ARTICLE XI.

VALUE OF CARDIO-SPHYGMOGRAPHY FOR THE DETERMINATION OF CARDIAC VALVULAR CONDITIONS AND OF ANEURISM, PARTICULARLY FOR EXAMINERS IN LIFE INSURANCE. By A. B. ISHAM, M.D., of Cincinnati, Ohio.

THE graphic method in diseases of the circulatory apparatus has, within the past few years, made such positive additions to our means of arriving at certain conclusions in regard to valvular affections of the heart and calibre changes in the principal arterial vessels, that no physician, who has to deal with such conditions, should content himself to rest in ignorance of the method and its results. It is of particular importance that examiners in life insurance should know what cardio-sphygmography has accomplished, and should be competent to avail themselves of the advantages which it offers in clearing up doubtful cardiac physical signs. They occupy a position of peculiar responsibility, both toward the company by which they are engaged and toward the general public. It is their duty to the former to recommend only clean risks, about which there hangs nothing to stand in relation to a future fatal disease. Therefore, in a person presenting with cardiac murmur, they cannot upon physical signs, and objective signs, and applicant's history, predicate a positive opinion that an existing murmur is purely functional without significance as regards the structural integrity of the organ, and it is manifestly obligatory upon them to class the risk as doubtful. In doing this, while the company may be deprived of some good risks, compensation is probably more than established by a preponderance of what might have proved bad risks. It might seem here that the balance is in favour of the company, and the obligation toward it fulfilled; but the balance is not in favour of the company, and the obligation is not fulfilled if there exists any possible way of separating the good from the bad. On the other hand, duty to the public demands that none who come within the limits of application physically sound, desiring the benefits of life insurance, should be excluded. If, then, a perfectly healthy applicant is rejected by reason of a sound, pertaining simply to some mechanical factor, standing in no sort of relation to a pathological process, but which appertaining to another individual would be indicative of grave alterations of vital structures, he suffers an injustice for which the medical examiner is not blameless if there be any way of discriminating as to the nature of the murmur in the one case or the other. The applicant and his assigns are injured in that they are deprived of the benefits which life insurance, in its various forms, affords, and to which they should be entitled.

It is the object of this paper to present in a plain practical light what assistance cardio-sphygmography has proved capable of rendering toward the elucidation of the dubious elements in the order of occurrences we have

referred to. By the term *cardio-sphygmography*, of course is meant the simultaneous tracing of the heart and some one of the arteries, one trace above the other, upon the same receiving slide or tablet, together with a time trace below, in seconds or fractions, so that differences in time between the two traces may be easily and accurately computed. The difference in time between the contraction of the ventricles of the heart and the impulse in an artery—or the time difference between two portions of the same artery, or an arterial trunk and one of its branches—forms the basis upon which the deductions from sphygmographic tracings are principally made. Hence it may be seen that instruments which are capable of registering only a single trace, and have no chronographic attachment, have little clinical or physiological value. To be able to draw correct inferences respecting the double registry in any particular case, we must know what are the normal time differences between the heart and the various arteries which permit of investigation. These have been very closely determined by Dr. A. T. Keyt, by means of his compound sphygmograph, as follows : with a heart beating at the rate of 72 pulsations per minute.

The average time difference between the contraction of the ventricle and the pulsation in the carotid artery is about .0833 of a second $\equiv$ to $\frac{1}{12}$ of a second.

The average time difference between the heart and the temporal artery in front of the external auditory meatus is about .100 second, or $\frac{1}{10}$ second.

Between the heart and the subclavian artery, above the clavicle, about .077 second $\equiv$ to $\frac{1}{13}$ second.

Between the heart and the radial artery about .1538 second $\equiv$ to $\frac{1}{6.5}$ second.

Between the heart and the femoral artery about .1428 $\equiv$ to $\frac{1}{7}$ second.

Between the heart and the dorsalis pedis artery about .216 $\equiv$ to $\frac{1}{5}$ second.

