The anatomy and histology of the atrioventricular conducting system in the hedgehog (*Hemiechinus auritus*) heart

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**Abstract:** This study examined the atrioventricular conducting system in 4 adult male hedgehogs (*Hemiechinus auritus*). The histological structure of these components was studied using routine histological methods. The AVN was located at the lower and anterior part of the interatrial septum, near the root of the aorta. It was almost oval and consisted of twisted cells. Internodal pathways in the hedgehog heart were not observed, but there were numerous purkinje-like fibers within the myocardium of the atrium. The AVB was a continuation of the AVN, as a compact structure, extended obliquely through the fibrous ring toward the apex of the interventricular septum, and was composed of many purkinje cells.

**Key words:** Hedgehog, heart, histology, atrioventricular node, atrioventricular bundle

**Introduction**

No other exotic animal has caught the attention of the public quite like the hedgehog has. Their spines, friendly nature, and an ever-smiling expression have endeared them to millions of confessed hedgehog lovers around the globe.

In the evolutionary development of the vertebrate heart, the specialized atrioventricular conduction system appears as a phylogenetically new structural entity, which, to date, has been documented only in mammals and birds (Szabo et al., 1986). Moreover, in considering its development, it is very important to compare the cardiac conducting system in different species.

Cardiovascular diseases are an important cause of human mortality worldwide, especially in developing countries. In addition to high rates of mortality, the costs associated with treating these diseases are high. The negative economic, social, industrial, and psychological effects of these diseases are significant. In order to understand cardiac function, research on the histological structure of the cardiac conduction system, especially the atrioventricular system, is necessary. Two principal components of the atrioventricular conducting system are the atrioventricular node (AVN) and atrioventricular bundle (AVB). For example, some cardiac arrhythmias are due to pathological lesions and anatomical defects in the AVN and AVB, or in their blood supply.

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The anatomy and histology of the AVN and AVB have been studied in humans (Lev and Lerner, 1955; Titus et al., 1963; James, 1970; Titus, 1973), dogs and monkeys (Nonidez, 1943; James, 1964), hoofed animals (Meyling and Terborg, 1957; Prasad and Sinha, 1980), rabbits (James, 1967), birds (Szabo et al., 1986), lizards (Prakash, 1990), camels (Ghazi and Tadjalli, 1993, 2002), cats (Ghazi et al., 1998; Tadjalli et al., 1999), cattle (James, 1965), horses (Bishop and Cole, 1967), goats (Nabipour, 2002; Nabipour et al., 2002), guinea pigs (Nabipour, 2004a, 2004b), and recently in ovine fetuses (Nabipour and Shahabodini, 2007). However, precise data are not available on the anatomy and histology of the AVN and AVB in hedgehogs. The present study follows others on the histological structure of the AVN and AVB in different animal species. Histological knowledge of the AVN and AVB provides the basis for understanding their physiological function, and delineation of their structure in the hedgehog will provide additional insights into the significance of their structure.

Materials and methods

The study included 4 adult male hedgehogs (Hemiechinus auritus) with an average weight of 357 g (Figure 1). They were euthanized with an overdose of sodium pentobarbital administrated intraperitoneally. After removal of the pericardium, the heart was flushed with warm (40 °C) normal saline and for fixation was perfused with 10% neutral buffered formalin solution. The lower part of the interatrial septum (from the level of the upper part with the coronary sinus) along with the upper part of the interventricular septum were removed. The samples were placed in the same fixative, and then through a series of graded alcohols and xylene, and eventually into paraffin wax. Serial sections 6-μm thick were made longitudinally, starting from the right side of the samples. The sections were preserved and then selected by the interval of 3, stained with Masson's trichrome green and PAS-Alcian blue (periodic acid Schiff-Alcian blue) (Luna, 1968). The stained sections were studied under a light microscope.

Results

The hedgehog AVN was located at the lower and anterior section on the right side of the interatrial septum, near the root of the aorta, and was almost oval (Figure 2). Morphologically, the hedgehog AVB was a continuation of the AVN. There was no detectable border between the node and the AVB. The AVB extended obliquely through the fibrous ring to the apex of the interventricular septum, as a compact structure (Figure 3).

Within the AVN there was a mass—an interlacing bundle of fibers that were smaller than ordinary
myocardial fibers. The myofibrils of the nodal cells were a little smaller than ordinary myocardial fibers. As such, the difference in color between the node and the surrounding myocardium was minimal (Figure 2). There was a framework of collagen fibers between the AV nodal fibers. There were 2 types of cells in the hedgehog AVN: P (pacemaker-like) cells and other cells with darker cytoplasm. The cytoplasm of P cells contained a perinuclear clear zone (Figure 4). There were no detectable mucosubstances in the cells of the atrial and ventricular myocardium, AVN, or AVB (Figure 5).

The AVB was composed of many purkinje cells. Myofibrils were located at the periphery of the cells and a perinuclear clear zone was obvious, whereas the other cells of the AVB had darker cytoplasm (Figure 6). Intercalated discs between the cells of the AVB were present. Internodal pathways were not observed in the hedgehog heart, but there were numerous purkinje-like fibers within the myocardium of the atrium and auricle (Figure 7). Several arterioles, nerve fibers, and ganglions were present at the caudodorsal section of the AVN and AVB to supply them. Additionally, there was fibrous cartilage in the hedgehog atrioventricular fibrous ring (Figures 8, 9).
Discussion

