RESPIRATORY WAVES OF BLOOD PRESSURE IN HUMAN SUBJECTS

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Although it is over a century since respiratory undulations of blood pressure were first described by K. Ludwig [16], and in spite of all the experimental studies devoted to this effect, divergent views are still expressed as to its nature. K. Ludwig [16], K. Vierordt, Einbrod [14], and L. M. Levashov [10] have shown that blood pressure rises during inspiration, and falls during expiration. These fluctuations were ascribed to changes in the rate of flow of blood to the heart during different phases of the respiratory cycle. During inspiration the negative pressure within the pleural cavity rises, and the flow of blood to the heart increases, leading to increase in the systolic volume of blood and to rise in arterial pressure. The converse relations prevail during expiration, and blood pressure falls. Such interpretations are to be found in textbooks of physiology (V. Ia. Danilevskii [7], L. Landua and Rozeman [9], R. Geber [4], A. G. Ginetsinskii and A. V. Lebendinskii [6], and K. M. Bykov [1]).

The chief factor responsible for respiratory undulations of blood pressure is generally held to be the mechanical effect. I. A. Spiriukov and V. Ia. Suetin, for example, consider that the respiratory undulations of blood pressure are due to the pressor action of the lumbar part of the diaphragm, and suggest that the respiratory undulations should be called diaphragmatic undulations. E. Bauereisen, H. Busse, and R. Wagner [15], applying a method of continuous recording of blood pressure of human subjects, examined the filling of the left ventricle during inspiration and expiration, and came to the conclusion that the cause of the respiratory undulations is to be found in the direct action of changes in intrathoracic pressure on the heart and blood vessels, and to changes in the filling of the heart owing to changes in flow of blood from the veins.

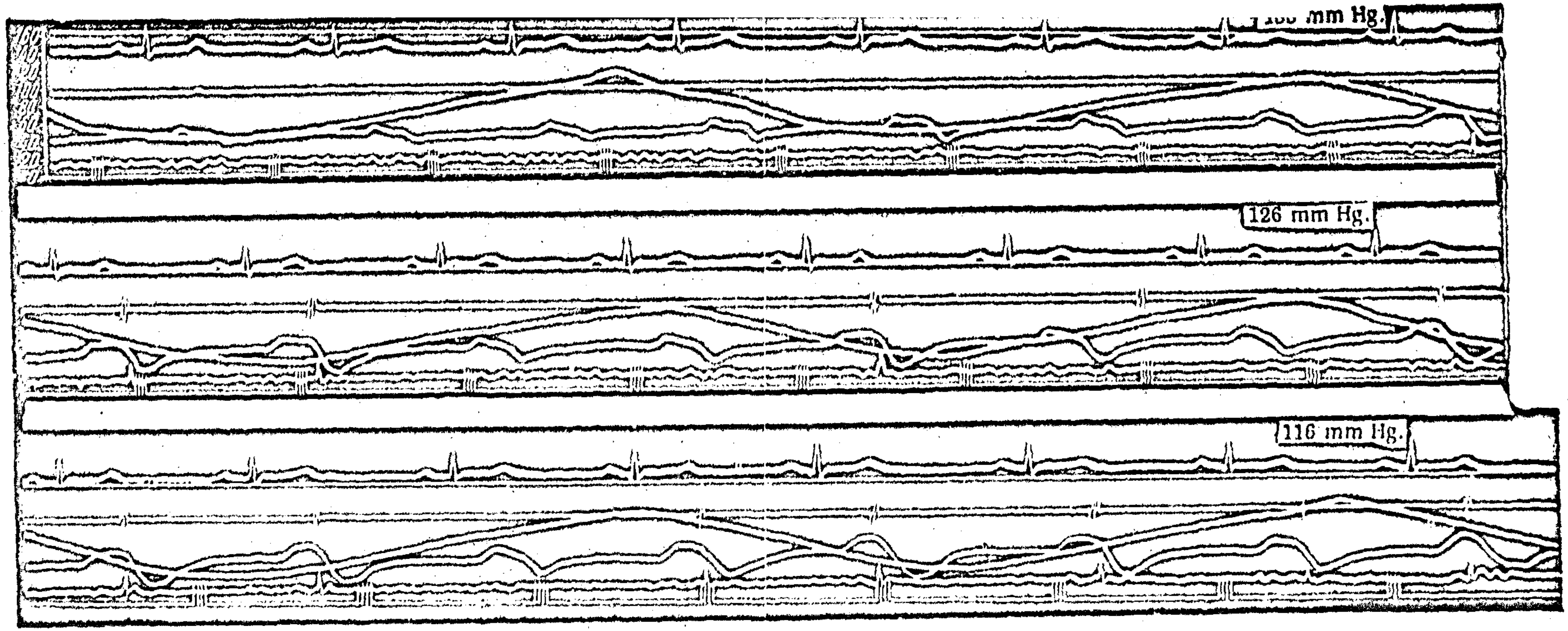
Conflicting views have, however, also appeared in the literature. Moro and Legrenier have shown, in experiments on rabbits, that blood pressure falls at inspiration, instead of rising, and falls during expiration. The same view was advanced by A. Mosso [17], who used a finger pletysmograph of measuring blood pressure of humans, and by J. Tomai [18], S. S. Zuev [8], G. A. Vaksleiger [2], A. M. Melik-Megrabov [11], and others.

