# STUDIES OF CONDUCTING SYSTEM

## STRUCTURE AND FUNCTION OF THE ACCESSORY A-V CONDUCTION PATHWAYS

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It has been believed from the concept of the syncytium that excitation is propagated to everywhere of the atrium or the ventricle when one of its portions is stimulated. Evidence of preferential routes, however, has been increased recently on the atrium[1]. There might be some atrial points which cannot be reached by ordinary sinus impulses but can be reached by impulses propagated in an abnormal direction from some ectopic focus. Such conduction might proceed through some unknown A–V bypass tracts. From such a working hypothesis a series of experiments has been made to find functioning A–V bypass tracts by the electrophysiological technique, and later they were confirmed by histological examination. This sort of approach seems to be important, since, although anatomical evidence for A–V bypass tracts has been presented by several investigators, functional studies were primarily very scanty except for the human bundle of Kent.

### METHOD

The heart was quickly isolated from the rabbit, perfused with oxygenated Tyrode solution through the aorta, and mounted in the muscle chamber containing about 70 cc of the Tyrode solution, which was gassed by a mixture of 95% $O_2$ and 5% $O_2$ and held at 37°C. Lead II or III electro-cardiograms were taken by electrodes placed at the three corners of the muscle chamber. The suction electrode was placed in the center of the right ventricular surface to obtain ventricular action potentials. According to the need of the experiments, close bipolar lead electrodes were placed on the surface of the atrium or at other sites, and micro-electrodes were inserted in the A–V node or other regions. After the functional studies were finished, the preparations were stored to conduct later ordinary histological examinations by making serial sections. Van Giesson's stain was employed mainly.

### RESULTS AND DISCUSSION

**A–V conduction of right atrial impulses[2,3]**

In the control state stimulation of various epicardial points of the right atrium induced conduction to the ventricle.

In four out of 21 experiments the following evidence for one type of bypass tracts of the A–V conduction was found. After acetylcholine was added, complete or incomplete A–V block eventually occurred when the usual points of the outer wall of the right atrium were stimulated. At this time stimulation of all the epicardial points of the right atrium was tried in order to find some points still inducing conduction to the ventricle. Such a point was found anterior to the root of the inferior vena cava. It was presumed that a bypass tract was still available for the A-V conduction, after the specialized A-V conduction system was blocked. In this conduction the interval between the stimulus artifact and the ventricular action potential was much shorter than that in the control state. No significant alteration of the QRS configuration was observed.

By employing microelectrodes and close bipolar leads we searched for the site of abnormal conduction. It was found functionally that this tract bypasses the A-V node and reaches either the His bundle or below.

The histological study of these preparations showed a direct connection of the ordinary cardiac muscle of the right atrium with the His bundle around its bifurcation bypassing the A–V node.

In two out of the 21 experiments, data suggesting a second bypass tract were obtained. After the normal A–V conduction was blocked by giving acetylcholine, stimulation of point close to and posteroinferior to the above-mentioned a point at the root of the inferior vena cava still induced a conduction to the ventricle. In this stimulation, the interval between the stimulus artifact and the ventricular action potential was much shorter than that of the control state. The QRS complex in the lead II was inverted and its duration was prolonged compared with the control. When a transverse incision was made below this point, a complete block of conduction occurred. At this time, stimulation below this incision caused a ventricular response similar as before. Therefore, another bypass tract was presumed to run through this incision.

Histological examination revealed an ordinary muscle connecting directly the right atrium and the right ventricle around the right lateral wall of the A–V groove.

A third bypass tract was suggested by the following observations in five experiments. Sinus rhythm was maintained and the interatrial septum was cut through transversely. No prolongation of the P–R interval was observed in lead II. When the incision reached some point of the posterior free wall, a marked prolongation of the P–R interval was induced. By this incision all the preferential pathways to the A–V node, as we reported previously[1], were presumed to be cut. Therefore, the delayed but still persistent conduction to the ventricle was supposed to occur via another A–V bypass tract. Then the incision was continued transversely in the free wall of the right atrium. When the incision reached some point far anteriorly, complete A–V block occurred. This showed that one bypass tract passed through this far anterior point.

