

## SPONTANEOUS RHYTHMIC FLUCTUATIONS OF THE CUTANEOUS BLOOD FLOW IN MAN

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### ABSTRACT

Using the reflection photoelectric plethysmograph, rhythmic fluctuations of the blood flow were investigated in the human skin. Frequency and amplitude of the rhythmic fluctuations were not synchronous with those in other skin areas. They increased with increase in ambient temperature as well as local heating of the skin. On the contrary they decreased with decrease in ambient temperature as well as local cooling of the skin. A rise in the local venous pressure caused an increase in frequency. The rhythm was suppressed by a cutaneous nerve block, though the suppression was not persistent. Intravenous injection of a large amount of chlorpromazine caused a marked increase in frequency. Rhythmic fluctuations of the blood flow through the fingers and toes of some patients were also investigated. The results suggest that the myogenic automaticity of the vessels may be mainly involved in the rhythmic fluctuations of the blood flow through the skin, and that it may be under the influence of sympathetic nerve activity, perhaps organized at the spinal level.

Spontaneous small fluctuations of the cutaneous blood flow in man have been supposed to contribute to a fine adjustment of the regional blood flow<sup>1)</sup>. However, little has been investigated on the mechanism involving the fluctuations. Intrinsic myogenic contractions of the vascular smooth muscles were confirmed by direct observations in animals by using the transparent chamber technique<sup>2)-5)</sup>. It may be, therefore, worthwhile to consider the fluctuations with relation to the intrinsic myogenic contractions of the vessels. The reflection photoelectric plethysmograph is a useful device to detect blood flow change in the human skin and by using the instrument the authors found the rhythmic fluctuations of the cutaneous blood flow of the ear lobe to be not synchronous with those in the opposite ear lobe<sup>6)</sup>. This suggests that although the cutaneous blood vessels are highly innervated organs contraction of the vascular smooth muscles is not wholly dependent on the integrated nerve discharges to the vessels. The present work, hence, was undertaken to study the features of the rhythm and to determine whether the nerve impulses could have an im-

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portant influence on the rhythmic fluctuations.

#### METHODS

Experiments were performed on lightly clothed young adults lying recumbent or sitting in a comfortable room; the temperature was maintained in the range of 18-26°C. The rhythmic fluctuations in blood volume of the ear lobes were recorded by means of the reflection photoelectric plethysmograph following local heating and cooling of the ear lobes and also following immersion of the subjects' feet in hot (45°C) or cold water (0°C). Other correlations under which the amplitude and period of the waves were observed included a) nerve block accompanied with xylocaine (0.5%) and local anesthesia effected by infiltrating the auricle, b) general anesthesia with barbiturate (5-10 mg/kg) and chlorpromazine (2-5 mg/kg), c) pain on the skin through a monophasic rectangular pulse with electrodes attached to the lower legs with saline paste, d) elevation of the intravascular pressure by compression of the jugular vein, e) Valsalva manouver, f) emotional stress by mental arithmetic and g) hyperventilation and general hypercapnea due to rebreathing expired air. The rhythmic waves of the ear lobes and the other skin areas in patients given 500 mg/day of chlorpromazine for 6 months and a patient with polyradiculoneuritis were also studied.

#### RESULTS

Fig. 1 shows the typical rhythmic fluctuations of the blood volume (spontaneous waves) in the ear lobes. They were consistent, shortly interrupted by silent period, but frequency and amplitude of the waves were not synchronous

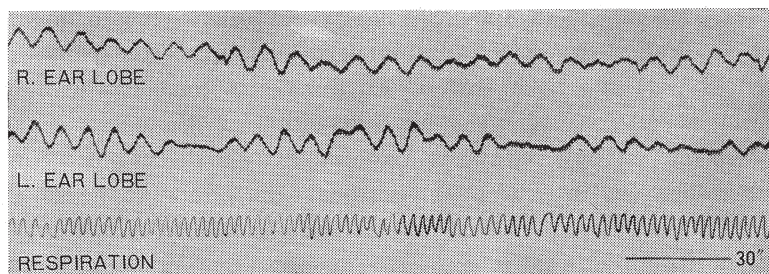


FIG. 1. Spontaneous rhythmic waves in the ear lobes, and respiration. Subject; 28 years old man. Room temperature; 23°C.

with those of the opposite side. They had no relation to changes in skin resistance, respiratory rhythm, rhythmic changes of the pupil size and other rhythmic fluctuations. Frequency and amplitude of the waves increased with

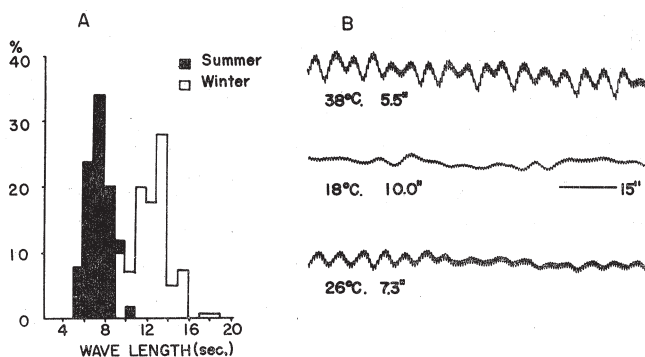


FIG. 2. Spontaneous rhythmic waves in the ear lobe at various ambient temperatures (right) and histogram of mean frequency of the waves in summer and in winter (left). Subject; 29 years old man.

