The Conduction System of the Heart

6

6.1 General Considerations

The conduction system of the heart, which provides the heart its automatic rhythmic beat, consists of cardiac muscle cells and conducting fibers that initiate impulses and conduct them rapidly through the heart, initiate the normal cardiac cycle, and coordinate contractions of the cardiac chambers. The events that occur in the cardiac cycle must be coordinated if the heart is to pump efficiently and the systemic and pulmonary circulations are to operate in synchrony.

6.1.1 Sinoatrial Node

Located in the front and upper side of RA, where the SVC enters, the sinoatrial (SA) node has a spindle shape (Fig. 6.1). Its upper end is coarse, stretches downward between the superior and IVC, and is covered only by visceral pericardium. The lower end is deep and contacts the endocardium. Nutrition of the SA node is supplied by a branch from the RCA in most (55–60 %) patients or the LCx in others (40–45 %).

6.1.2 Atrioventricular Node

The atrioventricular (AV) node is located in the lower right atrial septal plane, downward of the coronary sinus opening (Fig. 6.2). It is cylindrical and approximately 3 mm long and approximately 8–10 mm wide. Blood to the atrioventricular node is supplied by the atrioventricular node artery from the RCA. The AV node is surrounded by an abundance of conductive fiber called the *atrioventricular node area*.

6.1.3 The Internodal Conduction Bundle

An electric conduction pathway exists between the SA node and the AV node (Fig. 6.3). Impulses from the SA node to the AV node run through three channels or pathways called *internodal tracts*, which are divided into the anterior beam, the middle beam, and the posterior beam. The *anterior beam* extends from the SVC, descending anteriorly into the atrial septum, near the FO to the AV node. Branches from the anterior internodal beam to the LA are called the *Bachmann bundle*. The middle beam extends from the rear of the SVC and descends into the atrial septum, connecting with the anterior beam near the front of the FO. The posterior beam extends from the SVC and runs along the outer edge of the right atrial wall, continuing downward to the right atrial wall within the crista terminalis, along the valve attachment of the IVC, reaching the AV node.

When an abnormality or damage is associated with the three beams, arrhythmias, such as complete block or nodal rhythm, can occur. In the case of an atrial septal defect, the closure of an open surgery may damage the internodal conduction bundle.

6.1.4 The Bundle of His and Its Branches

The AV node sends forth a coarse beam called the *bundle of His* (Figs. 6.4 and 6.5). It is approximately 1–2 mm in diameter and 10–20 mm in length. Connecting with the distal part of the AV node, the bundle of His runs through the right fibrous trigone to the tricuspid septal leaflet until it reaches the lower edge of the membranous septum, where it divides into two branches (left and right) (Fig. 6.4). Because the bundle of His is affixed tightly to the posterior and inferior margin of the membranous septum, it is pushed to the bottom and backward in the cases of membranous VSD and endocardial cushion defect. Its left and right branches will shift and cause different degrees of conduction block (Fig. 6.6). Surgery can cause injuries to the lower edge of the membranous septum, which can result in a complete conduction block.

The right and left bundle branches cross the muscular ventricular septum on either side. The right bundle branch is

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a single beam that extends from the stem portion of the bundle of His (Fig. 6.7). It traverses along the right subendocardium beneath the crista supraventricularis, reaching the base of the anterior papillary muscle by coursing through moderator bands. In the process, former Purkinje fibers reach the visceral pericardium. In the case of right ventricular dilatation, the right bundle branch can be damaged, leading to atrioventricular block. The left bundle branch originates from the right side of the interventricular septum, arriving at the LV through the ventricular septum (Fig. 6.8). It divides into two beams, which are called the *left anterior fascicle* and *left posterior fascicle*, to the left side of the septum. The left anterior fascicle fans out toward the end of the Purkinje fiber mesh on the ventricular surface, and the left posterior fascicular branch fans out toward the posterior papillary muscle.

