

Temporal Relation Between Contraction of Right and Left Sides of the Normal Human Heart.

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Knowledge of the normal temporal relationship of contraction of the two auricles and ventricles is important in various clinical conditions. Only indirect or semi-direct evidence of the activities of the various cardiac chambers has been available so far in clinical cases. As a new method permits their direct observation, a study of normal subjects has been undertaken, as a preliminary to clinical studies.

Precedents. On the basis of simultaneously recorded right ventricular pressures, carotid surface pulses and ballistocardiographic recoils (direct method for the right ventricle only), Hamilton and co-workers¹ found an asynchronous ejection of the two ventricles in man. Either ventricle may precede the other.

The only available study on man with similar technique was briefly reported by Chamberlain and co-workers.² These authors studied the ascending aorta and the first part of the pulmonary artery by means of the electrokymograph. The study was made either with a single pickup device and subsequent tracings or with 2 separate pickups and 2 galvanometers. In the latter instance two simultaneous separate tracings were recorded, permitting comparison. These authors found a variable time relationship of the pulses of the 2 vessels; either ventricle might precede the other; in a few cases the pulses were simultaneous.

Method. The method used in this study is based on the combination of the fluoroscope, a photoelectric pickup unit, a screen with a slit and an electrocardiograph. The apparatus,

originally described by Henny, Boone and Chamberlain^{3,4} and called "electrokymograph" was subsequently modified by us together with Rappaport^{5,6} and the name "fluorocardiography" was proposed, as being more descriptive of the method.

The pickup unit is adjusted under fluoroscopic control so that the motion of a small section of the margin of the cardiac silhouette is seen within the slit. Any outward motion is recorded as a positive wave on the tracing; any inward motion, as a negative wave. Identification of these waves is possible by the simultaneous recording of a tracing of the heart sounds. The recorded tracings are similar to pulse tracings (arteries) and to volume tracings of the ventricles or auricles. Therefore, no new names are necessary for the waves, these being the same as in sphygmograms or cardiograms.

It is to be noted that the motions of the ventricular borders are somewhat less typical when recorded in the lateral positions even if the beginning and end of the various waves bears the normal temporal relation to the heart sounds.

Two Sanborn apparatus for fluorocardiography and a Sanborn Tri-beam Stethocardi-ette were used for the study. Observations were made on 8 normal subjects between the ages of 14 and 46.

The general method previously described by us for the positioning of the slit^{5,6,7} was followed. However, the simultaneous recording of

³ Henny, G. C., and Boone, B. R., *Am. J. Roentgen.*, 1945, **54**, 217.

⁴ Henny, G. C., Boone, B. R., and Chamberlain, W. E., *Am. J. Roentgen.*, 1947, **57**, 409.

⁵ Luisada, A. A., Fleischner, F. G., and Rappaport, M. B., *New England Heart Assn.*, Feb. 24, 1947.

⁶ Luisada, A. A., Fleischner, F. G., and Rappaport, M. B., *Am. Heart J.*, in press. 1948. Note I.

¹ Hamilton, W. F., Attyah, A. M., Remington, J. W., Wheeler, N. C., and Witham, A. C., *Proc. Soc. Exp. Biol. and Med.*, 1947, **65**, 266.

² Chamberlain, W. E., Boone, B. R., Ellinger, G. F., Henny, G. C., and Oppenheimer, M. J., *Fed. Proc.*, 1947, **6**, 88.

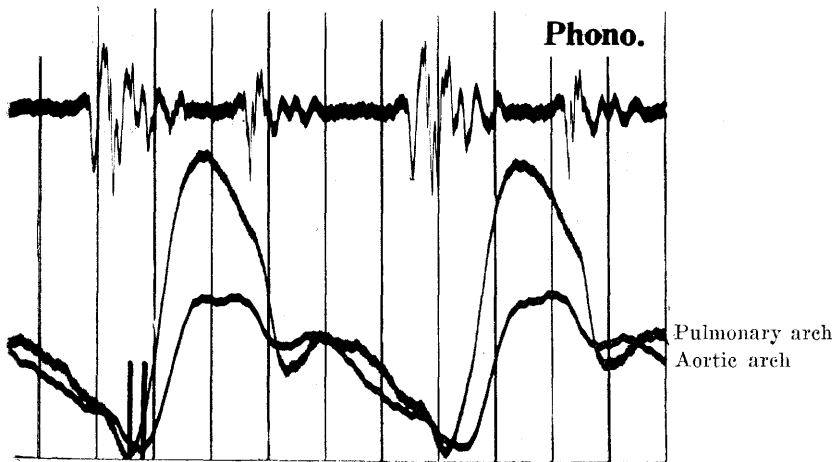


FIG. 1.

Simultaneous fluorocardiograms of the pulmonary and aortic arches. Phonocardiogram. The marks indicate the beginning of systolic expansion of the arteries.

