THE INTER-AURICULAR TIME INTERVAL

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INTRODUCTORY

In 1910, Wybauw (1) and Lewis (2) working independently, demonstrated that in the mammalian heart, the point of initial excitation corresponds to the location of the sino-auricular node. This finding has been confirmed by Eyster and Meek (3) and others. Although Erlanger (4) and his co-workers have placed a different interpretation on the records of the above named investigators, the view is generally held that the normal seat of impulse formation, is the sino-auricular node and more particularly the head of this node. Granting that this view is essentially correct, the excitatory process is then propagated from this area by muscle tissue to all parts of the heart. If the rate of propagation through auricular muscle is the same throughout, it may be expected that parts at a sufficiently greater distance from the sino-auricular node than nearby parts, would show an appreciable time difference in the onset of their contraction. Thus the left auricle, though in direct and common muscular connection with the right auricle, may be expected to contract later than the right. It is generally taught, however, that the contractions of the two auricles are synchronous.

Yet Chauveau (5), in 1894, stated that "in the horse, the right auricle begins its systole an appreciable time before that of the left auricle." Later Fredericq (6) took up the question and demonstrated the same fact in the dog's heart. Fredericq's pupils—Schmidt-Nielsen (7), Stassen (8)—confirmed his findings. The correctness of this statement has, however, been disputed by Hirschfelder and Eyster (9) who attribute Fredericq's results to the use of excised hearts; they believe that the heart in situ maintained under normal conditions, does not show any time interval in its auricular contractions and that such time
interval occurs only in dying hearts or in hearts suffering in their nutrition. The later work of Fredericq and his pupils, was done on hearts in situ. Hirschfelder and Eyster's failure to demonstrate any time interval between the two auricular contractions may have been due to the use of a too slowly moving kymograph and of too small animals. Leontowitsch (10) likewise disagrees with Fredericq and finds that contractions of the two auricular appendages as well as of the atria may occur in various sequences, although in the majority of his experiments the right atrium and auricle contracted before the homonymous parts on the left side. Recently, Lewis, Meakins and White (11), tracing the course of the excitatory process through the auricles by the method of primary negativity, came to the conclusion that "certain portions of the right auricle contract before certain portions of the left auricle, and vice versa;” that it is therefore “unprofitable” to discuss whether it be the right or the left auricle that first contracts. While individual parts of the auricles doubtless begin their contraction at different times the point of interest insular as the efficiency of the auricles as feed pumps is concerned, relates to the resultant of these differently timed contractions. In view, therefore, of these contradictory findings it has been thought worth while to submit again the question to experiment by the usual graphic (suspension) method.

METHOD

Dogs of fairly large size—7.7 to 21 kgm.—were employed. They were anaesthetized with ether; no other drug was used. The vagus nerves were exposed in the neck and loose ligatures passed around them. The sternum was removed after ligation of the internal mammary arteries. The phrenic nerves were cut; the pericardium split open and its edges stitched to the sides of the opening in the thorax. Artificial respiration was started meanwhile and maintained throughout the

1 It was realized early in the course of the experiments that the auricular myogram as obtained by the suspension method could not be depended upon to give an indication of the relative duration of right and left auricular systoles, still less any difference that might exist in the onset and duration of the period during which the blood is forced into the ventricles. Since then Wiggers (12) has published an interesting paper bearing on the relation between the auricular myogram and what he calls the "dynamic period" of the systole. While the relative duration of right and left auricular systoles may not be obtainable by the suspension method, the relative time of onset of the contractions is quite accessible to the method.
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experiment. The mixture of ether and air was kept in the neighborhood of 37°C by means of Brodie’s air warmer and anaesthetizer. The heart was prevented from drying by dropping upon it warm Ringer’s solution. Cooling of the exposed heart was prevented by means of an electric lamp placed an appropriate distance above it.

The tip of the right and left auricular appendages were connected to receiving tambours by means of François Franck pincettes. These tambours were covered with exceedingly thin and very elastic rubber dam (condom).

Rubber tubes of equal lengths joined the receiving to recording tambours provided with very light levers (thin straw and aluminum writing points). The recording tambours were placed upside down so that the curve of contraction is positive. An electro-magnetic tuning fork giving one hundred vibrations per second and a stimulation signal were mounted beneath the tambours. All writing points were adjusted to the same perpendicular line. The Hürthle kymograph was arranged for a speed of 180 mm. per second with the exception of experiment 1 where the speed was 320 mm. per second.