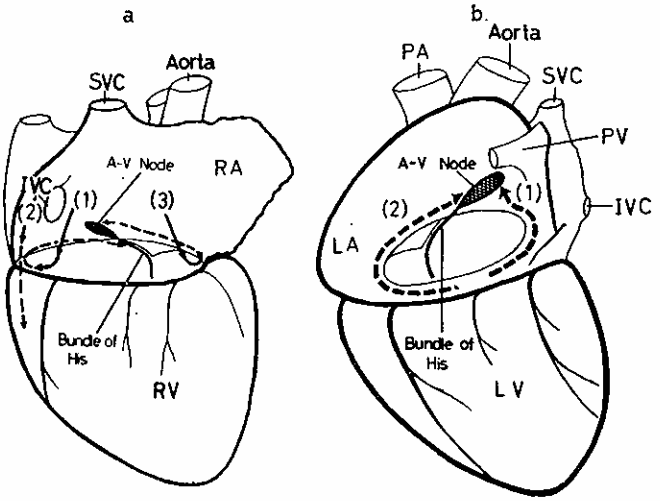


Fig. 1. Schemata of the accessory A-V conduction pathways from the right atrium (a) and from the left atrium (b). RA: right atrium. LA: left atrium. AV: right ventricle. LV: left ventricle. SVC: superior vena cava. IVC: inferior vena cava. PA: pulmonary artery. PV: pulmonary veins.

Histological examination revealed a muscle bundle entering the A–V node anterior to the normal A–N portion bypassing it. The prolonged P–R interval and the normal QRS complex in this conduction was explained by presuming that an abnormal entry to the A–V node caused a detour of conduction in it.

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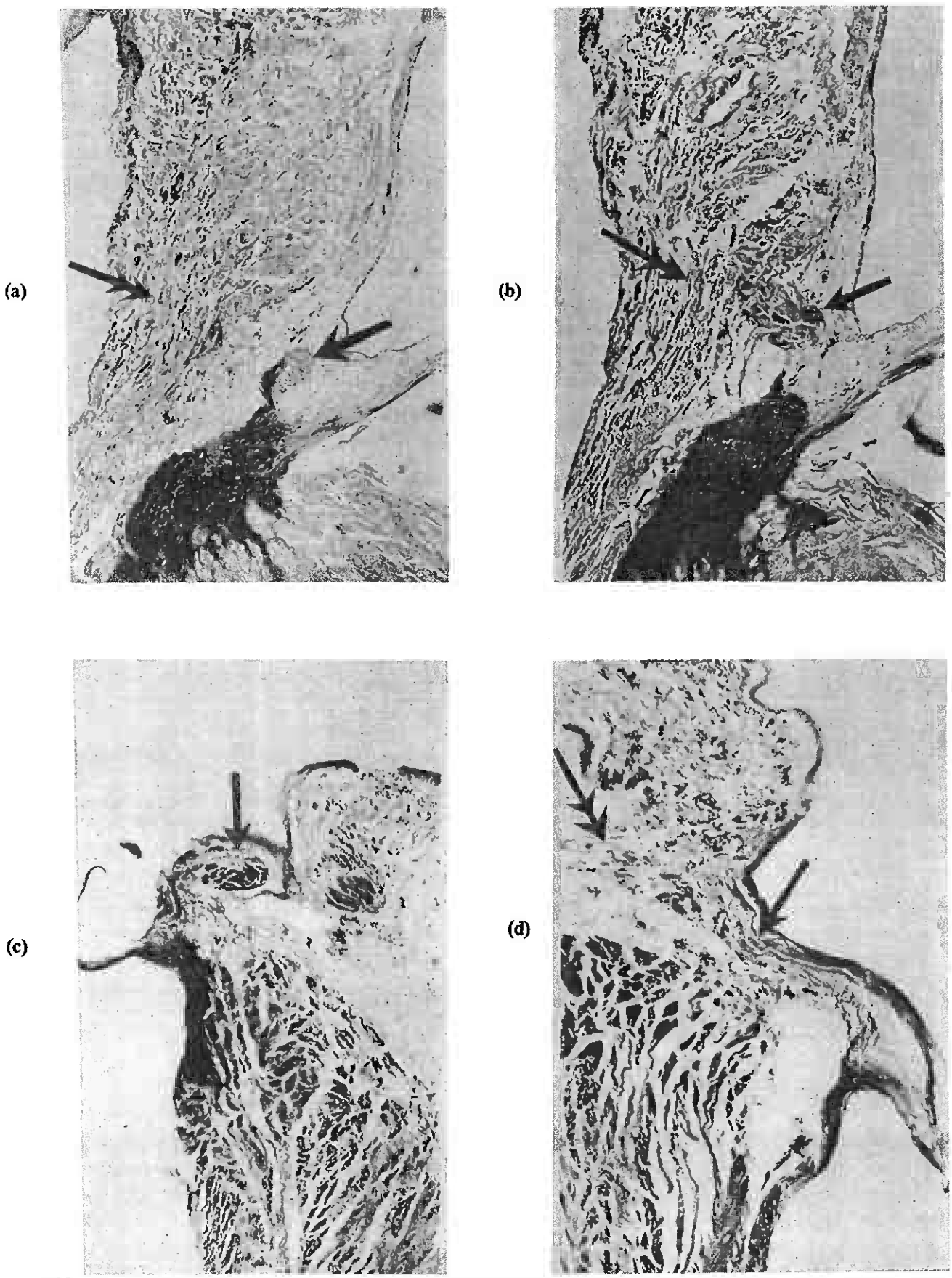