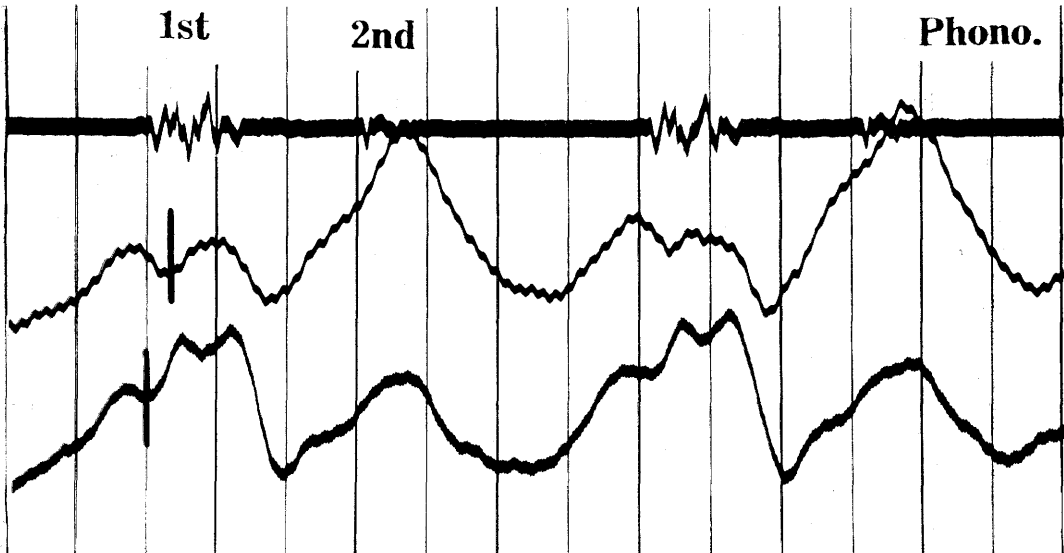


FIG. 2.

Simultaneous fluorocardiograms of the right (bottom) and left (middle) auricles. Phonocardiogram.

The marks indicate the maximum depth of the auricular contraction. The other waves bear a similar temporal relationship.

the activities of the right and left heart presented new problems, which were solved in the following way: (a) The study of the pulsations of the pulmonary arch and of the aortic arch was made with the subject in the postero-anterior position by applying the slits of the 2 pickup units across the borders of the curves corresponding to the 2 large ves-

sels. (b) The study of the pulsations of the 2 auricles was made with the subject in the right oblique position by applying the slits, one below the right bronchus (left auricle), the other much lower (right auricle). (c) The study of the pulsations of the 2 ventricles was made in the left lateral position applying one slit as low as possible across the anterior border of the cardiac shadow (right ventricle) and the other across the lower posterior

⁷ Luisada, A. A., Fleischer, F. G., and Rappaport, M. B., *Am. Heart J.*, in press, 1948. Note II.

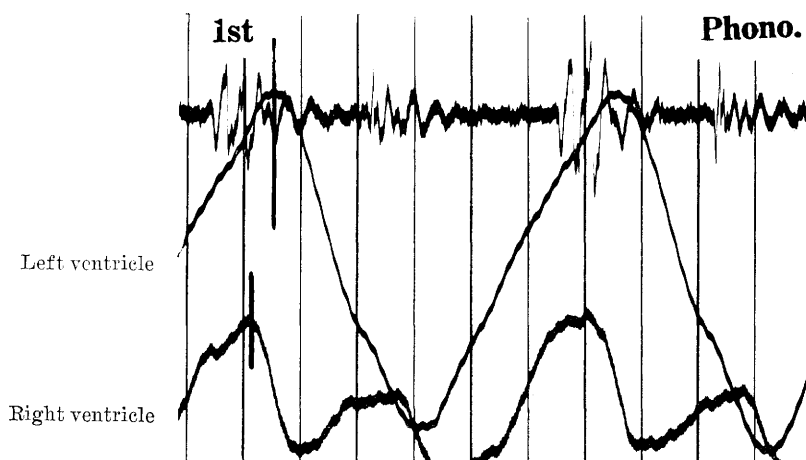


FIG. 3.

Simultaneous fluorocardiograms of the right and left ventricles. Phonocardiogram. The marks indicate the beginning of ventricular ejection.

border (left ventricle).

Results. (1) The simultaneous tracings of the pulsations of the pulmonary artery and the aortic arch (Fig. 1) show the following time relationship: (a) the rise of the pulse of the pulmonary artery precedes that of the aorta by 0.020 to 0.025 seconds (20 to 25 msc). (b) The peak of the pulse of the pulmonary artery precedes that of the aortic pulse by about 0.03 seconds (30 msc).