At the conclusion of the experiment, the heart was removed and the following measurements were taken (a-b) distance from the position of the head of the S-A node (auriculo-caval angle) to the tip of the right auricular appendage; (a-c) distance from S-A node to the tip of the left auricular appendage (see fig. 1). Great care was taken in making these measurements not to stretch the heart tissue although it was necessary to raise the appendages; even with the utmost care, such measurements are liable to error and must therefore be considered as merely approximate.

RESULTS

The beginning only of each experiment will be discussed in this paper. The study of the effect of vagus stimulation has not been completed and its report must be postponed. By confining the observations on the inter-auricular interval to the beginning of the experi-
ment, the criticism of cooling of the exposed heart and interference with nutrition through prolonged etherization, must be largely overcome. I may say, however, that usually, later phases of the experiment show but insignificant prolongation of the inter-auricular time interval.

A reference to table 1 shows that the average inter-auricular time interval in twelve dogs ranging in weight from 7.7 to 21.36 kilos was 0.013 second (fig. 2). This, therefore, corroborates the findings of Fredericq and his pupils. Moreover, the experiments which form

<table>
<thead>
<tr>
<th>NUMBER OF EXPERIMENT AND DATE</th>
<th>WEIGHT (kgms.)</th>
<th>RATE OF HEART BEAT</th>
<th>INTERVAL-BETWEEN-AURICULAR TIME INTERVAL</th>
<th>NUMBER OF MEASUREMENTS</th>
<th>A. DISTANCE FROM S-A NODE TO THE RIGHT AURICLE, AP. FACTURE</th>
<th>B. DISTANCE FROM S-A NODE TO THE LEFT AURICLE, AP. FACTURE</th>
<th>B-A</th>
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<td>29</td>
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<td>28</td>
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<td>237</td>
<td>0.0102</td>
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<td>25</td>
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<td>22</td>
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<td>30</td>
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<td>32</td>
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<td>28.2</td>
<td>51.5</td>
<td></td>
<td>23.3</td>
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the basis of this report have been remarkably uniform throughout; no such variations in the sequence of contraction as have been mentioned by Schmidt-Nielsen (loc. cit.) and by Leontowitsch (loc. cit.) were observed at any time.

It may be of interest to note in connection with the figure just given as the average inter-auricular time interval, that practically the same figure can be obtained from one of Lewis' tables (11) dealing with conduction time from S-A node to various points on the auricles. The conduction time from S-A node to the right appendage in 11 dogs was 0.0314 second; the distance was 28 mm. The conduction time from the node to the left appendage in 7 dogs was 0.0446 second; the distance
was 44.6 mm. The difference in conduction time from the S-A node to the right and left auricular appendages respectively is therefore 0.0132 second, a figure which is practically identical with the one given here. It is difficult to state what significance, if any, attaches to this similarity in time differences. The contractions recorded in the manner described in this paper, doubtless give a record of the action of the greater mass of the auricle whereas Lewis' work was confined to a determination of the time of onset of excitation of a very limited part of auricular muscle relatively to the S-A node. If, as we must believe,

![Tracing of right and left auricular contractions obtained from dog 1.](http://ajplegacy.physiology.org/)

the contraction of the auricle as a whole is the resultant of the differently timed contractions of its parts, the inter-auricular time interval obtained by recording the auricular contraction should be less than that obtained with the electrocardiograph, the contact points being S-A node and tip of appendages. The results presented in this paper may be so interpreted if reliance may be placed upon the measurements of the heart, for while in Lewis' animals the average difference in distance to be traversed by the excitatory wave was 16.6 mm., the difference in distance in our animals was 23.3 mm.

It occurred to the writer that in view of the solidarity of the auric-
cles, a special structure might exist whose special function would be that of inter-auricular conduction. An examination of the heart shows that a distinct band of muscle tissue stretches from the right auricle to the base of the left auricular appendage and forms apparently the most direct connection between the auricles. The same observation was made by Lewis, Meakins and White (loc. cit.) who call attention to the straight course taken by the fibers of this muscle band. This band has appropriately been called the inter-auricular band.