6.2 Specimen Demonstrations

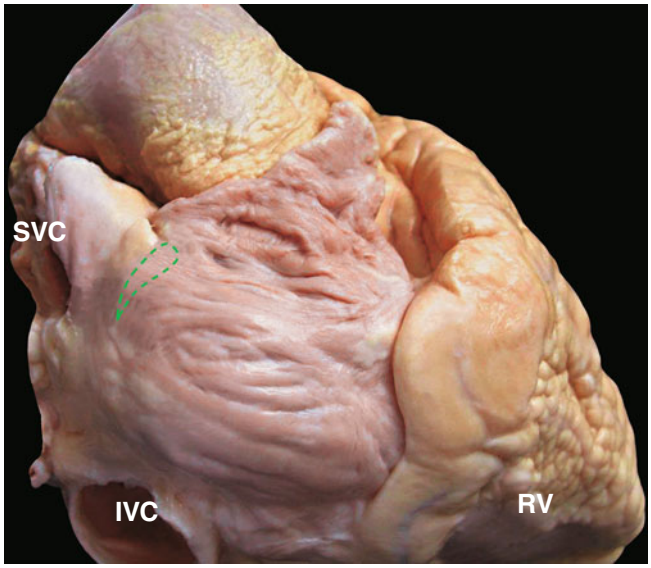

Fig. 6.1 Sinoatrial node. This is a specimen of a healthy heart. The sinoatrial node (*green label*) is located at the entrance of the SVC. It is spindle shaped and covered by the epicardium. Impulses sent by the sinus node traverse through internodal tracts to the atrioventricular node, which controls the rate and rhythm of the heart. *IVC* inferior vena cava, *SVC* superior vena cava, *RV* right ventricle. *Surgical tips*: High right atrial incision may damage the sinoatrial node. A right atrial to left ventricular roof incision may damage the coronary sinus branch and may cause arrhythmia

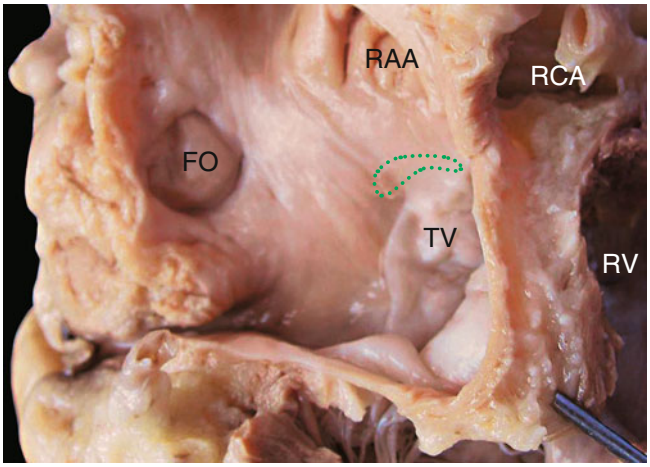

Fig. 6.2 Atrioventricular node. A right-side view is shown. Removal of the right atrioventricular anterior wall reveals the right atrial cavity. Opening the tricuspid annulus reveals the tricuspid septal leaflet (*TV*). The *green dotted line* indicates the atrioventricular node. The atrioventricular bundle from the node courses through the tricuspid annulus to the ventricular septum, where it separates into the right side (right bundle branch) and the left side (left bundle branch). *FO* fossa ovalis, *RAA* right atrial appendage, *RCA* right coronary artery, *RV* right ventricle. *Surgical tip*: in TV replacement surgery or valvuloplasty, a deep cut or stitches in the junction of the septal leaflet and the anterior leaflet can result in conduction block

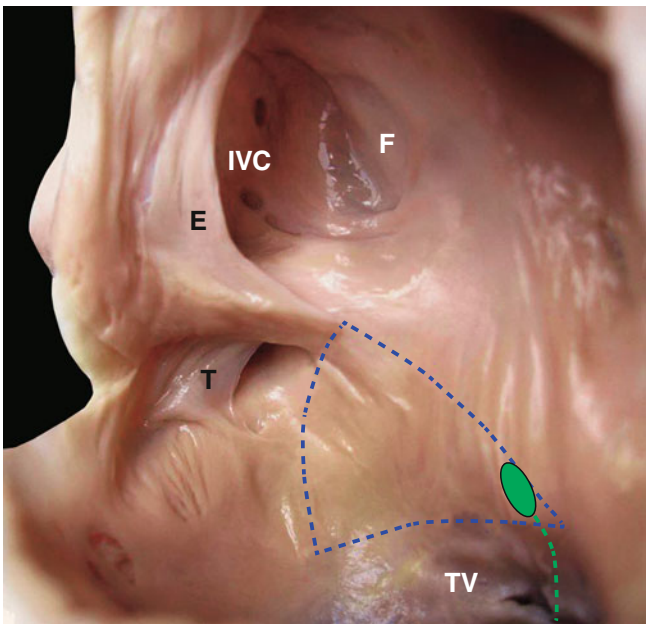

Fig. 6.3 Triangle of Koch and atrioventricular node position. The *blue dotted* area indicates the triangle of Koch, and the *green area* indicates the atrioventricular node. *E* eustachian valve, *F* fossa ovalis, *IVC* inferior vena cava, *T* Thebesian valve

