A STUDY OF THE RHYTHMS FOLLOWING DESTRUCTION OF THE SINO- AURICULAR NODE

By

HELEN BARDEEN

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The first people to observe that a different type of beat originated when the upper part of the sinus was destroyed were those who many years ago studied the frog or tortoise heart. It was found by these workers that when the sinus was injured a peculiar form of beat originated in which the auricles and ventricles beat simultaneously. This showed that the beat originated somewhere in the auricular-ventricular junction. This work was done many years ago before Keith and Flack[1] had discovered the sino-auricular node of the warm-blooded heart.

This structure had no sooner been described than workers began to study the rhythm following the destruction of the sino-auricular node. The results of these studies have differed so widely that even now it is difficult to draw any clear cut conclusions.

Those who have done some work on the problem are Zahn, Eyster and Meek, Cohn, Kessel and Mason[2]. These workers have found that on extirpation of the sinus node an auriculo-ventricular rhythm appeared. Now others have questioned these results, Among these are Jaeger, Magnus-Alsleben, Erlanger, Brandenburg, and Hoffmann.[3]

It may be said, however, that in recent years the majority of workers have been able to confirm the results of the workers of the first group. But even now, with extirpation of the sinus node, a rhythm with wide P-R interval has often returned. It is this circumstance that has made us again attempt

1. Keith and Flack: Jour. Anat. and Physiol., 1907, xli, 172.
2. Zahn, Eyster and Meek, Cohn, Kessel and Mason; Zeitschr. fur die Ges. Exp. Medizin, 68, 167.
3. Jaeger, Magnus-Alsleben, Erlanger, Brandenburg, and Hoffmann: Zeitschr. fur die Des. Exp. Medizin, 68, 168.

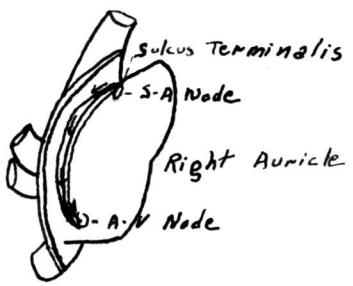
to study the problem.

The usual answer in regard to the cause of this wide interval is that the auricular part of the auriculo-ventricular node has taken up impulse formation. This auricular part is supposed to be more closely connected to the auricle and so it induces a beat there and the ventricles follow it at a later time.

Another explanation is that all parts of the sino-auricular node have not been destroyed, or that some part that has been injured has recovered. It will be seen that the story of our experiments more nearly fits into this point of view.

It is assumed that the electrical negative potential is associated with activity and therefore the pace maker is found by finding the point of initial negativity. This is determined by the use of a galvanometer which is connected to two points on the surface of the heart muscle, primary negativity of one contact being shown by the string deflecting in a known direction. In the normal heart the point of initial negativity is in the upper part of the sino-auricular node, a special neuro-muscular system lying at the junction of the free border of the appendix with the mouth of the superior cava, and extending downwards along the sulcus terminalis.

It is not known definitely, but Eyster and Meek[4] have experimentally shown that the conduction of the impulse arising in the highly specialized tissue goes to the auricle by fibers radiating from the sinus, especially in the direction shown in the diagram:



4. Eyster and Meek: Am. Jour. Physiol., Vol. LXI, No. 1, p.123.

Method: Dogs were used in these experiments. Electrocardiograms were obtained for two or three days previous to the operation on the heart and the influence of atropine was also recorded. The normal heart rate and P-R interval were thus obtained. The animal was then morphinized and prepared for the operation which was carried out aseptically under ether. The heart was exposed and a short tube of radon was sewed to the sino-auricular node in order to destroy it.

Operation Procedure: The right lateral chest from the clavicle to the sixth rib was carefully shaved and the part was cleansed and disinfected with iodine and alcohol. Artificial respiration was carried out by means of a rubber tube passed down as far as the trachea bifurcation. An incision was made following the line of the third rib and extending from the mid-axillary to the mid-clavicular lines. The underlying portion of the third rib was carefully resected, freed by means of a curved dissecting probe from the pleura and about five centimeters of the bone removed, leaving the pleura intact. The pleura was now incised and small retractors placed at right angles in the wound. This gave an oval shaped opening through which the caval regions and right auricle were seen. The pericardium was slit for a distance of several centimeters along the line of the sulcus terminalis and the edges were brought out and sewed temporarily to the edges of the opening in the thoracic wall. Hemostats were used to hold the fat along the lower caval auricular boundary and the anterior chest wall close to the edge of the sternum in the sixth or seventh interspace. The heart was rotated to the left by traction, bringing the sulcus terminalis into the center of the opening. A head mirror and light were necessary to illuminate the field of operation properly. Temporary stitches were laid above and below the node and were brought out to the upper and lower edges of the

