OBSERVATIONS ON THE ATRIOVENTRICULAR CONDUCTING (CONNECTING) SYSTEM OF THE HEART OF HUMAN TWINS OBTAINED FROM AN ABORTED FOETUS *

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INTRODUCTION

Kent (1893) believed that in the heart of cold blooded animals (fish, amphibia and reptiles) a perfect muscular continuity exists between atria and the ventricles. On this assumption he maintained that in the mammalian heart also there is no break or interval in the atrioventricular connexions and that the fibres sweep uninterruptedly through from atria to ventricles. According to Kent (1893) the number of such fibres between atria and ventricles is much larger in foetal hearts than in the hearts of adult mammals. Subsequent investigators, however, failed to confirm Kent. Keith and Flack (1906) stated, 'In short, all the evidence we have been able to collect from human and comparative anatomy, from embryology, physiology and pathology, substantiates the theory that the muscular bundle which perforates the central fibrous body of the heart and connects together its atrial and ventricular parts, is the sole path by which the atrial wave of contraction passes to, and is distributed within the ventricles.' Kistin (1949) also reported the absence of multiple connexions of Kent in the normal human hearts. He observed an atrioventricular bundle (bundle of His) at the cephalic end of the atrioventricular sep'um for conducting the cardiac stimulus to contraction from atria to ventricles. Prakash (1953, 1954*a*, *b*, *c*) on the basis of his studies on the heart of vertebrates derives the following conclusions: (1) The 'break' denied by Kent in the atrioventricular muscular continuity of lower vertebrates and mammals exists in both, (2) an atrioventricular plug in fishes and tadpoles of frog and an atrioventricular bundle in mammals and birds are present at the atrioventricular junction of the heart and that these structures only afford the necessary pathway through which cardiac impulse will pass from atria to ventricles, (3) the occurrence of multiple connexions of Kent in mammalian heart will cause anomalous atrioventricular excitations (Wolff-Parkinson-White syndrome). These conclusions (specially the last onė) require serious consideration. Moreover, Keith and Flack (1906), Kistin (1949) and Prakash (1954*b*) all have contradicted Kent (1893) as far as the hearts of newly born and adult mammals are concerned but to verify Kent's findings further, a study of foetal hearts is also desirable.

In the present investigation the atrioventricular conducting (connecting) system of the heart of human twins has been studied and described. The twins were obtained from an aborted foetus after about five months of pregnancy.

MATERIAL AND METHODS

The hearts after being removed from the twins of the aborted foetus were fixed in Bouin's picroformol. Blocks were prepared according to paraffin embedding

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method and serially sectioned at 8 μ. The sections were stained with acid fuchsin. Although a complete serial of sections was obtained of the heart of one of these twins, from the heart of the other only scattered sections could be mounted. The serial of the first heart included all the sections through the atrioventricular junction and as such the anatomy of the atrioventricular node, the atrioventricular bundle and of the limbs of the bundle, was easily studied. However, these observations were confirmed by having a look over the scattered sections of the second heart. As far as the author could ascertain the structure and disposition of the atrioventricular conducting tissue resembled in the hearts of the twins.

Observations

Atrioventricular node (*Node of Tawara*)*:* It lies as a well-marked and distinct structure on *the right lateral border of the interventricular septum at a little distance from its cephalic end* (Fig. 1). It can be located in the tissue lying between the right atrium and the ventricular septum. The node is easily distinguishable in cross-sections because of its circumscribed character. The atrial fibres penetrate freely at the dorsal and cephalic portions of the node. The atrioventricular node at its caudal side receives fibres from the interventricular septum. Ventrally the fibres from the node extend into the body of the atrioventricular bundle (bundle of His) which is situated just beneath the node on the interventricular septum.