The cardio-carotid time difference is approximately one-tenth the duration of the pulsation. Thus, if the pulse-rate is 60 per minute, the pulsation is one second long, and the normal time difference would be $\frac{1}{10}$ of a second; if the pulse-rate is 72, the pulsation has a duration of $\frac{60}{72} \equiv$ to $\frac{5}{6}$ of a second, and the normal time-difference between the heart and carotid artery would be $\frac{1}{10}$ of $\frac{5}{6}$, which equals $\frac{1}{12}$ of a second. This ratio of difference to duration of pulsation holds between 60 and 120 beats per minute, but beyond these limits there is no certainty that it obtains.

The carotid artery is commonly selected in making comparisons of time difference, because it is nearest the heart of any artery readily accessible for observation, and in points involving the integrity of the central organ, or the ascending or transverse portions of the aorta, it must necessarily furnish the least equivocal sphygmographic data.

Variations in the normal time interval are produced by aneurism, heavy aortic valves, aortic regurgitation, mitral regurgitation, and rigid arteries.

INCREASING TIME-INTERVAL.

Aneurism.
Heavy aortic valves.
Mitral regurgitation.

DECREASING TIME-INTERVAL.

Aortic regurgitation.
Rigid arteries.

INCREASING THE CARDIO-ARTERIAL TIME-DIFFERENCE OR INTERVAL. *Aneurism.*—It has been demonstrated by M. Francois Franck¹ and Dr. Keyt² that aneurism retards the transmission of the arterial wave between the heart and the vessels beyond the aneurism, which receive their blood-supply through it. However, according to the clinical observations of Dr. Keyt,³ aneurism, to cause pulse delay, must have “free communications, large cavity, and yielding walls,” while one with converse characteristics, “narrow orifice or small cavity, or resisting walls, may show no abnormal retardation. Deformation of the pulse has no value in the sphygmographic consideration of aneurism, indicating only “arterial obstruction which may originate from other conditions as well as aneurism.”

Fig. 1 supplies the tracings in a case of aneurism of left popliteal artery, showing the delay typical of the aneurismal condition.

Fig. 1.

Time-difference between posterior tibials about $\frac{1}{10}$ second. Normally there should be no difference in time.

Heavy Aortic Valves.—That heavy aortic valves induce abnormal pulse delay has been shown by Dr. Keyt.⁴ The influence of these factors upon the time-difference is well shown by the accompanying graphic delineation, Fig. 2, together with the more salient post-mortem features of the case from which it was obtained.

I made the *post-mortem* examination, assisted by Drs. Keyt and Lowry, April 9, 1881. Left ventricle hypertrophied, left auricle normal, right auricle and ventricle dilated and hypertrophied; mitral, tricuspid, and pulmonary valve normal. Aortic valves had deposited upon their upper

¹ Journal de l'Anat. de la Physiol., t. xv. (Mars-April, 1879).

² Boston Med. and Surg. Journal, Sept. 30, 1880.

³ N. Y. Med. Record, Nov. 29, 1879.

⁴ Med. Record, June 4, 1881.

Fig. 2.

Average time-difference in Fig. 2, .2275 second = to $\frac{1}{4}$ second. Normal time-difference $\frac{1}{12}$ second.

surfaces enormous masses of rough calcareous matter. The overlapping borders of two segments, in nearly half their extent were united, forming a rigid septum, and leaving a triangular space into which fitted the third segment. This segment was pliable, and though it contained a calcareous deposit, measuring three-eighths of an inch in its thickest part, it performed the office of opening and closing the orifice, and did not permit of regurgitation. When closed, the segment overlapped by a little the rigid border of the opening, but slight pressure would cause it to sink below the rim, where it remained, as if locked, until commensurate pressure was applied in the opposite direction.

Mitral Regurgitation.—The cardio-sphygmographic researches of Dr. Keyt¹ have revealed a notable pulse delay from mitral regurgitation. Fig. 3 is in illustration.

Fig. 3.

Cardio-carotid time-difference .117 second or between the $\frac{1}{8}$ and $\frac{1}{5}$ second. The normal time-difference with pulse at 100, as in this case, should be $\frac{1}{17}$ second.

¹ Cin. Lancet and Clinic, March 29, and April 19, 1879, and N. Y. Med. Record, Feb. 14, 1880.

The *post-mortem* examination of the subject furnishing the above tracings, as conducted by myself, assisted by Drs. Keyt and Mecum, showed cardiac hypertrophy, normal aortic, tricuspid, and pulmonic valves, while the segments of the mitral valves were thick and leathery, with a thick layer of firm vegetations upon the auricular surface of the larger segment ; the auriculo-ventricular orifice guarded by this valve was dilated, and permitted of free regurgitation.