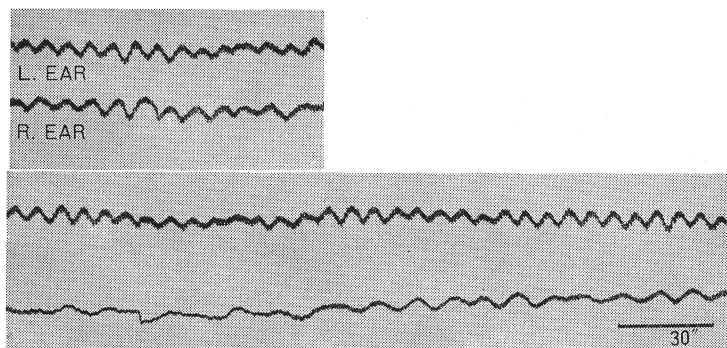


FIG. 3. Effect of local cooling on frequency of the waves in the ear lobes. Right ear lobe was cooled by ethyl-chloride during the recording for 1 min. Subject; 29 years old man. Room temperature; 23°C.

an increase in ambient temperature, and the mean period of the waves was longer in winter than in summer (Fig. 2).

Direct cooling of the ear lobe caused a marked decrease in frequency and amplitude of the rhythmic waves in the same side with little change on the opposite side (Figs. 3, 5), and direct heating of the ear lobe caused a marked increase in frequency and amplitude of the waves in the same side with no change on the opposite side (Figs. 4, 5). The frequency ran parallel with the local skin temperature. Indirect cooling caused, however, an increase in frequency of the waves on both side, an indirect heating caused a slight increase or no change in frequency and amplitude of the waves in both ear lobes (Table 1). A slow and irregular fluctuation different from the rhythmic waves became dominant in the plethysmograph of the ear lobes.

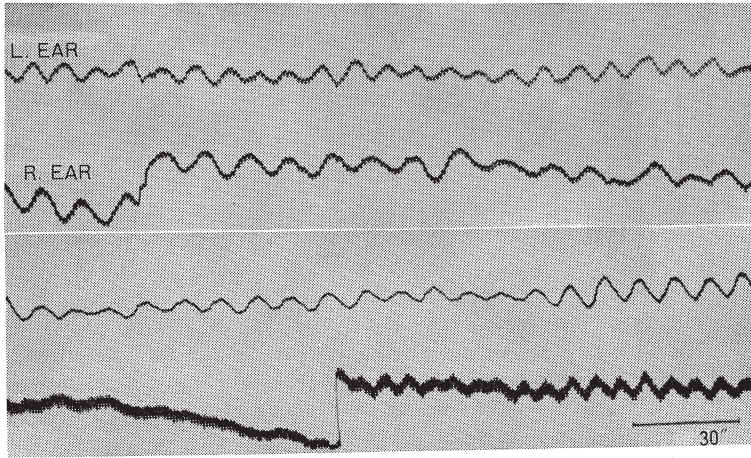


FIG. 4. Effect of local heating on frequency of the waves in the ear lobes. Right ear lobe was heated during the recording for 5 min. Subject; 20 years old man. Room temperature; 21°C.

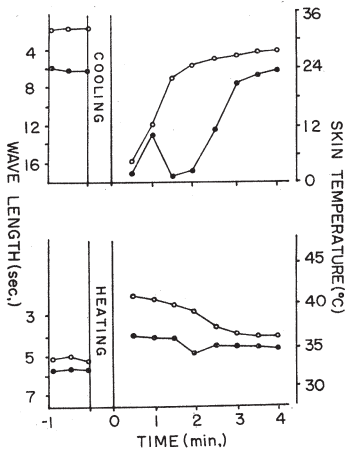


FIG. 5. Relationship between skin temperature and length of the rhythmic waves of the ear lobe. Solid circles; wave length. Open circles; skin temperature. Subject; 29 years old man.

The effects of noxious stimulation on frequency and amplitude of the waves are variable. A long lasting emotional stress such as mental arithmetic or anxiety about the experimental procedure caused a slight increase in frequency and amplitude of the waves. Similar rhythmic fluctuations in the blood volume were sometimes observed in the forehead and the cheek. A transient sharp pain applied on the lower leg caused a decrease in the volume of the ear lobes, but disturbance was not observed on the essential rhythm of the waves.

Voluntary hyperventilation causing vasodilatation in the upper arm or the forehead caused a slight decrease in frequency of the waves. When local

TABLE 1. Effects of various sorts of stimulations on the frequency and amplitude of the rhythmic waves in the ear lobes.