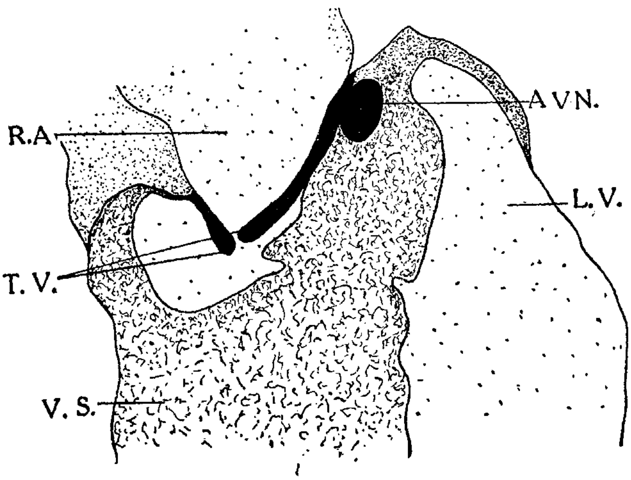

FIG. 1. Diagram of the longitudinal section of the heart passing through the atrioventricular node (Node of Tawara). Approx. ×22.

The fibres constituting the node are comparatively large but are very fine and narrower than those present in the atria or on the ventricular septum. These fibres of the node are crossing each other so as to look like cells in longitudinal sections. A number of nuclei are also present in the node. The fibres and the nuclei of the node resemble, in their general histological character, those described in the atrioventricular nodes of the rat (Prakash, 1954*b*) and the fowl (Prakash, unpublished). Almost similar histological peculiarities have been mentioned for Purkinje fibres by various authors (Purkinje, 1845; Davies, 1930 and Kistin, 1949).

Atrioventricular bundle (*Bundle of His*)*:* In serial sections it appears as if the bundle of His is arising from the mid-ventral region of the atrioventricular node. After taking its origin from the node, the bundle proceeds upwards towards the cephalic portion of the interventricular septum. The free cranial portion of this ventricular septum is membranous and is also curved so as to assume rather a sickle-shaped appearance (Gray, 1949). Because of its curved nature, this part of the septum intervenes not only between the right and the left portions of the ventricle but also between the right atrium and the left ventricle. The bundle of His which is present in close association with this portion of the septum thus occupies an important intermediate position between the right atrium and the left ventricle on the one hand and between the right and left ventricles on the other. Due to this the cardiac stimulus to contraction which is being transmitted from the right atrium will have no other probable pathway except that through the bundle of His to reach either of the ventricles.

Immediately before the interventricular septum is curved cranially, it is continuous at its right lateral surface with the caudal portion of the interatrial septum. As the bundle of His extends across this area (Fig. 2) it is sure to pick up the impulses from the interatrial septum also before they are conducted to the ventricles.

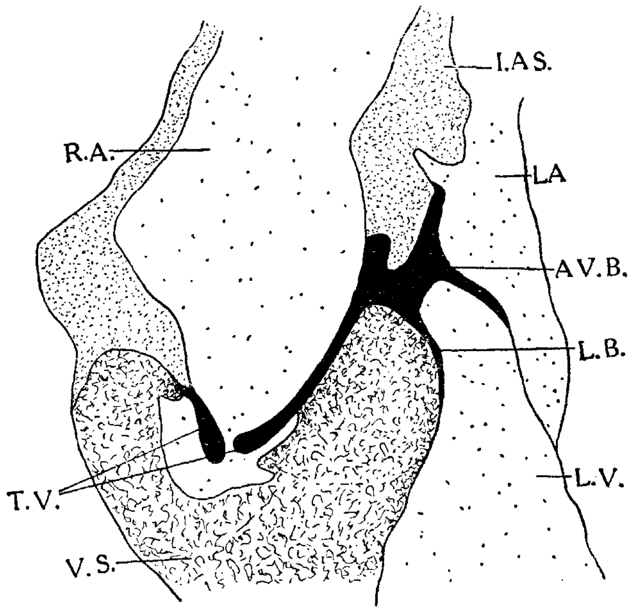

FIG. 2. Diagram of the longitudinal section of the heart to show the atrioventricular bundle (bundle of His) and its left branch. Approx. ×22.