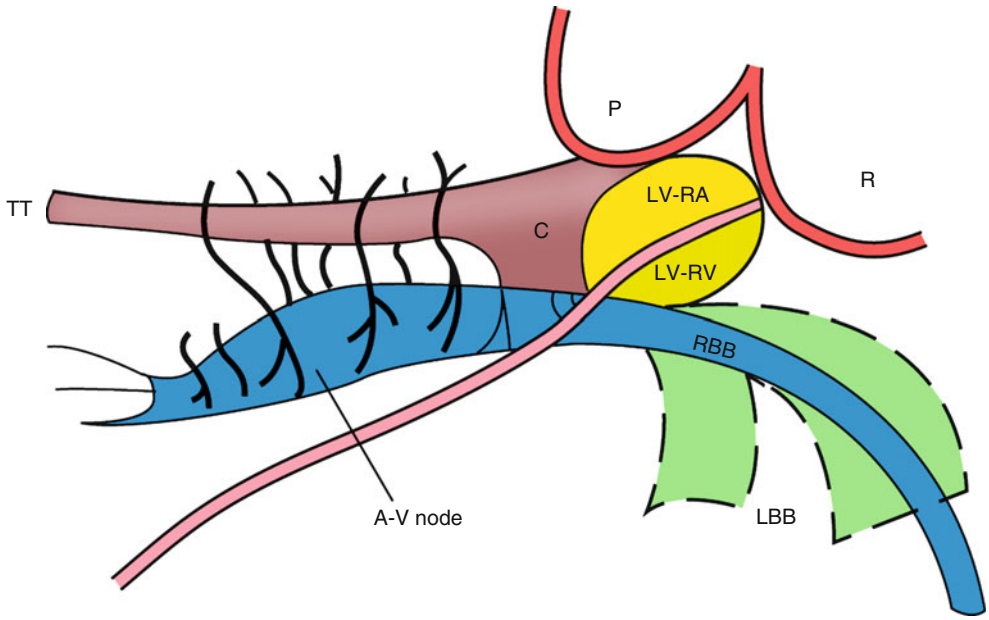

Fig. 6.4 The central fibrous body and the schematic diagram of the relationship with the atrioventricular bundle. Positive perspective demonstrates the central fibrous body and the position of the atrioventricular bundle projection. The *yellow area* represents the membranous septum, which is divided into two parts by the tricuspid annulus. The top portion is the septum of the left ventricle-right atrial septum (LV-RA); the lower portion is the member septum of the left ventricle-right ventricle (LV-RV). *A-V node* atrioventricular node, *C* the central fibrous body, *LBB* left bundle branch, *P* posterior of the aortic valve ring, *R* right aortic valve ring, *RBB* right bundle branch, *TT* Todaro tendon

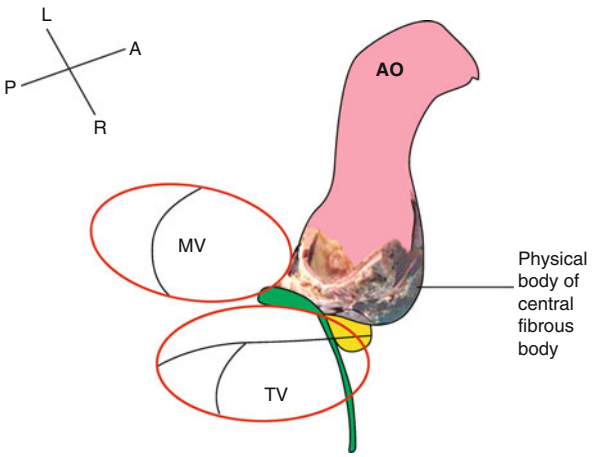

Fig. 6.5 Map of the central fibrous body. *AO* ascending aorta, *MV* mitral valve, *TV* tricuspid valve

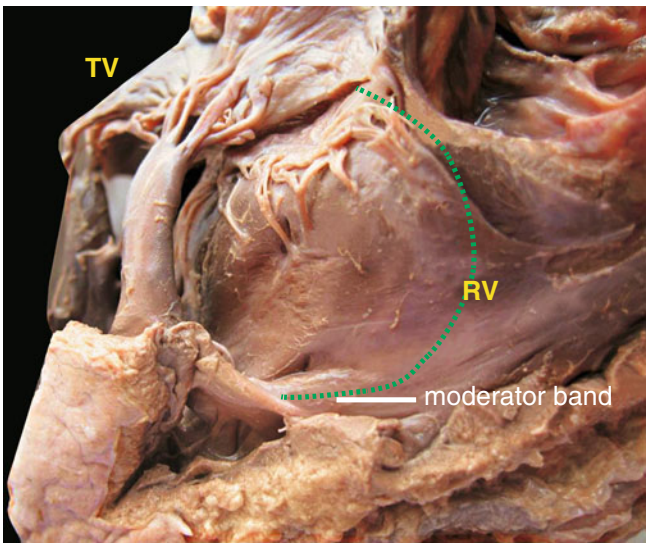

Fig. 6.6 Right bundle branch. These are specimens from the right ventricular cavity. The *green dashed lines* represent the right bundle branch. Running along the lower edge of the membranous septum from the front of the septal leaflet of the TV, the right bundle branch is separated by the atrioventricular bundle at the right side of the RV. It runs along the lower edge of the supraventricular crest into the moderator band and extends to the anterior papillary muscle. Injury to the moderator band during surgery can cause right bundle branch block. *RV* right ventricle, *TV* tricuspid valve