opening in the thoracic wall. The radon tube was then sewed directly over the linea alba of the sino-auricular node of the heart. The amount of radon used varied from three to eight mc. and the tubes were one or two centimeters in length. After the radon tube was in place the holding stitches were removed and the pericardium was closed by single line of sutures. The pleura was now brought together by a line of sutures and before the last one was tied the lungs were inflated by a continuous blast of air, the air being thus largely removed from the interthoracic cavity. The thoracic muscles were now approximated by sutures and finally the wound was closed by a row of subcutaneous stitches and a continuous skin suture.

Results: Nine dogs were operated on. In two of the cases the radon tubes broke and so the operations were unsuccessful. In dog No. 18 the broken tube was left sewed to the nodal tissue and the dog was used as a control. No effects were observed on the heart due to the operation itself. Three of the dogs showed disturbed heart beat with a shortened P-R interval shortly after the operation, but the interval lengthened after a short time and gradually came back to normal. Two dogs went into complete nodal rhythm following the operation. One of these died while still in nodal rhythm twelve days after the operation. The heart of the other dog showed some irregularities, some beats were skipped, and after a time a P-R interval appeared which gradually increased in length, the beat coming back to normal.

In dog No. 13, immediately after the operation the P-R interval was seen to be quite short, but the interval lengthened until a long P-R interval resulted.

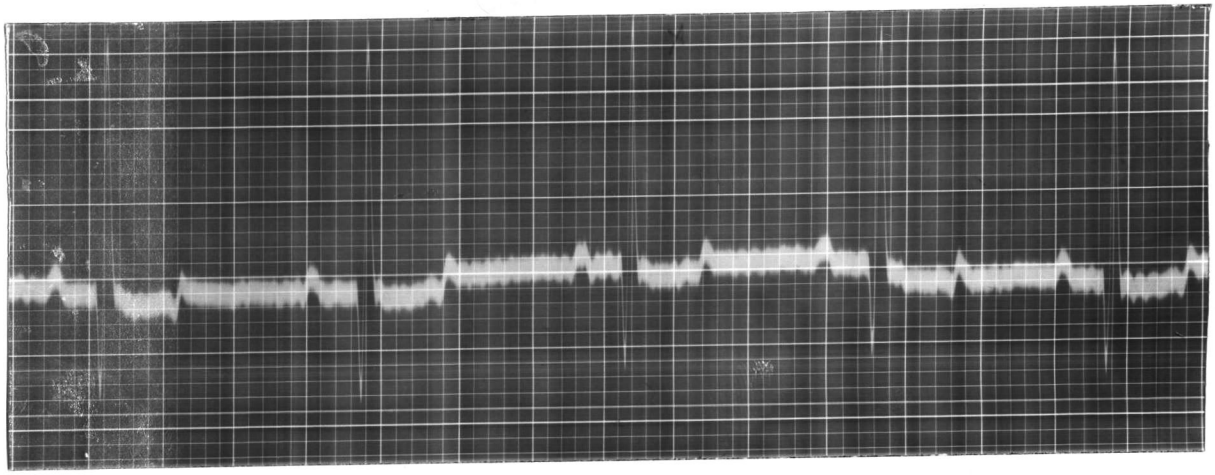


Figure 1. Electrocardiogram of a normal heart showing a normal P-R interval.