The anatomic location of the AVN in the hedgehog heart was similar to that in rabbits (James, 1967), guinea pigs (Nabipour, 2004a), and ovine fetuses (Nabipour and Shahabodini, 2007). Because the ostium of the coronary sinus is so large in the rabbit (James, 1967) and guinea pig (Nabipour, 2004a), the AVN is displaced anteriorly and occupies the entire region, and the AVB is foreshortened. As these animals normally have a left cranial vena cava, the ostium of the coronary sinus (embryologically derived from the terminal portion of the left cranial vena cava in most mammals) is unusually large. This effectively displaces the AVN and AVB anteriorly toward the root of the aorta. However, in sheep (Copenhaver and Truex, 1952), humans (Titus et al., 1963), dogs (James, 1964), horses (Bishop and Cole, 1967), cattle (James, 1965), camels (Ghazi and Tadjalli, 2002), cats (Tadjalli et al., 1999), and goats (Nabipour, 2002) the AVN is located in the posterior section of the interatrial septum, anterior to the coronary sinus. The hedgehog AVN was oval, whereas in ovine fetuses, as in adult sheep (Copenhaver and Truex, 1952), the AVN is almost spherical. It is oval or fan-shaped in humans (Titus et al., 1963), is like a tiny spleen in dogs (James, 1964), has a flattened oblong shape in horses (Bishop and Cole, 1967), is ovoid in cattle (James, 1965), is an irregular elongated oval in goats (Nabipour, 2002), is an irregular ellipse in camels (Ghazi and Tadjalli, 2002), is an irregular elongated oval in cats (Tadjalli et al., 1999), and is almost spherical in guinea pigs (Nabipour, 2004a). The AVN in avian hearts is not morphologically definable (Szabo et al., 1986).

The hedgehog AVB was displaced anteriorly, near the root of the aorta. This location is similar to that in rabbits (James, 1967), guinea pigs (Nabipour, 2004b), and ovine fetuses (Nabipour and Shahabodini, 2007). The shortness of the hedgehog AVB is also similar to that in goats (Nabipour et al., 2002), ovine fetuses (Nabipour and Shahabodini, 2007), and cattle and horses (Meyling and Terborg,
Due to the absence of the membranous part of the interventricular septum in these animals, the AVB is short; however, in animals in which the membranous part is present, e.g. cats (Ghazi et al., 1998), the AVB is long.

The AV node cells and their arrangement as a mass of interlacing bundles interwoven with collagen fibers in the hedgehog is similar to that in humans (Titus et al., 1963), dogs (James, 1964), horses (Bishop and Cole, 1967), cattle (James, 1965), camels (Ghazi and Tadjalli, 2002), goats (Nabipour, 2002), cats (Tadjalli et al., 1999), rabbits (James, 1967), guinea pigs (Nabipour, 2004a), and ovine fetuses (Nabipour and Shahabodini, 2007). The difference in color between the node and ordinary myocardial fibers we observed in the hedgehog is less than has been reported in other animals, which is because there were more myofibrils in the cytoplasm of the cells of the hedgehog AVN. There is a small quantity of elastic fibers scattered within the AVN in humans (Titus et al., 1963), dogs (James, 1964), and cats (Tadjalli et al., 1999).

The number of P cells in the hedgehog AVN was low, which is similar to other animals, while the AVN of the guinea pig (Nabipour, 2004a) and ovine fetus consisted of numerous P cells. The level of carbohydrates in the AVN cells of ovine fetuses is high (Nabipour and Shahabodini, 2007); however, there is no glycogen in the AVN cells in goats (Nabipour, 2002), camels (Ghazi and Tadjalli, 2002), or guinea pigs (Nabipour, 2004a). There is a small quantity of nerve fibers within the hedgehog AVN; in this respect it is similar to that in humans (Titus et al., 1963), dogs (James, 1964), cats (Tadjalli et al., 1999), guinea pigs (Nabipour, 2004a), and ovine fetuses (Nabipour and Shahabodini, 2007). In contrast, in cattle (James, 1965), horses (Meyling and Treborg, 1957), and goats (Nabipour, 2002) an abundance of nerve fibers are present in the node. In the hedgehog heart, as in that of humans (Titus et al., 1963), dogs (James, 1964), horses (Bishop and Cole, 1967), cattle (James, 1965), camels (Ghazi and Tadjalli, 2002), cats (Tadjalli et al., 1999), rabbits (James, 1967), goats (Nabipour, 2002), and ovine fetuses (Nabipour and Shahabodini, 2007), ganglia are present in the posterior part of the AVN, but not in the node. Additionally, there are no ganglia at the periphery or within the node in the guinea pig. In the present study internodal pathways in the hedgehog heart were not observed, but there were numerous purkinje-like fibers within the myocardium of the atrium and auricle. The distribution of these fibers suggests that they may be involved in the interatrial spread of excitation. In humans (James, 1963), dogs (Glomset and Glomset, 1940), rabbits (James, 1967), and guinea pigs (Nabipour, 2004a) internodal pathways are connected to the margins of the AVN.

Histologically, there were 2 types of cells in the hedgehog AVB: purkinje cells and cells that did not have the typical characteristics of purkinje cells. In this respect it is similar to that in guinea pigs (Nabipour, 2004b) and ovine fetuses (Nabipour and Shahabodini, 2007). Typical purkinje cells (Copenhaver and Truex, 1952), as seen in the AVB of ungulates (James and Sherf, 1971), have a distinct perinuclear light zone and a much larger diameter than cardiac cells. Ungulate purkinje cells are almost spherical or polyhedral, and make contact with other cells along virtually their entire periphery, whereas the cells in the AVB of canines and humans are elongated and oblong, and make contact to some extent along their lateral margins, but more often at their terminal ends (James and Sherf, 1971). Partitioning of the AVB was not observed in the hedgehog heart, which is in contrast to the results reported for humans and other animals.

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References


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