When the heart is hardened with 10 per cent formalin under a pressure of 30 cm. of the solution, the form and relations of the inter-auricular band are well brought out (see fig. 3).

The inter-auricular band. In a dog's heart of average size the right extremity of the band originates about 5 mm. to the mesial side of the auriculo-caval angle and in a direct line with it. This extremity of the band is immediately back of the aorta and spreads in a fan-like manner onto the mesial (right) auricular wall and the root of the su-
perior vena cava. From this origin the band sweeps in an almost straight line to the base of the left auricular appendage but, so far as superficial appearance indicates, its fibers can be traced to near the tip of the left appendage. The band is thinnest near its origin on the right side where it has an angular appearance. It then broadens gradually as it passes to the left auricle. The band is slightly concave from right to left, the concavity being directed upward. It has a length of about 20 mm.

THE EFFECT OF CLAMPING THE INTER-AURICULAR BAND

If this band is of special importance in conduction its compression should lead to at least a lengthening of the inter-auricular time interval. A number of experiments were accordingly conducted in which the band was crushed about its middle between the jaws of a hemostatic forceps, care being taken not to injure the auricular tissue either above or below the band.

Extracts from the Protocols

January 4, 1916. Dog 6. After registering the auricular contractions for five minutes, an attempt was made to clamp the band by sliding a hemostatic forceps against the left wall of the pulmonary artery, the forceps being slightly inclined toward the right of the animal. The first attempt failed, a part of the auricular appendage near the base being compressed instead of the band proper. There was no apparent effect following this attempt. A second attempt succeeded. The inter-auricular time interval lengthened from an average of 0.0133 second to 0.98 second, many measurements showing an interval of 0.1 second (fig. 4). The inter-auricular time interval was therefore lengthened 73.68 times by the crushing experiment.

At the conclusion of the experiment examination of the heart showed, besides the compression at the base of the auricular appendage already mentioned, that the band was crushed transversely, the part crushed measuring 5 mm. The portion of uncompressed auricular tissue below the band measured 4 mm.; the portion above the band measured 10 mm.; these are external measurements and do not, of course, comprise any part of the auricular septum that may have been affected by the clamping.

January 6, 1916. Dog 7. In this and subsequent experiments the contractions of the left ventricle were registered simultaneously
with those of the auricles. The first attempt to clamp the band was successful. The inter-auricular time interval passed from an average of 0.0132 second to 0.053 second an increase, therefore, of 4 times the normal average (fig. 5). The differently timed contractions of the two auricles were quite appreciable to the eye. The average rt.A–lt.V interval at the beginning of the experiment was 0.082 second; there was a gradual increase in this interval toward the close of the experiment, and it was 0.09 second just before clamping the inter-auric-

![Fig. 4. Tracing from dog 6 showing the effect on the inter-auricular conduction time of injury to the inter-auricular band.](http://ajplegacy.physiology.org/)

ular band. This interval after clamping showed an average of 0.102 second.

Examination of the heart showed that the forceps was applied on the band at about the same point as in the preceding experiment, this point being immediately to the left of the location of the auricular septum. The blades, however, included a little more of the tissue above and below the band. Viewed from the interior of the auricles there was no evidence of the compression on the right side of the auricular septum; but on the left side evidence of the compression was seen half-way between the opening of the right pulmonary vein and the
opening leading into the left auricular appendage. The compression
affected, in part, the roof of the auricle above the septum and, in part,
the septal wall in front of the position of the fossa ovalis.

January 19, 1916. Dog 8. The inter-auricular time interval at
the beginning of the experiment was 0.01 second; the heart rate 203
per minute. After section of the right vagus the heart rate rose gradu-
ally to 257 per minute; at the same time the inter-auricular time inter-
val gradually decreased to 0.005 second. This was the time interval
just before clamping. The clamp was applied in the same position
as in dog 7; the inter-auricular time interval immediately after clamp-
ing and thereafter, had an average of 0.023 second an increase of 4.6
times the average observed before clamping. There was no apprecia-
able change in the rt.A–lt.V interval, the average being 0.07 seconds.