Thus the literature shows a lack of unanimity as to the nature of the respiratory undulations of blood pressure. This is a consequence of the complex nature of the phenomenon, which cannot be ascribed solely to mechanical factors (effects of changes in intrathoracic pressure).

It is known that the Traube-Hering waves are due to reflex effects from pulmonary receptors acting on vascular tonus.

It was shown by P. M. Nikiforovskii [12], in I. P. Pavlov's laboratory, that distension of the lungs caused a reflex acceleration of heart rate, and that collapse of the lungs had the opposite effect. V. V. Parin [13] perfused an isolated lung, with intact nervous connections with the central nervous system, and noted that raising of pressure in the pulmonary blood vessels caused a reflex fall in the systemic blood pressure, with a retardation of heart rate. This effect disappeared after division of the vagi.

Other pulmonary effects on the systemic circulation have been reported. V. A. Vinokurov and M. V. Sergievskii [3] found that changes in pressure within one or both lungs were followed by vascular waves of the third order. This effect persisted after division of the vagi, and removal of the stellate ganglia and the thoracic sympa-



Respiratory undulations of blood pressure in a human subject.
Explanation of tracings (from above down): pressure in the cuff, electrocardiogram (II lead), Korotkov sounds in the artery, respiration, oscillation of the arterial wall, pulse in the artery distal to the cuff, time marker 1 second (distance between small spikes 1/50 second). Graduations of the sphygmomanometer given at the beginning of the first tracing. Each successive strip is a continuation of the preceding one. Rate of motion of film: 27 mm/sec. The tracings are reproduced without enlargement. The rising part of the respiration tracing corresponds with inspiration, and the falling part with expiration. Subject I. I. M-o, age 56, recorded January 3, 1956.

thetic ganglia. These authors consider that vascular waves may arise not only from reflex impulses, but also from changes in vascular rhythmicity in response to localized humoral factors.

K. Heymans and D. Cordier [5] have shown that, in the thoracic type of respiration, inspiration is associated with rise in blood pressure, and expiration with fall in blood pressure, whereas in the abdominal type of respiration the opposite effects are found. With the mixed type of respiration, or with inspiratory and expiratory pauses, polyphasic changes in blood pressure are observed. These authors remark that the mechanisms whereby respiration affects blood pressure may be hydrodynamic, cardiac, vasomotor, arterial, or venous in origin.

The mechanisms responsible for the appearance of respiratory waves of arterial pressure may thus be of many kinds, and there are also contradictory descriptions of the phenomenon, given by different authors. Far too little work has been done on respiratory undulations in human subjects, under clinical conditions.

We have attempted to obtain more precise information on the nature of respiratory effects on arterial pressure in the human, using for this purpose our method for the simultaneous recording of Korotkov sound effects, arterial oscillograms and pulse rates, pressure in a pneumatic cuff, electrocardiograms, and respiration.

EXPERIMENTAL METHODS AND RESULTS

Our recordings were made with the aid of a system of pickups and amplifiers, using an 8-channel oscillograph, Mark MPO-2, which permitted the simultaneous registration of a number of processes. Pressure within the cuff and respiration were measured by means of sensitive optical manometers with pneumatic transmission mounted within the body of the oscillograph.

The Figure gives an example of recordings made in one of our experiments.

As appears from the tracings, the first sound effect, with intensification of the oscillations of the arterial wall and of the pulse below the cuff appeared when the pressure within the cuff amounted to 136 mm Hg, and they appeared at the moment of expiration, and were absent during inspiration.