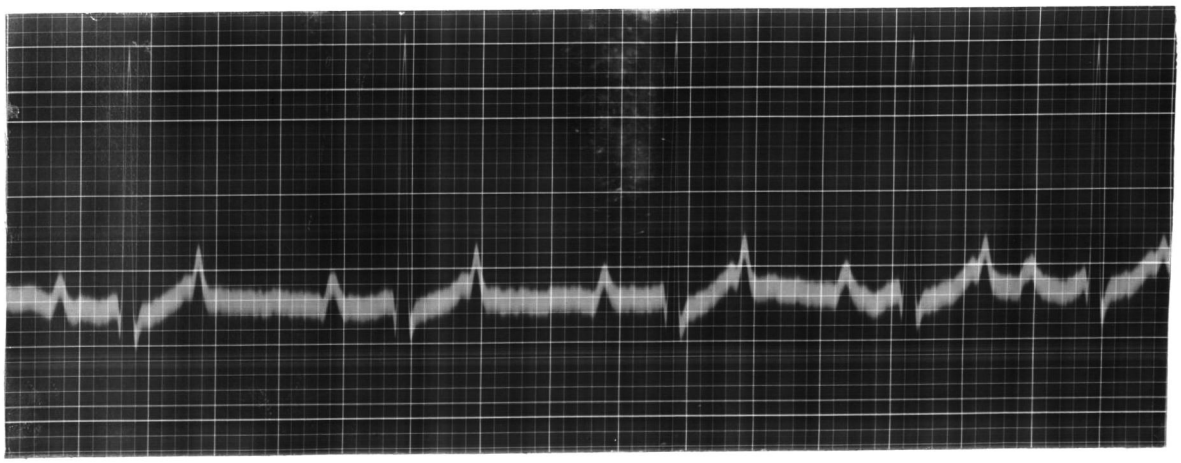


Figure 2. Effect of destroying part of the sino-auricular node in dog No. 13. The pacemaker has shifted to the upper part of the node resulting in lengthened P-R interval.

Dog No. 19 showed almost complete nodal rhythm soon after the operation. Two days later there was observed an A-V block and an inverted P-R interval. Complete nodal rhythm and heart block were found six days after the operation. On the eighth day, after atropine was given, the nodal rhythm changed and a short P-R wave resulted. The dog was observed for

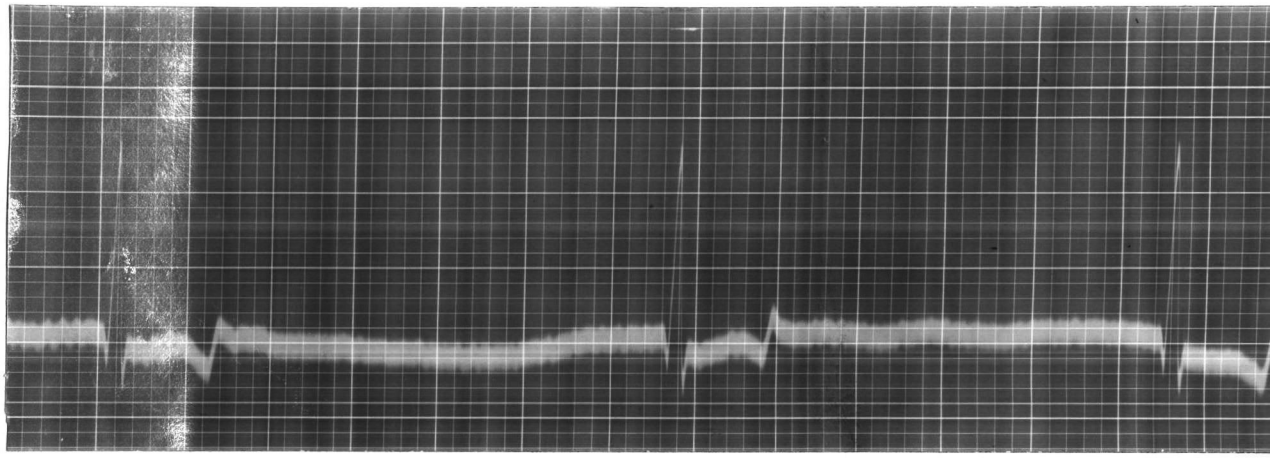


Figure 3. Effect of almost complete destruction of the sino-auricular node in dog No. 19. The pacemaker has shifted to the auriculo-ventricular node resulting in nodal rhythm.

twenty-one days, the beats during this time sometimes being nodal and sometimes showing a short P-R interval.

Determination of the seat of impulse origin was made by opening the thorax under artificial respiration and ether anesthesia and determining the seat of initial negativity by means of pairs of electrodes connected to the string galvanometer. The electrodes were placed (1) on the upper part of the sino-auricular node and on the auriculo-ventricular node, (2) on the lower part of the sino-auricular node and the auriculo-ventricular node, and (3) on the lower part of the sino-auricular node and the upper part of the node, the electrodes being reversed each time as a check-up. The point showing initial negativity was determined by the direction of the initial movement of the string in the curve obtained, the direction of movement having been determined beforehand when one pole of the galvanometer was made electro-negative to the other.

This determination was done on two of the dogs, No. 13 and No. 19. In dog No. 13, in which a long P-R interval was observed, the determination was done twenty days after the operation. With stimulation of the vagus nerve the P-R interval was much shortened. The heart was then made to beat at a faster rate and the point of initial negativity determined. It was found to be in the upper part of the sino-auricular node.