(2) The simultaneous tracings of the pulsations of the 2 auricles (Fig. 2) show the following time relationship: (a) The beginning of the auricular contractions is not always apparent owing to the rotation of the patient. When visible, the right auricle precedes the left. (b) The maximum depth of contraction is reached by the right auricle about 0.025 seconds (25 msc) before the left. (c) The maximum dilatation of the auricle, at the moment in which the auriculo-ventricular valve opens, is reached by the right auricle from 0.025 to 0.030 seconds (25 to 30 msc) before the left.

(3) The simultaneous tracings of the pulsations of the anterior and posterior aspects of the heart, namely of the 2 ventricles (Fig. 3) show that these bear the following relationship: (a) The beginning of ventricular contraction (isometric contraction) cannot be accurately ascertained in the lateral posi-

tion. (b) The beginning of the ejection period is indicated by a sharp fall of the tracing after the maximum has been reached subsequent to auricular contraction. This occurs about 0.025 seconds (25 msc.) earlier for the right ventricle (anterior surface) than for the left ventricle (posterior surface).

Temporal relation between contraction of right and left sides of the heart are further shown in the schemes of Fig. 4.

Comment. These observations concerning the temporal relations in cardiac action confirm each other. Actually, the final conclusions concerning the time relationship of the ventricular pulsations are based on the correlation of tracings obtained from the auricles indicating the opening of the A-V-valves; from the ventricles showing the beginning of ejection from both ventricles; and from the large vessels revealing the beginning rise of the aortic and pulmonic pulses. The evidence indicates that the right ventricle contracts first, and the interval between the contractions of the 2 ventricles is between 0.025 and 0.030 seconds (25 to 30 msc). The same interval exists between the pulmonic and aortic pulses. The latter is due to various facts: (a) the pulsation of the middle arch is actually that of the left branch of the pulmonary artery,⁸ taking place, therefore, somewhat after the beginning of ejection of