It may therefore be taken that arterial pressure rises during expiration, and falls during inspiration. The sound effect appeared and disappeared periodically, and with further fall in pressure within the cuff, and only when this had reached 120 mm or less did the arterial sounds persist during inspiration. The amplitude of the respiratory undulations of arterial pressure amounted in the given case to 15 mm Hg.

Similar recordings of respiratory undulations of arterial pressure were made on 18 cases. In most of these, respiratory undulations were normally either absent, or were insignificant. They made their appearance, or became more accentuated, in all cases when the depth of respiration was increased. Respiratory undulations were observed during normal respiration in patients suffering from pulmonary tuberculosis.

According to S. S. Zuev [8] and G. A. Vaksleiger [2] such undulations constitute one of the characteristic signs of lung disease.

It should be noted that all our observations of respiratory undulations were of the same type: blood pressure fell during inspiration, and rose during expiration. The belief that blood pressure rises during inspiration, and falls during expiration, is therefore disputable; it was evidently based on observations made during acute experiments on animals, which cannot be applied to human subjects.

The fact that blood pressure falls at the moment of inspiration, and rises during expiration, is evidence that respiratory undulations of blood pressure in the human may be due not to mechanical factors (changes in intrathoracic pressure), but rather to reflex effects. Respiratory undulations of blood pressure are similar in type, in the human, to Traube-Hering waves.

SUMMARY

The respiratory waves of arterial blood pressure were studied in man with the aid of the following simultaneously performed tests: objective registration of Korotkov sound phenomenon, pressure in the cuffs, oscillation of arterial wall, pulse in the artery distal to the cuff, electrocardiogram and respiration. Registration was carried out with the aid of corresponding pickups, amplifiers and an 8-channel oscillograph. In all cases it was noted that there is decrease of arterial blood pressure on the height of inspiration and increase on the height of expiration. Respiratory waves of the blood pressure in man are similar in type to Traube-Hering waves and are rather reflex than mechanical in origin.

LITERATURE CITED

[1] K. M. Bykov, Textbook of Physiology,* Moscow, 1955.

[2] G. A. Vaksleiger, Tr. Kuibyshev Voenno-Med. Akad. 5, 73-82 (1941).

[3] V. A. Vinokurov and M. V. Sergievskii, Tr. Kuibyshev Gos. Med. In-Ta. 3, 40-48 (1950).

[4] R. Geber, Human Physiology,* Moscow-Leningrad, 1935.

[5] K. Heymans and D. Cordier, The Respiratory Center,* Moscow-Leningrad, 1940.

[6] A. G. Ginetsinskii and A. V. Lebedinskii, Principles of Human and Animal Physiology,* Leningrad, 1947, 1956.

[7] V. Ia. Danilevskii, Human Physiology,* Vol. 1. Moscow, 1913.

[8] S. S. Zuev, Sov. Vrachebnaia Gaz. No. 21, 1671 (1935).

[9] L. Landua and R. Rozeman, Textbook of Human Physiology,* Moscow, 1913.

[10] I. M. Levashov, Vrach 22, 1433, 1471, 1504 (1901).

[11] A. M. Melik-Megrabov, Contemporary Problems of Physiology, Biochemistry and Pharmacology,* pp. 519-521 (Moscow, 1949).

[12] P. M. Nikiforovskii, Izvest. Voenno-Med. Akad. 21, No. 3, 221-231 (1910).

[13] V. V. Parin, Role of the Pulmonary Blood Vessels in Reflex Regulation of the Circulation,* Moscow, 1946.

[14] Einbrod (1860), Cited from M. V. Sergievskii's The Respiratory Center,* Moscow-Leningrad, 1950.

[15] E. Bauereisen, H. Busse and R. Wagner, Archiv. ges. Physiol. 1949, Bd. 251, S. 645-663.

[16] C. Ludwig, Arch. Anat., Physiol. and wissenschft. Med. 1847, N. 2, S. 242-303.

[17] A. Masso, Arch. ital. di biolog. 1895, N. 23 p. 177.

[18] J. Tomai, Z. klin. Med. 1910, Bd. 70, S. 235-242.

[19] K. Vierordt, Die Lehre vom Arterienpuls in gesunden und kranken Zustanden, Braunschweig, 1855.

* In Russian.