Fig. 3. Histological confirmation of the conduction pathways from the left atrium passing the anterior portion (a,b) and the posterior portion (c, d) of the left A-V ring.
a and b : frontal sections of the anterior portions of the base of the interatrial septum, b being slightly posterior to a.
c : a saggital section of the free wall of left A-V ring.
d : a frontal section of the posterior portion of the base of the interatrial septum.
Black arrows show the conduction pathways from the left atrium, and double black arrows show the A-V node.

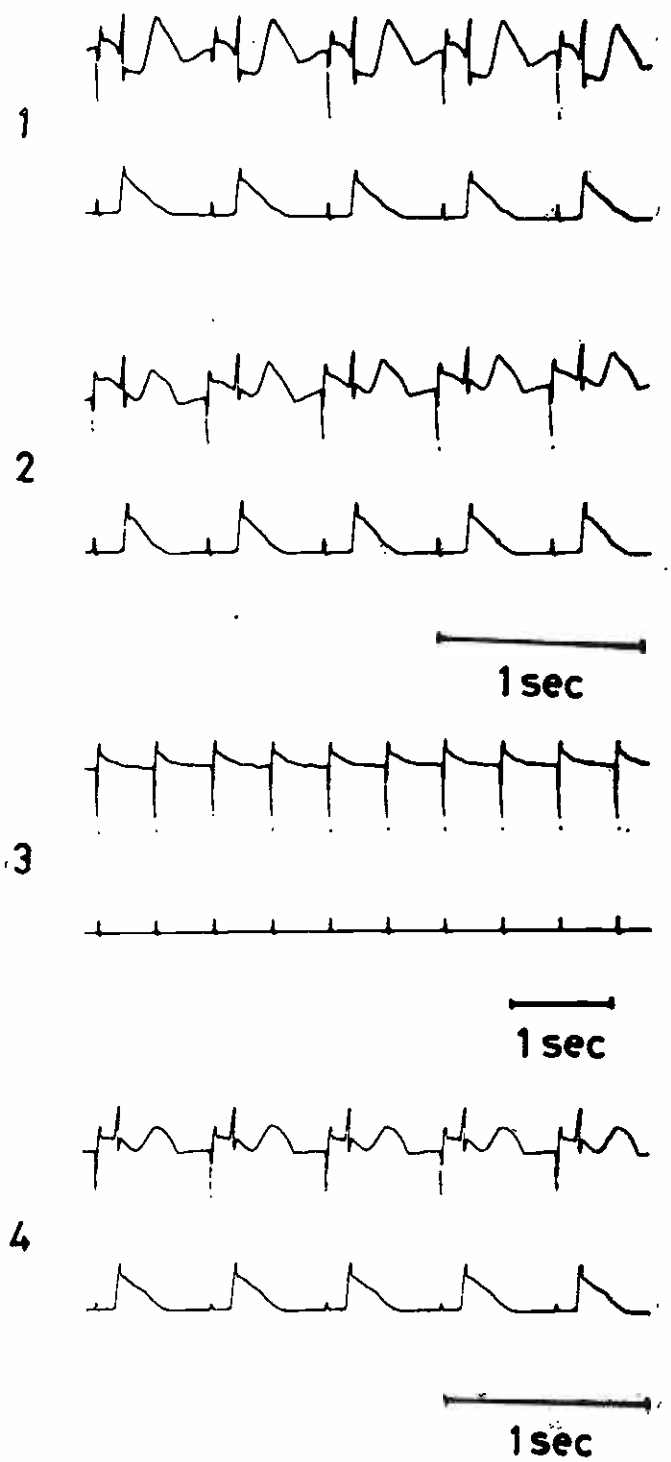


Fig. 2. An experiment by which a conduction pathway from the left atrium through the anterior portion of the left A-V ring was found. The upper tracings were lead II electrocardiograms and the lower tracings were action potentials obtained by suction electrodes placed in the center of the anterior free wall of the right ventricle.

1. Control. The interatrial septum and the right atrium were removed.
2. A vertical incision was made at the posterior portion of the left A-V ring.
3. Another vertical incision was made at the anterior portion of the left A-V ring.
4. Stimulation was made in the central portion of the incision 3.

### The conduction of left atrial impulses

Since all impulses originated from the left atrium are primarily abnormal, all the conduction routes from the left atrium may be regarded as accessory pathways in a sense. Many excitation waves probably proceed to the right atrium and take the normal His-Tawara A–V conduction route or some of above-mentioned accessory A–V conduction routes of right atrial impulses. Therefore, all the interatrial and A–V conduction routes of left atrial impulses revealed so far, namely four routes, are described below.

By preliminary experiments it was revealed gradually that conduction pathways from the left atrium existed in four regions. Each one region was successively pursued more in detail after cutting three other regions. When the first two routes were searched for, various points on the left atrium were stimulated in each case. By examining the shape of the P waves in each stimulation the localization of the interatrial conduction pathway was roughly estimated. The more precise localization was made by observing the disappearance of conduction to the right atrium by cutting and the reappearance of conducted response of the similar shape as before by electrical stimulation of the distal end of the cut. In this way the first route from the left atrium was found to be the sino-atrial ring bundle which roughly corresponds to Bachmann's bundle of the human and dog hearts. The second route was found to be the interatrial connection in the atrial septum above the A–V node, which was anatomically suggested by James[4].