The band was less well developed than usual; moreover, it had not

Fig. 5. Tracing from dog 7; it shows the usual effect of clamping the inter-
auricular band.
been so well crushed by the forceps as the blades had failed to come completely together.

January 21, 1916. Dog 9. An attempt to clamp the band with Erlanger's clamp failed, the clamp being found imbedded in connective tissue on the side of the pulmonary artery. The experiment came to a premature close owing to an extensive tear in the left auricular appendage caused by an accidental pull on the pincette.

January 24, 1916. Dog 10. The band was clamped with Erlanger's clamp, but as it caused hemorrhage it had to be removed and the forceps applied. There was but slight increase in the inter-auricular time interval, viz., from 0.0137 second to 0.019 second—an increase of 1.38 times. The rt.A–lt.V interval had an average of 0.09 second. The records were obtained with difficulty owing to the restlessness of the animal (hemorrhage?).

The band and the auricular tissue immediately adjacent were found crushed by the forceps.

February 2, 1916. Dog 11. Immediately on clamping the band the inter-auricular time interval passed from 0.0169 second to 0.047 second—an increase of 2.8 times. The rt.A–lt.V interval maintained an average of 0.07 second throughout.

The band was found clamped a little to the left of the position described in the previous experiments, namely just above a connective tissue band which binds it to the base of the left ventricle (this connective tissue band is shown in figure 1).

February 9, 1916. Dog 12. Immediately after clamping the band the inter-auricular time interval passed from 0.0165 second to 0.052 second—an increase of 3.15 times. The rt.A–lt.V interval had an average of 0.07 sec. throughout.

The band was found clamped about its middle.

The results have been fairly uniform, in that, crushing of a portion of the band has invariably brought about a distinct interference with conduction as shown by the lengthening of the inter-auricular time interval from its average of 0.013 of a second to about 0.05 of a second. If we except the experiment on dog 10 in which there was considerable hemorrhage and the reading of the tracings was difficult, and the experiment on dog 6 where not only the band but also the base of the auricular appendage were crushed, it will be seen that the conduction time following injury to the band was from 3 to 4.6 times greater than the normal average.
The fact that the fibers of the band run a straight course from the region of the sino-auricular node to the left auricle and the recent findings of Lewis, Meakins and White (loc. cit.) that the highest rate of propagation of the excitatory process in the auricles is along this band (1252 mm. per second) offers an obvious explanation of the effect of injury to this structure. That it is the most direct and rapid route for the excitatory process is likewise demonstrated by comparing the effects of crushing the entire inter-auricular junction as described by Fredericq (12) with the effects of crushing the band alone as described here. Fredericq found that a complete crushing of the junction causes a complete dissociation of auricular action, the right auricle beating at its customary rate while the left auricle beats at a lower rate, viz., that of the idio-ventricular rhythm. The same phenomenon had been observed by Erlanger and Blackman (13) under different experimental conditions. When the compression is moderate the inter-auricular allorhythmia is temporary, each contraction of the right auricle is followed by a left auricular contraction but the inter-auricular time interval is considerably prolonged. In a tracing illustrating this condition the time interval is about 0.08 second. It would seem, therefore, that of the entire inter-auricular junction, the inter-auricular band constitutes the most important conduction path.

The clamping experiments here reported have demonstrated, I believe, the special importance of the inter-auricular band as a path of conduction between the auricles, for in all the experiments there was a considerable amount of uninjured tissue. This band, however, has not the same importance as a conducting medium as the auriculo-ventricular bundle for while, in the latter, crushing leads to a complete block, in the former, the same injury causes only a prolongation in the time of conduction.

**SUMMARY**

The time of onset of right and left auricular contraction, contrary to general belief, is not synchronous.

The excitatory wave originating in the sino-auricular node reaches the right auricle sooner than the left; hence the right auricle contracts an appreciable time before the left. The time difference averages 0.013 second.

The most important path of conduction between the two auricles appears to be the inter-auricular band. This special importance is
demonstrated by the effects of crushing the band, the conduction being delayed 3 to 4.6 times the normal average.

The inter-auricular band has not the same importance relatively to the auricles that is possessed by the auriculo-ventricular band, as crushing does not cause a complete block. Its importance lies in the circumstance that its fibers form the most direct inter-auricular path and that the rate of conduction is highest along this path.

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