Either of the three agencies already mentioned, operating singly, occasion plainly discernible retardation of the pulse, but when they are combined the delay becomes very marked. An example of all three factors, acting together, may be viewed in the tracings exhibited by Fig. 4.

Fig. 4.

Cardio-subclavian time-difference, $.40 = \frac{2}{5}$ sec. Normal time-difference $\frac{1}{15}$ sec.

The subject from whom these tracings were obtained died November 16, 1879. From the *post-mortem* notes at the Cincinnati Hospital was gleaned the following: Heart fatty, weight 15 ounces; just above the aortic valves were two aneurismal pouches, one projecting forward and to the right, the other forward and to the left. The first contained no clots, the other was filled with laminated fibrin, was the size of a small apple, pushed its way in various directions, and pressed upon the pulmonary artery in such a manner as to occlude this vessel entirely. The aortic valves were much *thickened*, but competent by the hydrostatic test. The mitral valve was filled with nodular vegetations and incompetent. Tricuspid and pulmonary valves were normal.

The next cardio-sphygmograms, Fig. 5, instance the pulse delay arising from a combination of heavy aortic valves and mitral regurgitation:—

The person supplying tracings Fig. 5 died in the Cincinnati Hospital February 23, 1879. The autopsy showed the aortic valves to be the seat of extraordinary vegetations, not permitting regurgitation, but so heavy as to require material augmentation of the ventricular pressure to

Fig. 5.

Cardio-carotid time-difference, $.25 = \frac{1}{4}$ sec. Normal time-difference $\frac{1}{2}$ sec.

force them open. The segments of the mitral valve were thickened, rigid, and manifestly incompetent.

DECREASING THE CARDIO-ARTERIAL TIME-DIFFERENCE OR INTERVAL. Aortic Regurgitation.—To M. Francois Franck¹ and Dr. Keyt² we owe the knowledge we possess of the influence of aortic insufficiency upon the transmission of the arterial pulse wave. By the graphic method these investigators have been enabled to ascertain a decrease in the cardio-arterial time-difference as the effect of aortic regurgitation. Cardio-sphygmograms, Fig. 6, are illustrative.

Fig. 6.

Cardio-carotid time-difference $\frac{1}{32}$ sec. Normal time-difference at 103 about $\frac{1}{17}$ sec.

The case from which were derived the above tracings was in the Cincinnati Hospital, service of Dr. C. G. Comegys. All the usual physical

¹ Op. cit.

² Op. cit.

signs of free aortic regurgitation were present. As yet no opportunity has been met with to verify pure aortic insufficiency post-mortem. But where the demonstration is so complete that aneurism of sufficient degree causes pulse delay, graphic tracings in which this condition figures with aortic regurgitation, become available in determining the influence of the latter upon the arterial wave transmissions. Such a combination is marked by tracings Fig. 7:—

Fig. 7.

Cardio-carotid time-difference $.0833 = \frac{1}{12}$ sec. Normal time-difference $.0833 = \frac{1}{12}$ sec.

Tracings Fig. 7 are from a man who had been under the professional care of both Dr. Keyt and myself, in whom we found, post-mortem, the left ventricle hypertrophied, the mitral valves slightly thickened toward the base, but competent; aortic orifice enlarged and aortic valves thickened, corrugated, and calcified throughout, and evidently wholly incompetent. The ascending aorta was greatly dilated, atheromatous, and studded with calcareous matter, while the transverse portion of the arch was the seat of a large aneurism fully three inches in internal diameter, and with soft and flabby walls.

The aneurism in this case was such as must have caused notable pulse delay had it not been counterbalanced by the precipitation of the pulse incident upon aortic regurgitation. The precipitation, Dr. Keyt¹ explains, by presuming that "the base of the arterial column rests against the sides of the ventricle instead of against the aortic valves, and is advanced, causing rise of the pulse with the first movement of ventricular contraction."

