HR, beats/min; *b, c*) the power of HR oscillations (beats/min)^2.

tortion is especially important to keep in mind when analyzing HR oscillation spectra in subjects whose low-frequency power is reduced by a disease (subacute period of myocardial infarction) or by age-related factors [3,8]. Interestingly, in the oldest subject (37 years) only one deglutition-induced tachycardia wave appeared during ECG recordings, but after its elimination the power of low-frequency HR oscillations decreased from 0.96 to 0.45 (beats/min)^2, i.e. by 53%.

Thus, the contribution of even a single wave of deglutition-induced tachycardia to the power of low-frequency HR oscillations can be weighty. These waves should be recognized by recording respiratory cycles with impedance respirography, or better by recording of deglutition [11,12]. The cardiotachogram should be edited before computing the spectral power to avoid overestimation for low-frequency HR oscillations.

In conclusion, it should be noted that fasting gastric contractions also can induce irregular waves of

TABLE 1. A Decrease in the Power of HR Oscillations in Different Spectral Ranges after Elimination of Deglutition-Induced Single Waves of Tachycardia ($M\pm m$, n=6)

Frequency range, Hz	Initial values (beats/min)^2	Decrease		p
		(beats/min)^2	%	
0.005-0.05	2.08±0.28	-0.96±0.17	46	0.0003
0.05-0.15	3.67±0.58	-1.54±0.40	42	0.003
0.15-0.40	4.10±0.63	-0.14±0.03	3	0.0004

tachycardia. In healthy individuals, these contractions occur 3 times per minute, which corresponds to the frequency of 0.05 Hz, and increase HR by 8-10 beats/min or more (up to 30 beats/min) [4]. The origin of tachycardia waves in the range of very slow HR oscillations (0.005-0.05 Hz) can be determined by electrogastrography.

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