In order to find other possible conduction routes almost the entire interatrial septum was removed. Only the base of the interatrial septum which was supposed to be composed of a fibrous tissue except for the specific A–V conduction system was retained. In such a preparation the A–V conduction occurred from whichever point on the epicardial surface of the left atrium which was stimulated. When the right atrium was removed also, the conduction to the ventricle is the same. When the microelectrode was inserted into the A–V node in other similar experiments, the A–V nodal action potential was obtained by the left atrial stimulation. Therefore, this conduction from the left atrium to the ventricle and to the right atrium seems to occur via the A–V node.

In such a preparation from which the interatrial septum and the right atrium were removed, when a vertical incision was made at the anterior or posterior portion of the left A–V ring, after cutting the similar posterior or anterior portion, respectively, the ventricular response such as was shown by the QRS complex and ventricular action potential disappeared suddenly. When the central portion of the incision was stimulated, same ventricular responses as before appeared again. So it was presumed that the impulses from the left atrium go through the anterior and posterior part of the left A-V ring, and through the A-V node, to the ventricle.

This was confirmed histologically. In the fibrous tissue of this portion a muscle bundle composed of probably ordinary heart muscle fibers was found to extend above the root of the mitral valve in its anteromedial and posteromedial portions and eventually reach the A–V node.

## SUMMARY

In the isolated rabbit heart three accessory A-V conduction pathways were found from the right atrium. From the left atrium four interatrial and A–V conduction routes were found, all of which may be regarded as accessory A–V conduction pathways in a sense, since all the impulses from the left atrium are primarily abnormal and all of them induced usually A–V conduction eventually. These pathways were found first electrophysiologically and confirmed later by histological examinations.

### REFERENCES

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