Rigid Arteries.—Rigid arterial vessels, such as are met with in the aged, increase the rate of pulse transmission, as may be seen by tracings Fig. 8:—

Tracings Fig. 8 were from Mrs. B., æt. 78. She suffered from dyspnoea, cough, dropsy, and debility, and had an irregular, and, at times, slow pulse. There was a systolic murmur distinct over the cardiac area,

¹ Boston Med. and Surg. Journal, Sept. 30, 1880.

Fig. S.

Cardio-carotid time difference about $\frac{1}{15}$ sec. Normal time-difference $\frac{1}{12}$ sec.

plainly heard at both base and apex, but emphasized at a spot midway between these sites. The second sound was pure and clear. Tracings were taken at the Cincinnati Hospital May 9, 1881, where she was a private patient under the care of Dr. Keyt. Death occurred at Newtown, O., from dysentery, July 9, 1881, while under the treatment of another physician. I performed the post-mortem July 11, 1881, in the presence of Drs. Keyt and Witham and medical student Jones. The heart was fatty. There were calcareous and fatty alterations of arterial walls. The aorta was of normal size, and its orifice was uncontracted. The aortic valves were competent, but two segments presented rough calcareous nodules upon their upper aspect. A prominent nodule projected from the ventricular surface of one segment near its attached border. One segment was free from calcareous matter, but was slightly expanded and thickened. The valves were perfectly pliable and competent by the hydrostatic test. The mitral and tricuspid valves were slightly thickened, but competent, as were also the pulmonic valves.

In the above case the cardiac second sound was perfectly clear, and there was a systolic murmur with greatest intensity midway between the base and apex. The absence of all indications of aortic regurgitation led to the decision of pulse precipitation from rigid arteries, and the absence of marked evidences of cardiac hypertrophy gave warrant to the conclusion that even in the right heart there could be no material disturbance of valvular action. The precipitation in the case is really much greater than the figures show, since, with a pulse at even 60 per minute, the normal delay is greater than that which we have given for a pulse of 72 per minute. We will have occasion to revert again to these tracings in the course of this article.

Having considered the conditions which may affect the rate of pulse transmission, a few words may be devoted to the cardio-sphygmographic indications in aortic and mitral stenosis. Aortic stenosis does not alter

the transmission rate of the pulse. A marked degree of stenosis deforms the pulse trace, producing one with sloping ascent and rounded top. It may also occasion intermittency. It all depends, however, upon the degree of narrowing. If the orifice is sufficient to permit of pretty free filling of the aorta by the ventricular contraction, the sphygmographic evidence of aortic stenosis is nil. In regard to mitral stenosis, no cases have as yet come under observation. From the markings of aortic stenosis, and deductions drawn from the course and mechanism of the circulation, it would make no variation in the pulse-rate transmission, but would give rise to a pulse of small tension, and one which might present intermittency at times. The auricular portion of the trace would undoubtedly have unusual prominence.

Affections of the valves and orifices of the right heart, of course, only have a negative bearing upon cardio-sphygmography, because the blood current which traverses them does not pass into channels accessible for investigation. The negative value of the sphygmograph in right heart complications is well exhibited by tracings Fig. 9.

Fig. 9.

Cardio-carotid time-difference about $\frac{1}{15}$ sec. Normal time-difference with pulse at 90 about $\frac{1}{15}$ sec.

Tracings (Fig. 9) were from Mrs. Smith, *at.* 59. Her symptoms were shortness of breath, inability to exercise, some cough, anasarca of the lower extremities, ascites, and intermittent pulse. The area of cardiac dullness was much increased, showing decided cardiac hypertrophy. There was a loud diffused systolic murmur, plainly accentuated at the apex, and in all respects, apparently, a typical example of a mitral regurgitant murmur. The second sound was clear and intensified at the pulmonic site. Tracings were taken in May, 1880, and February 12, 1881. Death occurred May 7, 1881. At the post-mortem, Dr. Keyt being present, we discovered the heart generally enlarged, walls of right auricle and ventricle greatly thickened and the great veins dilated. Pulmonic valves normal; right auriculo-ventricular orifice dilated, and tricuspid valves wholly in-

competent, one segment being firmly bound down by adhesions to the side of the ventricle. Aortic valves normal; mitral valves slightly thickened, but competent. Texture of heart fatty and friable.

In the absence of all indications of aortic regurgitation, it was concluded that, in this case, the left heart was properly functioning, and that the lesion must be located in the right heart, where it would not affect the cardio-arterial tracings.