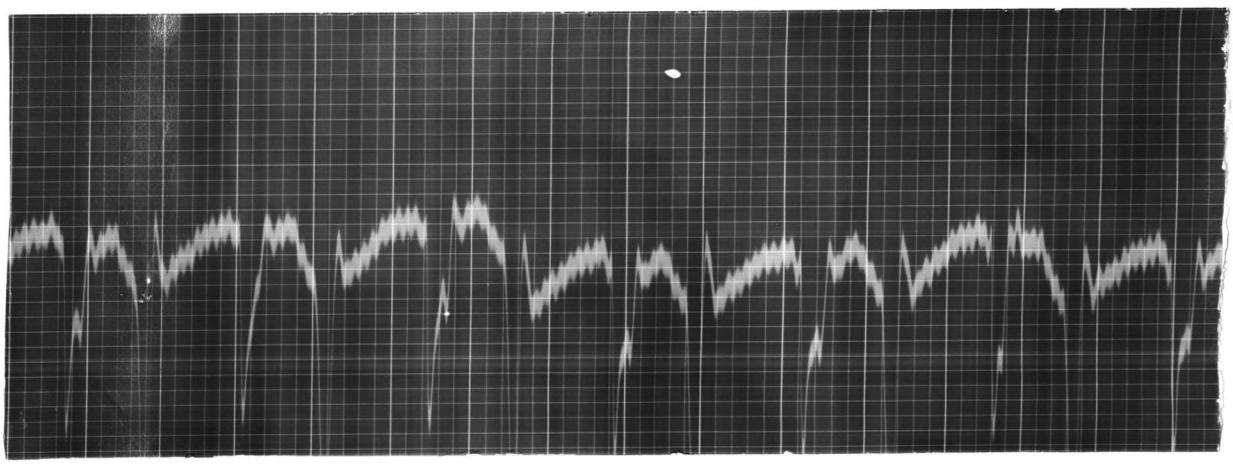


Figure 4. If the upstroke comes before the downstroke the right hand is negative first, but if the downstroke precedes it indicates the left hand is negative before the right hand. In the above record of dog No. 13, the the left hand of the electrodes was placed on the upper sinus and the right hand on the lower sinus. The downstroke precedes showing the left hand to be negative first. The upper sinus, therefore, was negative before the coronary sinus.

Dog No. 19 showed nodal rhythm and a short P-R interval. The point of initial negativity was determined after the nodal beats decreased in number and a short P-R interval was established.twenty-one days after the operation. The point of initial negativity was found in the lower part of the sino-auricular node. When one of the records was being taken the

heart fell back against one of the electrodes which stimulated the A-V node to action, causing nodal rhythm. In the next record a P-R interval was again seen.

There seemed to be a relation between the amount of radon used to destroy the nodal tissue and the length of time it took for the heart to come back to normal, if it did at all. In dogs No. 12 and No. 15, in which 3.0 mc. and 3.59 mc. were used, respectively, the shortened P-R interval was of short duration, coming back to normal in a few days. In dog No. 19, in which 8.0 mc. radon were used the heart remained in nodal rhythm for some time and then showed only a shortened P-R interval. When more of the nodal tissue is destroyed it takes a longer time for the few fibers left to assume activity, but gradually this is often accomplished and the point of initial activity finally is located at the point where there are still enough fibers left undestroyed to take up the responsibility of pacemaker.

These results indicate that only a very small part of the sino-auricular node is necessary to be present in order to have the beat originate in that part of the heart. A few fibers of the node appear to function as well without the rest of the node being present. In most of the cases observed, probably a sufficient part of the sino-auricular node was left undestroyed to enable the heart to beat normally. In dog No. 13 the fibers remaining were in the upper part of the node.

In dog No. 19 the sino-auricular node looked to be entirely destroyed and as the point of initial negativity was found far down in the sinus it is probable that it lay in the fibers belonging to the node and connecting it with the auricular-ventricular node, these fibers not being affected by the radon.

The rhythm following our attempts at the destruction of the sino-auricular node is, therefore, nor permanent. If a sufficient part of the node is destroyed nodal rhytham developes temporarily, but a P-R interval comes into the rhythm every now and then and gradually this P-R interval increases as the beats again originate in the sino-auricular node. Only a few fibers need to be present in order to carry out their normal function. Indeed it seems impossible to destroy the node completely, because some of its fibers extend down, forming some bit of a pathway toward the auricular ventricular node. These fibers probably cannot be destroyed, because they are quite diffuse and are intermingled with other tissue.

In order fully to determine the conclusions arrived at, it would be necessary histologically to examine the tissue in the hearts, in order to see what part, if any, of the sino-auricular node remained. This is to be undertaken by Dr. Borman, who was also interested in the experiment. It could be seen, however, that the body of the node was destroyed, because of the scar tissue formation and the lesions formed.

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Approved Walter J. Meek

Professor of Physiology