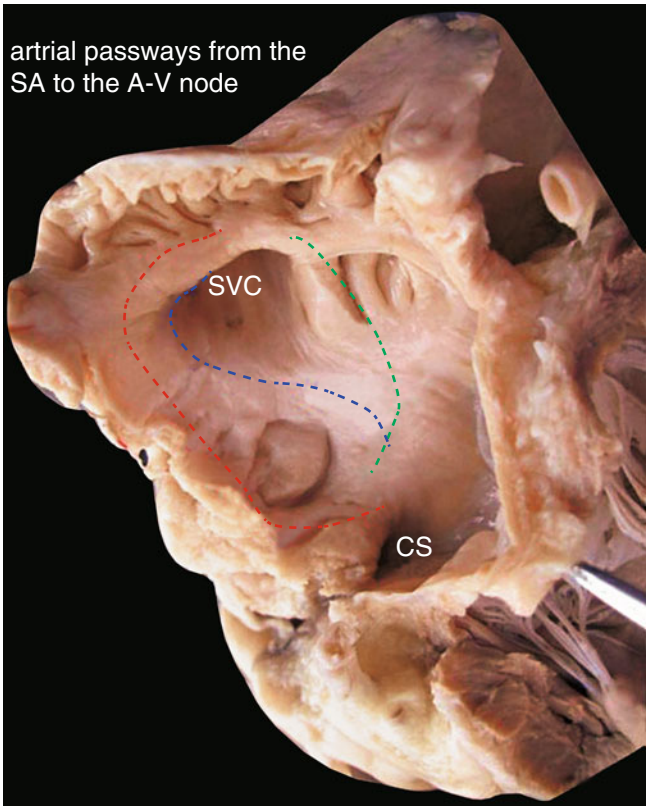

Fig. 6.7 Internode beam tract. Anatomy from the right-side view reveals three impulse pathways to the atrioventricular node between the sinoatrial node and the atrioventricular node by electrophysiological confirmation. The three pathways are called the internodal tracts. The *green dotted line* indicates the anterior internode tract, along the FO front walk down; the *blue dotted line* represents the intermediate tract, from the SVC down also to the marginal branch of the FO. The *red dotted line* indicates the lateral internode tract, coursing along the crista terminalis of the right atrial wall downward through the IVC into the Todaro tendon to the atrioventricular node. *CS* coronary sinus, *FO* fossa ovalis, *IVC* inferior vena cava, *SVC* superior vena cava. *Surgical tip*: a right atrial incision that cuts off the crista terminalis or the marginal branch of the oval fossa may lead to atrial arrhythmias

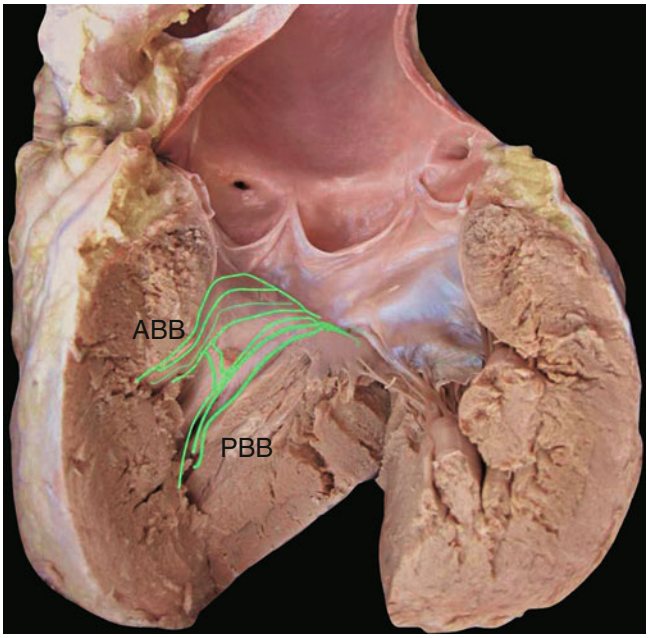

Fig. 6.8 Left bundle branch. This figure shows the interventricular septum from the left ventricle view. The *green line* represents the left bundle branch. These conductions spread in the left-sided endocardium of the septum and are divided into two groups: the left anterior bundle branch (*ABB*) and the left posterior bundle branch (*PBB*)