The negative evidence the sphygmograph furnishes of perfect valvular mechanism in the left heart finds good illustration in tracings Fig. 8, together with the data and observations thereto pertaining. The negative evidence supplied by the compound sphygmograph is not less valuable than its positive evidence, and it becomes positive evidence taken in connection with clinical symptoms and physical and objective signs.

From what has preceded, though it has been presented rather in the form of an easy lesson in cardio-sphygmography, it is thought that enough proof has been advanced to establish the graphic method as an important adjunct in differentiating some of the complex instrumentalities which induce disorders in the course of the circulation, and alterations in normal cardiac and arterial sounds. Assuming that this much will be admitted, its advantages in life insurance examinations are great.

It is one of the prerequisites to a life insurance policy that the holder shall be a healthy person. Individuals come up for examination presumably as those who regard themselves perfectly sound, or, at least, presenting no traces of disease detectable to the medical examiner. The examination is made, and an abnormal cardiac murmur is heard. Neither symptoms or appearance or anything in the history of the applicant show disqualifying lesion,—there is nothing but this little whistling sound, bearing some relation to the heart beats. Without the graphic method the examiner cannot determine whether the sound be structural or functional. Provided the sound be constant, its character and location go for nothing in the differentiation. The risk cannot be given a clean recommendation. The examiner may say that he *believes* the murmur to be functional, and the risk a good one, but he cannot state that he has any warrant for this opinion beyond the appearance and history of the applicant, and the probabilities are that if a medical examiner mentions a heart murmur, the medical director will reject the risk no matter how strongly the former expresses his confidence in a sound of functional character. On the other hand, an examiner, by the aid of the graphic method, conjoined with other means of investigation, may base his opinion upon the functional or structural significance of a murmur with almost as much certainty as upon a mathematical demonstration. If the normal pulse delay obtains between the heart and carotids, and radials and dorsal arteries of the feet, he may say that an instrument of precision gives unequivocal evidence of simple functional or mechanical origin of the murmur. But before he is entitled

to make so confident an announcement, he must have ascertained that there is no aneurism and aortic regurgitation to counterbalance each other in their influence upon pulse transmission, and that there are no valvular lesions of the right heart. This he may do by an entire absence of the clinical symptoms and physical signs indicative of these troubles. Then, too, if the cardio-sphygmograph reveal abnormal pulse delay or pulse precipitation, or pulse deformation or marked prominence of the auricular portion of the trace, the examiner may say that the instrument of precision, in connection with the other features in the case, writes a record of aneurism, or mitral regurgitation, or aortic regurgitation, or aortic or mitral stenosis, as the condition may be. Can an examiner without the assistance of a compound sphygmograph arrive at a conclusion with equal certainty? Without exception, where autopsies have been obtained, the conditions of the circulatory organs have corroborated the deductions derived from a study of the cardio-sphygmographic tracing during life.

Every competent physician of considerable experience knows how fallacious many cases of heart murmurs prove themselves. He finds murmurs in some instances in which he is apprehensive of grave cardiac mischief and discovers that they have disappeared, after a time, without any apparent harm surviving them. On the contrary, instances are unfortunately not wanting of supposed innocent murmurs becoming the heralds of serious cardiac disease. It is the uncertainty which even the most accomplished clinician must feel in regard to many cases presenting cardiac murmurs that makes insurance companies so chary about accepting risks in which there may be possible danger from this source. We think that, with the progress already made in cardio-sphygmography, it is perfectly practicable to distinguish the acceptable from the non-acceptable risks in almost every instance of persons coming under examination with heart murmurs. This method of investigation is new, its data, as yet, comparatively limited, but it promises to be developed until nearly every point in cardio-vascular pathology finds its interpretation by this means.

WALNUT HILLS, CINCINNATI, O.

ARTICLE XII.

A REPORT OF THREE HUMAN MONSTROSITIES. By M. A. KOOGLER, M.D.,
of De Graff, Ohio.

OF late the village of De Graff, Ohio, gave record to three monstrosities: one cyclops and two acrania, in less than two months.

The first occurred in Dr. D. W. Richardson's practice, the second in that of Dr. F. M. Galer's, and the third in the writer's practice.