Frequency increase	Amplitude increase	Frequency decrease	Amplitude decrease	Regularity increase	
‡‡	‡			‡	local heating
		‡‡	‡		local cooling
‡	+			‡	ambient temperature increase
		‡‡	+		ambient temperature decrease
		+	+		indirect heating
+	+			+?	indirect cooling
		no effect			noxious stimulation
‡	+			+	emotional stress
		+	+		CO <sub>2</sub> inhalation
+	+	disappearance of the waves			O <sub>2</sub> inhalation
‡			+		local anesthesia and nerve block
‡	+			‡	pressure on the juglar vein
		no effect?			holding breath
		‡	‡		general anesthesia (1-2 phase)
					(3 phase with barbiturate)
+	+			‡‡	chlorpromazine
+	+			‡‡	spinal transection

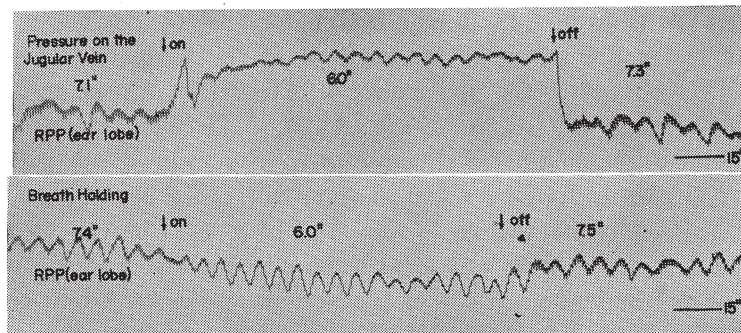


FIG. 6. Effects of compression of the jugular vein (upper tracing) and of holding breath (lower tracing) on the rhythmic waves. Subject; 29 years old man. Room temperature; 23°C. Mean wave lengths before, during and after the procedures are shown by figures in seconds.

venous pressure was elevated, frequency of the waves increased but amplitude of the waves decreased (Fig. 6). Holding breath causing an increase in general blood pressure increased both frequency and amplitude of the waves (Fig. 6).

When nerve supply to the blood vessels of the ear lobe was blocked with 0.5% xylocaine, the rhythmic waves in the same side disappeared, although this disappearance of the waves was not persistent. Surgical doses of barbiturate obliterated the waves, but large doses of chlorpromazine facilitated the

rhythmic waves. In some cases, a marked increase in frequency and amplitude was observed. In patients being administered continuously large doses of chlorpromazine for a long time, this type of wave was observed even in the fingers. The waves were not synchronous in time with those in the opposite hand and ear lobe, but they were very consistent and persistent. Spontaneous waves in the toes of a patient suffering from polyradiculoneuritis at Th 2 were also rhythmically characteristic, and failed to synchronize in time with those in the opposite foot.

#### DISCUSSION

The main evidences which the authors wish to report are that there are characteristic rhythmic vasomotor waves in the human skin, especially in the ear lobes, and the frequency and amplitude of the rhythmic waves in one side are not synchronous with those in the opposite side. Local heating and a rise in intravascular pressure facilitated the rhythm in every subject without altering the rhythm of the opposite side, and local cooling or a fall in intravascular pressure suppressed the rhythm without changing it in the opposite side. Based on such evidences, the rhythmic vasomotor waves do not seem to be under the control of the higher vasomotor centers.

In studies on the myogenic contractions of the peripheral vessels, many workers<sup>7)8)</sup> have reported the importance of intravascular pressure change in triggering rhythmic contractions of the vessels. The importance of the intravascular pressure seemed to be also confirmed in man by this experiment, but the rate of change in frequency and in amplitude is far less than that caused by the local temperature change (Table 1). Local skin heating in increasing the frequency and amplitude and local cooling in decreasing them suggest that this type of rhythmic fluctuations may contribute to some extent to the mechanisms which control local skin temperature. The fact that the rhythm was slower in cold environment than in warm environment may also account for such assumption.

Arteriovenous anastomoses have been abundantly observed in the human external ear<sup>9)</sup> and also in other skin areas where the rhythmic fluctuations can be observed<sup>10)</sup>. Lewis<sup>11)</sup> and Grant<sup>12)</sup> suggested that the functional significance of the arteriovenous shunts is in accordance with the requirement of temperature regulation. Therefore, it seems highly reasonable to suppose that the arteriovenous structure causes the characteristic rhythmic fluctuations in the blood volume of the skin. However, the arteriovenous anastomoses of the skin are highly innervated organs. The disappearance of the rhythm by local nerve block suggests also that the vessels concerned with these rhythmic changes are dependent on nerve activity. The neural pathways which are involved may

not include the higher vasomotor centers, because this type of rhythm could be easily observed in the toes or fingers of patients suffering from spinal disease, whose arterioconstrictor reflex activity has been greatly reduced. When the pathways from the higher vasomotor centers were interrupted with a large dose of chlorpromazine and other drugs, the characteristic rhythmic waves appeared in the fingers and toes where one can hardly observe such rhythmic waves under normal condition. The authors, hence would like to believe that myogenic automaticity of the cutaneous vessels is also under the influence of the sympathetic impulses, perhaps organized at the spinal level.

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