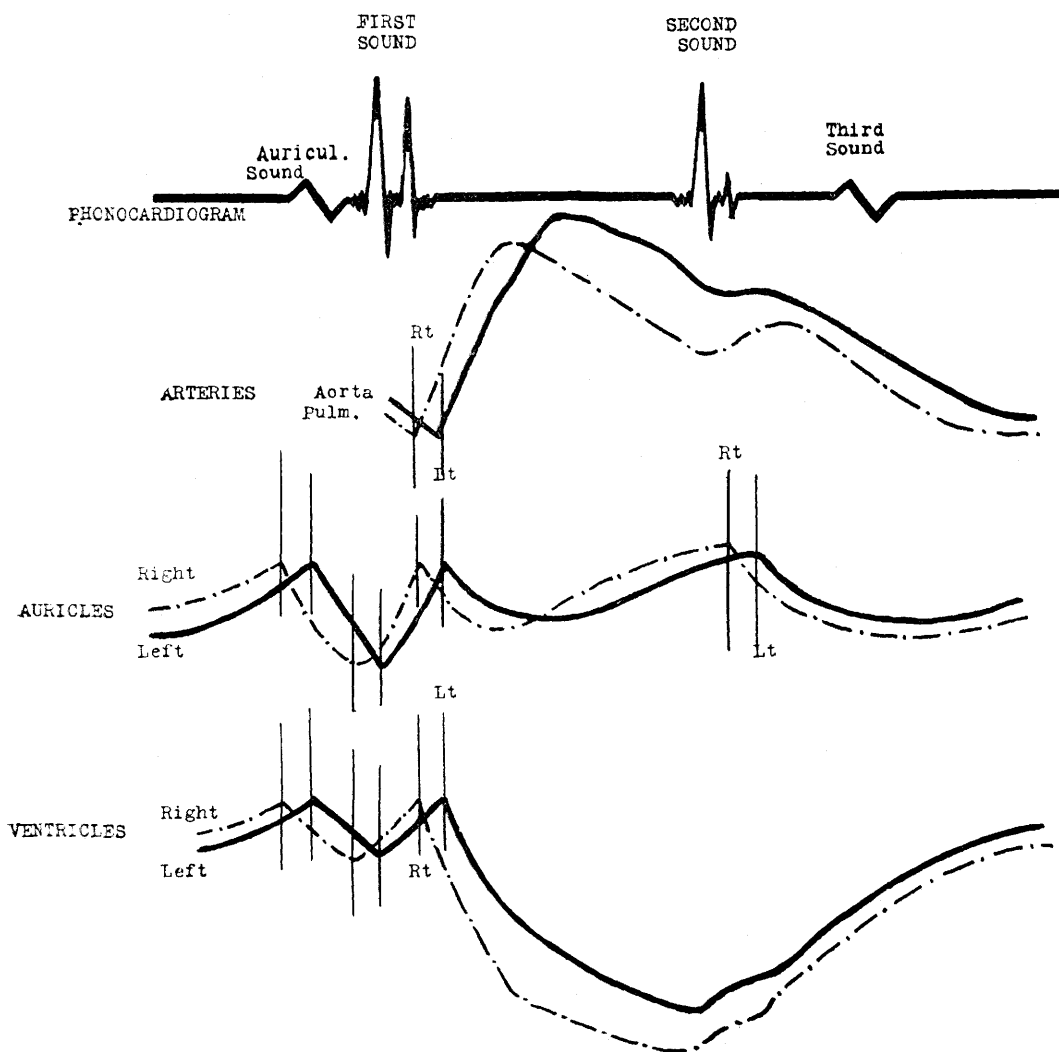


FIG. 4.

Temporal relation between contraction of right and left sides of the normal human heart. Schemes made from tracings of the various subjects.

the right ventricle. (b) The pulsation of the aortic arch takes place some time after the beginning of the ejection of the left ventricle. (c) The speed of the pulse wave is lower in the lesser than in the greater circulation, as indicated by Hamilton⁹ and confirmed by us.⁷ Therefore, in spite of the different length of the 2 large vessels, it is understandable that

the time relationship between their pulses turns out to be about the same as that between the beginning of ejection of the 2 ventricles. We can conclude that all data point to the fact that under normal conditions the right ventricular contraction precedes the left. This fact is in accord with the demonstration that, while the left side of the septum is excited before the right, the external wall of the left ventricle is reached after that of the right (Lewis¹⁰). The time

⁸ Chavez, L., Dorbecker, N., and Celis, A., *Am. Heart J.*, 1947, **33**, 560.

⁹ Hamilton, W. F., in *Howell's Textbook of Physiology* by John Fulton, Philadelphia, Saunders, 1946, p. 841.

¹⁰ Lewis, T., *The Mechanism and Graphic Registration of the Heart Beat*, London, Shaw, 1925.

interval between excitation of the right and left ventricles was found by Lewis to be only 0.01 seconds. As we found it, the interval was greater; this may be attributed to the fact that we measure the interval between the beginning of the ejection from the two chambers. We know that in the human heart the isometric contraction of the right ventricle lasts 0.01 sec. (Richards and co-workers¹¹) but we do not yet know the duration of the isometric contraction of the left. It is likely that the higher pressure existing in the aorta causes a slightly longer duration of the period of tension of the left ventricle, thereby exaggerating the delay already existing.

Our observations on the pulsations of the auricles indicate that, here too, there is a brief interval, the right auricle contracting before the left. Again our observation confirms known physiological facts. In the dog, the sino-auricular impulse reaches the left atrial appendage 0.015 seconds later than the right (Lewis,¹⁰ Wiggers¹²). It is logical

¹¹ Richards, D. W., Courmand, A., Motley, H. L., Dresdale, D. T., and Ferrer, M. I., *Trans. Assn. Am. Phys.*, 1947, in press.

to assume that the interval is longer in the human heart owing to the greater length and difference in length of the muscular bundles leading from the sino-auricular node to either auricle respectively.

The constancy of our findings is in contrast with the variability of results of previous studies.^{1,2} This can be explained by the fact that those studies were performed partly with indirect measurements¹ or with a different technique.²

Summary. The temporal relation between the contractions of the left and right heart chambers was studied by means of fluorocardiography and simultaneous recording of 2 pulse tracings on one strip. The study was performed on 8 normal subjects and included the observation of the pulsations of the aorta and the pulmonary artery, both auricles and both ventricles. In all observations the contraction of the right auricle preceded that of the left auricle and the contraction of the right ventricle that of the left. The delay of action of the left chambers was found to be between 25 and 30 milliseconds.

¹² Wiggers, C. J., *Physiology in Health and Disease*, Philadelphia, Lea and Febiger, 1944.

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The Effect of a *Sporosarcina ureae* Preparation on Tumor Cells *in vitro*.*

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The report that cell division in sea urchin eggs was inhibited by penicillin¹ was the incentive for these experiments designed to test the effect of microbial products on tumor

cells. Cornman² and Lewis³ found tumor cells in tissue culture damaged or killed by the addition of suitable concentrations of penicillin, though Lewis believed the selective carcinoclastic effect was due to impurities in the preparations.

In experiments not otherwise reported, we injected penicillin into Webster strain mice bearing spontaneous mammary carcinomata. Damage to the tumor in the form of hemorrhage, necrosis, and pyknosis was apparent but only after 50-100,000 units of penicillin

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¹ Henry, R. J., and Henry, M. D., *J. Gen. Physiol.*, 1945, **28**, 405.

² Cornman, I., *J. Gen. Physiol.*, 1944, **28**, 113.

³ Lewis, M. R., *Science*, 1944, **100**, 314.