The fibres of the bundle are rather thicker and are more compactly interlaced than the fibres of the atrioventricular node. The cells which are formed by the intercrossing of the fibres appear to be thick-walled and show prominent nuclei. The whole structure takes a deep stain with acid fuchsin showing its special histological nature.

A considerable amount of connective tissue is present between the atria and the ventricles particularly in the region of the free membranous portion of the interventricular septum. The bundle of His extends over this connective tissue and proceeds forwards to reach the cephalic end of the ventricular septum. At this point the bundle of His bifurcates to form a right and a left limb. These limbs immediately descend on to the respective sides of the ventricular septum. The right limb which is a continuation of the bundle itself at its caudal end proceeds downwards to reach the base of the tricuspid valve. It appears as if the fibres of the limb are extending into the component of the medial cusp of the tricuspid valve. Davies and Francis (1946) believe that due to functional requirement it is only in the avian heart that the right muscular valve receives a special early branch from the right limb of the bundle. According to these authors in mammals where the corresponding valve (tricuspid) is fibrous such a continuity between the fibres of the limb of the bundle and the valve is not necessary. To verify the validity of such an assertion further investigation is desirable.

The left limb of the bundle travels downwards a relatively long distance along the left side of the interventricular septum. Afterwards its fibres become indistinguishable from those of the septum. A thick band of Purkinje fibres arises from beneath the cranial portion of the atrioventricular bundle and proceeds across the left ventricular cavity to become continuous with the fibres of the ventricular wall (Fig. 2).

In none of the sections a direct continuity between the atrial and ventricular fibres of the heart was observed. The disposition of the bundle of His as revealed by the present study is such that the atrial wave of contraction is sure to be picked up by the bundle before it is distributed within the ventricles. The atrioventricular gap is bridged over by the bundle of His and the atrioventricular node.

Discussion

The object of this research had been to find out if in the heart of human embryos the atria are connected to the ventricles directly or through an atrioventricular bundle only. The present investigation confirms the absence of multiple atrioventricular connexions of Kent (1893) and points out that in the foetal hearts also as in the hearts of newly born and adult mammals (Kistin, 1949; Prakash, 1954*b*) there exists a constant muscular atrioventricular bundle at the atrioventricular junction of the heart. The bundle of His is the only connecting tissue between the atria and the ventricles, and as such plays an important rôle in transmitting the cardiac stimulus to contraction from the former chamber to the latter. The clinical importance of the bundle becomes all the more greater because now it is apparent that if it is cut or damaged the atria will have no connexion with the ventricles and the atrial stimulus to contraction will fail to reach the ventricles. There will be no co-ordination in atrial and ventricular contractions and disturbances of rhythm may arise leading to partial or complete heart block. Keith and Flack (1906) also emphasised this and further maintained that the bundle passes along the upper margin of the interventricular septum because it is the least disturbed part during systolic changes of the heart.

The absence or otherwise of the multiple muscular connexions between atria and ventricles rather assumes special significance in the light of the observations of Davies (1930) who found in birds the bundle of His as well as the multiple connexions of Kent. He correlated this with functional requirements of the avian heart and remarked that due to the rapid rate of heartbeat in birds, a rapid diffusion of the impulse through different cardiac chambers is necessary and hence the presence of both the bundle of His and the multiple connexions of Kent to act as transmitting apparatus. This means that multiple connexions are desirable in birds where they serve as accessory pathways in addition to the bundle of His, for conveying the cardiac stimulus of contraction from atria to ventricles. In mammals as the rate of heartbeat is comparatively slow a quick transmission of the impulse from atria to ventricles is to be prevented but if multiple atrioventricular connexions are present the atrial wave of contraction is bound to reach the ventricle much earlier than has hitherto been noted in normal hearts without such connexions. In those hearts where the bundle of His is the sole transmitting apparatus for the cardiac stimulus between atria and ventricles, because of the peculiar structure of the bundle (Prakash, 1954*b*) sufficient time elapses between the atrial and ventricular contractions. This 'pause' or delay in the passage of the impulse allows the ventricle to be filled completely with blood before it in turn begins to contract (Prakash, 1954*b*) and thus checks premature excitation of the ventricle. The absence of any other connexion other than through the bundle of His in foetal hearts also thus confirms the view that anomalous atrioventricular excitation (Wolff-Parkinson-White syndrome) may be due to accessory pathways at the atrioventricular bridge.

The right atrioventricular valve in mammals is membranous while the corresponding valve in birds is muscular. Davies and Francis while referring to the avian heart (1946) stated 'To prevent regurgitation of blood into the right atrium, it is necessary that this muscular valve should contract at the *outset* of ventricular systole, and it is noteworthy that a special early branch from the right limb of the A.V. bundle (the branch erroneously homologised by Drennan (1927) with the mammalian right limb) passes directly into the valve and becomes continuous with its musculature'. The present investigation reveals that in the heart of mammals also the right limb of the bundle proceeds towards the base of the tricuspid valve to enter into the component of its medial cusp. However, further study specially of the adult human heart is desirable to decide whether Drennan was right or wrong to homologise this branch of the atrioventricular bundle of the bird's heart with the right limb of the mammalian bundle of His.

Kistin (1949) for the first time drew attention to the two different interpretations of the term 'Purkinje fibres'. One view is that only those fibres of the heart should be designated as Purkinje fibres which resemble in their microscopical characteristics the fibres first described by Purkinje (1845) in sheep and other mammals. While some authors (Tawara, 1906) believe that the fibre component of the atrioventricular connecting tissue may be regarded to be of Purkinje type irrespective of its histological nature. Tawara (1906) also stated that the fibres described by Purkinje (1845) and the bundle demonstrated by His (1893) are parts of a single atrioventricular conducting system which is involved in the conduction of the cardiac stimulus from atria to ventricles. Kistin (1953) in a private communication to the author informed that Purkinje's paper does not assign any conduction function to the fibres now known as Purkinje fibres.

It has been observed by the author in the hearts of rats (Prakash, 1954*b*) and fowls (Prakash—unpublished) that continuous tracts of 'Purkinje fibres' (fibres resembled those described by Purkinje) exist at the junctional sites of the various cardiac chambers. Specially a thick band of Purkinje fibres was seen to connect the caudal ends of the atrial septum and the atrioventricular node which suggested that the impulse travels from the septum along this band to reach the node. Moreover, it has been seen that as in the hearts of the fowl and the rat so also in the heart of human embryos, the node of Tawara and the bundle of His are composed of Purkinje fibres. And as it has now been established that the node and the bundle are the only structures to convey the cardiac stimulus from atria to ventricles and that they consist of 'Purkinje fibres', there seems to be sufficient basis to believe that 'Purkinje fibres' are impulse-conducting fibres.

SUMMARY

1. The anatomy of the atrioventricular conducting (connecting) tissue resembles in the heart of twins.

2. Multiple muscular atrioventricular connexions of Kent are absent in the heart of human embryos also. It is argued that these accessory connexions, if present in the heart of mammals, may be responsible for anomalous atrioventricular excitations (Wolff-Parkinson-White syndrome).

3. Views regarding the atrioventricular bundle to be the only connexion between atria and ventricles for the propagation of the cardiac stimulus to contraction in mammalian heart have been confirmed and expanded.

4. Evidence has been produced to show that 'Purkinje fibres' form an integral part of the impulse conducting tissue.

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Abbreviations

A.V.B.—Atrioventricular bundle.
A.V.N.—Atrioventricular node.
I.A.S.—Interatrial septum.
L.A.—Left atrium.
L.B.—Left branch of the bundle of His.
L.V.—Left ventricular cavity.
R.A.—Right atrium.
T.V.—Tricuspid valve.
V.S.—Interventricular septum.

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